REUSE OF DOMESTIC WASTEWATER FOR IRRIGATION
(A Case study Of Q-Block Hostel, FUT Minna.)

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DEDICATION

This project is dedicated to the **Glory of God and for the benefit of mankind**.

I also dedicate it to my father**, PRINCE OSAMWONYI OSAGIE**. Thank you and God bless.

CERTIFICATION

This is to certify that this project was carried out by OSAGIE, KIZITO in the department of Agricultural Engineering, Federal University of Technology, Minna.

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ABSTRACT

This study presents the design and construction of a model waste stabilization pond (WSP), and reuse of its discharged effluent for irrigation. The Biochemical oxygen demand (BOD_5) of the influent domestic sewage was analysed and found to be 356mg/l. The WSP comprises of one facultative pond, three maturation ponds and a contact filteration unit, all in series. The effluent of the WSP had a BOD_5 of 32mg/l, this implies a 91% BOD_5 removal. After filteration through the clay media, the BOD_5 reduced to 21mg/l, indicating a 94.1% removal level. A faecal coliform (FC) count of the influent sample gives 1×10^8 FC/100ml. whereas the effluent gave 9 FC/100ml, which is 99.99% faecal coliform removal. The effluent from the WSP is therefore suitable for irrigation of both restricted and unrestricted irrigation. A rice husk filter media was found to be non-promising in the removal process. The treatment system can be recommended to institution or private/public estates in order to have a more environmental friendly discharge of domestic sewage.

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Principal Notation

A	area, m^2
D	depth, m
Fr	froude number
K_b	rate constant for first order removal of FC, d^{-1}
K_r	rate constant for first order of BOD, d^{-1}
L	BOD_5, mg/l
n	number of maturation ponds
Q	daily flow of wastewater, m^3/d or m^3/s
T	temperature, ^{0}c
t	detention time, days
x	width, m
θ	Arrhenius constant
λ_s	BOD_5 surface loading, kg/ha.d
λ_v	BOD_5 volumetric loading, g/m^3.d

Subscripts

e	effluent
i	influent
m	model
p	prototype
T	temperature
t	time

Abbreviations

BOD_5	5 day biochemical oxygen demand
BOD_u	ultimate biochemical oxygen demand
FC	faecal coliforms
SS	suspended solids

CHAPTER ONE

INTRODUCTION

1.1 General Background

As urban and industrial development increases, the quantity of waste generated also increases. These wastes pose a serious threat to public health when they are not readily disposed off. When these wastes are removed by water carriage system, they are termed wastewater

Wastewater is the used water or liquid waste of a community, which includes human and household waste together with street washings. Industrial waste and such ground and storm water may be mixed with it. The constituents of wastewater are;

1. Domestic wastewater, which include human body waste (urine and faeces) and sullage, which is the discharge from kitchen, baths, lavatories etc from public and private buildings.
2. Industrial and trade waste from manufacturing processes such as tanneries, slaughter houses, distilleries, mills, laundries, chemical plants etc.
3. Ground water or subsoil water entering sewers through leaks; and
4. Storm water, which is rainwater from house roads along with surface water.

The wastewater contains a large number of potentially harmful compounds capable of causing the pollution of a watercourse when they are discharged directly into it. Serious damage might result to the many forms of life, which inhabit this water. In addition watercourse utilized by man, either as a source of potable water or for washing or bathing would present potentials risk for the transmission of large number of water-related diseases To ensure that such problems are avoided or minimized, attention should be paid to the management of our aquatic resources and also of the pollutants, which enter them.

A complete chemical and microbial analysis of wastewater is never performed; instead the components that comprise wastewater are defined in terms of three broad categories, namely:

1. Organic material
2. Inorganic materials
3. Microbial content

The organic components of wastewater comprise a large number of compounds that have in common the possession of at least one carbon atom and are thus known as carbonaceous compounds. These carbon atoms may be oxidized both chemically and biologically to yield carbon dioxide. This reaction results in a net yield of energy, and consequently carbonaceous compounds are oxidized by the majority of the microorganisms to provide the energy necessary for their growth. A typical simple carbonaceous compound is glucose and this is oxidized according to the equation

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2o$

Oxidation reaction of this kind may be carried out both microbial and by the use of chemica oxidizing agents. They are exploited as non-specific test to indicate the amount of organi material present in wastewater.

Unlike organic materials, there is no simple procedure available which is equivalen to the oxygen demand test that allows a gross determination of the pollution potential of th inorganic material present in a wastewater. Fortunately, however, the numbers of inorgani compounds that pose the threat to serious pollution are limited, and it is quite feasible t perform simple assay to detect those individual compounds, which are most likely to prov troublesome like nitrogen and phosphorus. Nitrogen and phosphorus in a watercours originate from many sources including artificial fertilizers applied to farmland, farm anim wastes, and many manufacturing processes and in particular effluents from wastewater treatment works. The nitrogen in wastewater effluent arises primarily from metabolic interconversions of excreta-derived compounds; where as 50% or more of the phosphorus arises from synthetic detergents. The principal forms in which they occur in wastewater are NH_4 (ammonium); NO^-_2 (Nitrite); NO^-_3 (Nitrate); PO^{3-}_4 (orthophosphate). These two elements are known as nutrients and their removal is known as nutrient stripping.

A wide variety of microorganisms are found in wastewater including viruses, bacteria, fungi, protozoa, and nematodes. These organisms occur in very large numbers; in particular, the bacteria for which total occurrence range in 1 to $38x10^6ML^{-1}$ are routinely recorded. It would be extremely time consuming and provide little information of use for engineers to identify all the species of microorganism found is wastewater. The main aim in the microbiological examination of water, as far as the engineer is concerned is to detect the presence of pathogenic microorganism that would constitute a danger to human health through contact with the contaminated water.

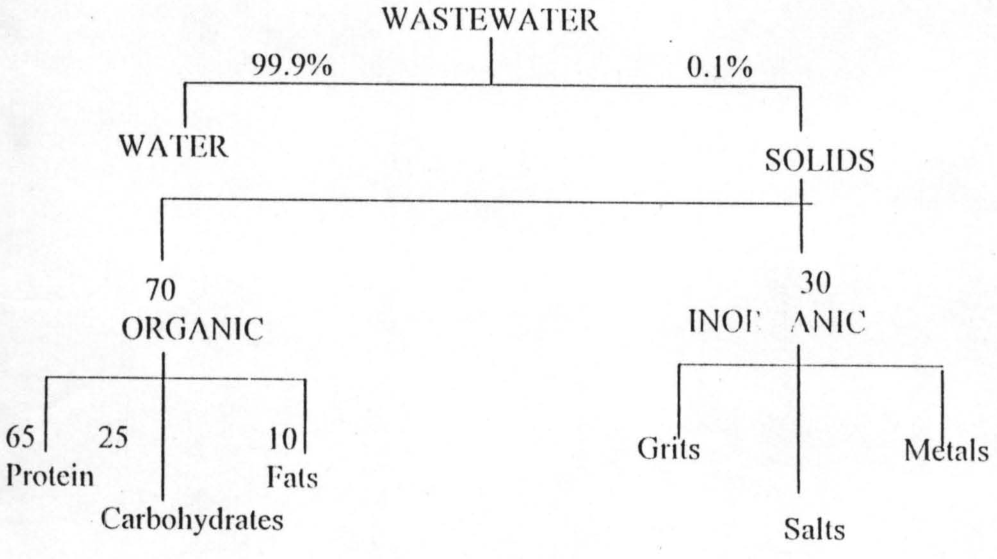


Figure 1.1: Composition of wastewater (Tebbutt, 1970)

Domestic wastewater, which is the cause of concern, poses a major environmental problem that requires money and energy to be spent for the appropriate treatment and disposal. This is due to the obnoxious manner of the decaying organic matter and the pathogenic organism they harbour. However, since domestic wastewater contains beneficial constitutes, their reclamation would not only conserve potable water supplies, but also helps to protect the quality of the environment.

Treated domestic wastewater may be used for industrial and non-potable purposes and also in agriculture (i.e. for irrigation).

The use of domestic wastewater for irrigation is advantageous for many reasons including; water conservation, ease of disposal, nutrient utilization and avoidance of surface water pollution. On the other hand, it must be borne in mind that although the soil is an excellent adsorbent for most soluble pollutants, domestic wastewater must be treated before they can be used for crop irrigation to present risk to both public and the environment.

1.2 Nature of the Problem

The use of wastewater for irrigation was first practiced in ancient Athens in mid 19th century without much regard to unpleasant condition produced at the farmland (Horan, 1990). This was the only way of its disposal. In most developing countries, farming system depends solely on rainfall, which restrict production of food only during the rainy season, whereas the population and the demand for this food is on the increase.

The problems associated with the use of domestic wastewater for irrigation include;

1. Assessment of its pollution potential in order to establish the likely effects of discharge on receiving farmland.
2. The type and degree of treatment, which would be required in order to render the wastewater harmless.

3. Assessment of strength and flow rate in order to levy the discharge with an appropriate treatment charge.
4. Economic analysis of the project to determine whether the estimated cost is returnable from the potential benefit.
5. Design of storage reservoirs to assure necessary treated domestic wastewater effluent.

Therefore, there is the urgent need to address some of the problems for the successful implementation of the project. The treatment method should produce an effluent with a quality that meet established guideline, but with the minimum operational and maintenance requirement. In this respect, waste stabilization ponds are superior to conventional treatment processes (Mara 1976). As the simpler a wastewater treatment process, the greater the likelihood that the reuse scheme will be successful, provided the system is properly managed

1.3 Aim of the Project

To design and construct a model waste stabilization pond and final contact filteration unit, for the treatment of influent domestic wastewater for irrigation use.

The specific objectives were;

1. To determine the BOD_5 and other bacteriological pathogenic parameters in the influent domestic wastewater.
2. To design and construct a model treatment unit that will remove (reduce) the pathogenic parameters in the influent wastewater and make it suitable for irrigation purposes.
3. To carry out a performance evaluation of the treatment unit.
4. To analyse the treated effluent and compare with set standard for irrigation water.

1.4 Justification of the Objective

The use of domestic wastewater for irrigation can cause unpleasant condition to the environment and its treatment and reuse of the effluent for irrigation will involve a little capital. The success of using domestic wastewater for irrigation depends on the treatment method employed to remove the harmful pollutant in the wastewater so as to meet the required standard set for irrigation water quality; by so doing potable water for irrigation is being conserved and it can be used for other domestic purposes.

Irrigation farming is one of the means to enhance food supply for the humanity that is geometrically increasing is population.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview of Waste Stabilization Ponds

The most appropriate wastewater treatment to be applied before effluent use in agriculture or discharge to a watercourse is that which will produce as effluent meeting the recommended microbiological and chemical quality guidelines both at low cost and with minimal operational and maintenance requirements (Arar 1988). Adopting as low a level of treatment as possible is especially desirable in developing countries, not only from the point of view of cost but also in acknowledgement of the difficulty of operating complex systems reliably. In many locations it will be better to design the reuse system to accept a low-grade of effluent rather than to rely on advanced treatment, which continuously meets a stringent quality standard.

Waste stabilization ponds (WSP) are now regarded as the method of first choice for treatment of wastewater in many parts of the world. In Europe, for example, WSP are very widely used for small rural communities (approximately up to 2000 population but large system exists in Mediterranean France, and also in Spain and Portugal) (Bucksteeg, 1987). In the United States one third of all wastewaters treatment plant are WSP, usually serving population up to 5000 (EPA, U.S.A 1983). However in warmer climates (the Middle East, Africa, Asia and Latin America) ponds are commonly used for large population (up to 1 million). In developing countries like Nigeria and especially in the tropical and equatorial regions wastewater treatment by WSPs has been considered an ideal way of using natural processes to improve wastewater effluents.

