TREATMENT OF TEXTILE WASTE-WATER USING WASTE STABILIZATION PONDS.

BY

AMUSAN, TAOHEED ABAYOMI
B.ENG (CIVIL)

DEPARTMENT OF WATER RESOURCES AND ENVIRONMENTAL
ENGINEERING, AHMADU BELLO UNIVERSITY, ZARIA

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DECLARATION

I hereby declare that the research work presented in this thesis, for the award of Master of Science (Water Resources and Environmental Engineering) has been written and compiled by me. The research, is exclusively the report of the investigation conducted.

I also declare, that, this thesis has not been written or submitted in any form whether partly or wholly for any other degree. All sources of publications and other related reports cited in this research have been identified in the reference section.

A.T.A. AMUSAN (STUDENT)

13-02-92
DATE

C E R T I F I C A T I O N

This thesis entitled "TREATMENT OF TEXTILE EFFLUENTS USING WASTE STABILIZATION PONDS"

by AMUSAN, TAOHEED ABAYOMI meets the regulations governing the award of the degree of Master of Science (Water Resources and Environmental Engineering) of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

PROF. J.A. OGUNROMBI
(Chairman, Supervisory Committee

DATE 14/1/92

DR. C.A. OKUOFU
(Member, Supervisory Committee

DATE 13/1/92

PROF. J.A. OGUNROMBI
(Head of Department)

DATE 14/1/92

(Dean, Postgraduate School)

DATE 20/3/92

DEDICATION

May Allah accept this work as my humble contribution towards better living condition of man.

To my Brother, Tajudeen and my Sister, Faoziat, for their foresight and sincere committments.

To the memory of Abdul Fattah (Bro. Bolaji) who died while I was putting this work together.

ACKNOWLEDGEMENT

Abundant praise is due to Allah, the designer of the most complex machine - Man, the giver of infinite knowledge. I worship Him, I adore Him and I continue to seek for His Mercies which are unbounded.

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The contributions and efforts of Dr. Femi Peters are not only significant and highly appreciated, they remain ever green in my memory.

I would also like to place on record the understanding, maturity, concern and sacrifice of my darling, Muinah, she contributed significantly to the realisation of this work.

Lastly, my greatest personal indebtedness is to our parents who brought us into the world and continue to grant their untiring support.

Taoheed Yomi Amusan

ABSTRACTS

This study investigates the performance of waste stabilization ponds including an anaerobic and facultative ponds in series in the treatment of Textile Wastes.

Wastewater from Mario Industries Limited was subjected for treatment at different detention times. The efficiency of the pond was determined by the degree of removal of Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), colour, suspended solids, phosphates, Ammonia nitrogen, Nitrate-Nitrogen and pH. Samples from the facultative pond were further subjected to chemical coagulation using aluminium sulphate as coagulant.

At detention periods of 5, 10, 15 and 20 days in the anaerobic pond and corresponding detention periods of 3.5, 7.0, 10.5 and 14.0 days respectively in the facultative pond, total BOD removals of 51.31, 65.93, 67.63 and 70.36% respectively were achieved. Suspended solids was reduced to a negligible level while total phosphates removal of about 90.00% was observed. The highest colour removal (60.00%) was achieved at 10 days detention period in the anaerobic pond.

The chemical coagulation of the effluent from the entire stabilization ponds system achieved a total BOD reduction of about 90.00%, COD reduction of 75.00% and colour reduction of up to 87.00%.

The study shows that although waste stabilization ponds can achieve high removal of the measured parameters from the textile wastewater, tertiary treatment will be desirable for upgrading the effluents to meet quality objectives. This can be achieved by chemical coagulation.

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CHAPTER ONE

INTRODUCTION

1.1 The Pollution Problem

Consequent upon man's ability to develop and use high Technology, the rate of pollution today is very high, due to corresponding high rate of industrialization. If man is to survive on earth, pollution control is unavoidable. Water for example must be fit for human and animal consumption.

In the last two decades Nigeria has witnessed an upward trend in industrial activities. Such industries as Textiles, Paints, Food and Beverage, Iron and Steel, Agro Allied and a host of others have sprung up especially around the capital cities of Lagos, Port-Harcourt, Kano, Benin, Kaduna etc. Adequate attention has not been paid to the nature and control of wastes produced by these industries.

The growth of the textile industry, for example, has been so great that it has become a very large employer of labour in the country today. When in full operation, it is expected to employ about 150,000 employees.

The quantity of water required for the operation of the textile industry is tremendous and so also is the amount of wastewater generated. If wastes from these industries are not treated before being disposed, the usual disposal media (land and water), would become polluted. In cases where rivers are used for disposal, such effluents deny other users downstream of many beneficial uses of the water. Aquatic life would be adversely affected and the cost of treating water from such rivers for water supply would be high.

Recently the long overdue attention was given to the environment through the establishment of the Federal Environmental Protection Agency (FEPA), in late 1989.

1.2 The Textile Industry

Spinning and weaving are among the oldest industrial activities man has been involved in. It is probably no exaggeration to state that industrialization started with spinning and weaving. The textile industry was one of the very first industrial activities in which mechanization on a large scale took place, followed by automation and mass production (Boom, 1981).

Textile products are an integral part of every person's daily life. They provide the basis for clothing, for home furnishings, and for various domestic fabrics. Textiles are encountered in vehicular transportation, in recreational equipment, the construction industry, space exploration etc.

Textile wastes fall into the class of wastes that contain both organic and mineral impurities. These wastes are derived from deterging and fiber preparation and from dyeing, printing and other finishing processes (Steel et al 1985).

There are various kinds of fibres (wool, cotton, silk, linen, synthetics etc.) and the colours of good produced are equally numerous, and it is responsible for the variability in the composition and strength of textile wastes.

Fair et al (1954) noted that waste waters from textile works are so variable in volume and composition that experimentation should precede the selection of a plan for treatment.

According to Fair et al (1954) and Steel et al (1985), the significant pollutants of textile wastes include organics, colour, suspended solids and high pH.

1.4 Zaria Industries Limited - Background Information

Zaria industries limited (ZIL) is one of the few industries that derived all its raw materials locally. The industry is located in Dakace village along old Jos road in the outskirts of Zaria city. The industry was established in 1975 at an initial cost of ₦3 million by the North Central State Government in conjuction with two Japense firms, Untika Limited and Nichiem. The industry was established primarily for the manufacture of tarpaulin, and started with a staff strength of 250 workers. The staff strength has now risen to about 370.

ZIL manufactures over 1200 tons of yarn annually from which a wide selection of different types of tarpaulin in various colours are made. ZIL products are developed for various essential uses. 100% canvas tarpaulin is useful in covering of all items that should be protected from intense heat, e.g. fertilizers, chemicals and other items packed with paper. Other uses include lorry covers, camping tents and vehicle shades. Apart from tarpaulin, ZIL also produces other textile goods like school uniforms.

1.5 Production of Textile Goods

The general activities in a textile industry may be divided into three namely: spinning, weaving and finishing/printing. At Zaria industries these activities are carried out apart from printing. Yarn is made during spinning of cotton. The yarn is later turned into cloth through weaving. Weaving involves interlacing of the yarn, first by warping and sizing, then pirn winding and lastly cone-winding. Waste-water is hardly generated in the spinning or weaving activities, the only instance where water is used is in the sizing where starch is used on the material undergoing weaving.

The finishing stage is where over ninety percent of the total water demand in the textile factory is expended. The factory manager puts the monthly water demand of ZIL at about $7000m^3$. Finishing works at ZIL include desizing and scouring with Turkey red and sodium hydroxide. Other activities in the finishing shop are bleaching with hydrogen peroxide, colouring using vat dyes, under treatment with calcium carbonate and final treatment with parafin emulsion.

1.6 The Objectives of Study

The present study is aimed at investigating the performance of stabilisation ponds in the treatment of textile wastes from Zaria Industries Limited. Tertiary treatment for polishing the effluent is also carried out by chemical coagulation.

The choice of this biological process for industrial waste treatment is its ability to produce effluents of reasonably high quality, comparatively low cost of construction and operation and the ease of maintenance by locally available and relatively unskilled labour.

CHAPTER TWO

LITERATURE REVIEW

2.1 The Textile Wastewater

The bulk of water in the textile mill is used in the finishing shop of the factory where the dyeing and washing take place. The wastewater is generally characterised by high pH, BOD and Solids (Steel, 1985; Fair *et al* 1954). The main contaminant is the dye used in colouring the garment. Dyes are classified into direct, acid, basic, sulphur, vat and miscellaneous. The direct, acid, and basic dye wastes are all highly coloured and generally have higher BOD than domestic sewage.

Direct dyes are soluble and may be used without any mordants or adjuvants which themselves are often more toxic than the dye itself. Because of their high solubility, direct dyes (which are Azo compounds), are difficult to remove from industrial wastes. They are used mainly on cotton, rayon, and vegetable fibres. Some direct dyes are derivatives of benzidine and tolidine (Desselievre, 1976).

Acid dyes are used on animal fibres such as wool. They are salts of color acids and are also Azo compounds of benzidine and tolidine. Basic dyes are capable of dyeing animal fibres directly but they require tarning mordant for vegetable fibres. They are salts of colour bases.

Sulphur dyes contain sulphur compounds and are used in conjunction with sodium sulphate in the dye bath but are used exclusively on vegetable fibres. They are difficult to treat and their effect on streams is frequently quite detrimental (Besselievre, 1976).

Vat dyes acquire their dyeing properties as a result of the reducing action in the dye vat just prior to dyeing. They are generally used with cotton, and they may be compounds of anthracene or indigo (Besselevre et al, 1976).

The quantity, strength and character of wastes from a textile factory depend on the way in which the dye is applied and how often dyes are changed in the operation of each process (Besselevre et al, 1976).

2.2 Wastewater Treatment Processes

According to Steel et al (1985) and Hammer, (1975), wastewater treatment follow the following general processes

(a) Preliminary Treatment

(b) Primary Treatment

(c) Secondary Treatment

(d) Advanced or Tertiary Treatment.

The preliminary treatment is designed to remove varying quantities of floating and suspended solids, some of considerable size. These are materials such as rags, pieces of wood, metal, plastic or rubber or fragments of masonry which may enter sewers and eventually reach the treatment plant. These constituents are removed when their presence would interfere with subsequent treatment processes or mechanical equipment.

Primary treatment is mainly a sedimentation process which is intended to remove suspended organic solids. Rectangular, circular and square tanks are used for sedimentation.

According to Steel et al (1985), primary clarifers are usually designed to remove particles with settling velocity of 0.3 to 0.7mm/s. Within this range, suspended solids removals range from 30 to 60 percent depending in part upon the original concentration.

Secondary treatment is intended to remove the soluble and colloidel organic matter which remain after primary treatment. Secondary treatment is usually a biological treatment process. However material removed in this process can be brought about by physico-chemical means (Steel et al, 1985).

The secondary treatment consists of application of a controlled natural process in which micro-organisms remove soluble and colloidal organic matter from the waste.

The design of secondary treatment systems require that a large active mass of bacteria is maintained within the system. The techniques used in secondary processes may vary widely, but the basic principles remain the same. The systems may be broadly classified as either attached (film) growth or suspended growth processes.

Attached growth processes utilize a solid medium upon which bacterial solids are accumulated in order to maintain a high population. Attached growth processes include intermittent sand filters, trickling filters, rotating biological contactors and a variety of similar proprietory devices. Suspended growth processes maintain an adequate biological mass in suspension within the reactor by employing either natural or mechanical mixing. Suspended growth processes include activated sludge and it's various modifications, oxidation pond, and sludge digestion systems (Steel et al 1985).

