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THE CHEMICAL PRECIPITATION AND  
BIOLOGICAL TREATMENT OF COTTON  
TEXTILE WASTES

BY

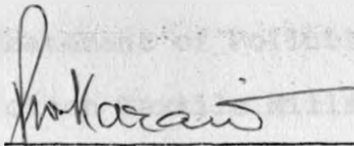
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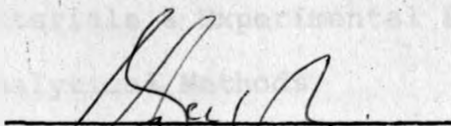
DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.



CANDIDATE

This thesis has been submitted for examination with my approval as University Supervisor.

  
SUPERVISOR

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SUMMARY

The performance of a stabilization pond is affected by physical and environmental factors among others. Temperature, light, mixing and pH variation are some of the major changing environmental factors. Depth, shape, loading and the nature of waste are some of the physical factors which will affect the organic removal efficiency. Optimum performance can only be achieved if the pond loading meets with the design requirements. A study was carried out on the sources, characteristics and quantities of cotton textile wastes and on the performance of six model ponds, each operating at a difference loading with cotton textile wastes in admixture with a constant volume of domestic waste. The organic removal efficiencies of the ponds were studied.

The six perspex model ponds were located in a well lighted room. Composite textile waste from a cotton textile mill and domestic sewage were used for this experiment. A set of six experiments using different textile waste loadings were performed. The samples taken were analysed for COD, DO and pH. Another series of experiments were carried out to precipitate organic load from cotton textile wastes using inorganic coagulants. In a third series of

experiments five perspex model ponds were used to study the effects of various direct dyes concentrations on stabilized domestic sewage. Samples taken were analysed for COD, BOD, DO, pH and chlorophyll 'a' concentrations.

From the observations and experimental results obtained, it was found that dissolved oxygen decreases with increased organic loading of the ponds with cotton textile wastes- and that where loadings were low a higher efficiency with regard to organic removal was achieved. From the results of precipitating organic load from cotton textile wastes using inorganic coagulants it was found that potassium aluminium sulphate was more effective than ferric chloride or ferrous sulphate. On the effects of direct dyes on the efficiency of domestic sewage, it was found that a direct dye concentration in excess of 10 mg/l had deleterious effects on algae.



### INTRODUCTION

The importance of the textile industry in a country like Kenya does not need to be over-emphasized. It provides the essential clothing required for the countries growing population. The textile industry in Kenya includes cotton, wool and synthetic fibres. The cotton textile industry is however dominant than the others. This becomes more important because cotton clothing is comparatively cheap and comfortable to wear especially in warm climates as those prevalent in this country throughout the year. To meet this local demand for cotton clothing such cotton textile industries as Thika United Textile Mills, Thika Cloth Mills, Rivatex at Eldoret and Kisumu Cotton Mills have been established. The raw cotton used in these mills is partly made available locally with a certain fraction being met through import. Efforts are however under way to increase the acreage of land under cotton cultivation and consequently satisfy locally the cotton demand for these factories.

This expansion of the cotton textile industry is a concern to the public health authorities in as far as satisfactory disposal of wastes originating from these factories is concerned. The cotton textile industry requires enormous quantities of water for processing of cloth into finished goods. A major

portion of the water used in these factories is discharged from the mill as waste water. Owing to the large quantities of the waste waters, the high degree of their chemical and physical complexity, and variation in quantity and quality, it becomes problematic to the layman to satisfactorily dispose off such waste waters. Disposal could take the form of direct discharge into a river course. This could contribute to depletion of dissolved oxygen in the receiving waters due to the high concentration of putrescible organic matters in wastes. As the wastes are usually highly alkaline and occasionally contain toxic matter, aquatic life may also be affected and may consequently die off. The receiving waters may also be rendered unsuitable for domestic, agricultural, recreational or industrial purposes. Disposal may also be through direct discharge into a municipal sewerage treatment works. This may result into overloading of such sewerage works and consequently a reduction in the efficiency of the sewerage works. Non-biodegradable synthetic matter may also pass through such works and finally be discharged into a receiving stream. Such persistent materials may end up into a water treatment works and may render domestic water supply substandard or may incur extra expense in the treatment of raw water.