Waste stabilization ponds (WSP) often referred to as oxidation ponds or lagoons are holding basins used for raw wastewater treatment where decomposition of organic matter is processed naturally, i.e. biologically. The activity in the WSP is a complex symbiosis of bacteria and algae, which stabilizes the waste and reduces pathogens. The result of this biological process is to convert the organic content of the effluent to more stable and less offensive forms. WSP are used to treat a variety of wastewater, from domestic wastewater to complex industrial water and they function under a wide range of weather conditions i.e. tropical to arctic. They can be used alone or in combination with treatment processes.

A WSP is a relatively shallow body of wastewater contained in an earthen man-made basin into which wastewater flows and from which after certain detention time (time it takes the effluent to flow from inlet to outlet) a well-treated effluent is discharged. Many characteristics make WSP substantially distinguished from other wastewater treatment. This includes design, construction and operation simplicity, cost effectiveness, low maintenance requirement, low energy requirements, easily adaptive for upgrading and high efficiency.

2.2 Waste Stabilization Ponds System

A World Bank report (Bucksteeg, 1986) came out strongly in favour of stabilization ponds as the most suitable wastewater treatment system for effluent use in agriculture. Table 2.1 provided a comparison of the advantages and disadvantages of ponds with those of high rate and low rate biological wastewater treatment processes (note that Aerated Lagoons and WSP system are considered low rate biological wastewater treatment processes). Stabilization ponds are the preferred wastewater treatment process in development countries, where land is often available at reasonable opportunity cost and skilled labour is in short supply.

Table 2.1 Advantages and disadvantages of various wastewater treatment systems.

	Criteria	Package plant	Activated sludge plant	Extended aeration activated sludge	Biological filter	Oxidation ditch	Aerated lagoon	Waste stabilizatio pond system
Plant performance	BOD removal	F	F	F	F	G	G	G
	FC removal	P	P	F	P	F	G	G
	SS Removal	F	G	G	G	G	F	F
	Helminth removal	P	F	P	P	F	F	G
	virus removal	P	F	P	P	F	G	G
Economic factor	Simple and cheap construction	P	P	P	P	F	F	G
	Simple operation	P	P	P	F	F	P	G
	Land requirement	G	G	G	G	G	F	P
	Maintenance cost	P	P	P	F	P	P	G
	Energy Demand	P	P	P	F	P	P	G
	Sludge Removal Cost	P	F	F	F	P	F	G

FC =	Faecal Coliform
SS =	Suspended solids
G =	Good
F =	Fair
P =	Poor

Source, Arthur (1983)

Wastewater stabilization pond systems are designed to achieve different forms of treatment up to three stages in acries depending on the organic strength of the input waste and the effluent quality objectives. Ease of maintenance and flexibility of operation, at least two trains of ponds in parallel are incorporated in any deign. Strong wastewater, with BOD_5

concentration in excess of about 300mg/L, will frequently be introduced into first-stage anaerobic ponds, which achieve a high volumetric rate of removal. Weaker waste or, where anaerobic ponds are environmentally unacceptable, even stronger wastes (say up to 1000g/l BOD_5) may be discharged directly into primary facultative ponds. Effluent from first-stage anaerobic ponds will overflow into secondary a facultative pond, which comprises the second stage of biological treatment. Following primary or secondary facultative ponds, if further pathogen reduction is necessary maturation ponds will be introduced to provide tertiary treatment. Maturation ponds enhance better bacteriological quality of the effluent. Typical pond system configurations are given in fig 1. (Though other combinations may be used)

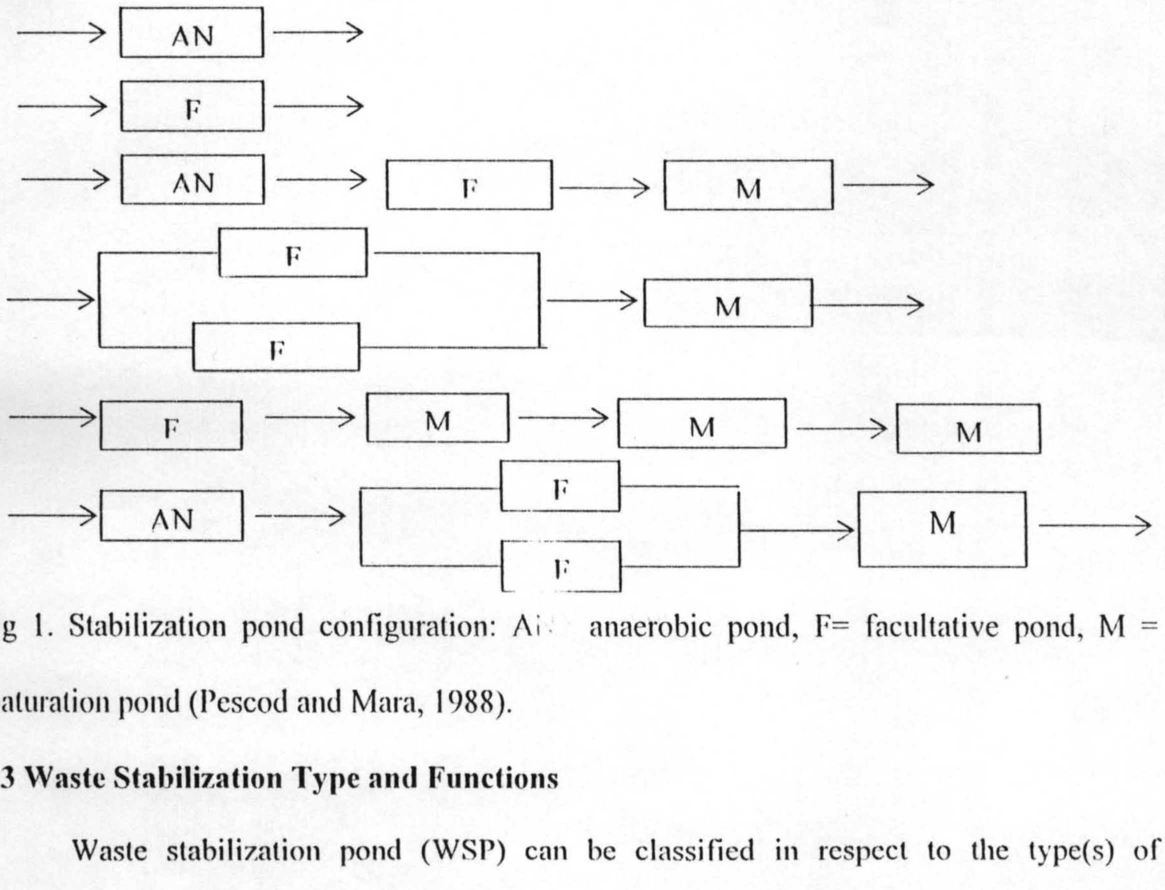


Fig 1. Stabilization pond configuration: AN= anaerobic pond, F= facultative pond, M = maturation pond (Pescod and Mara, 1988).

2.3 Waste Stabilization Type and Functions

Waste stabilization pond (WSP) can be classified in respect to the type(s) of biological activity occurring in a pond. Three types are distinguished: Anaerobic, facultative and maturation ponds. Usually a WSP system comprises a single series of the aforementioned three ponds types or several such series is parallel. In essences anaerobic and facultative ponds are designed for BOD removal (Biological oxidation demand) and maturation ponds for pathogen removal, although some BOD removal occur in maturation ponds and some pathogen removal is anaerobic and facultative ponds. In Many instance only anaerobic and facultative ponds are required. In general maturation ponds are required only when stronger wastewater are to be treated prior to surface water discharge and when treated wastewater is to be used for unrestricted irrigation (irrigation of vegetable crops). Generally, in WSP systems effluent flows from the anaerobic pond to the facultative pond and finally, if necessary to maturation pond. However, for better result, wastewater flowing into anaerobic pond shall be preliminary treated in order to remove coarse solids and other large materials often found in raw wastewater. Preliminary treatment operations typically include coarse screening, grit removal and, in some cases, comminuting of large objects.

2.3.1 Anaerobic Ponds

Anaerobic ponds are deep treatment ponds that exclude oxygen and encourage the growth of bacteria, which break down the effluent. It is in the anaerobic pond that the effluent begins breaking down in the absence of oxygen "aerobically. The anaerobic pond acts like an uncovered septic tank. Anaerobic bacteria break down the organic matter in the effluent, releasing methane and carbon (iv) oxide, sludge is deposited on the bottom and a crust forms on the surface as shown in fig. 2.2. Anaerobic ponds are commonly 2-5m deep and receive such a high organic loading (usually > 100g BOD/m^{3}d equivalent to > 3000kg/ha/day for a depth of 3m). They contain an organic loading that is very high relative to the amount of oxygen entering the pond, which maintains anaerobic conditions to the pond surface. Anaerobic ponds don't contain algae, although occasionally a thin film of mainly Chlamydomonas can be seen at the surface. They work extremely well in warm climate (can attain 60-88% BOD removal) and have relatively short retention time.

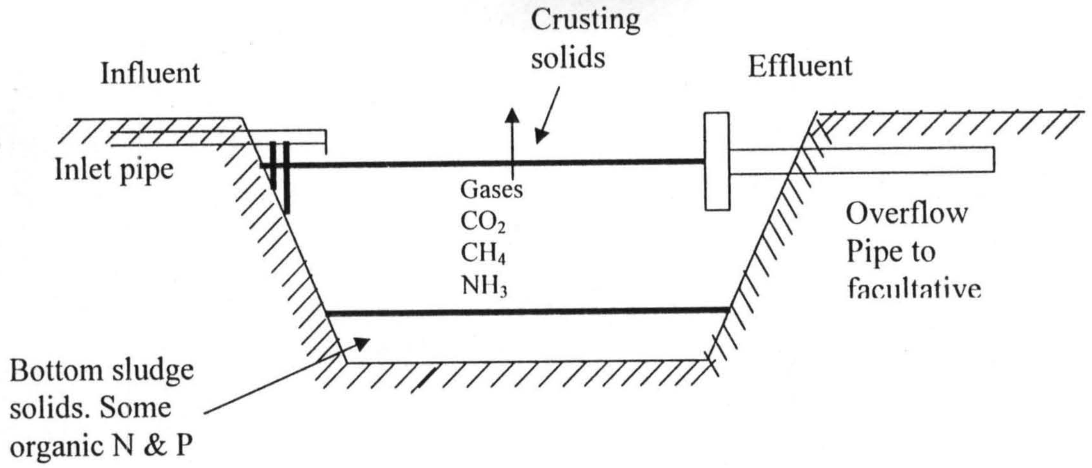


Fig .2 Operation of the anaerobic pond

Anaerobic ponds reduce Nitrogen, Phosphorus and potassium and pathogenic microorganisms by sludge formation and the release of ammonia into the air. As a complete process, the anaerobic pond serves to

- Separate solid from dissolved materials as solid settle as bottom sludge
- Dissolve further organic material
- Break down biodegradable organic material
- Store undigested materials and non-degradable solids as bottom sludge
- Allow partially treated effluent to pass out

These fermentation processes and the activity of anaerobic oxidation throughout the pond remove about 70% of the BOD_5 of the effluent. This is a very cost – effective method of reducing BOD_5. Normally single anaerobic pond in each treatment train is sufficient if the strength of the influent wastewater is less than 1000mg/LBOD_5.