Advanced wastewater treatment techniques are performed for polishing effluent from conventional secondary treatment processes. The best demonstrated procedures include intermittent sand filtration (Harris, et al, 1977), dissolved air flotation (Stone, et al, 1975), coagulation, sedimentation and filteration (Parker, et al 1975). The impurities may include soluble inorganic compounds such as phosphorus or nitrogen, which may support algal growths in receiving waters; organic materials contributing biochemical oxygen demand, chemical oxygen demand, colour, taste and odor; bacteria; viruses; colloidal solids contributing turbidity; or soluble minerals which may interfere with subsequent re-use of the wastewater (Culp, 1971).

The purpose of advanced waste treatment is to alleviate pollution of a receiving water-course or to provide a water quality adequate for re-use, or both. The advanced waste treatment process may be used in conjunction with, or to replace the conventional secondary process.

2.3 Treatment of Industrial Wastes

It is difficult to treat all waste in the same manner. Before any reasonable statement can be made about the methods of treatment, some classification must be applied to the various types of industrial wastes. Wastes could be classified as either biological or non biological. Waste from living or previously living sources are called biological wastes. The treatment of such wastes is generally different from wastes from non-living, non biological sources.

Biological wastes include discharges from municipalities, tanneries, paper mills, food manufacturing plants, slaughter houses, textile plants etc. Non biological wastes include wastes from metal-plating industries, aircraft manufacturing industries, sheet-metal industries, and printed circuit board manufacturing (Besselievre, 1976). Most of these industries discharge what is commonly referred to as "spent chemicals" into the plant effluent.

Treatment processes employed depend upon the nature of the waste and may be physical, chemical, biological or any combination of the three. Characteristics and possible treatment techniques are summarized in Table 1.

TABLE 1: INDUSTRIAL WASTES AND TREATMENT PROCESS (Steel et al, 1985)

SOURCE	CHARACTERISTICS	TREATMENT
Food Industries		
breweries	high nitrogen and carbohydrates	biological treatment, recovery, animal feed
dairies	high fat, protein, and carbohtdrate	biological treatment
meat processing	high protein and fat (may be warm)	screens, sedimentation, flotation, biological treatment
soft drinks	high BOD and solids	screening, biological treatment.
Chemical Industries		
acids	low pH, low organics	neutralization
detergents	high BOD and phosphate	flotation, precipitation
Materials Industries		
foundries	high soids (sand, clay, and coal)	screens, drying
oil	dissolved soilds, high BOD, odor, phenols	injection, recovery of oils

TABLE 1 (CONT'D)

Materials Industries		
steel	low pH, phenols, high suspended solids	neutralization, coagulation
textiles	high pH, and BOD, high solids	neutralization, precipitation, biological treatment

2.4 Treatment of Textile Effluents

Textile effluents may be treated biologically or by some physical and chemical processes. Fair et al (1954) for example, noted that textile wastes could be treated biologically and that the colours in them could be removed chemically (by coagulation, bleaching or adsorption), although decolorization is rarely complete. Furthermore they established that wastes from textile works are so variable in volume and composition that experimentation should precede the selection of a plan of treatment.

Newlin (1971) observed that because textile wastes have very high BOD values and are high in carbonaceous contents, they should be easily decomposed bacteriologically, if the pH is not too high or too low and if appropriate nutrients are present. He further observed that what may seem to be an adequate solution to the waste treatment problems of the textile industry at present may in future be obsolete due to advances in the textile manufacturing process or to new treatment methods. Thus there is no simple solution to the problem of treating textile wastes and estimating their associated costs because of their changing nature from plant to plant over a period of time.

Noguchi *et al* (1974) observed that the use of high rate trickling filter was required for greater than 70 percent biochemical oxygen demand removal in degumming and dyeing wastes. The trickling filter process alone, however did not remove colour appreciablly.

Singer and Porter (1974) studied the effect of ozone at acidic, neutral, and alkaline pH's in removing chemical oxygen demand and colour from three textile wastes, and from standard colour solutions.
At ozone level of 1g/1, essentially all of the colour was removed after 1 hour of contact. Colour analysis was affected by suspended solids produced during the oxidation of organics. Up to 55% COD was removed by ozonation.

According to Mizumoto and Horie (1974), treatment of dye wastes with a combination of ozone and activated carbon display a synergistic effect. Ozone removed only about 10% of the BOD while activated carbon removed 60 to 80%. Ozone removed most of the colour while activated carbon absorbed that which remained.

2.5 Waste Stabilization Ponds

2.5.1 Definition and Types

Waste stabilisation ponds are large shallow basins enclosed by earthen embankment in which raw sewage is treated by entirely natural processes involving both algae and bacteria.

Considerable advantages are associated with stabilisation pond treatment particularly the cost of construction and maintenance and the removal of faecal bacteria. In hot climates where sufficient land is most favourable for their operation, pond systems are the most important method of treatment (Mara, 1976).

Waste stabilisation ponds include three major types: Facultative, Maturation and Anaerobic ponds (Mara, 1976; Gloyna, 1971; Lumbers, 1979).

2.5.2 Facultative Ponds

The term "facultative" refers to the existence of both aerobic and anaerobic conditions within the basin. In a facultative pond, aerobic conditions are maintained in the upper layers while anaerobic condition exist towards the bottom (Mara, 1976). Complex biological activities go on in a facultative pond which result in the symbiotic interaction between bacteria and algae in the presence of sunlight. Dissolved Oxygen (D.O) in the pond is utilized by the aerobic bacteria to break down the complex organic matter and release CO_2, H_2O, NO_3^-, PO_4^{3-} and other inorganic nutrients. In the presence of sunlight these end products are assimulated by photosynthetic algae with the release of oxygen as an end product. Thus there is an association of mutual benefit ('Symbiosis') between algae and bacteria in the pond. Apart from the liberated oxygen by photosynthetic algae, the aerobic degradation at the upper layer of the pond is further facilitated by oxygen derived from surface re-aeration.

A number of environmental factors influence the performance of facultative ponds. These include solar radiation, temperature, organic load, pH, variation in soluble, settleable and non-settleable solids, toxicity of the influent and the depths and shapes of the ponds (Gloyna, 1972; Marais, 1974). Diurual variation of dissolved oxygen concentration occurs in a facultative pond. During daylight, algae produce most of the oxygen required in the aerobic zone. As long as they can produce an excess of oxygen above the bacteria-oxidation requirement, an aerobic environment, which may even be supersaturated with oxygen, will be maintained. At night, however, algae will demand oxygen in the same manner as bacteria for respiration (Marais, 1974; Mara, 1976). The bacteria and algae at night rely on the excess oxygen produced in the daylight and the additional from wind re-aeration for survival.

2.5.1.2 <u>Maturation Ponds</u>

This is designed as second stage to facultative ponds. It's main function is to reduce the number of pathogenic micro-organisms through extended detention time in an inhospitable environment. It also achieves nitrification of treated effluent especially as it is wholly aerobic. BOD removal in a Maturation pond is small, Mara (1976). It would require two ponds in series, each with detention period of 7 days, to reduce the BOD from about 50-70 mg/L to 25mg/L.

A maturation pond usually has the same depth as the preceeding facultative pond. Due to its shallow depth (1 - 1.5m), destruction of bacteria and viruses is quicker than in deep ones (Marais, 1974; Mara, 1976).

2.5.1.3 Anaerobic Ponds

These are deep ponds (usually 2-4m deep) specially designed to receive and treat wastewater of high organic loadings. Though it can treat dilute organic wastewater, it is most advantageously employed in the pretreatment of very strong wastewater with high solids content. The solids settle to the bottom of the deep pond where they are digested anaerobically, while the partially clarified supernatant is further treated (usually in a facultative pond) before it is discharged into a receiving body of water. Provided the pH is higher than 6 and the temperature is greater than 15^{o}C, the anaerobic pretreatment pond has been observed to achieve BOD reductions of up to 70% within 5 days detention time (Mara, 1976).

The processes in the anaerobic pond involve the acid formers that first convert the complex organic matter by hydrolysis and fermentation to simple fatty acids mainly, and to some aldehydes and alcohols. Secondly, anaerobic bacteria (the methane formers) convert the acid to methane and carbon-dioxide. It is at this stage that waste stabilisation occurs, and it is directly proportional to the amount of methane produced (Metcalf, et al, 1972). The successful operation of anaerobic ponds depends on the delicate balance between the acid-forming bacteria and the methane formers (Methanogenic bacteria). According to Mara (1976), a temperature greater than 15^{o}C is necessary and the pond pH must be greater than 6 for a suitable equilibrium to exist in the pond.

2.5.2 Applicability, Advantages and Disadvantages of Waste Stabilisation Ponds

2.5.2.1 Applicability

Apart from being used in hot climates, waste stabilisation ponds are used at all latitudes even as far as Alaska (Mara, 1976) and by both developed and developing countries. Though some failures have been reported, tney are usually due to human error at the design stage. These failures involve inadequate capacity, leakage or flow control and poor maintenance (Mara, 1976), Waste stabilisation ponds are suited for the following applications according to Gloyna, (1971); Hammer, (1975); and Mara, (1976).

(i) Treatment of domestic wastewater and some forms of biodegradable agricultural and industrial wastes, either as primary, secondary or tertiary treatment ponds.

(ii) Complex industrial wastewates containing toxic substances, dye works wastes, milk processing plant wastes, slaughter house wastes etc. These may require special pretreatment before being introduced into waste stabilisation ponds.

2.5.2.2 Advantages

The advantages of waste stabilisation pond system include:

(a) Ability to achieve high degree of wastewater purification at low cost. Infact, it is the least expensive of the major conventional wastewater treatment systems.

(b) It is easily operated and maintained, needing mainly unskilled locally available labour.

(c) It is able to withstand both organic and hydraulic shock loads.

(d) The removal of pathogens is considerably greater than that in other methods of sewage treatment.

(e) It can effectively be used to treat a wide variety of industrial and agricultural wastes.

(f) It can easily be reclaimed should the land be required for some other purpose (Hammer, 1975; Mara 1976; Lumbers, 1979).

2.5.2.3 Disadvantages

The disadvantages of waste stablization pond include:

(a) The large area of land required for it's construction (Mara, 1976).

(b) The high concentration of algae in the effluent and consequent effect on the receiving body of water.

2.5.3 DESIGN METHODS

2.5.3.1 Design Preliminaries

In order to maintain the optimum liquid depths necessary for efficient operation, adequate provision should be made to

(i) Accomodate the maximum run-off contribution and maximum subsoil infiltration which generally occur in the rainy season and

(ii) Maintain adequate liquid depth in the pond during dry season when minimum infiltration, maximum evaporation and maximum seepage losses occur. (Mara, 1976). The range of depths most commonly used for each type of pond is as follows:

Facultative	Ponds	1.0 - 1.5m
Maturation	"	1.0 - 1.5m
Anaerobic	"	2.0 - 4.0m.

The length and breath are usually in the ratio 2-3 to 1 - Mara (1976).

The mid-depth area is given by

$$A = \frac{Qt^*}{D} \qquad \text{Eqn. } 2.1$$

where Q = Volumetric flow rate, m^3/d

t^* = Retention time, d

D = Pond depth, m

The surface BOD_5 loading Ls which is the weight of BOD_5 applied per unit area per day expressed as Kg/ha.d: is

$$Ls = 10\,\frac{LiQ}{A} \qquad \text{Eqn. } 2.2$$

where Li = Influent BOD_5 in mg/L

Q = flow rate in m^3/d

A = Mid-depth area in m^2.

Mara (1976).

2.5.3.2 Design of Facultative Ponds

The design of a facultative pond is currently based on empirical and rational methods. The rational methods include the completely mixed flow, the plug flow, and the dispersed flow. Other design methods are the empirical formulations of Gloyna, (1972), Mara, (1976) and Lumbers, (1979).

(a) The Rational Method

(i) Completely mixed flow: This design method is based on the assumption that the contents of incoming waste are instantaneously mixed with the pond contents, and that the effluent is identical in composition with the contents of the pond. It also assumes a first order process Kinetics (Lumbers, 1979; Mara, 1976).