It therefore becomes apparent that satisfactory disposal of industrial wastes is of prime importance

to the society and requires thorough investigation if the quality of the receiving waters is to be maintained in an acceptable condition to the community. This thesis is based on experimental work undertaken by evaluate the basis upon which satisfactory disposal of cotton textile wastes can be achieved. The work carried out involves the evaluation of the potential pollutional load originating from United Textile Mill at Thika. The degree to which cotton textile wastes can be treated in lagoons has been investigated using model lagoons at the University of Nairobi. Treatment of cotton textile wastes using inorganic coagulants and effects of direct dyes on domestic sewage has also been investigated and presented in this thesis. In addition to the experimental work carried out, processing of cloth from raw cotton to finished cloth at United Textile Mill at Thika has been investigated and also presented. Review work on the sources and characteristics of cotton textile wastes, the methods through which reduction of pollution load from cotton textile mills, and various methods of treatment of such wastes as carried out by various researchers has also been presented.

The information obtained from the investigations is used to evaluate the treatability of cotton textile wastes from the Thika United Textile Mill in the Thika Municipal sewerage stabilization Ponds without lowering their efficiency. Currently the ponds are

under investigation as to whether fish farming can be undertaken.

CHAPTER 1

PROCESSED AND MANUFACTURE OF CLOTH

The United Textile Mill at Taka Municipality has a yearly production of 5,000,000 running metres of 100 per cent cotton fabrics per year. This reduces to a production of 12,500 metres per day with a daily usage of 2,000 kg of raw cotton. The consumption of water is equally high with an average rate of 500 m<sup>3</sup> (500,000 litres) per day. In the mill, not all the cotton fabrics are printed. Out of the five million metres produced annually about 15 per cent is bleached and dyed. The remaining percentage is printed.

Conversion of raw cotton in the mill into finished fabric is done in the standard method used in many other mills. This can be broadly divided into two subdivisions. (Fig. 1). Firstly the raw cotton is converted into fabric through such complex operations as carding, spinning, slashing or sizing and then weaving and knitting. Then follows the second major step which involves processing of the fabric from the first stage into cloth.

The cloth fabrication starts with the opening of cotton bales received in the factory. The raw cotton is prepared by carding and spinning by

CHAPTER 1

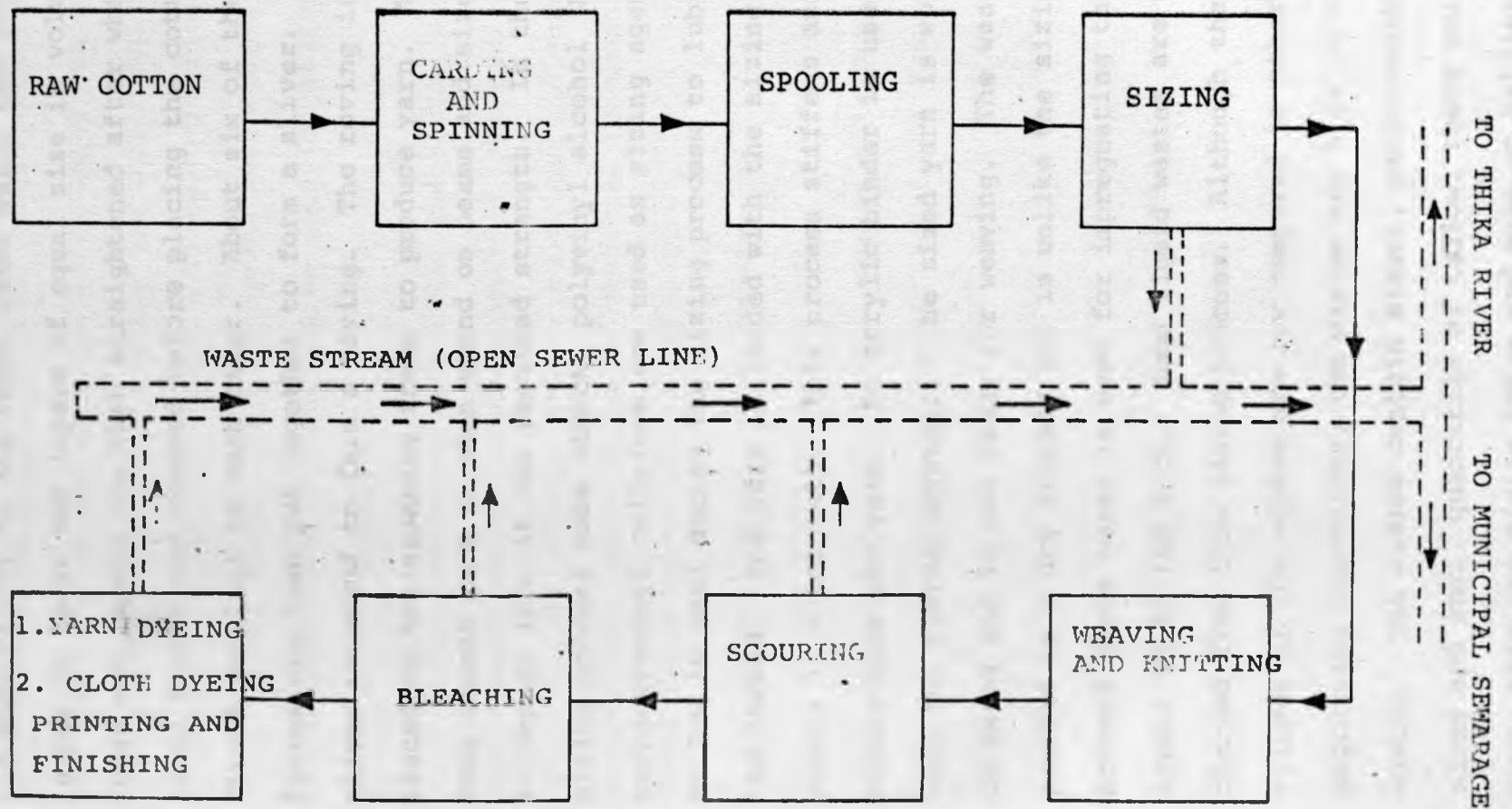
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The cloth fabrication starts with the opening of cotton bales received in the factory. The raw cotton is prepared for carding and spinning by