For high strength industrial waste, up to three anaerobic ponds in series might be justifiable but the retention time in any of these ponds should not be less than 1 day (Mara, 1976). Designers have in the past too afraid to incorporate anaerobic ponds in case they cause odour. Formation of oduor is strongly dependent on the type of waste to be treated in the plant, notably its sulphate (SO_4) concentration and volumetric loading rate, respectively. SO_4

is reduced hydrogen sulphide (H_2S) under anaerobic conditions. H_2S is the compound mainly responsible for obnoxious odours. Other components besides H_2S and originating from the anaerobic decomposition of carbohydrate and protein may contribute to obnoxious odour too.

However, odour is not a problem if the recommended design loading is not exceeded and if the sulphate concentration in the raw wastewater is less than 300mg SO_4/l (Gloyna and Espino, 1969). A small amount of suphide is beneficial as it reacts with heavy metals to form insoluble metal sulphide, which precipitates out. In the case of typical municipal wastewater, it is generally accepted that a maximum anaerobic pond loading of 300g BOD_5/m^3 day at 20^0c will prevent our nuisance (Mara et al. 1992). However, results obtained from a more recent study in northern Brazil carried out by Pearson et al. (1996) suggest that maximum design volumetric loading may increase to 350g BOD_5/M^3 d at 25^0c rather than restricting it to 300g BOD_5/m^3d at 20^0c. Further more Mara and Pearson (1986), proposes maximum surface volumetric loading rate at 500g $30_4/m^3$d in order to avoid odour nuisance

2.3.1.1 BOD Removal Rates and Factors

First, the concept of Biochemical Oxygen Demand (BOD) should be introduced. Organic compounds in wastewater may be used as food for bacteria, which can biochemically digest or oxidize the organic compounds to produce energy for growth. This oxidation of organic materials if done under aerobic condition is presence of oxygen "consumes" oxygen and produce carbon (iv) oxide. An organic waste can therefore be said to have a biochemical oxygen demand, i.e. the amount of oxygen required by aerobic bacteria to oxidize it.

The term BOD is used to refer to the organic material in a waste and can be used in quantitative expressed relating to organic materials, i.e. the expression g BOD or kg BOD describes an amount of organic materials. The amount of BOD is a specific volume of wastewater is the concentration or the strength of the wastewater and is expressed in terms such as g/m^3or mg/l or parts per million, PPM of BOD call numerically equivalent. The loading rate of organic waste to a treatment system or a receiving environment (i.e. land) is expressed as a mass of BOD/ volume (or area) of treatment system per unit time: i.e. g BOD/m^3 day for loading rate of an anaerobic pond: g/BOD/m^2/day to a facultative and maturation ponds or land. BOD is measured in a five-day test of oxygen consumption. The BOD value derived from this test is usually expressed as the BODs of the waste water/wastewater.

In anaerobic ponds BOD removed is achieved (as in septic tank) by sedimentation of settleable solids and subsequent anaerobic digestion in the resulting sludge layer. This is particularly intense at temperature above 15^{0}c when the pond surface literally bubbles with the release of biogas around 70% methane and 30% carbon (iv) oxide. Methane production increases sevenfold for every 5^{0}c rise in temperature (Horan, 1990). Table 2.2 shown the expected BOD$_5$ removal for different retention times in treating wastewater, given by Mara (1976)

Anaerobic ponds are normally designed on the basis of a temperature dependent empirical value for the permissible organic loading rate. Land requirements will be lowest if the maximum possible BOD loading can be applied. The upper limit of the volumetric BOD loading is determined by odour emission and minimum pH threshold value at which the anaerobic decomposition processes cease to work. The maximum BOD loading rate acceptable to avoid odour nuisance was discussed in earlier section

Table 2.2 BOD removals is anaerobic ponds loaded at 250g $BOD_5/m^3/d$

Retention time (days)	BOD_5 removal %
1	50
2.5	60
5	70

Source, Mara (1976)

However, the effect of pH must be taken in consideration. Concentration of H_2S, which is the sulphur responsible for odour, increases sharply as the pH drop below 7.5, phenomenon which may occur if an anaerobic pond, is heavily loaded or overloaded (Bases on a BOD loading criterion). Acidic waste water thus requires neutralizing prior to treatment in anaerobic pond as a low pH can be considered a toxicant for anaerobic bacteria Determination of the maximum BOD loading rate beyond which pH is likely drop this threshold value is, therefore, important.

Another factor may affect the BOD and COD removal, which is the ammonia (NH_3) toxicity to anaerobic bacteria. Experiment conducted by Sergrist (1997) showed a 50% growth inhabitation at a NH_3 N/L concentration of 25-30mg/l. Strong ammonia inhibition in anaerobic pond can occur at concentration >80mg NH_3-N/L and may reduce significantly COD elimination to as low as 10% in primary anaerobic pond.

In certain instances, anaerobic ponds become covered with a thick scum layer, which is thought to be beneficial but not essential, and may give rise to increased fly breeding. Solid in the raw wastewater, as well as biomass produced, will settle out in first stage anaerobic ponds and it is common to remove sludge when it has reached half depth in the pond. This usually occurs after two years of operation at design flow is the case of municipal wastewater treatment

2.3.1.2 Pathogen Removal

In natural treatment systems such as WSP, the pathogens are progressively removed along the pond series with the highest removal efficiency taking place in the maturation ponds (Mara et al, 1992). However, the following observations can be carried out from different studies that discussed anaerobic ponds" participation in pathogen removal.

- Knorr and Torrella (1995) reported a higher removal efficiency of total coliforms in anaerobic ponds when compared to the facultative ponds. Some figures from this research carried out at a WSP system in the Mediterranean coast of Spain showed removals of one log unit for total coliforms in the anaerobic pond. Mean while, the viral removal efficiency was very poor in the anaerobic pond.
- Arridge et al (1995) working on an experimental WSP complex in Northeast Brazil found a one-log unit removal in the anaerobic pond for each of the following indicators. Faecal coliforms, faecal streptococci and clostriodium perfringens. Salmonellae were reduced from 130 to 70 MPN/100 ml and Vibrio cholerae 01 was reduced from 40 to 10 MPN/L respectively. Anaerobic ponds appear to be essential for high level of V.cholerae removal
- Oragui et al (1995) reported the removal of one log unit for rotaviruses in the anaerobic pond of the experimental WSP complex located in Campina Grand in Northern Brazil.
- Gromason et al (1993) studied the occurrence and removal of crrplosporidium SPP. Oocysts Giardia spp. Oocysts in eleven WSP system located in towns that a significantly higher concentration of Giardia cysts was detected is raw wastewater compared to anaerobic pond effluent

2.3.1.3 Nutrient Removal

Nitrogen

In WSP systems the nitrogen cycle is at work, with the probable exception of nitrification and identification in anaerobic ponds organic nitrogen is hydrolysed to ammonia, so ammonia concentration in anaerobic pond effluents are generally higher than in the raw wastewater unless the time of travel is the sewer is so long that all the urea has been converted before reading the WSP. Volatilization of ammonia seems to be the only likely nitrogen removal mechanism occurring to some extent in anaerobic ponds. Soarse et al (1996) carried out experiment and found that a very low removal of nitrogen in anaerobic ponds.

Phosphorus

The mechanism of phosphorus removal most likely takes place in maturation ponds (Mara et al 1992).

2.3.1.4 Environmental consideration

Physical as well as chemical factors affect the habitant of microorganism and consequently the anaerobic wastewater treatment process. The most important environmental factors to take into consideration are; temperature, pH, degree of mixing, nutrient requirements, ammonia and sulphide control and the presences of toxic compound is the influent (Duggal, 1993)

2.3.2 Facultative Ponds

Facultative ponds (1-2 m deep) are of two types primary facultative ponds, which receive raw wastewater, and secondary facultative ponds which receive settled wastewater (usually the effluent removal on the basis of a relatively low surface loading (100-400kg BOD/had at temperature of a healthy algal population as the oxygen for BOD removal by the pond bacteria is mostly generated by algal photosynthesis. Due to the algal, facultative ponds are coloured dark green although they may occasionally appear red or pink (especially when slightly overloaded) due to the presence of anaerobic purple sulphide-oxidizing photosynthetic bacteria. The algae that tend to predominate in the turbid waters of facultative pond are the motile genera (such as chlamydomona, pyrobotrys and Englena) as these can optimize their vertical position in the pond water column in relation to incident light intensity and temperature more easily than non-mobile forms (such an chlorella, although this is also fairly common is facultative ponds). The concentration of algae in a healthy facultative pond depends on loading and temperature, but is usually in the range 500-2000μg chlorophyll per litre.

How they work?

Effluents entering the facultative pond from anaerobic pond are converted into carbon (iv) oxide, water and new bacteria and algae cells in the present of oxygen- "aerobically".

Algae population within the aerobic ponds requires sunlight. They develop and produce oxygen in excess of their own requirements. It is this excess of oxygen that is used by bacteria to further breakdown the organic matter within the effluent. The algal production of oxygen occurs near the surface of aerobic ponds to the depth to which light can penetrates (i.e. typically up to 500mm). Oxygen can also be introduced by wind

Aerobic pond is move accurately termed "facultative," as in practice the pond usually has an aerobic upper larger and anaerobic lower layer.

This facultative condition occurs because high oxygen level cannot be maintained to the total depth of aerobic ponds. So a fully aerobic surface layer develops along with an aerobic/anaerobic inter mediate layer, and a fully anaerobic layer on the pond bottom oxygen is unable to be maintained at the lower layer if;

- The ponds is too deep and the colour too dark, to allow light to penetrate fully.
- The demand for oxygen in the lower layer is higher than the supply. Demand is increased with high levels of organic matter. The anaerobic layer will be deeper in on aerobic pond where there is an extremely high organic matter content of the in flowing effluent.
- The surface layer, rich in oxygen, is not adequately mixed with the bottom layer
- There is a combination of these condition

As a result of the photosynthesis activities of the pond algae, there is a diurnal variation in the concentration of dissolved oxygen. For a typical facultative pond, the water column will be predominately aerobic at the time of peak sun radiation and predominately anaerobic at sunrise. After sunrise, the dissolved oxygen level gradually rises to the maximum in the mid-afternoon, after which it falls to a minimum during the night. The position of the oxypause (the depth at which dissolved oxygen concentration reaches zero) similarly changes, as does the pH since at peak algae activity, carbonate and bicarbonate ion react to provide more carbon (iv) oxide for the algae, so leaving an excess of hydroxyl ion with the result that the pH can rise to above of which kills faecal bacteria. The wind has an important effect on the behaviour of the facultative ponds, as it induces vertical mixing of the pond liquid Good mixing ensures a move uniform distribution of BOD, dissolved oxygen, bacteria and algae and hence a better degree of waste stabilization. In the absence of wind induced mixing, the algal population tends to stratify in a narrow band, some 20cm thick, during daylight hours. This concentrated band algal moves up and down through the top 50cm of the pond in response to large fluctuation in effluent quality (especially BOD and suspended solids) if the effluent take off point is within this zone. The operation of the facultative pond is shown in fig.3