The design equation based on these forgoing assumptions is given by the following expression:

$$\frac{Le}{Li} = \frac{1}{1 + k_1 t} \qquad \text{Eqn. } 2.3$$

where

Le = Effluent BOD (mg/L)

Li = Influent BOD (mg/L)

K_1 = Reaction rate constant (d^{-1})

t = Retention time (d)

The reaction rate constant K is reported to vary with temperature (T) of the pond (Mara, 1976).

South African practice suggests that Le should be 50 to 70 mg/l in order to keep the pond predominantly aerobic for depths of 1.0 to 1.5m. The value of k_1 is about $0.3d^{-1}$ at $20^{\circ}C$ (Mara, 1976); and its variation with temperature is described by the equation

$$K_1 (T) = 0.3 (1.05)^{T-20} \qquad \text{Eqn. } 2.4$$

where

$K_1(T)$ = value of K_1 at $T^{\circ}C$ (Mara, 1976; Lumbers 1979).

(ii) The plug flow: The assumption here is that all flow elements move with uniform velocity in the direction of flow and that there is no longitudinal mixing along the line of flow. However there is mixing in directions perpendicular to the line of flow (Mckinney, 1962); Lumbers, (1979); Nenerow, (1971).

The design equation for plug flow is as follows

$$\frac{Le}{Li} = e^{-kt} \qquad \text{Eqn. } 2.5$$

All parameters are as defined previously. Though the ideal plug flow assumption has been used in biological waste treatment designs (Gloyna, 1972), investigations have shownthat hydraulic flow pattern cannot exist as plug flow in facultative ponds.

(iii) <u>The dispersed flow Method</u>: This method is based on a non-ideally mixed reactor, given by Wehner and Wilhem (1958) as

$$\frac{Le}{Li} = \frac{4a \exp(\tfrac{1}{2}d)}{(1 + a)^2 \exp(a/2d) - (1 - a)^2 \exp(-a/2d)} \qquad \text{Eqn. } 2.6$$

where $a = (1 + 4\ k_1 t \cdot d)^{\frac{1}{2}}$

The degree of intermixing that occurs is usually expressed in terms of dimensionless dispersion number - d where $d = D/UL$

D = Coefficient of longitudinal dispersion (m^2/hr)

U = the mean velocity of travel (m/hr)

L = the mean path-length of a typical particle in the reactor (m).

Equation (2.6) reverts to equation (2.5) for "plug flow" if d = 0, and to equation (2.3) for "completely mixed flow" if $d = \infty$. The dispersion number can be evaluated by the "Tracer method." Most stabilisation ponds are reported to have dispersion number in the range of 0.1 to 2.0 (Mara, 1976; Gloyna 1972). Thirumurthi (1969), however stated that for waste stabilisation ponds, d will seldom exceed 1.0 because of low hyeraulic loads."

When d is less than 2.0 equation (2.6) can be approximated to

$$\frac{Le}{Li} = \frac{4\ a \exp\ (1 - a)/2d}{(1 + a)^2} \qquad \text{Eqn.} \quad (2.8)$$

The use of equations (2.6) and (2.8) for design is cumbersome and inconvenient. The Thirimurthi chart (Thirimurthi, 1969; Gloyna, 1972; Mara, 1976) has been prepared from it for design purposes. This is shown in Figure 1.0.

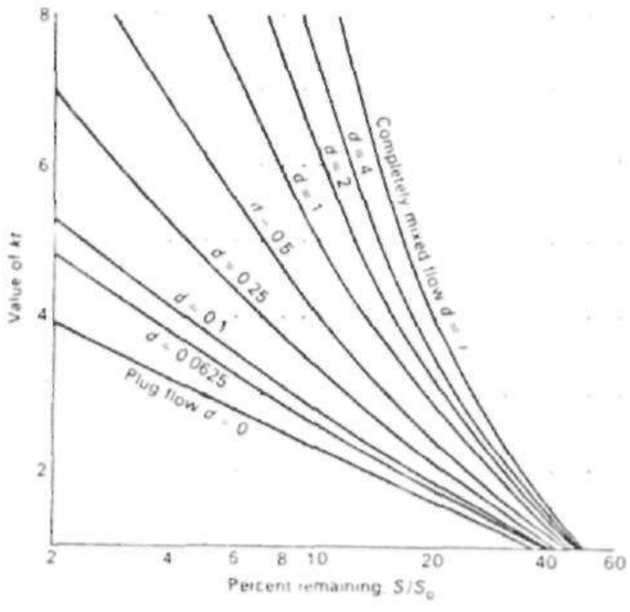

Fig. 1.0 DESIGN FORMULA CHART FOR DISPERSED FLOW.THIRUMUTHI (1969)

(b) Other Design Methods

(i) Organic load per unit Surface Area of Pond

Past experience of stabilisation ponds performance under various climatic conditions and various organic loadings has led to some suggested loading for design purposes. Table 2 indicates such suggested values. Gloyna (1971) and Lumbers (1979) suggested that these values should be used only where limited information is available.

Table 2

ORGANIC LOAD PER UNIT SURFACE AREA OF POND (Lumbers, 1979)

Surface Loading ($kgBOD_5$/ha.d)	Retention Period (days)	Environmental Conditions
10	200	Frigid zones, icy low water temperature variable cloud cover.
10 - 50	100 - 200	Cold seasons, icy, temperate, short summer season.
50 - 150	33 - 100	Temperate to semi-tropical. No prolonged cloud cover. Ocasional ice cover.
150 - 350	17 - 33	Tropical, uniform distribution of sunshine and temperature. No season cloud cover.

(ii) McGarry and Pescond Formula

After analysis of operational data from many facultative ponds all over the world, it has been shown by McGarry and Pescond (1968) that the maximum BOD_5 surface loading that could be applied to a facultative pond before it failed (i.e. become completely anaerobic) is related to the mean monthly ambient air temperature as follows

$$L_s = 11.2\ (1.054)^T \qquad (2.9)$$

where

L_s = maximum BOD_5 loading, Kg/ha.d.

T = temperature, ^oF.

However for design purposes, introduction of a factor of safety would be required:

Therefore equation (2.9) is modified as

$$L_s = 7.5\,(1.054)^T \qquad (2.10)$$

An alternative design equation for L_s is

$$L_s = 20T - 20 \qquad (2.11)$$

where T is in $^{\circ}C$

The design equation for A is then simply obtained from 2.2 as

$$A = \frac{LiQ}{2T - 12} \qquad (2.12)$$

(iii) Indian empirical procedure

Experience of pond operation in India has yielded a design which relates the permissible loading to latitude

$$L_s = 375 - 6.25\,L \qquad (2.13)$$

where L = Latitude (range in India 8 – 36°N).

This design procedure is basically similar to the McGarry and Pescond procedure because latitude is some measure of temperature.

2.5.3.3 Design of Maturation Pond

Maturation ponds are designed using complete mixing, first order Kinetics to predict bacterial die-off, rather than BOD removal (Lumbers, 1979; Gloyna, 1972). In addition some design criteria are used. Mara (1976) suggested that to produce an effluent with a BOD_5 25 mg/1, two maturation ponds in series, each with a detention time of 7 days are required. This is based on the assumption that the BOD_5 of influent is less than about 75 mg/1. Pond depth of 1.0 - 1.5m is also suggested. Ponds in series achieve better results than single ponds of equivalent retention time in the removal of bacteria and reduction of algae concentration in the final effluent (Mara, 1976).

2.5.3.4 Design of Anaerobic Pond

The optimum retention time is 5 days with observed BOD reduction of 70% (Mara, 1976). However, retention times of less than 5 days have also been observed to achieve BOD reductions of between 50% and 60%. The above is achievable at temperature greater than $20^{\circ}C$ and pH higher than 6. The depth adopted vary from 2 to 5 meters; BOD surface loadings are in range 1000 to 6000 kg/ha.d while volumetric loadings are in the range 0.19 to 0.24 kg $BOD/m^3.d$.

The volumetric loading parameter has been found to be the most useful design criterion for the design of anaerobic ponds, provided the depth is sufficient to maintain thorough anaerobic conditions (Metcalf, 1972).

An empirical design relation derived by vincent *et al* (1963) also known as the South African procedure is given by

$$Le = \frac{Li}{1 + Kn\left(\frac{Le}{LI}\right)^{n} t}$$

where Kn = Digestion rate constant (d^{-1})

n = constant

t• = Detention time (days)

Li = Influent BOD (mg/l)

Le = Effluent BOD (mg/l).

For Zambian conditions, Kn and n were found to be 6.0 and 4.8 respectively for a pond temperature of 20°C.

CHAPTER THREE

EXPERIMENTAL PROCEDURE

3.1 MATERIALS

3.1.1 Model Stabilisation Ponds

The laboratory waste stabilisation ponds used consisted of a rectangular storage tank, an anaerobic pond, and a facultative pond. The capacity of the storage tank was 100 litres. The working capacity of the anaerobic pond was 60 litres with dimensions of 40cm x 30cm x 60cm. The dimensions of the facultative pond were 50cm x 100cm x 10cm with operational capacity of 42 litres. The sides of the anaerobic pond were covered with a black polythene sheet to prevent light penetration into the pond. Figure 2.0 shows the arrangement of the laboratory stabilisation ponds.

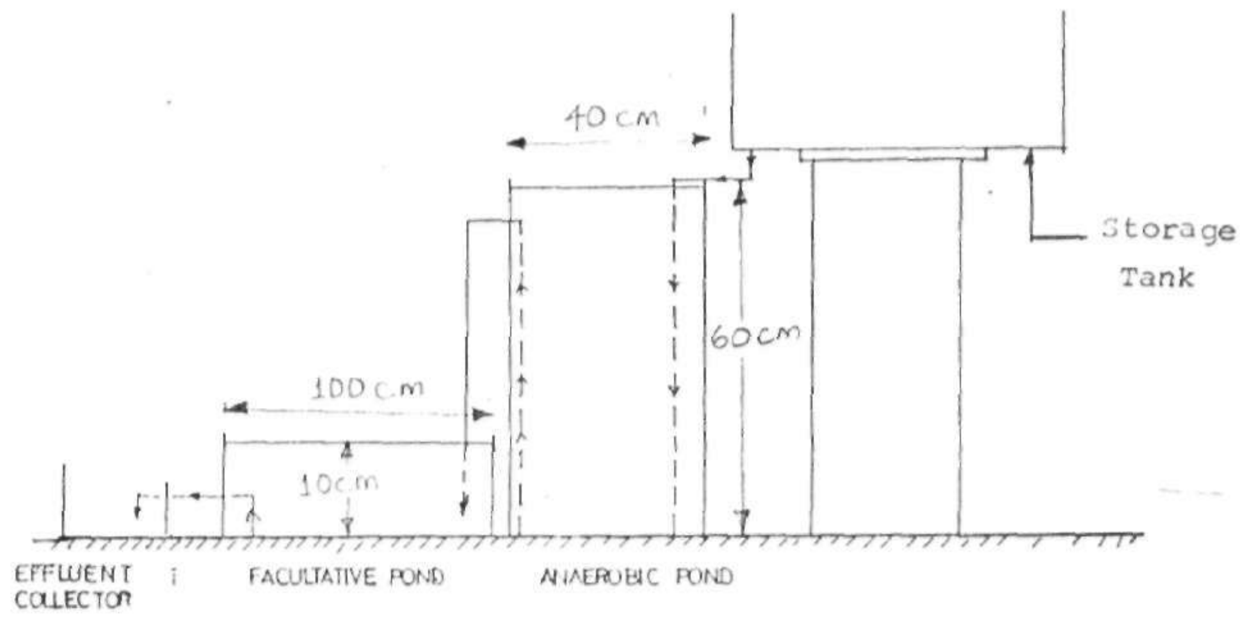

FIG.20 SERIES ARRANGEMENT OF LAB STABILIZATION PONDS

3.1.2 The Jar-Test Apparatus (for Coagulation Treatment)

The standard laboratory Jar-Test equipment manufactured by Paterson Candy International Limited England was used.