FIG. 1 FLOW SHEET OF CLOTH PROCESSING FROM COTTON AT THIKA UNITED TEXTILE MILL.



cleaning the cotton fibres to remove dust particles and other impurities. It is then mixed thoroughly and made fluffy to the touch after which the cotton is put in loose mat layers of equal size in volume. These mat layers are then straightened after which loose fibres are removed before placing the cotton fibres parallel to each other. About six of these fibres are then put together to form a sliver. The sliver is wound to form a roving. The roving is then placed on the spinning frame to produce yarn. The cone shaped yarn is then wound on beams and sized to impart into it the required strength. In the sizing process maize starch, polyvinyl alcohol (PVA) carboxymethyl cellulose are used as sizing agents. Tallow is used during the sizing process to lubricate the thread. The yarn is loaded with the sizing agents in a hot bath. This process stiffens and strengthens the yarn. An acrylic binder is used to hold the fibres together. The sized yarn is wound on beams and is now ready for weaving. The weaving process is a dry process and is unlike the sizing process where water is used for impregnating the sizing agents on to the yarn. Some liquid wastes are discharged from this sizing process. Although the volumes of the wastes are low compared to other processing operations, the wastes are high in organic wastes. The wastes contain starch, carboxymethyl cellulose and small quantities of tallow, these being left-overs from the sizing baths and make up kettles.



The yarn is then woven on looms into a fabric. Surface fibres and protruding yarn ends are removed in the singeing process. During singeing the loose fibres and ends are burnt using gas burners. Plain water is used for cooling the fabric which is afterwards termed grey goods. No water is used in this process except for cooling and humidifiers. The threads at this stage can be used for knitting underwears or hosiery.

Occasionally the yarn after raw cotton has been cleaned and just before weaving, the yarn is dyed. This is dyeing the raw stock and the wastes produced here are similar in character to those of final dyeing process after bleaching.

The next major operation after cloth fabrication is the processing of cloth. The whole of this operation is composed of many complex unit processes which vary depending on the nature of the finished cloth required. The individual unit operations require a high water consumption. In the cotton mill under investigation it was observed that over 90 per cent of the total water consumption is utilized in the whole of the processing of cloth. The unit processes through which the fabric passes through to end up as finished cloth include scouring, bleaching, dyeing and finishing. Mercerizing is an operation that is not undertaken at the mill. Kiering



and desizing are carried out together and form the scouring process.

The scouring process prepares the fabric for the subsequent bleaching and dyeing processes. Scouring at the United Textile Mill involve the boiling of the fabric in a bath of caustic soda at temperatures of 120°C. The scouring process is carried out to remove the sizing agents and also non-cellulose impurities, greases and waxes from the fabric. Starch which was put on the yarn during the sizing process is removed through this process using bacterial agents to breakdown the starch into soluble sugars. Apart from the use of large quantities of caustic soda, alkaline synthetic detergents are also used. Wastes from this process are characterized by high alkalinity and contain organic matter removed from the cloth during the boiling of the fabric. The high alkalinity results from leftovers of caustic soda. The volumes of waste constitute about 20 per cent of the total waste water volume from the mill (Table 1). Apart from wastes having a high alkalinity, the wastes also contain starch breakdown products. The wastes are therefore highly polluting, and constitute more than 50 per cent of the total BOD load originating from the mill.