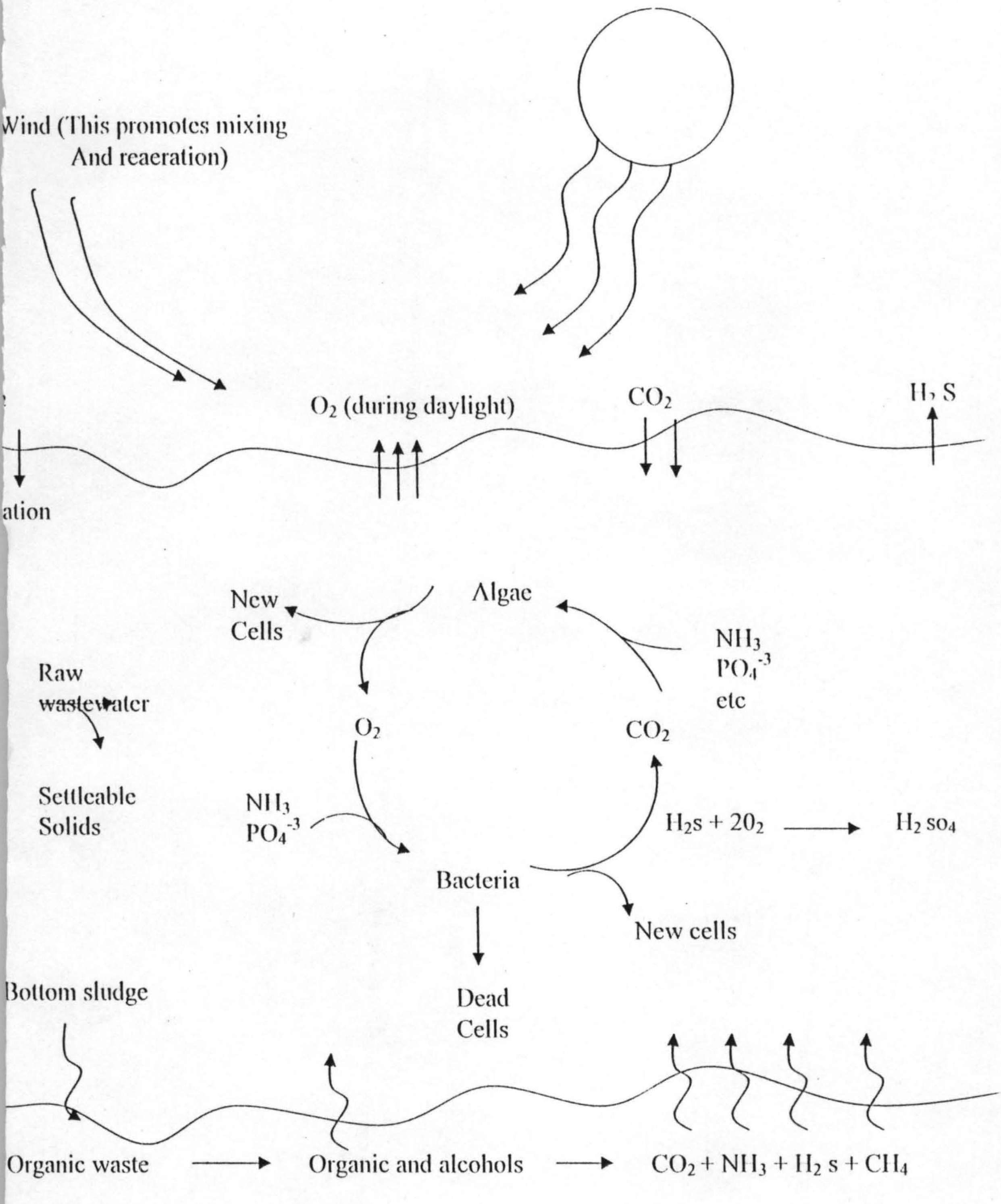


Fig 3: operation of the facultative Ponds (Tchobanoglous and Schroeder, 1987)

The facultative pond will remove odour and kill most pathogenic microorganism. As a complete process the facultative pond serves to.

- Further treat the effluent anaerobically through separation, dissolving and digestion of organic material.
- Aerobically breakdown most remaining organic solids near the pond surface
- Reduce the amount of disease-causing microorganism.
- Allow the lose of 20% to 30% of the ammonia, contained within the effluent, into the air.
- Store residue from digestion, as well as non degradable solid, as bottom sludge
- Allow treated effluent to pass out into a water way or additional treatment system (i.e. an additional pond wetland system of for land application)

Sometimes two or move consecutive similar facultative ponds are constructed instead to a very large one. This many be more practical for effective desludging and stirring or when the pond is too long for the site and interferes with existing structures.

In primary facultative ponds (those that receive raw wastewater) the above function of anaerobic and secondary facultative ponds are combined. Around 30% of the influent BOD leaves a primary facultative pond in the form of methane (Mara, 1976). This type of ponds is designed generally for the treatment of weaker wastes and in sensitive location where anaerobic ponds odours would be unacceptable.

2.3.2.1 BOD Removal

The activity of further anaerobic oxidation and the aerobic conversion of effluent to carbon (iv) oxide, water and new bacteria and algae cells can result in removal of 80% of the BOD of the effluent flowing into the facultative pond (which means an overall removal is the order of 95% over the two ponds). This removal, and the subsequent quality of the out flow, depends on

- An adequate oxygen supply
- Sufficient retention time
- Warm temperature

- An absence of high concentration of chemical pollutants. High concentrations of cleaning chemicals and drenches will slow the system ability to breakdown affluent solids

Moreover, as a result of the algal-bacterial activities described in the previous section, a high proportion of the BOD that does leave the pond as methane ends up as algal cells. Thus is secondary facultative ponds (and in the upper layers of primary facultative pond) "wastewater BOD" is converted into "Algal BOD" and this has important implication for effluent quality requirements. This provides even better BOD quality of the effluent from facultative ponds as most of the BOD contained (70 to 90%) will be "algal BOD"

2.3.2.2 Pathogen Removal: Bacteria Viruses and Parasites

Faecal bacteria are mainly removed in facultative and especially in maturation ponds whose size and number determine the numbers of faecal bacteria (usually modeled in terms of faecal coliforms) in the final effluent, although there is some removal in anaerobic pond principally by sedimentation of solid associated bacteria. The principal mechanism for faecal pond are know to be:

- Time (retention time as pathogen attenuation occurs over time)
- Temperature (faecal bacterial dies off with increase temperature)
- High pH (>9); and
- High light intensity together with high dissolved oxygen concentration

Little is known about the mechanism of viral removal in WSP, but it is generally recognized that it occurs by adsorption on the settleable solids (including the pond algae) and consequent sedimentation. Some parasites can be removed as well. Protozoan cysts and helmeted eggs are removed by sedimentation. Their settling velocities are quite high and consequently most removal takes in the anaerobic and facultative ponds. It has recently become possible to design WSP for helminthes egg removal (Arar, 1992)

2.3.2.3 Nutrient Removal.

Nitrogen

In facultative and maturation ponds, ammonia is incorporated into new algal biomass. Eventually the algae become moribund and settle to the bottom of the pond; around 20% of the algal cell mass is non-biodegradable and the nitrogen associated with the fraction remains immobilized in the pond sediment. That, associated with the biodegradable fraction eventually diffuses back into the pond liquid and is recycled back into algal cells to start the process again. At high pH, some of the ammonia will leave the pond by volatilization. Mara and Pearson (1986) point out that under certain conditions, some algal species are able to adapt to and withstand concentration of up to 50 mg/l.

Phosphorus.

The efficiency of total phosphorus removal is WSP depend on how much leaves the pond water due to sedimentation as organic P in the algal biomass and precipitation as inorganic P (principally as hydroxypatite at pH leaves above 9.5) compared to the quantity that returns through mineralization and resolubilization. The best way of increasing phosphorus removal in WSP is to increase the number of maturation ponds, so that progressively moves and more phosphorus become immobilized in the sediments. From a well functioning 2 ponds system, 70% mass removal of the total phosphorus may be expected

Ieavy Metals

A study by Moshe (1972), that high concentration of metal ions (C_d, C_u,N_i,Z_n and C_r) are oxic to chlorella species, the most common species is stabilization ponds, and adverse ffect: pond efficiency. However, pond pH (>8.0) causes metal ion to precipitate and al ond purification processes to occur normally.

2.3.2.4 Removal of Algae from Facultative Pond Effluents

Many techniques have been developed to remove the algal from the effluent of facultative ponds these include Rock filteration, grass plots, floating macrophytes and herbivores fish. Also, the use of maturation ponds can reduce the algal concentration considerably provided the system is not overloaded

2.3.3 Maturation Ponds

Maturation ponds are used as a second stage of facultative ponds. Their major role is in the removal of pathogenic microorganism such as the viruses bacteria and helminthes. This is achieved by providing a retention time long enough to reduce the numbers to the required level. The number and size of maturation ponds will therefore depend on the standard of effluent, which is required; this is normally expressed as faecal coliform/100 ml. Rational design of maturation ponds is hindered by a lack of information on the mechanism of pathogen removal. There is general agreement that the excreted eggs of helminthes such as Ascaris, Trichuris and taenia are removed by sedimentation, due to their large size (from 20 to 70 μm). Protogoal cyst of organism such as Giardia and Entamoeba behave in a similar way, although they are generally much smaller (14μm long and 8μm) broad in the case of Giardia, and thus require longer retention times. Removal will take place across the pond series and complete removal can be expected in pond, with overall retention times of 11 days or more. Although they are removal from the pond effluent, they are not necessarily inactivated, and can remain viable in the sludge layer for several years, this is an important consideration during disludging.

Over 100 different viruses are excreted by man in his faeces, and very little is known about their survival is ponds. As most viruses carry a strong negative charge, it is assumed that the major mechanism for their removal is adsorption to particulate material, followed by sedimentation. The limited data available suggest that ponds with overall retention times of greater than 30 days should achieve at least a 4 log reduction in enteroveruses and a 3 log reduction in numbers of enter uses. In a similar way to the helminthes, removal from the effluent does not mean inactivation, and virus may be capable of remaining viable in the sludge layer for long periods.

2.3.3.1. Pathogen Removal Mechanics

The faecal caliform bacteria have been universally adopted as indicators of excreted pathogen removal consequently much of the work into elucidation of removal mechanisms has been carried out using these bacteria. The rate of die-off of faecal coliforms is maturation ponds is much faster than in other pond types and increases with increasing temperature. A number of mechanisms have been suggested for pathogen removal in maturation ponds of which the most important ones are nutrient starvation, enhanced pH, high dissolved oxygen concentration, lethal UV irradiation from sunlight and protozoa predation. All of the above mechanism are closely inter linked; for instance increased sunlight causes increase UV irradiation, and by stimulating algal photosynthesis leads to an increased pH and dissolved oxygen concentration. It is therefore difficult to delineate and quantify the contribution of each potential removal mechanism, thus this approach has not yet featured is pond design.

In addition to reduced pathogens, the effluent from maturation pond is also lower in suspended solids. The suspended solids content of a facultative pond effluent is composed mainly of algae. These are predominantly motile flagellates which form dense bands of most effectively utilize the incident sunlight. In maturation pond these are replaced by non – motile algae, which out grow the flagellates due to the increased light penetration. As these algae are non-molite that are distributed evenly throughout the pond and their concentration in the effluent is reduced.

2.3.3.2 Nutrient Removal.

Algae play a further role in maturation ponds by removing nitrogen and phosphorus. The major mechanism of phosphorus removal is sedimentation as organic phosphate, at elevated pH value, phosphate becomes insoluble and chemical precipitation occurs. Many algae, such as the cyanophytae, are able to store phosphate in the form of granules, and algae also represent the largest fraction of bound organic phosphate in the pond. The transition from the anaerobic layer of a facultative pond to an aerobic pond theoretically provides ideal conditions for luxury uptake of phosphate by Acinetobacter calcoaceticus, but there are as yet us report of this organism contributing to phosphate removal in ponds.

A similar removal mechanism appears to operate for nitrogen in maturation ponds. Soluble nitrogen is almost exclusively in the form of ammonia, and algae in preference of nitrate nitrogen take up this form. This nitrogen will enter the pond sediments as organically bound nitrogen when the algae tie and settle, and although a fraction of it is biodegradable up to 60% remain in degraded in the pond sediment.

2.4 Other Methods of Wastewater Treatment

2.4.1 Conventional Treatment

Conventional treatment is the term used to describe the standard method of wastewater treatment is temperate climates. It comprises four stages of treatment.