3.1.3 Other Laboratory Equipment

The following laboratory equipments were also used.

(i) The Reflux apparatus manufactured by Gallenkamp England was used for determination of COD.

(ii) The spectrophotometer (Spectronic 20) manufactured by Bausch and Lomb Incoporated New-York. U.S.A. was used for determination of Nitrate-Nitrogen and phosphates.

(iii) The Incubator manufactured by Gallenkamp of England was used for incubation of BOD bottles and petri-dishes (inoculated) for bacteria count.

(iv) The pH meter, model 292 MK2 manufactured by PYE UNICAM, England was used for pH determination.

(v) The Oven made by Griffin and George Limited, Middlesex was used for suspended solid determination.

(vi) A chemical balance Mettler P 160N manufactured by Gallenkamp Limited England was used for Weighing.

(vii) Stop clock manufactured by English Clock Systems, Great Britain was used for timing.

(d) Glassware. The following Glasswares were used

(i) BOD bottles made by wheaton U.S.A.

(ii) Measuring cylinders - Kinax U.S.A.

(iii) Conical flasks - "Pyrex" - England

(iv) Beakers - " "

(v) Petri-dishes - " "

(vi) Refluxing flasks - Borosilicate England

(vii) Nessler-Tubes - "Pyrex England

(viii) Burette - Technico-England

(ix) Pipette - " "

3.1.4 The Sample

The wastewater used in this study was obtained from Zaria Industries Limited. The sampling was carried out between August and December 1990.

The waste was collected just at the point of leaving the finishing shop (the last stage of production activities) with buckets attached to ropes. Grab samples were collected once in every 30 minutes for 3.0 hours and mixed.

3.2 Methods

The storage tank, anaerobic pond and the facultative pond were connected in series as shown in Fig. 2.0. The flow was by gravity. At the start of experiments, the anaerobic and facultative ponds were filled with tap water and seeded with raw sewage (from A.B.U. sewage treatment plant) and with some of the textile wastewater. The ponds contents were throughly mixed and left for 10 days. Algae suspension developed after 7 days in the facultative pond.

The anaerobic pond was operated at detention periods of 5, 10, 15 and 20 days. The corresponding hydraulic loadings are 0.4, 0.20, 0.15 and 0.10 $m^3/m^2.d$ while the organic loadings are 4266.68, 2133.34, 1925.00 and 1474.00 kg/ha/day respectively. The facultative pond was operated at detention periods of 3.5, 7, 10.5 and 14.0 days. The corresponding hydraulic loadings are 0.096, 0.058, 0.032 and 0.024 $m^3/m^2.d$ while the organic loadings are 529.60 277.05, 174.61 and 147.02 kg/ha/day respectively.

The initial 5 days detention time was chosen for the anaerobic pond in order to avoid some short comings observed by Mara (1976) with anaerobic ponds operated at detention times less than 5 days. Some of the shortcomings are:-

(i) The release of odour is greater

(ii) The interval between successive desludging operations is shorter.

(iii) The bacteriological quality of the final effluent is poorer.

(iv) The BOD removal is smaller.

The effluents from the anaerobic pond was admitted into the facultative pond by gravity and maintained at the required detention times. For each detention time, measurements of quality parameters started when the contents of the ponds appeared to have been completely flushed out. Measurements were made at 2-days intervals until the experiments were terminated when steady state conditions were reached as indicated by little variations in the values of the effluent parameters.

The effluents from the facultative pond system for each detention time were subjected to coagulation using aluminium sulphate coagulant. The purpose of coagulation was to further reduce the colour from the waste which was not adequately removed by stabilisation ponds.

The following parameters were measured.

1. The 5-day Biochemical Oxygen Demand (BOD_5) mg/L
2. The chemical Oxygen Demand (COD) mg/L
3. pH
4. Colour (Chloroplathiate colour unit)
5. Suspended solids (mg/L)
6. Nitrate-Nitrogen (mg/L)
7. Ammonia -Nitrogen (mg/L)
8. Phosphates (mg/L)

All measurements were carried out in accordance with "Standard Methods for the Examination of Water and Wastewater" (American Public Health Association 16th Edition, 1985).

CHAPTER FOUR

RESULTS

The results reported in this chapter are grouped into three sections:

(i) Raw wastewater characteristics.

(ii) Effluent characteristics of the treated wastewater.

(iii) Chemical coagulation.

4.1 Characteristics of Raw Wastewater

Table 4.1 shows the characteristics of the raw wastewater from ZIL Textiles and the corresponding effluents in River Galma. These are the average values of the daily measurements at different detention time as shown in appendices 1 - 4.

Table 4.1 Characteristics of Raw Wastewater

Characteristics	Effluent from ZIL Industry		Outfall into River Galma	
	Range	Average	Range	Average
1. Colour(Unit)	400–700	512.5	350–500	425
2. pH	7.3–8.0	8.0	8.1–9.3	8.5
3. BOD (mg/l)	1066–1474	1270.67	700–910	820
4. COD (mg/l)	2530–2996	2764.33	2000–2260	2150
5. Nitrate Nitrogen (mg/L)	90.05–107.0	96.16	109–120	114.75
6. Ammonia-Nitrogen (mg/l)	10.0–12.0	11.0	15.0–22.0	19.0
7. Suspended Solids	14.9–77.28	36.12	20.0–53.0	35.75
8. Phosphates (mg/l)	3.76.620	5.18	4.0–6.8	5.05

4.2 Effluent Characteristics of the Treated Wastewater

4.2.1 Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD)

Tables 4.2 and 4.3 show the average stabilized BOD and COD concentrations of the effluents from the stabilization pond system at the various detention periods and their corresponding percentage removal. The stabilized values of BOD and COD are obtained from Appendices 1 - 4.

Table 4.2: BOD_5 (mg/l) Concentrations

Detention Period (days) *AN.	*FAC	Influent (Average)	Stabilized Effluent From AN. POND	% age Removal From AN. POND	Stabilized Effluent From FAC. POND	Total % age Removal
5.0	3.5	1066.67	551.67	48.28	280.00	73.75
10.0	7.0	1066.67	477.67	55.22	225.00	78.90
15.0	10.50	1283.33	545.67	57.48	232.67	81.86
20.0	14.0	1474.00	612.62	58.44	254.67	82.72

* AN = Anaerobic Pond
* FAC = Facultative Pond

Table 4.3: COD (mg/l) Concentrations

Detention Period (days) *AN.	*FAC	Influent (Average)	Stabilized Effluent From AN. POND	% age Removal From AN. POND	Stabilized Effluent From FAC. POND	Total % age Removal
5.0	3.5	2533.33	1433.33	43.42	1233.33	51.28
10.0	7.0	2400.00	1100.00	54.16	817 .67	65.93
15.0	10.5	2880.00	1296.67	54.96	932 .33	67.63
20.0	14.0	2996.00	1306.67	56.40	888.10	70.36

Fig. 4.1 and 4.2 show the plots of BOD and COD removals with respect to detention time and organic loading.

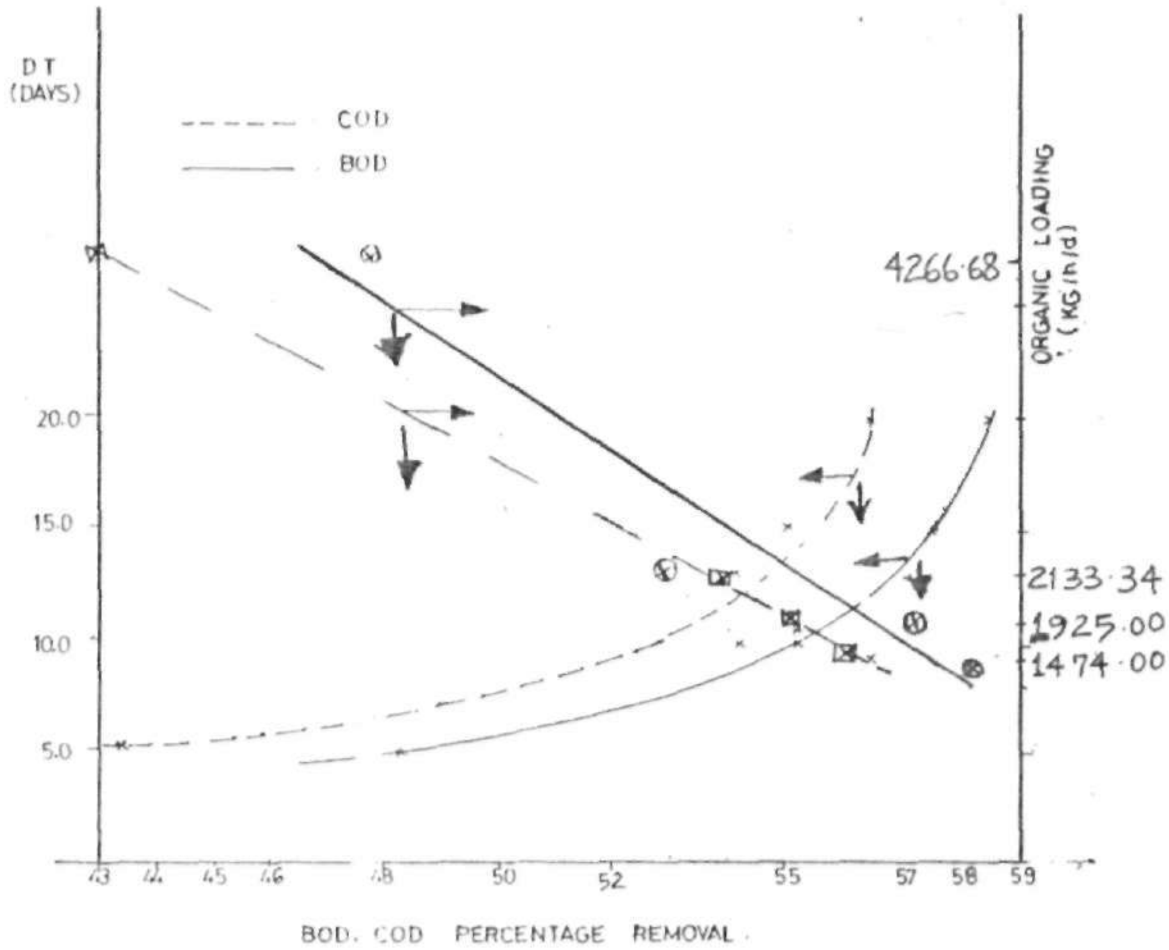

Fig. 4.1: Plots of BOD and COD removal against detention time and organic loading (Anaerobic Pond).