1. Preliminary treatment
2. Primary or physical treatment
3. Secondary or Biological treatment (biofilteration or activated sludge)
4. Sludge treatment (anaerobic digestion of sludge produced in stage (2) and (3))

2.4.2 Aerated Lagoons

Aerated lagoons are activated sludge unit operated without sludge return. Historically they were developed from waste stabilization ponds in temperate climates where mechanical aeration was used to supplements the algal oxygen supply in winter. It was found, however that soon after the aerators where put into operation the algae disappeared and microbial flora resembled that of activated sludge. They achieve a BODs removal of $> 90\%$.

2.4.3 Oxidation Ditches

The oxidation ditch is a modification of the conventional activated sludge process. It essential operational features are that it receives screened or comminuted raw wastewater and provides long retention times. The hydraulic retention times are commonly 0.5 – 1.5 days and that of solids 20 – 30 days. The major difference from the conventional process lie is shape and type of aerators. The oxidation ditch is a long continues channel, usually oval is plans and 1.0-15m deep. The ditch liquor is aerated by one or more cage rotors placed across the channel. The rotors also impart a velocity of 0.3-0.4 m/s to the ditch contents, sufficient to maintain the active solids is suspension.

2.4.4 Septic Tanks

Septic tanks are small rectangular chambers, usually sited Just below ground level, in which wastewater is retained for 1-3day. During this time the solid settle to the bottom of the tank where they are digested anaerobically. A thick crust of scum is formed at the surface and this help to maintain anaerobic conditions. Although, digestion of the settled wastewater (solids) is reasonably good, some sludge accumulates and the tank must be desludge at regular internals usually once every 1-5 years. Although septic tanks are used to treat the wastewater from individual household, they can be used as a communal facility for population up to about 300. All the household wastewater should be led to the septic tank.

2.5 Effluent Re-Use

2.5.1 Re-Use and Reclamation

The general scarcity of water in the tropics and subtropics and the high costs of developing new water supplies are the two major factors responsible for the increasing recognition of the need to conserve water resources by effluent re-use (e.g. for aquaculture or irrigation) or by affluent reclamation to produce a water suitable for industry (e.g. cooling water) or even one of drinking quality

2.6.2 Aquaculture

Aquaculture means “water farming” just as agriculture means ‘ field farming’. It is the growing of plant and animal for their eventual harvesting as food, either for man or domestic animals; rice growing is a classic example of aquaculture. The dense algal booms is waste stabilization ponds not only provide oxygen for the bacterial oxidation of the influent wastewater, they are also a reliable food source being approximately 50% protein. The algae may be harvested from maturation pond effluent by one of several tertiary treatment processes and then used as an animal food supplement. They have been successfully fed to chickens, pig, cattle and sleep. Since tertiary treatment process is difficult to maintain and install, the algal protein is WSP is most conveniently exploited by growing algae-eating fish in the maturation ponds. The tilapia is particularly tolerant of high algal densities and grows extremely well in maturation ponds, moreover it very good to eat. Other type of fishes can also be grown in the maturation pond.

2.5.3 Agricultural Reuse

The re-use of effluent is agricultural practice is mostly restricted to crop irrigation, stock watering is out recommended because of health risk to the animals. The two major considerations that govern the suitability of an effluent for irrigation are its chemical quality and the potential risk to public health arising from its use. The hazard to health can be reduced by the treatment of wastewater before use in Agriculture, but such treatment is often impossible for economic reasons. It is a poor practice to use raw wastewater for irrigation. This consideration is based solely on the health risks to those working on such an irrigation scheme and to the general public which way consume contaminated produce.

2.5.4 Municipal Re-Use

Effluent which has received tertiary treatment which include chlorination is suitable for watering municipal parks and golf courses and street flushing. It is often cheaper to use effluent for these purposes than fully treated drinking water. Effluent can also be used in municipal fishpond to replace evaporation losses and provide nutrients. It is now technically possible and economically feasible to reclaim maturation pond effluent and even wastewater that has received only primary settling.

2.5.5 Industrial Reuse

The reuse of water within industry is often practiced as a means of minimizing water charges, the most common example being the re-use of the wastewater of one process as cooling water for another. Wastewater effluent has been used as industrial cooling water but this practice is not wide spread as a result of the troublesome growth of slime organisms is pipes and cooling towers

2.6 Irrigation Methods

The methods of applying irrigation water may be classified as subsurface, surface, sprinkler, and trickle irrigation.

2.6.1 Subsurface irrigation

This is where water is applied below the surface of the soil. The system maintains a water table allowing the water to move up through the root zone by capillary action. Water may be introduced into the soil profile through open ditches, mole drains, or pipe drains. Since subirrigation allows no opportunity for leaching and establishes an upward movement of water, salt accumulation is a hazard, thus the salt content of the water should be low.

Water may also be introduced into the soil through perforated pipes. Water introduced into these pipes moves throughout root zone by capillary action. (Uguru, 1981)

2.6.2 Surface Irrigation

This include wild flooding where the flow of water is essentially uncontrolled and surface application where flow is controlled by furrows, corrugations, border dikes, contour dikes, or basins. Except in the case of wild flooding, the land is carefully prepared before irrigation water is applied. In order to conserve water, the rate of water application should be carefully controlled and the land properly graded. (Uguru, 1981)

2.6.3 Sprinkler Irrigation

This is the use of irrigation pipe systems for distributing water to sprinkler heads. Lightweight portable pipes with slip joint connection are common. It is particularly common is humid region because surface ditches and prior land preparation are not necessary and because pipes are easily transported and provides no obstruction to farms operations when irrigation is not needed. It provides reasonably uniform application of water. On coarse - textured soil, water application efficiency may be twice as high as with surface irrigation (Uguru, 1981).

2.6.4 Trickle Irrigation

It could also be known as the drip system where water is applied at low rate often to individual plants. This rate is accomplished through the use of specially designed emitters or porous tubes. These system provide an opportunity for efficient use of water because of minimum evaporation losses and because irrigation is limited to the root zone due to high cost, their use is generally limited to high value crops. Since the distribution pipes are usually at or near the surface, operation of field equipment is difficult. Both sprinkler and trickle system are well adapted to application of agricultural chemical, such as fertilizer & and pesticides with the irrigation water (Uguru, 1981).

2.7 Filteration

Filteration is a purification process where water to be treated is passed through a filtering media which is permeable for liquid and impermeable for solid particles. The process involves a large drop of pressure and therefore, a substantial consumption of energy.

When water is passed through a layer of granular material, three kinds of filteration are possible,

1. Retention of impurities on the surface of filtering bed which is described by Hansen's formula

$D = 0.01\ (d_{ef}V)^{0.5}$

Where D= diameter of the smallest particles which are retained, mm;

d_{ef} = effective diameter of grains of the medium

V = Rate of filteration m/h

2) Retention of impurity particles is pores of the filtering bed (volume filteration)

3) Simultaneous formation of a film of impurities and deposition of impurities in pores of the filling

It's found that the bacteria removal decreased as filteration rate is increased, as water temperature decrease, as bed depth decreased and the size of the medium is increase

2.7.1 Mechanics of filteration

Water is introduced at low velocity to replace filtered water. Unfiltered water passes through a filter media, where near the surface the fine media eliminate or reduce incoming turbidity. The filter water is conveyed through the supporting media and an under drained system to a storage area. When filter experiences a loss of head due to difficulty of unfiltered water to pass through the fine media, the filter beds are drained and water pressure is provided under the filter media to backwash the fine media and settled at the top

2.7.2 Filtering material

The choice of one is governed by its cost, availability at the construction site, and certain engineering requirement such as uniformity of grain size, mechanical strength and chemical stability of the material. The grains size distribution is usually determined by sieve analysis.

2.8 Rice Husk

The Rice husk is obtained as a by-product in rice milling. It is not valuable as food, not only because of its low nutritive value, but because of its high silica content renders it harmful to the digestive and respiratory organs of animals. Its chief use is as fuel to supply power for the mill. It's also a building material. Due to its binding agent or properties, it contains the following chemical composition as shown in table 2.3 below.

Table 2.3: Typical chemical composition of Rice husk

Constituents	Percentage %
SiO_2	92.15
Al_2O_3	0.41
Fe_2O_3	0.2
CaO	0.41
M_gO	0.45
Na_2O	0.08
K_2O	2.13

Source, Uguru, (1981)

It can be seen that Rice husk contains the highest percentage of silica

2.9 Composition of Clay

The clay-size grade minerals, which make up the rock clay, are always present in varying percentages. Coarser grades composed generally of the non-clay minerals are thus also present in varying relative amounts. In addition to clay minerals and water- soluble salts.

The designation of a material as clay is often based solely on its bulk properties and appearance. Importantly, in many such materials the clays-size grade and clay mineral fraction comprise less than 50% of the total rock. A more complete study and analysis of the materials often warrant classification of the rock as silk or even sand.

Some material called clay does not meet all the above specifications-so-called flint clay, a refractory ceramic clay, does not develop plasticity when mixed with water. It does, how ever, have the other attributes of clay.

Some times sedimentary rocks are substantially of the same composition as clay, but differ from clays in their textual characteristics. The expression clay material is often used for any fine-grained, natural, earthly, argillaceous material, when a more precise designation is not possible or desirable. Clay materials include clays, shales, and argillites. Soils would also be included if such materials contain an appreciable quantity of clay size grade materials and were argillaceous.

CHAPTER THREE

METHODOLOGY

For the reuse of domestic wastewater for irrigation to be successful, i.e. cause no harm to the farmer and the crops to be irrigated; it has to be treated to meet the FAO /WHO standards. The processes involved include the design and construction of a Waste Stabilization Pond; which is the cheapest and most efficient method used in the treatment of domestic wastewater especially in hot climate where sufficient land is available and where the temperature is most favourable for their operation.

3.1 Design Parameters

The most important parameter for facultative pond and maturation pond design are:

3.1.1Temperature: The usual design temperature is the mean air temperature in the coldest month or period of irrigation. From data collected pond the meteorological center in Minna Airport, the coldest temperature and their corresponding month are shown below in table 3.1.

Table 3.1 Months and their corresponding temperatures

Month	Temperature (^{0}C)
June	30
July	27
August	25
September	26
October	30
November	32

The mean temperature can be calculated, thus

$$\frac{(30+27+25+26+30+32)^0C}{6} = \frac{170}{6} = 28.3^0C$$

Therefore, the average coldest temperature is 28.3^0C

3.2.1 Wastewater Flow

A suitable flow design value is 80% of the in house water consumption. This is dependent on population, per capital consumption.

The population of male students in Q block (Sheraton) hostel was determined as follows.

We have, 120 rooms

8 Bed spaces per room

An average of 6 squatters per room.

Therefore, we have 8 + 6 = 14 people per room.

This implies that, 14 x 120 = 1680 people in Q block (Sheraton) hostel.

From Questionnaire carried out in Q block of the Boys hostel, An average Person use the quantity of water for the following domestic activities as in shown in Table 3.2 below.

Table 3.2. Quantity of water and corresponding domestic activity

Domestic activity	Quantity used (L/day)
Drinking	3.0
Cooking	8.0
Launching	20.0
Bathing	30.0
Sanitation	20.0
Washing of plates	10.0
Total	91.0

Thus, the total quantity of water used by the boys in the hostel is Q

Q = population x per capital used

= 1680 x 91

= 152,800 litres / day = $152.88m^2$ / day.

152.88m3 / day are the in house water consumed in the hostel.

Since 80% of the water consumed is given as the wastewater flow, therefore, Q, which is the daily wastewater flow, is given as

$$Q = \frac{80}{100} \times 152.88 = 122.30 m^3 / day$$

122.30m3 / day of wastewater is given off in the Q block of the Boys hostel.

3.1.3 Biochemical Oxygen Demand $(BOD)_5$

This is the amount of dissolved oxygen used by bacteria for the chemical oxidation of organic matter after a 5-day incubation period at 20^0C.

The BOD_5 of the influent wastewater samples was determined by the BODTrack equipment at the Water Monitoring Control Laboratory, Minna. The procedures used are stated below:

1. The sample was heated to within 2^0C of its inoculation temperature, usually 20^0C.
2. Using a clean graduated cylinder, the sample volume was poured into a BODTrack sample bottle.
3. A 3.8cm magnetic stir bar was placed in each sample bottle
4. The content of one BOD nutrient Buffer pillow was added to each bottle for optimum growth of bacteria.
5. Stopcock grease is then applied to the seal lip of each bottle and to the top of each seal cup.
6. A seal cup was placed in the neck of each bottle.
7. Using the funnel, the content of one lithium hydroxide powder pillow was added to each seal cup. Lithium hydroxide particles are not allowed to face into the sample. If this occurs, the sample is discarded and a fresh one is prepared.
8. The bottles are placed on the chassis of the BODTrack, the appropriate tubes is connected to the sample bottle and firmly tighten to the cup. Each tube is tagged with the channel number and the channel number set up will be reflected on the control panel.

9. The instrument is placed in the incubator

10. The instrument is started (connect the electrical play and turn on the instrument).

11. It was ensured that all the stir bars are rotating. If a stir bar slide to the side of the bottle, the bottle is lifted off the nut and gently replaced. The channel is not started until the stir is rotating properly.

12. The test duration is selected.

13. To start a test, the channel number corresponding to the bottle is pressed.

14. The ON key is pressed. A menu for selecting was displayed and the required range is selected.

15. The ON key Press and held to start a test. A graph will be displayed

16. The BOD result is read from the BODTrack displayed by pressing the key corresponding to the sample.

17. A brush and soapy water is used to clean the bottle. Stir bars suds seal cup and it is rinsed thoroughly with distilled water.

From the BOD_5 test, the influent BOD_5 of the wastewater sample was given as 356mg/l.

3.2 Microbial Analysis of Wastewater

The microbiological quality of wastewater is expressed in terms of the concentration and frequency of occurrence of particular species of bacteria. This analysis was done at the Microbiology Laboratory of Federal University of Technology Minna. The following tests were conducted.

3.2.1 Presumptive Test

This is the preliminary test of water sample. It gives an idea of water sample condition. The result of the test is shown in chapter 4.

3.2.2 Confirmatory Test

This is the analysis to confirm the result obtained from preliminary test. It involves the use of solid medium so as to know the colonial morphology of the microorganism isolated

3.2.3Completed Test

This is the final analysis of sample. It involved the grains morphology that explains the evolutionary trend of microorganism in a given sample. It was followed by series of biochemical test so as to know the name of microbial isolates and their pathogenicity; that is, disease causing or not. All the result are shown in the next chapter

3.3 Design Preliminaries

The design of waste stabilization pond is part rational and part empirical. The ranges of depth are as follows;

Facultative pond	1-1.5m
Maturation pond	0.4 – 1.2m

The length and breath ratio are usually 2:1 or 3:1 (Mara, 1976)

The area of the pond is given as

$$A = \frac{Qt}{D} \quad \text{.......} 1$$

where; Q = Volumetric flow rate, m^3 / day

t = detention time, day

D= periods depth. (m)

The surface BOD_5 loading λ_s is the weight if BOD_5 applied per unit area per day and this is given by;

$$\lambda_s = L_i Q \quad \text{.......} 2$$

Where; $L_i = BOD_5$ of influent

Expressing λ_s in its normal unit Kg /ha.d

$$\lambda_s = \frac{10^{-3} L_i Q Kg./d}{10^{-4} Aha} = \frac{10 L_i Q}{A} {Kg}/{had} \text{.......} 3$$

An alternative equation for λ_s, given by "McGarry and Pescod" empirical procedure is,

$$\lambda_s = 20T - 120 \text{.......} 4$$

T is in ^{0}C

Volumetric flow rate have some time been used.

$$\lambda_v = \frac{L_i Q}{AD} \text{.......} 5$$

$$But, \ t = \frac{AD}{Q} \text{.......} 6$$

$$thus, \ \lambda = \frac{L_i}{t} \text{.......} 7$$

3.4 Design of Facultative Pond

Assuming that the pond is completely mixed reactor in which BODs removal follows first order kinetics.

$$\text{Thus,} \quad \frac{dL}{dt} = -K_1 L \text{.......} 8$$

L is quantity of BOD remaining at time t

K_1 is first order rate constant for BOD removal

$\frac{dL}{dt}$ is the rate at which the organic matter is oxidized and the minus sign indicates a decrease of L with time.

Integrating equation (8)

$$\int \tfrac{dl}{L} = -K_1 \int dt$$

$$\ln L \quad = -K_1 t$$

$$\ln(L - L_0) = -K_1 t$$

$$\ln \frac{L}{L_0} = -K_1 t$$

$$\frac{L}{L_0} = e^{-K_1 t} \quad \text{.......................} 9$$

L_0 = amount of BOD before oxidation occur, also known as the ultimate BOD

$$L = L_0 e^{-K_1 t} \quad \text{.......................} 10$$

$$Y = L_0 - L \quad \text{.......................} 11$$

Y = BOD satisfied at any time

Substituting equation 10 into 11

$$Y = L_0 - L_0 e^{-K_1 t}$$

$$Y = L_0\left(1 - e^{-K_1 t}\right) \quad \text{.......................} 12$$

Equations 10 and 12 describe the bio – oxidation of a given quantity of organic matter to which no further addition is made. They represent conditions in a batch oxidation process. But wastewater treatment works operates a continuous inflow of wastewater and a continuous outflow of treated effluent.

Thus, the quantity of organic matter entering the reactor per day must equal the quantity leaving the reactor per day plus that removed by bio – oxidation.

Quantity of BOD entering the reactor, g/d = L_i Q

Quantity of BOD leaving the reactor, g/d = L_e Q

Quantity of BOD removed in g/d by bio – oxidation per unit volume (m^3)

Is equal to K_1 L_eV

Where,

L_i = BOD of influent

L_e = BOD of effluent

V = working volume of the reactor

Q = the flow in m^3/d

So that;

$$L_iQ = L_eQ + K_1L_eV \qquad \text{.......13}$$

Dividing through by Q

$$L_i = L_e + K_1L_e V/Q$$

Divide through by L_e

$$\frac{L_1}{L_e} = 1 + K_1\frac{V}{Q}$$

$$\frac{L_e}{L_1} = \frac{1}{\left(1 + K_1\frac{V}{Q}\right)}$$

The ratio V/Q is the mean hydraulic retention time t,

Thus, $$\frac{L_e}{L_1} = \frac{1}{(1 + K_1t)} \qquad \text{.......14}$$

Cross-multiplying

$$L_e(1+K_1t)=L$$

$$1+K_1t=\frac{L_1}{L_e}$$

$$K_1t=\frac{L_1}{L_e}-1$$

$$t=\left[\frac{L_1}{L_e}-1\right]\frac{1}{K}\text{.........}15$$

Substituting t into equation 1

$$A=\frac{Qt}{D}$$

Therefore, $\mathrm{A}=\frac{\mathrm{Q}}{\mathrm{DK}_1}\left[\frac{L_i}{L_e}-1\right]=\frac{Q}{DK_1}\left(\frac{L_i-L_e}{L_e}\right)$ 16

The rate constant varies with temperature because it is temperature sensitive. This is described by Arrhenius equation of the form,

$K_T = K_{20}\,\theta^{T-20}$

K_T and K_{20} = value of K for T^0C and 20^0C

θ = Arrhenius constant which is usually between 1.01 and 1.09 for wastewater treatment process. But for waste stabilization ponds, θ is between 1.05 and 1.09.

From literature, K_1 for raw wastewater is $0.3d^{-1}$ and the value should be in the range 50 – 70 mg/L for pond depth of 1- 1.5m

Thus, $K_{1(T)} = 0.3\ (1.05)^{T-20}$ 17

Substituting equation 17 into 16

$$A=\frac{Q(L_1-60)}{18D(1.05)^{T-20}}\text{.........}18$$

A = Area of the pond

Q = volumetric flow rate = Daily flow of wastewater which was determined as 122.30m^3/day

D = Depth of the pond which is 1.5m

T = Average temperature of the coldest month and was determined to be 28.3^{0}C.

L_i = BOD_5 of the influent and was estimated as 356mg/L

$$Area = \frac{122.3(356-60)}{18\times 1.5(1.05)^{28.3-20}}$$

$$= 36200.8/40.48 = 894.29\text{m}^2$$

$$\text{Detention time } t = \frac{AD}{Q}$$

$$t = \frac{894.29 \times 1.5}{122.3}$$

$$= 10.96\text{days}$$

$$= 11 \text{ days}$$

The length and breath ration of a facultative pond is usually 3:1

3x X x= area of the pond

$3x^2 = 894.29$

$x^2=894.29/3 =298.10m^2$

$x=(298.1m^2)^{1/2} =17.3m$

therefore, $3x =3x\ 17.3=51.9m$

The dimensions of the ponds are as follows,

Length = 51.9m

Breath = 17.3m

Depth = 1.5m

3.3 Design of Maturation Pond

3.3.1 Design Consideration

1. The minimum acceptable value of t_m is 3days, below which the danger of hydraulic short-circuiting becomes too great.

   t_m = detention time in maturation pond.

2. The value for t_m should not be higher than that of t_f.

   t_f = detention time in facultative pond

3. The surface BOD loading on the first maturation pond does not exceed the surface BOD loading on the facultative pond.

3.5.2 Bacterial Reduction

The reduction of faecal bacteria in a pond whether anaerobic, facultative or maturation has been found first order kinetics, which is given by

$$N_e = \frac{N_1}{1 + K_b t}$$

N_e = number of faecal coliform /100ml of effluent

N_i = number of faecal coliform/100ml of influent

K_b = first order rate constant for FC removal, d^{-1}

For a system of facultative pond and n number of maturation ponds, equation 1 becomes

$$N_e = \frac{N_1}{(1 + K_b t_f)(1 + K_b t_m)^n}$$

Where

t_f = detention time in facultative pond

t_m = detention time in maturation pond

n = number of maturation pond

N_i = 1 x 10^8 FC/100ml, this is higher than average value normally found in practice

$t_f \quad = 11\text{days}$

From the design consideration, $t_f > t_m$, and $t_m \geq 3$days. Thus, we assume,

$t_m \quad = 4\text{days}$

Assume n = 2

$$K_b = 2.6\,(1.19)^{T-20}$$

$$= 2.6(1.19)^{28.3-20}$$

$$= 11.02\text{d}^{-1}$$

$$N_e = \frac{1.0 \times 10^8}{[1 + (11.02 \times 11)][1 + (11.02 \times 4)]^2}$$

$$= \frac{1.0 \times 10^8}{(122.22)(2032.21)}$$

$$N_e = 402.61 \ FC/100ml$$

The value of N_e, signifies that the 2 maturations and 1 facultative ponds will treat the domestic wastewater, and the effluent can only be used for restricted irrigation whose limit is 5000 FC/ 100ml

Assuming n =3

$$N_e = \frac{1.0 \times 10^8}{(122.22)(45.08)^3}$$

$$= 8.93 FC/100ml$$

The value of N_e signifies unrestricted irrigation effluent standard that is 100 FC/100 ml.

Thus, 3 maturation ponds are satisfactory for the treatment of Boys hostel wastewater (Q block) along with one facultative pond.