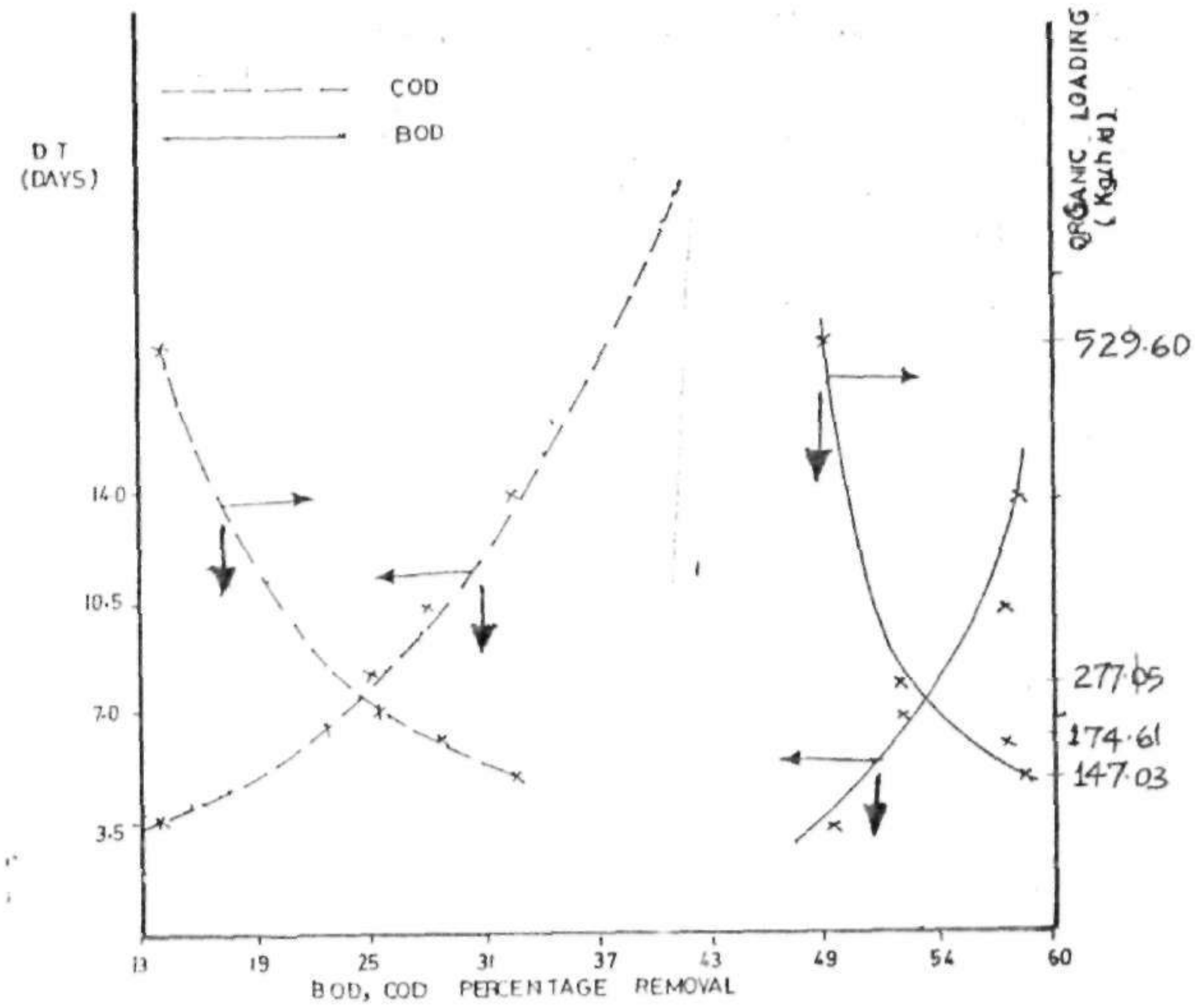

Fig. 4.2: Plots of BOD and COD removal against detention time and organic loading (Facultative Pond).

4.2.2 Non-Biodegradable Organic Material

The value of the Non-Biodegradable Material (NDM) in the two ponds were calculated by subtracting BOD_5 concentrations from corresponding COD values at various detention times. These are shown in Appendix 5. The respective percentage concentrations of non-biodegradable material were also obtained. Fig. 4.3 shows the plots of percentage N.D.M. against detention time.

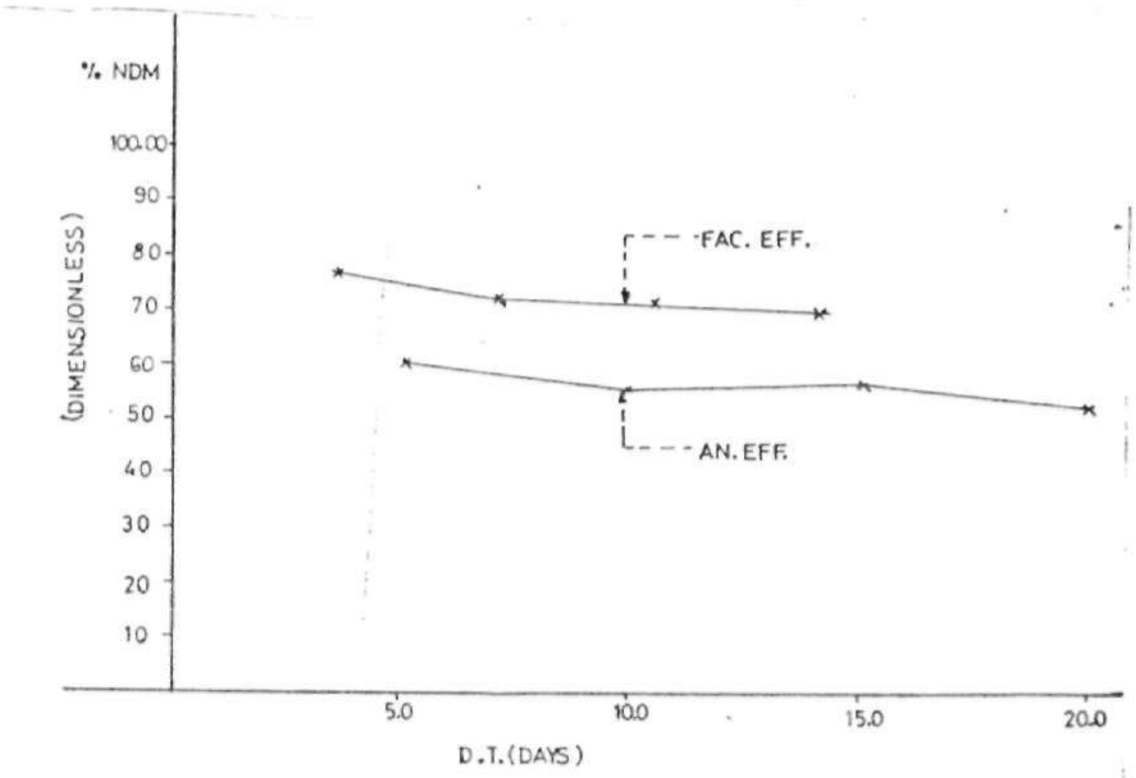

Fig. 4.3: Plots of percentage N.D.M. with respect to Detention time (D.T.).

4.2.3 Solids

Table 4.4 shows the concentration of the suspended solids from the stabilization ponds effluents.

Table 4.4: Suspended Solids (mg/l) Concentrations

Detention Period (days)		Influent	Effluent from AN POND	Effluent from FAC POND
AN	FAC			
5.0	3.5	16.37	Negligible	Negligible
10.0	7.0	14.90	"	"
15.0	10.5	35.93	"	"
20.0	14.0	77.28	"	"

4.2.4 Colour

Table 4.5 shows the concentration of the colour of both the raw wastewater and the treated wastewater and the corresponding percentage removal.

Table 4.5 Colour (Chloroplatinate Colour Unit)

Detention Period(days) AN	FAC.	Influent	Effluent from AN POND	% age Removal from AN POND	Effluent from FAC. POND	Total % age Removal	Remarks
5.0	3.5	400.00	200.00	50.00	200.00	50.00	Deep/sky Blue Dye
10.0	7.0	350.00	150.00	57.14	140.00	60.00	Deep Red Dye
15.0	10.5	600.00	400.00	33.33	400.00	33.33	Deep Green Dye
20.0	14.0	700.00	450.00	35.71	500.00	28.57	Deep Green Dye

4.2.5 pH

Table 4.6 show the trend in pH values of both the influent and effluent wastewater. The pH values for the raw and the effluent are in the alkaline range.

Table 4.6: pH Values

Detention Period (days) AN.	FAC.	Raw Influent	Effluent from AN. POND	Effluent from FAC. POND
5.0	3.5	8.0	7.9	7.8
10.0	7.0	8.0	8.0	8.4
15.0	10.50	7.3	8.3	8.4
20.0	14.0	7.9	8.5	8.5

4.2.6 Phosphates

Table 4.7 shows the phosphate concentrations of both the influent and effluent wastewater and their corresponding percentage removal with detention time.

Table 4.7: Phosphates (mg/L) Concentrations

Detention Period (days) AN.	FAC.	Raw Influent	Effluent from AN. POND	% age Removal	Effuent from FAC POND	Total % age Removal
5.0	3.5	6.26	2.50	60.06	0.88	85.94
10.0	7.0	6.88	4.25	38.22	1.02	85.17
15.0	10.50	3.76	1.56	58.51	0.44	88.30
20.0	14.0	3.86	1.48	61.66	0.38	9[illegible].16

4.2.7 Nitrate and Ammonia-Nitrogen

Table 4.8 shows the nitrate nitrogen and ammonia nitrogen of the influent wastewater and the trend in the effluent concentration with respect to detention time.

Table 4.8: Nitrate-Nitrogen and Ammonia-Nitrogen (mg/l) at Different Detention Periods

Detention Periods(days) AN.	FAC.	Nitrate-Nitrogen (mg/l) Raw Influent	Effluent from AN. POND	Efflu-ent from FAC. POND	Ammonia-Nitrogen (mg/l) Raw Influ-ent	Efflu-ent from AN. POND	Effluent from FAC. POND
5.0	3.5	107.00	136.00	121.00	12.00	20.00	12.00
10.0	7.0	90.10	126.80	150.00	12.00	26.00	16.00
15.0	10.5	90.48	116.67	141.00	10.00	80.00	40.50
20.0	14.0	97.05	126.80	154.00	10.00	90.00	50.00

4.2.9 Total Bacteria Count

Table 4.9 indicates the total bacterial counts for both the influent and effluent wastewater with the detention periods.

Table 4.9: Total Bacteria Count (per 100ml) at Different Detention Periods

Detention Period (days) AN.	FAC.	Influent	Effluent from AN. POND	Effluent from FAC. POND
5.0	3.5	4.4×10^2	6.0×10^3	5.6×10^4
10.0	7.0	5.3×10^2	4.1×10^4	4.0×10^5
15.0	10.5	3.5×10^3	2.6×10^5	2.4×10^6
20.0	14.0	4.6×10^3	1.4×10^6	1.5×10^6

4.3 Chemical Coagulation

Jar-Tests experiments were conducted on the effluents from the facultative ponds at the different detention period to determine the optimum coagulant dosages. The results are shown in Appendix 6.

Table 4.9 - 4.12 show the characteristics of the effluents coagulated at the different optimal coagulant dosages.

Table 4.9: Effluent Characteristics before/after Optimum Coagulant dosage (4g/1) at 5.0/3.5 Detention Periods

Characteristics	From FAC. POND	After Coagulation (4g/1)	% age Removal
1. Colour	200 (Units)	39 (Units)	80.50
2. pH	7.8	6.4	
3. BOD (mg/1)	280	41.44	85.20
4. COD (mg/1)	1,200.0	465.60	61.20
5. Nitrate-Nitrogen (mg/1)	121.0	120.0	
6. Ammonia-Nitrogn (mg/1)			
7. Suspended Solids (mg/1)	-	-	-
8. Phosphates (mg/1)	0.875	-	100

Table 4.10: Effluent Characteristics before/after Optimum Coagulant dosage (3.5g/l) and 10.0/7.0 Detention Periods

Characteristics	From FAC. POND	After Coagulation (3.5g/l)	% age Removal
1. Colour	150.0	35.0	76.66
2. pH	8.4	6.70	
3. BOD (mg/l)	220.0	18.0	91.81
4. COD (mg/l)	803.0	200.0	75.09
5. Nitrate-Nitrogen (mg/l)	151.0	150.0	-
6. Ammonia-Nitrogen (mg/l)	16.0	16.0	-
7. Suspended Solids (mg/l)	-	-	-
8. Phosphates mg/l	10.0	-	100

Table 4.11: Effluent Characteristics before/after Optimum Coagulant dosage (4.0g/l) at 15.0/10.5 days Detention Periods

Characteristics	From FAC. POND	After Coagulation (4.0g/l)	% age Removal
1. Colour	400 Units	50.00 Units	87.5
2. pH	8.3	6.90	
3. BOD (mg/l)	230.00	22.00	90.43
4. COD (mg/l)	897.00	250.00	72.13
5. Nitrate-Nitrogen (mg/l)	141.00	140.00	0.71
6. Ammonia-Nitrogen (mg/l)	41.00	36.00	12.20
7. Suspended-Solids (mg/l)	-	-	-
8. Phosphates (mg/l)	0.43	-	100.00

Table 4.12: Effluent Characteristics before/after Optimum Coagulant dosage (6.0g/l) at 20.0/14.0 days Detention Periods

Characteristics	From FAC. POND	After Coagulation (6.0g/l)	% age Removal
1. Colour	500 Units	65.00	87.00
2. pH	8.40	6.40	
3. BOD (mg/l)	250.04	32.0	87.20
4. Nitrate-Nitrogen (mg/l)	154.00	154.00	-
5. Ammonia-Nitrogen (mg/l)	50.00	51.00	-
6. Suspended Solids (mg/l)	-	-	-
7. COD (mg/l)	889.55	300.00	66.27
8. Phosphates (mg/l)	0.37	-	100.00

CHAPTER FIVE

ANALYSIS AND DISCUSSION

5.1 Raw Wastewater

In general textile processes use large quantities of water and the wastewaters are usually strongly polluted with organic matter in solution or colloidal form and are generally alkaline. Also the raw wastewater is highly coloured.

From Table 4.1, the BOD values of ZIL Textile Industry was observed to range from 1066 mg/l to 1474 mg/l (average 1222.67); the COD values ranged from 2530 mg/l - 2996 mg/l (average 2702.33 mg/l). The COD/BOD ratio for the faw wastewater was found to be 2.22. The pH ranged from 7.3 to 8.0 (average of 8.0). The colour ranged from 400 units to 700 units (average 512 units).

5.2 Effluent Characteristics

5.2.1 Physical Observations

During operation, thick Scum was formed at the surface of the anaerobic pond when operated at 5 days and 10 days detention period. However the Scum disappeared at the 15 and 20 days detention periods. This observation was also noted by Mara(1976) with ponds operating at detention times greater than 5 days.

Also odour was observed to develop in the anaerobic pond when operated at 5 days detention period. However, the odour faded to a slight one which persisted till the end of the experiments. Odour development may be due to overloading which is expected at a shorter detention time.

5.2.2 Chemical Analysis

5.2.2.1 BOD_5 and COD

The concentrations of BOD_5 and COD remaining in the effluent at various detention period was presented on Tables 4.2 and 4.3. The tables also show the corresponding removal efficiencies.

The BOD_5 of the effluent from the anaerobic pond varied from 477.67 mg/l to 612.62 mg/l with percentage removal of between 48.28% at 5 days to 58.44 at 20 days. The BOD_5 of the effluent from the facultative pond varied from 225 mg/l to 280 mg/l. The total percentage removal from the anaerobic and facultative ponds in series ranged between 73.75% at 5 and 3.5 days to 82.72 at 20 and 14.0 days detention period respectively.

Values of COD of effluents from the anaerobic pond varied between 1100.00 and 1433.33 mg/l representing percentage removals of between 43.42% and 56.40% respectively. The overall removals in the stabilisation pond ranged between 51.28% and 70.36%.

At long detention periods, the removal efficiency though increases but at a decreasing rate.

A. The Non-Biodegradable Organic Material

Fig. 4.3 (4.2.2) shows the plots of percentage N.D.M. aganist detention time. The plots indicates that the percentage N.D.M. gradually decreases from 61.51% to 53.10 in the anaerobic pond and from 77.29% to 71.32% in the facultative pond. The decrease in the N.D.M. may result from micro-organisms getting more adapted to the environment at higher detention period and are able to degrade more proportion of the organics that appear non bio-degradable at lower detention periods.

B. The BOD - COD Relationships

Effort has been made to establish some relationships between BOD, COD and Detention times. The relationships are valid within the limits of experimental investigation, that is between detention period of 5 and 20 days for anaerobic pond and detention period of 3.5 and 14.0 days for facultative pond.

(a) Correlation Between Influent and Effluent BOD and Detention Period

Multiple linear regression analysis was used to establish relationship between Influent and Effluent BOD and Detention Period for the anaerobic and facultative ponds respectively.

(i) For Anaerobic Pond

$$BOD_{Effl.} = -134.42 + 0.7165\ BOD_{INF.} - 15.58\ D.T. - \qquad 5.1$$

Coefficient of correlation = 0.89

(ii) For Facultative Pond

$$BOD_{Effl.} = -263.87 - 0.0035\ BOD_{INF.} - 1.58\ D.T. - \qquad 5.2$$

Coefficient of Correlation = 0.98.

(b) BOD, COD Removal Efficiencies Vs Detention Periods

Equations 5.3 to 5.6 show the relationship between BOD_5 removal efficiency with respect to detention period and COD removal with respect to detention period for the anaerobic and facultative pond effluents

(i) Anaerobic Pond Effluent

$$BOD_{R.Eff.} = 46.65 + 0.66\ D.T. \qquad 5.3$$

Coefficient of correlation = 0.92

$$COD_{R.EFF.} = 42.3 + 0.79\ D.T. \qquad 5.4$$

Coefficient of Correlation = 0.86

(ii) Facultative Pond Effluent

$$BOD_{R.EFF.} = 46.48 + 0.91\ D.T. \qquad 5.5$$

Coefficient of Correlation = 0.98

$$COD_{R.Eff.} = 10.14 + 1.69\ D.T. \qquad 5.6$$

Coefficient of Correlation = 0.94.

C. The Reaction Rate Constants K

The reaction rate constants, K were calculated at the different detention period for the two ponds assuming plug flow, completely mixed flow and dispersed flow system. The values of the average influent and effluent BOD were used in the estimation. Equations 2.3 and 2.5 (Chapter Two) were used for completely mixed flow and plug flow, while the Thirumuthi Chart (Fig. 1.0) was used to estimate K values for dispersed flow. Coefficient of dispersion was assumed to be 1.0 based on reasons advanced in 2.5.3.2. (iii). The result of the calculation is as shown.

Table 5.1: Reaction Rate Constants, K (per day)

Detention Period (days) AN.	FAC.	ANAEROBIC POND Plug flow	Com- pletely mixed	Dis- persed flow	FACULTATIVE POND Plug flow	Com- pletely mixed	Dis- persed flow
5.0	3.5	0.13	0.18	0.20	0.19	0.28	0.29
10.0	7.0	0.08	0.12	0.11	0.11	0.16	0.15
15.0	10.50	0.06	0.09	0.08	0.08	0.13	0.11
20.0	14.0	0.04	0.07	0.06	0.06	0.01	0.09

An examination of the trend indicates that the K value decreases with higher detention period. It is also observed that the K values for dispersed flow lie between the K values for the plug flow and the completely mixed flow. This observation confirms the fact that the dispersed flow lies between the plug flow and the completely mixed flow conditions.

5.5.2.2 Suspended Solids

According to Mara (1976) and substantiated by this investigation ponds have a high capability of removing solids from wastewaters. As the sewage enters the pond the settlable solids settle at the bottom to form a sludge layer. In this study, the effluent from anaerobic and facultative ponds have negligible suspended solids. The low suspended solids in the effluent is perhaps influenced by the low suspended solids in the raw wastewater which was between 14.90 mg/l and 72.28 mg/l (Table 4.4).

5.2.2.3. Colour

The colour removal by the stabilization pond was presented on Table 4.5. The colour was mainly removed in the anaerobic pond. Colour removal by the facultative pond was either very negligible or nil. It was observed that colour intensities fluctuated between 140 to 500 units in the facultative pond effluent.

It is evident from these results that stabilization pond is not efficient in removing colour from textile wastewater. According to Fair *et al* (1954), colour in textile wastes is mainly removed chemically (by coagulation, bleaching or adsorption).

(i) The use of phosphates for metabolism by micro-organism in both the anaerobic and facultative ponds.

(ii) The use of phosphates by algae in the facultative pond for photosynthetic activities.

The stabilisation pond is adequate for removal of phosphates.

5.2.2.6 Ammonia Nitrogen and Nitrate Nitrogen

The raw wastewater ammonia-nitrogen concentration was between 10 mg/l and 12 mg/l (Table 4.8). The increase of ammonia-nitrogen concentration between 20 mg/l at 5 days detention period and 90 mg/l at 20 days detention period for the anaerobic effluents may be due to anaerobic decomposition of organics (Mara, 1976; Hammer, 1975). However, a decrease in this parameter was observed in the facultative pond effluent. This may be due to oxidation of ammonia-nitrogen to nitrate in the facultative pond. This observation is collaborated by the observed increase in the nitrate-nitrogen in the facultative pond effluent.

5.2.2.7 Total Bacteria Count

Table 4.9 shows the total bacteria count (per 100 ml) in both the anaerobic and facultative pond effluents. It would appear from the table that the

5.2.2.4. pH

Table 4.6 shows the pH of the raw and the treated wastewater. The wastewater is generally alkaline with the pH fluctuating between 7.3 and 8.0 which, according to Newlin (1971) is a good environment for biological decomposition. It would appear that the wastewater require no neutralization before biological treatment.

The pH of the effluents from the anaerobic and facultative ponds fluctuated between 7.9 and 8.5. The slight rise in pH was probably due to the production of Ammonia (which is alkaline in nature) during biological oxidation.

5.2.2.5 Phosphates

Table 4.7 shows that the concentrations of phosphates in the raw wastewater was between 3.76 mg/l and 6.00 mg/l. The anaerobic pond effluent phosphates concentration was between 1.56 mg/l and 4.25 mg/l while the facultative pond effluent phosphates concentration was between 0.38 mg/l and 1.02 mg/l. The total percentage removal of phosphates being between 85.17% and 90.16%.

The high removal efficiency observed may be due to:

total bacteria count increased in the effluent. It is difficult to ascertain why this is so, but previous works by Lonsane <u>et al</u> (1967) for example revealed that membrane filter count of coliforms from samples held for up to 48 hours were not significantly different from those found initially. They (Lonsane <u>et al</u>) suggested that the increase or decrease in the number of coliforms depends largely on the prevailing conditions. These conditions include temperature, storage time and initial degree of sterility. On the other hand Geldreich <u>et al</u> (1955) revealed that the mean coliform density at 24 hours for 18 samples collected from wells, lakes and rivers and held at 5°C was 72 percent of the mean at 12 hours. It has also been reported by Shuval <u>et al</u> (1972) that coliforms and feacal coliforms are capabable of regrowth even in chlorinated wastewater. Dutka and El-Shaarawi (1980) stored waters with various pollutional loads at 1.5°C. They found that at least 75 percent of the samples had a constant level of bacteria for 24 hours, but that there was little evidence that microbial populations were stable over 48 hours.

In this situation, it is not possible to say what is particularly responsible for the increase in the total bacteria count in the effluent because this investigation was not specifically carried out.

5.4 The Design of Ponds

Choosing detention periods of 10 days and 10.5 days for the design of anaerobic pond and facultative pond respectively based on results of laboratory sampling. At ZIL, the average discharge of wastewater, Q, is 350 m^3/day. Two design approaches shall be employed:

(i) Without using the design curves developed on Fig. 4.1 and 4.2 (5.4.1 and 5.4.2).

(ii) Using the design curves developed on Fig. 4.1 and 4.2 (5.4.3).

5.4.1 Anaerobic Pond Design

Depth of 3.0m shall be choosen Mara (1976) t* (detention period) = 10.0 days.

Mid-depth area, A can be calculated from equation (2.1) i.e.