$\therefore$ Area of maturation pond $= \dfrac{Qt_m}{D}$

$Q =$ daily flow of wastewater = $122.3m^3 / day$

$t_m =$ detention time of maturation pond = 4days

$D =$ depth of maturation pond = 1.2m

$$Area = \frac{122.3 \times 4}{1.2}$$

$= 407.67m^s$

Each of the ponds will have an area of $407.67m^2$

Length to breath ratio is 3:1

Let x= Breath of the pond in m

Length x breath = $3x \times x =$ Area

$3x^2=407.67m^2$

$x^2=407.67/3=135.89m^2$

$x=(135.89m^2)^{1/2}=11.6$

$3x^2=11.6 \times 3=34.97=35m$

The dimensions of each of the maturation ponds are: -

Length = 35m

Breath = 12m

Depth = 1.2m

3.6 Modelling of Facultative Pond

Using a scale of 1: 14.1 model; the daily flow of wastewater in the model can be computed.

By equating Froude numbers Fr;

$Fr_m = Fr_p$

Where, subscript m and p are models and prototype respectively,

$$Fr = \frac{V}{\sqrt{Lg}}$$

V = flow velocity

L = length

g = acceleration due to gravity

Thus :

$$\left(\frac{V}{\sqrt{Lg}}\right)_m = \left(\frac{V}{\sqrt{Lg}}\right)_P$$

Since g is a constant,

Then,

$$\frac{V_m}{\sqrt{Lg}} = \frac{V_p}{\sqrt{Lg}} = \frac{V_m}{V_p} = \sqrt{\frac{L_m}{L_p}}$$

Flow rate may be determined by introducing the area ratio,

$$\frac{A_m}{A_p} = \left(\frac{L_m}{L_p}\right)^2$$ (By dimensional analysis)

$$\frac{A_m}{A_m} = \left(\frac{L_m}{L_p}\right)^2 = (scale)^2 = \left(\frac{1}{14.1}\right)^2$$

$$\frac{Q_m}{Q_p} = \frac{A_m V_m}{A_p V_p} = \frac{L^2_m}{L^2_p} \times \sqrt{\frac{L_m}{L_p}}$$

$$\frac{Q_m}{Q_p} = \frac{A_m V_m}{A_p V_p} = \frac{L^2_m}{L^2_p} \times \sqrt{\frac{L_m}{L_p}}$$

Where Q_m and Q_p are the daily wastewater flow in the model and prototype respectively

$$\frac{Q_m}{Q_p} = \left(\frac{L_m}{L}\right)^2 \left(\frac{L_m}{L}\right)^{0.5}$$

$$= \left(\frac{L_m}{L}\right)^{2.5}$$

$$Q_m = Q_p \left(\frac{L_m}{L}\right)^{2.5}$$

Q_p $= 122.3\text{m}^3$ /day (from previous calculation)

$= (122.3 / (60 \times 60 \times 24))\ \text{m}^3/\text{s}$

Q_p $= 0.00142\ \text{m}^3/\text{s}$

Q_m $= 0.00142\ (1 / 14.1)^{2.5}$

$= 1.9 \times 10^{-6}\ \text{m}^3/\text{s}$

$= 0.1643\ \text{m}^3$ / day (164.3 L / day)

But $Q = \frac{AD}{t}$

Where

A = Area (m^2)

D = depth (m)

t = detention time (day) = 11days

Q = daily wastewater flow (m^2/day)

Qt = AD

Using a scale of 1:3.2 for the model to prototype detention time

t = 3.43days

$(0.1643 \times 3.34)\text{m}^3$ = AD = Volume of model pond

0.5365m^3 = volume of the model pond

Using a scale of 1:2.14 for the model depth

$$\frac{D_p}{D_m} = \frac{1}{2.14}, D_m = \frac{D_p}{2.14}$$

Where D_m and D_p are model depth and prototype depth respectively

$D_p = 1.5m$

$$D_m \frac{1.5}{2.14} = 0.7m$$

$$0.563m^3 = 0.7A$$

Area of model pond = $\frac{0.5635m^3}{0.7m} = 0.805m^2$

Area = $0.805m^2$

Using a length to breadth ratio of 1:1.64

⇨ $1.64X^2 = 0.805m^2$

$$x^2 = \frac{0.805m^2}{1.64} = 0.49m^2$$

$$x = (0.49)^{1/2} = 0.7m$$

$$1.64x = 0.7 \times 1.64 = 1.15m$$

Dimensions for the model facultative pond are

Length = 1.5m = 115cm

Breadth = 0.7m = 70cm

Depth = 0.7m = 70cm

3.7 **Modelling of Maturation Pond**

Also using a scale of 1:14.1, the daily scale wastewater flow to the maturation pond was estimated as

$Q_m = 0.1643m^3$ / day

$$Q = \frac{AD}{t}$$

t = 3 days for maturation pond.

A scale of 1:1.33 was used for the detention time in maturation pond (model) to that of the prototype

Qt = AD

0.1643 x 3 = volume of the maturation pond

$0.4929m^3$ = volume of pond.

Volume = area x depth

Using a scale of 1:2.4 for the model depths

$$\frac{D_m}{D_p} = \frac{1}{2.4}$$

$$D_p = 1.2m$$

$$D_m = \frac{D_p}{2.4} = \frac{1.2}{2.4} = 0.5m$$

$$\text{Area} = \frac{\text{Volume}}{\text{Depth}}$$

$$= \frac{0.4929}{0.5} = 0.9858\text{m}^2$$

Using a length to breadth ratio of 1:1.6

$$1.6x^2 = 0.9858m^2$$

$$x^2 = \frac{0.9858}{1.6} = 0.616m^2$$

$$x = \sqrt{0.616m^2} = 0.78m$$

$$1.6x = 1.2m$$

Dimension of the model maturation ponds are;

Length = 1.2m = 120cm
Breadth = 0.78m = 78cm
Depth = 0.5m = 50cm

3.8 Filter Design and Construction

3.8.1 Filter box

The design consideration for the filter box is an follows:-

- Filter area should be according to required capacity of the treatment plant
- Always provide 2 or more units for cleaning reason.
- The shape of the box used is rectangular

3.8.2 Filter Media

The filter media used is the clay. It was molded in a circular shape with an effective diameter of 10 to 15mm. the filter bed thickness is 1-1.5m and it should not be lower than 0.6m.

3.8.3 Filter bottom

This has two tasks;

- Support of filtering materials
- Provision of outlet and even extraction of filtered (effluents)

The following criteria must be observed:

i. $d_{90}/d_{10} \leq \sqrt{2} = 1.41$ for each layer of gravel

ii. The diameter of the top most ($\varnothing_{top}$) layer should be at least such that:

$4 \times d_{15} \leq \varnothing_{top} \leq 4 \times d_{85}$

iii. From layer to layer the gravel size should increase by a factor of ≤ 4

iv. With regard to clogging of the under drainage system, the diameter of the bottom layer ($Ø_{bottom}$) should be at least = 2x Ø opening of drain

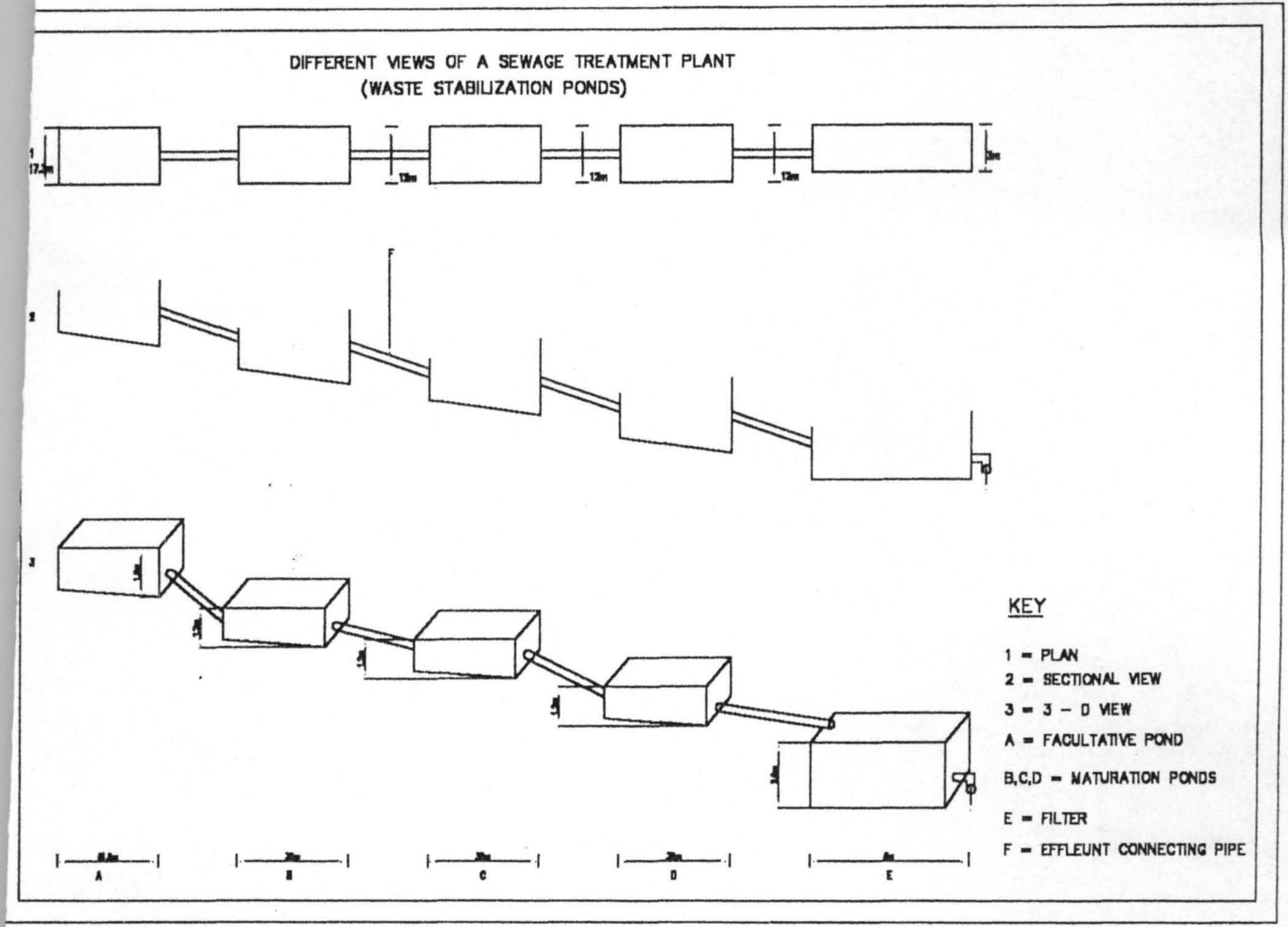
v. Minimum thickness of individual gravel layers;

Finer layers: 5-7cm,

Coarser layer 8-12cm.

3.9 Experimental Site

The study area is around the side of Q-Block (Sheraton) hostel for the male student. Federal University of Technology, Minna Niger state, Nigeria. It is located approximately 4^0 -14' latitude and 3^0-15' longitude. With an average temperature of 28.3^0C during the irrigation period. Rainfall start in April and Ends in October. The heat from the sun is pretty intense all year round but more during the dry season



DIFFERENT VIEWS OF A SEWAGE TREATMENT PLANT
(WASTE STABILIZATION PONDS)

KEY

1 = PLAN
2 = SECTIONAL VIEW
3 = 3 – D VIEW
A = FACULTATIVE POND
B,C,D = MATURATION PONDS
E = FILTER
F = EFFLEUNT CONNECTING PIPE

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Results

The Bacteriological Examination of wastewater i.e. the microbial analysis of the wastewater before treatment is presented below.

Presumptive test

Table 4.1: Result of presumptive test

Sample	LB 2X 10.0ML			LB 1X 1.0ML			LB 1X 0.1 ML			Reading	MPN
Wastewater from Q-block Hostel FUT minna	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	3-3-3	1,100

Key

LB = Lactose Broth

2x = Double strength

1x = single strength

MPN = Most probable number of microorganism in 1.0 ML of wastewater sample

Confirmatory test

Table 4.2: result of confirmatory test

Sample	EMB	MCA	Portable	Not Portable
Sample from Q-block hostel. FUT Minna	Too numerous to be described	Too numerous to be described	——	✓

Key

EMB = Erosin methylene Blue Algae

MCA = McConkey Algae

Completed test

This is the final analysis of the wastewater and the following microorganisms where isolated in the sample;

1. E. Coli
2. Salmonella Spp
3. Staphlococus Spp
4. Streptococcus Spp
5. Khebsella Spp
6. Pseudomonas aeroginosa
7. Bacillus Spp

The results of the Biochemical oxygen demand (BOD_5) of the various samples after each stage of the treatment are represented below.

Table 4.3: Result of BOD_5 analysis

SAMPLE	OBSERVED BOD_5 mg/L	CALCULATED BOD_5 mg/L	OBSERVED PERCENTAGE REMOVAL %	CALCULATED PERCENAGE REMOVAL %
INFLUENT	356	-	-	-
EFFLUENT FROM FACULTATIVE POND	195	137	45.2	61.5
EFFLUENT FROM SERIES OF MATURATION PONDS	32	18.3	83.6	90.6
FINAL EFFLUENT AFTER FILTERATION	21	-	94.1	-
WATER DOWN STREAM	98			

Calculations

Assuming that the waste stabilization ponds are completely mixed reactors in which the BOD_5 removal follows first order kinetics; therefore

$$\frac{L_e}{L_i} = \frac{1}{1 + k_i t}$$

L_e = BOD_5 of effluent (mg/l)

L_i = influent BOD_5 (mg/l)

K_i = first order rate constant for BOD removal

t = detention time (days)

For facultative pond

$$L_e = \frac{L_i}{1 + k_i t}$$

K varies with temperature according to the equation. $K_i (_T) = 0.3\,(1.05)^{T-20}$

T = Temperature = 28.30°c

$K = 0.3\,(1.05)^{28.3-20}$

$= 0.3\,(1.05)^{8.3} = 0.40\mathrm{d}^{-1}$

$$L_e = \frac{356}{1 + (0.40 \times 4)} = \frac{356}{2.6} = 137 \text{ mg/l}$$

Observed percentage removal

L_i = 356 mg/l

L_e = 195 mg/l (Observed)

$$\% \text{ Removal} = \frac{L_i - L_e}{L_i} \times 100$$

$$= \frac{356 - 195}{356} \times 100$$

$$= 45.2\%$$

Calculated percentage removal

$$\% \text{ Removal} = \frac{365 - 137}{356} \times 100$$

$$= 61.5\%$$

<u>For maturation ponds</u>

$$L_e = \frac{L_i}{1 + k_i t}$$

From the first pond $L_e = \dfrac{195}{1 + (0.4 \times 3)}$

$$L_{e1} = \frac{195}{2.2} = 88.6\text{mg/l}$$

From 2nd pond, $L_{e2} = \dfrac{88.6}{1 + (0.4 \times 3)}$

L_{e2} = 40. 27 mg/l

From the 3rd pond

$$L_{e3} = \frac{40.27}{1 + (0.4 \times 3)} = 18.3 \text{ mg/l}$$

Observed percentage removal

$L_i = 195$ mg/l

$L_e = 32$ mg/l (Observed)

$$\% \text{ Removal} = \frac{195 - 32}{195} \times 100$$

Calculated percentage removal

$$\% \text{ Removal} = \frac{195 - 18.3}{195} \times 100$$

$$= 90.6\ \%$$

After filteration

Observed BOD_5 = 21 mg/l

$$\% \text{ Removal} = \frac{356 - 21}{356} \times 100$$

$$= 94.1\%$$

The overall percentage removal for the treatment plant is **94.1%**

4.2 Discussion of Results

Table 4.1 shows the result of the presumptive test, which is the preliminary test of the wastewater sample. It gives an idea of the wastewater sample condition. It gave the most probable number of microorganism in 100ml of the sample to be 1,100.

Table 4.2. Shows the result of the confirmatory test. This is the analysis to confirm the result obtained from preliminary test. It involves the use of solid medium so as to know the colonial morphology of the microorganism isolated. The result shows that the Erosin methylene blue Algae and the McConkey Algae to be too numerous to be described.

The completed test, which is the final analysis of the wastewater sample, involves the grain's morphology that explains the evolutionary trend of microorganism in a given sample. It is followed by series of biochemical test so as to know the name of microorganisms isolated and their pathogenicity. The names are shown is the previous section. The microbial analysis of the influent wastewater shows that coliforms are too numerous to count and the density of the colonies is too heavy to be counted.

Table 4.3 shows the result of the BOD_5 analysis and it gives the BOD_5 of the influent sample to be 356 mg/L which is higher than WHO/FAO standard for irrigation water quality of $\leq$ 100 mg/L. After the first stage of treatment, which is the facultative pond, the BOD_5 reduced to 195 mg/L. The facultative pond was able to remove 45.2% of the BOD. After the second stage of treatment which comprises 3 maturation ponds is series the BOD_5 was reduced to 32 mg/L. The second stage has a percentage removal of 83.6%. After filteration through the clay media the BOD_5 was reduced to 21 mg/L. This is the final BOD_5 of the treated wastewater which is far less than the WHO/FAO standard for irrigation water quality of $\leq$ 100 mg/L. The total percentage removal of BOD_5 of the treatment process is 94.1%. From table 4.3, it could be seen that the calculated BOD_5 from each stage of the treatment is less than the observed BOD_5. This is because the Ponds are assumed to be completely mixed reactors, that is, oxygen is constantly supplied to the pond at any point by either mechanical mean or other wise; But this is usually not the case with the waste stabilization pond that receives oxygen from the air that blows at the surface.

The effluent from down stream has a BOD_5 of 98mg/l, which is higher than the WHO standard of 25mg/l for discharge into the environment but within the limit of the FAO standard of 100mg/l, thus safe for irrigation.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The result of the microbial analysis of the influent wastewater shows that the microorganism in the influent wastewater will be harmful to the farmer and the crops if they are used for irrigation without any treatment. The BOD_5 result of the influent wastewater is 356mg/L; this exceeds the WHO/FAO standard of 100mg/L for irrigation water. This necessitated the design and construction of treatment system that is cheap and efficient, which is the waste stabilization pond (WSP). The result from the treatment process reduced the BOD_5 to 21mg/L and a significant reduction of the microorganism such as the faecal coliform.

Thus, it is concluded that the effluent from the treatment process can be used for unrestricted irrigation without any harm done to the crop or the farmer. There will be an increased yield because of the nutrient which are contained in the effluent. The effluent can also be used in the industry as cooling water to minimize water charges or in areas where water is scarce. The effluent can also be used for growing Tilapia fish (Sarotherodon mossambica) that is particularly tolerant to high algal densities and grows extremely well in maturation ponds.

5.2 Recommendations

It is recommended that a large-scale construction of this treatment process be made, so that the effluent can be used for irrigation to minimize water charges and ensure availability of portable water for other domestic activities.

It is further recommended that the Federal Environmental Protection Agency (FEPA) should ensure the design and construction of waste stabilization pond in every part of the country to checkmate the unlawful discharge of wastewater into our water bodies.

Also, in the course of analyzing water samples, precision and careful handling of reagents and equipment should be the watchword so as to ensure that results obtained are very accurate and correct.

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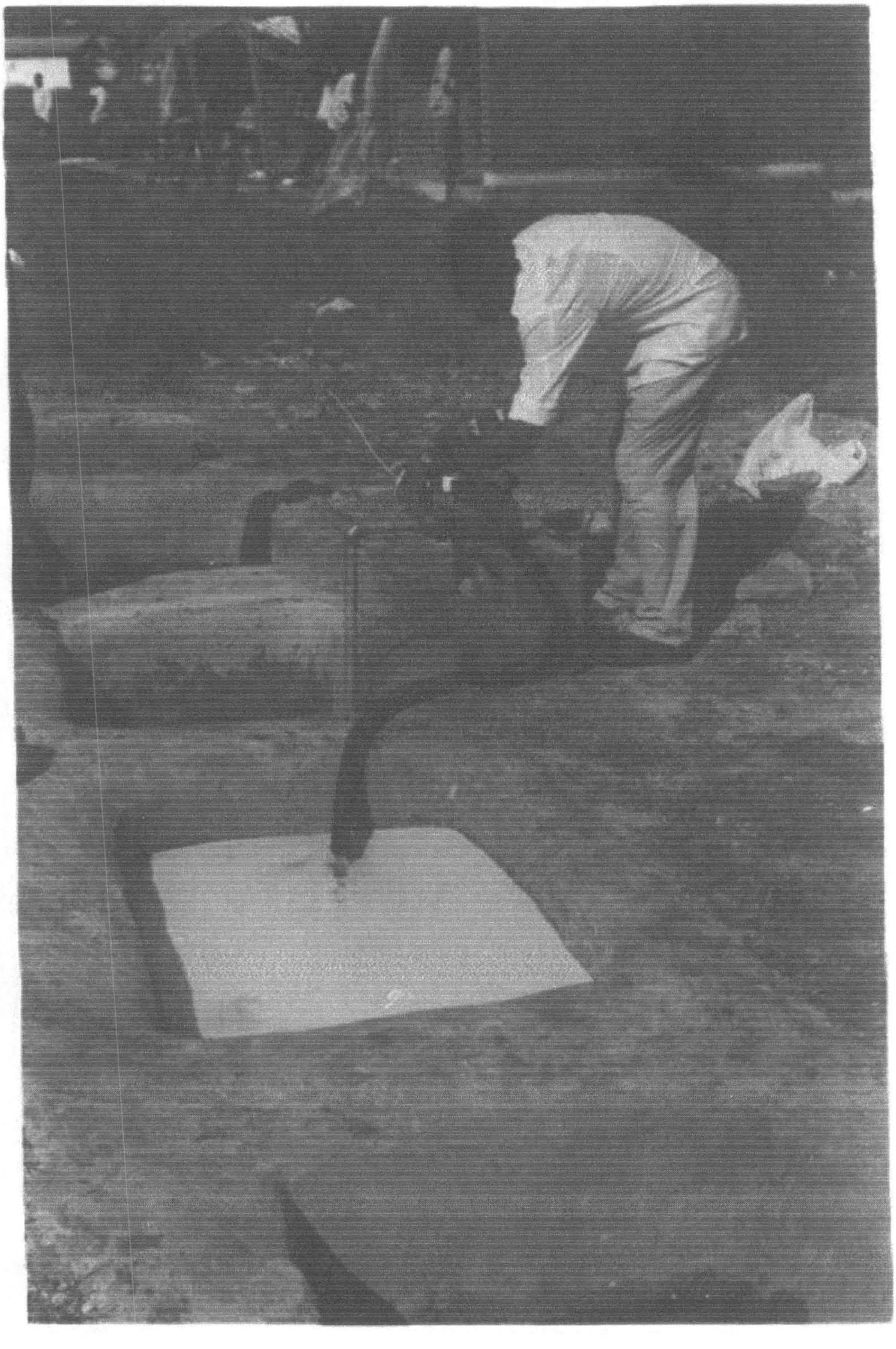
APPENDIX

WASTE STABILIZATION POND

Transfering effluent from facultative Pond to 1st Matuaration Pond



WASTE STABILIZATION POND.

Transfering effluent from 1st Maturation to 2nd Maturation Pond.

EXCAVATION OF POND.