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

$$A = \frac{350 \times 10}{3.0} = \frac{3500}{3.0} = 1166.666m^2$$

$$= 1166.67m^2.$$

The surface BOD_5 loading which is the weight of BOD_5 applied per unit area per day shall be

$$Ls = \frac{10\ LiQ}{A} \quad \text{from} \quad (2.)$$

$$Li = BOD_5 \text{ influent in mg/l}$$

Take average Li = 1270 mg/l

$$\therefore \quad Ls = \frac{10 \times 1270 \times 350}{1166.67} = 3809.989$$

$$= 3810.00 \text{ kg/ha.d.}$$

This is safe. Therefore design mid-depth area of anaerobic pond

$= \underline{1166.67 \text{ m}^2}$

The Depth = $\underline{3.00}$m and

surface loading = $\underline{3810.00 \text{ kg}}$/ha.d

5.4.2 Facultative Pond

Calculation of Mid-depth Area, A.

From equation (2.1)

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

Choose D = 1.5 m - Mara (1976)

t* = 10.5 days

$$A = \frac{350 \times 10.5}{1.5}$$

$$= 2450 \text{ m}^2$$

Using Influent BOD_5 = 0.45 x 1270.00 (55% reduction in (anaerobic pond)

Li = 571.50 mg/l

The surface loading $Ls = \frac{10QLi}{A}$ (Mara 1976)

$$= \frac{10 \times 571.50 \times 350}{2450}$$

$$= 816.43 \text{ kg/ha/d.}$$

Therefore, mid depth area of facultative pond kg/ha/d.

= 2450

The depth = 1.5

The BOD total percentage removal is 79.0% (Table 4.2).

5.4.3 Using the Curves on Fig. 4.1 and 4.2

To use this curve, 58% removal of BOD shall be assumed in the anaerobic pond while 54% BOD removal shall be assumed in the facultative pond. Lower percentage choosen in the facultative pond is because of the large surface area required by this pond compared to anaerobic pond.

(i) For anaerobic pond

Choosing 58% removal of BOD (This is hypothetical)

The corresponding detention period = 15.5 days

(from Fig. 4.1)

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

$Q = 350 \text{ m}^3/\text{d}.$

Choosing D = 3.0m (Mara, 1976)

$A = \frac{350 \times 15.1}{3.0}$

$\therefore \quad A = 1808.33 \text{ m}^2$

Surface Loading, Ls = 1474.00 kg/1/d (from Fig. 4.1) Therefore provide pond of 60m by 30m and Depth of 3.00m

(ii) <u>For facultative pond</u>

Choosing 54% removal of remaining BOD in the anaerobic pond effluent (also hypothetical)

The corresponding detention time = 6.8 days (Fig. 4.2)

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

Choosing D = 1.5 (Mara, 1976)

$$A = \frac{350 \times 6.8}{1.5}$$

$$A = 1633.33 \text{ m}^2$$

Also Organic Loading = 190 kg/ha/d

(It is safe)

∴ Mid-depth area = 1633.33 m^2

Provide pond of 30m by 54m and

Depth of 1.5m

BOD_5 of effluent from anaerobic pond

= 1270 x 0.42 (58% removal)

= 533.40

BOD_5 of effluent from facultative pond

= 533.4 x 0.46 (54% removal)

= 245.36

Total percentage removal

$$= \frac{1270 - 245.36}{1270} \times 100\% = \underline{81.0\%}$$

The two design approaches achieved about the same total efficiency. Designing without the curves, a total efficiency of about 79.00% is achievable while with the curves total efficiency of about 81% is achievable. The design output of 5.4.3. shall be recommended, this is because the organic loadings on the two ponds are safer than indicated by calculation on 5.4.1 and 5.4.2.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 C O N C L U S I O N S

Based on the present study the following conclusions can be arrived at:

1. The textile industry is a consumer of large volume of water generating large volume of waste-water.
2. Most of the water use and wastewater generation occur in the finishing shop where dyeing, washing and final treatment are performed.
3. The wastewater generated by the Zaria Industries Limited which is essentially a textile industry could be classified as being strong. The average BOD of the raw sample is 1270 mg/l while the average COD is 2764.50 mg/l.
4. The wastewater is highly coloured and alkaline in nature. The colour ranged from 400 units to 700 units.
5. Stabilization ponds including an anaerobic and facultative ponds in series operating at detention periods of 20 days and 14 days respectively could achieve total BOD reduction of 82%, COD reduction of 70% and colour reduction of 60%.
6. Other parameters such as suspended solids, phosphates and ammonia-nitrogen can also be considerably reduced by waste stabilization ponds.

7. From regression equations, linear relationships exist between the influent BOD, effluent BOD and the detention periods and between the BOD/COD removal efficiencies and detention periods.

8. Although waste stabilization pond can achieve high removal of organic matter and colour from the raw textile wastewater, additional tertiary treatment is desirable for upgrading the effluents as the final effluent still contain as shown in this study significant quantities of these parameters.

9. Chemical coagulation using alluminium sulphate is an effective tertiary treatment. Coagulant dosage of between 3.5 g/l and 6.0 g/l will provide a reasonably good degree of improved effluent quality.

6.2 RECOMMENDATION

The following are recommended for further studies.

1. The use of activated carbon, sand filter etc. as a means of tertiary treatment after biological treatment of textile wastewater.

2. Pre-coagulation of textile wastewater before lagoon treatment.

3. Studies should be carried out on other textile industries in order to have a reasonable amount of knowledge of the characteristics of textiles wastewater throughout the country. Studies should also be carried out to establish the best method of treatment that will satisfactorily reduce the concentration of these parameters which may exert a deleterious effect on down stream aquatic systems.

R E F E R E N C E S

1. Besselievre, E.B. and Schwartz, M. (1976) The Treatment of Industrial Wastes McGraw-Hall Book Company New-York.

2. Boom, G.K. (1981) Technology Transfer in Fibres, Textiles and Apparel SIJHOFF AND NOORDHOFF, New-York Pg. 149.

3. Culp, R.S. and Gulp, G.L. (1971) Advanced Waste Water Treatment Van Nostrand Reinhold Company New-York.

4. Dutka, B.J and El-Shaarawi (1980) Microbiological Water and Effluent Sample Preservation. Canadian Jour. Microbiol., 26:921.

5. Fair, G.M.; Geyer, J. Morris, J. (1954) Water Supply and Waste-Water Disposal John Wiley and Sons, Inc., New-York, London, Pg. 878-879.

6. Geldreich, E.E. (1955) A delayed incubation Membrane filter test for coliform bacteriain Water Amer. Jour. of Public Health, 45:1462.

7. Gloyna, E.F. (1971) Waste Stabilisation Ponds World Health Organisation, Geneva.

8. Gloyna, E.F. and Davies, E.M. (1972) Bacterial Die Off in Ponds J. Sanit. Eng. Div., ASCE 98, SAI.

9. Hammer, M.J. (1975) Water and Wastewater Technology John Wiley and Sons London, Pg. 296 - 298.

10. Harris, S.E. (1977) Intermittent Sand Filtration for Upgrading Waste Stabilisation Pond Effluents Journal Water Pollution Control Federation, 49:1:83.

11. Lonsane, B.K., Parha, N.M. and Rao N.U. (1967) Effect of Storage, Temperature and Time on the Coliforms in Water Samples. Water Res. 1:309-317.

12. Lumbers, J.P. (1979) Waste Stabilisation Ponds; Design Consideration and Methods The Public Health Engr. Vol. 7, No. 2.

13. Marais, G.V.R. (1974) Faecal Bacterial Kinetics in Stabilisation Ponds J. Environ. Eng. Div. ASCE, 100, EEI.

14. Mara, D.D. (1976) Sewage Treatment in Hot Climates John Wiley, London, Pg. 69-90.

15. Mckinney, R.E. (1962) Microbiology for Sanitary Engineers, McGraw-Hill, New York.

16. Metcalf and Eddy (1972), Wastewater Engineering Mc.Graw-Hill, New York.

17. Mizumoto, K. and Horie, M. (1974) Dying Waste Water Treatment by Combination of Ozone and Activated Carbon Japan Textile News, 238.

18. Nemerow, L. (1971) Liquid Waste of Industry - Theories, Practices, and Treatment Addison-Wesley, Reading, Mass.

19. Newlin, K. (1971) The Economic Feasibility of Treating Textile Wastes in Municipal Systems, Water Pollution Federation.

20. Noguchi, S. (1974) Treatment of Degumming and Dyeing Wastewater Through Flocor Tower Shaped Biofilter Process Japan Textile News, 232, 91.

21. Parker, D.J. and Warren, R.U. (1975) Discussion Technique For Algae Removal From Oxidation Ponds. Journal Water Pollution Control Federation, 47:9: 2330.

22. Shuval, H.I.; J. Cohen and R. Kolodney (1972) Regrowth of Coliforms and Faecal Coliforms in Chlorinated Wastewater Effluent Water Research 7: 537 - 546.

23. Sinder, E.H. and Porter, J.J. (1974), Ozone Treatment of Dye Wastes Poll. Control Federation 46, 886.

24. Steel, E.W. and Terence, J.M. (1985) Water Supply and Sewerage McGraw-Hill Book Company, London. Pg. (289 - 290) (518 - 521) & 572.

25. Stone, R.W.; Parker, D.S.; Cotteral, J.A. (1975) Upgrading Lagoon Effluent for Best Practical Treatment, Journal Water Pollution Control Federation, 47:8:2019.

26. Thirumurthi, D. (1969) Design Principles of Waste Stabilisation Ponds. J. Sanitary DIV., ASCE, Vol.95 No. SA2.

27. Vincent, J.L.; Algie, W.E. and Marais, G.V.R. (1963) London Commission for Technical Co-operation, South of Sahara (Publ. No. 84 Pg. 135 - 172).

28. Wehner, J.F. and R.F. Wilhelm (1958) Boundary Conditions of Flow Reactors, Chem. Eng. Sci., Vol.6, Pg. 89.

APPENDICES

APPENDIX 1: LAB. READINGS SERIES 1

(5/3 • 5-DAYS DETENTION PERIOD)

Table A1.1: BOD_5 (mg/l)

TIME INTERVALS (DAYS)	RAW SEWAGE	AN. EFF.	FA. EFF.
1.	1100.00	610.00	310.00
3.	1100.00	580.00	290.00
5.	1200.00	560.00	280.00
7.	1100.00	555.00	280.00
9.	1100.00	550.00	280.00
11.	1000.00	550.00	280.00
STABILISED AVERAGE	1066.67	551.67	280.00

Table A2.2: COD (mg/l)

TIME INTERVALS (DAYS)	RAW SEWAGE	AN. EFF.	FA. EFF.
1.	2600.00	1600.00	1400.00
3.	2500.00	1600.00	1300.00
5.	2600.00	1500.00	1300.00
7.	2600.00	1400.00	1200.00
9.	2400.00	1400.00	1200.00
STABILISED AVERAGE	2533.33	1433.33	1233.33

Table A1.3: pH

TIME INTERVALS (DAYS)	RAW SEWAGE	AN. EFF.	FA. EFF.
1.	9.3	8.0	8.10
3.	8.2	7.4	7.6
5.	7.7	8.2	7.7
7.	7.5	7.7	7.80
9.	7.5	8.0	7.80
AVERAGE	8.04	7.86	7.8

Table A1.4: COLOUR

TIME INTERVALS (DAYS)	RAW SEWAGE	AN. EFF.	FA. EFF.
1.	450 units	300 units	300 units
3.	450 "	250 "	150 "
5.	400 "	200 "	200 "
7.	400 "	200 "	200 "
9.	400 "	200 "	200 "
11.	400 "	200 "	200 "
STABILISED AVERAGE	400.00	200.00	200.00

Table A1.5 SUSPENDED SOLIDS (mg/l)

TIME INTERVALS (DAYS)	RAW SEWAGE	AN.E.	FAC.EFF.	TOTAL REMOVAL EFF. %
1.	16.67	–	–	100
3.	16.50	–	–	"
5.	16.52	–	–	"
7.	16.00	–	–	"
9.	16.20	–	–	"
11.	16.34	–	–	"
AVERAGE	16.37			

Table A1.6 NITRATE NITROGEN (mg/l)

TIME INTERVALS (DAYS)	RAW SEWAGE	AN.E.	FACE. E.
1.	108.00	122.00	95.00
3.	108.00	125.00	85.00
5.	108.00	134.00	120.00
7.	106.00	136.00	121.00
9.	107.00	136.00	212.00
11.	106.00	136.00	212.00
STABILISED AVERAGE	107.00	136.00	212.00

Table A1.7 AMMONIA NITROGEN (mg/1)

TIME INTERVALS (DAYS)	RAW SEWAGE	AN. E.	FAC. E.
1.	12.00	36.00	4.00
3.	12.00	24.00	12.00
5.	12.00	20.00	14.00
7.	12.00	20.00	12.00
9.	12.00	20.00	12.00
11.	12.00	20.00	12.00
AVERAGE	12.00	20.00	12.00

Table A1.8 PHOSPHATES (mg/1)

TIME INTERVALS (DAYS)	RAW SEWAGE	AN. E.	FAC. E.
1.	6.25	2.50	0.875
3.	6.25	2.75	0.875
5.	6.30	2.50	0.875
7.	6.27	2.50	0.875
9.	6.25	2.50	0.875
11.	6.26	2.50	0.875
STABILISED AVERAGE	6.26	2.50	0.875

APPENDIX 2: LAB READINGS - SERIES 2

(10/7.0 - DAYS DETENTION PERIOD)

Table A2.1: BOD_5 (mg/1)

TIME INTERVALS (DAYS)	RAW SEWAGE	AN. EFF.	FA. EFF.
1.	1000.00	500.00	300.00
3.	1100.00	490.00	240.00
5.	1000.00	470.00	235.00
7.	1100.00	480.00	220.00
9.	1100.00	481.00	220.00
STABILISED AVERAGE	1066.67	477.67	225.00

Table A2.2: COD (mg/1)

TIME INTERVALS (DAYS)	RAW SEWAGE	AN. EFF.	FA. EFF.
1.	2400.00	1300.00	1000.00
3.	2500.00	1200.00	900.00
5.	2400.00	1100.00	890.00
7.	2400.00	1100.00	800.00
9.	2400.00	1050.00	803.00
STABILISED AVERAGE	2400.00	1100.00	817.67

Table A2.3: pH

TIME INTERVALS (DAYS)	RAW SEWAGE	AN. EFF.	FA. EEF.
1.	7.5	7.6	8.4
3.	7.5	7.7	8.2
5.	9.0	8.1	8.3
7.	8.1	8.3	8.5
9.	8.0	8.3	8.4
AVERAGE	8.02	8.00	8.36

Table A2.4: COLOUR

TIME INTERVALS (DAYS)	RAW SEWAGE	AN. EFF.	FA. EFF.
1.	400 Units	200.00	200.00
3.	400 "	150.00	150
5.	350 "	150	150
7.	350 "	150	120
9.	350 "	150	150
STABILISED AVERAGE	350	150	140

Table A2.5: SUSPENDED SOLIDS (mg/l)

TIME INTERVALS (DAYS)	RAW SEWAGE	AN. EFF.	FA. EFF.
1.	15.00	-	-
3.	14.00	-	-
5.	16.00	-	-
7.	15.00	-	-
9.	14.00	-	-
AVERAGE	14.90		

Table A2.6: NITRATE NITROGEN (mg/l)

TIME INTERVALS (DAYS)	RAW SEWAGE	AN. EFF.	FA. EFF.
1.	89.00	123.00	108.00
3.	90.00	123.00	110.00
5.	90.00	121.00	123.00
7.	89.5	133.00	149.00
9.	92.00	134.00	151.00
AVERAGE	90.10	126.80	150.00

Table A2.7: AMMONIA NITROGEN (mg/l)

TIME INTERVALS (DAYS)	RAW SEWAGE	AN. EFF.	FA. EFF.
1.	12.00	24.00	14.00
3.	12.00	24.00	16.00
5.	14.00	26.00	16.00
7.	12.00	26.00	16.00
9.	12.00	26.00	16.00
AVERAGE	12.00	26.00	16.00

Table A2.8: PHOSPHATES (mg/l)

TIME INTERVALS (DAYS)	RAW SEWAGE	AN. EFF.	FA. EFF.
1.	6.89	4.25	1.00
3.	6.80	4.24	1.00
5.	7.00	4.25	1.00
7.	6.85	4.25	1.13
9.	6.88	4.25	1.00
AVERAGE	6.88	4.25	1.02

APPENDIX 3: LAB READINGS - SERIES 3

(15/10.5 - DAYS DETENTION PERIOD)

Table A3.1: BOD_5 (mg/l)

TIME INTERVALS (DAYS)	RAW SEWAGE	AN. EFF.	FA. EFF.
1.	1300	500	230
3.	1300	530	233
5.	1250	543	235
7.	1300	548	233
9.	1300	546	230
AVERAGE	1283.33	545.67	232.67

Table A3.2: COD (mg/l)

TIME INTERVALS (DAYS)	RAW SEWAGE	AN. EFF	FA. EFF.
1.	2900	1200	1000
3.	2900	1300	1100
5.	2800	1290	1000
7.	2900	1300	900
9.	2900	1300	897
AVERAGE	2880	1296.67	932.33

Table A3.3: pH

TIME INTERVALS (DAYS)	RAW SEWAGE	AN. EFF.	FA. EFF.
1.	6.7	8.1	8.3
3.	7.3	8.5	8.6
5.	7.3	8.5	8.6
7.	7.5	8.4	8.2
9.	7.8	8.1	8.3
AVERAGE	7.32	8.32	8.40

Table A3.4: COLOUR

TIME INTERVALS (DAYS)	RAW SEWAGE	AN. EFF.	FA. EFF.
1.	600	500	400
3.	600	300	350
5.	600	400	400
7.	600	400	400
9.	600	400	400
AVERAGE	600	400	400

Table A3.5: SUSPENDED SOLIDS (mg/l)

TIME INTERVALS (DAYS)	RAW SEWAGE	AN. EFF.	FA. EFF.
1.	40.90	–	–
3.	30.70	–	–
5.	35.5	–	–
7.	40.30	–	–
9.	32.23	–	–
AVERAGE	35.93		

Table A3.6 NITRATE NITROGEN (mg/1)

TIME INTERVALS (DAYS)	RAW SEWAGE	AN. EFFL.	FAC. EFFL.
1.	89.9	133	149
3.	90.3	110	134
5.	90.5	114	140
7.	89.7	118	142
9.	92.0	118	141
STABILISED AVERAGE	90.48	116.67	141

Table A3.7: AMMONIA NITROGEN (mg/1)

TIME INTERVALS (DAYS)	RAW SEWAGE	AN. EFFL.	FAC. EFFL.
1.	10.00	32.00	18
3.	10.00	56.00	16
5.	10.00	80.00	28
7.	10.00	80.00	40
9.	10.00	80.00	41
STABILISED AVERAGE	10.00	80.00	40.50

Table A3.8: PHOSPHATES (mg/1)

TIME INTERVALS (DAYS)	RAW SEWAGE	AN. EFFL.	FAC. EFFL.
1.	3.76	1.6	0.43
3.	3.78	1.58	0.45
5.	3.74	1.60	0.44
7.	3.75	1.50	0.43
9.	3.76	1.60	0.43
AVERAGE	3.76	1.58	0.44

APPENDIX 4: LAB READINGS - SERIES 4

(20/14.0 - DAYS DETENTION PERIOD)

Table A4.1: BOD_5 (mg/1

TIME INTERVALS (DAYS)	RAW SEWAGE	AN. EFF.	FA. EFF.
1.	1500.00	625.00	258.00
3.	1480.00	636.00	264.00
5.	1500.00	626.00	264.00
7.	1400.00	568.00	236.00
9.	1490.00	608.00	250.00
AVERAGE	1474.00	612.62	254.67

Table A4.2: COD (mg/1)

TIME INTERVALS (DAYS)	RAW SEWAGE	AN. EFF.	FA. EFF.
1.	3000.00	1287.00	858.00
3.	3000.00	1305.00	911.00
5.	3000.00	1317.00	897.00
7.	2980.00	1307.00	885.00
9.	3000.00	1316.00	890.00
AVERAGE	2996.00	1366.37	888.10

Table A4.3: pH

TIME INTERVALS (DAYS)	RAW SEWAGE	AN. EFF.	FA. EFF.
1.	8.00	8.60	8.50
3.	8.20	8.50	8.40
5.	8.10	8.60	8.50
7.	7.50	8.40	8.50
9.	7.80	8.50	8.40

Table A4.4: COLOUR

TIME INTERVALS (DAYS)	RAW SEWAGE	AN. EFF.	FA. EFF.
1.	600.00	400.00	400.00
3.	600.00	400.00	350.00
5.	700.00	400.00	400.00
7.	700.00	450.00	500.00
9.	700.00	450.00	500.00
AVERAGE	700.00	450.00	500.00

Table A4.5: SUSPENDED SOLIDS (mg/l)

TIME INTERVALS (DAYS)	RAW SEWAGE	AN.E.	FAC.E.
1.	72.34	-	-
3.	73.20	-	-
5.	85.45	-	-
7.	85.43	-	-
9.	70.00	-	-
AVERAGE	77.28	-	-

Table A4.6: NITRATE NITROGEN (mg/l)

TIME INTERVALS (DAYS)	RAW SEWAGE	AN.E	FAC. E.
1.	95.72	128.00	154.00
3.	98.32	128.00	154.00
5.	97.30	126.00	154.00
7.	96.40	126.00	154.00
9.	97.50	126.00	154.00
AVERAGE	97.05	126.80	154.00

Table A4.7: AMMONIA NITROGEN (mg/l)

TIME INTERVALS (DAYS)	RAW SEWAGE	AN. E.	FAC. E.
1.	10.00	90.00	50.00
3.	10.00	90.00	50.00
5.	10.00	90.00	50.00
7.	10.00	90.00	50.00
9.	10.00	90.00	50.00
AVERAGE	10.00	90.00	50.00

Table A4.8: PHOSPHATES (mg/l)

TIME INTERVALS (DAYS)	RAW SEWAGE	AN. E.	FAC. E.
1.	3.90	1.42	0.38
3.	3.84	1.43	0.40
5.	3.82	1.53	0.37
7.	3.80	1.50	0.37
9.	3.81	1.52	0.37
AVERAGE	3.83	1.48	0.38

APPENDIX 5: NON-BIODEGRADABLEMATERIAL (NDM)

DETENTION PERIOD (DAYS)		N.D.M. (mg/l)		% N.D.M. (NDM/COD x 100)	
AN.	FAC.	AN	FAC.	AN.	FAC.
5	3.5	881.06	953.33	61.51	77.29
10	7.0	622.33	592.67	56.57	72.48
15	10.50	751.00	699.66	57.91	75.04
20	14.0	693.75	633.43	53.10	71.32

Table A6.3: Jar-Test Results, for Effluents from 15/10.5 Days Detention Periods

Coagulant Dosages	pH	Turbidity	Colour	Remarks
3.0g/l	7.1	45.50 NTU	60 Units	Very light green
4.0g/l	6.9	30.00 "	50 "	Clear
5.0g/l	6.6	130.70 "	80 "	Slightly Milky
10.0g/l	5.7	99.00 "	90 "	Yellowish Milky
15.0g/l	5.0	50.00 "	70 "	Slightly Yellow

Table A6.4: Jar-Test Results; for Effluents from 20.0/14 days Detention Periods

Coagulant Dosages	pH	Turbidity	Colour	Remarks
2g/l	7.4	130.0	300.0	Dark Coloured
4g/l	6.8	120.0	150.0	Deep Yellow
5g/l	6.7	100.0	70.0	Light Yellow
6g/l	6.4	100.0	65.0	Very slightly Milky
7g/l	6.1	110.0	80.0	Milky
10g/l	5.5	80.0	200.0	Highly Coloured