Bleaching process is carried out after the scouring operation. At the United Textile Mill,

the cloth is passed through a bath of hydrogen peroxide solution. Chlorine and sodium hypochlorite are not used in the mill. The bleaching operation removes any colouring matter on the cloth. The fabric is rendered suitable for the dyeing process and printing operation which follow the bleaching operation. Apart from hydrogen peroxide the bleaching operation also involves the use of caustic soda and a wetting soluble oil termed commercially the calsoline oil - HS. This oil is used as a wetting agent. The cloth is then washed after this operation to remove any salts remaining on the fabric. After bleaching, polyvinyl alcohol is used instead of starch to strengthen the cloth and render it weighty and impart to it the desired feel and appearance. The waste produced during this process include the spent bleach liquor which contain the peroxide, sodium hydroxide, oils and polyvinyl alcohol remains, as well as the rinse waters. The wastes are similar to those of the scouring operation and amount to about forty eight per cent of the total; waste volume from the mill (see Table 1).

The cloth at this stage is ready for dyeing and printing. The mercerizing operation is not carried on the cloth in the mill investigated. Dyeing of cloth is carried on a variety of ways which differ, this depending on the dyestuff used. Various types of dyes are used in this process and these

include direct, pigment reactive, vat sulphur and naphthol dyes. The major dyeing processes in the mills rely on the use of direct dyes of which an average quantity of 50 Kg. is used daily. Direct dyes are neutral substances with a high degree of solubility in water and a high affinity for cotton. Use of direct dyes makes about 95 per cent of the total use of all dyes in the mill. As such most of the waste water from the dyeing processes contain large amounts of this soluble dyestuff. The waste is also highly coloured. To a lesser extent (see Table 2) pigment, naphthol, vat and sulphur dyes are used. When used sulphur dyes are applied to the cloth in reduced state and then oxidized to fast colours with such reagents as sodium sulphide which acts as a reducing agent as well as a solvent. Wastes resulting from sulphur dyeing contain sulphur compounds. They are highly alkaline, coloured and are toxic. When on the other hand vat dyes are used on cloth, they are dissolved in reducing agents such as hydrosulphate. The cloth is then immersed in the vat containing dye reducing agents and alkali. The material is then oxidized through exposure to air. After neutralizing the alkali remaining on the cloth, the cloth is rinsed with water. The wastes from vat dyeing contain rinse water, are highly alkaline, contain dye liquor, as well as organic wastes. Naphthol dyes are applied to the fibre by first treating the fibre with beta naphthol which is a

developer. This is then diazotized in a dye bath with the consequent developing of the colour on the fibre. A hot soap bath and caustic soda bath is used after treatment. Wastes from this process contain beta naphtho, diazotized dyes, caustic wastes as well as soaps and rinsing water.

For colour printing pigments are used. The initial stages involve the preparation of the pigment in colour cooking containers. During the preparation of the pigment, resin emulsions are used. Polyvinyl alcohol and large volumes of turpentine which acts as a thickner for the emulsion. Various methods of cloth printing are thereafter used. In the photographic method screens are engraved and prepared for printing machine. This is followed by film preparation, coating of the screen with lacquer, exposing, and preparation for fixing and printing. Reagents used during this process include soaping agents, light sensitive synthetic resins for coating, araldite which is a coating agent and a stripping chemical SCR31 used for stripping lacquer from the engraved screen. Small quantities of wastes emanate from the printing process, and these include wash waters and remains or reagents used for the printing process.

During the dyeing and printing process, dyes and pigments are largely used. The average consumption of dyes in the month of February is shown in Table 2.

The volume of wastes originating from these two process counts to about 20 per cent of the total waste water volume.

TABLE 1

THE AVERAGE WATER QUANTITIES DISCHARGED FROM THE VARIOUS DEPARTMENTS AT THIKA UNITED TEXTILE MILL DURING PROCESSING OF CLOTH

DEPARTMENT	QUANTITIES OF WASTE WATER PER DAY (LITRES)	PERCENTAGE OF THE TOTAL
Sizing	16,515	3
Scouring	111,600	22
Bleaching	238,000	48
Dyeing & Printing	102,000	48
Others	31,415	7

The waste water originating from the factory is discharged directly into Thika River and partly into Municipal sewers. Plans are however under way to ensure that no further discharge into the river is effected unless the factory management is to pre-treat the waste water to standards acceptable to the Ministry of Water Department. This leaves the factory management with the alternative of discharging into Municipal sewers and therefore into the Municipal sewerage works

for which levy is charged at KSh. 2/50 for every 1000 litres of wastewater.

ITEM	QUANTITY (kg)	AV. CONSUMPTION PER DAY (kg)	REMARKS
Hydrogen Peroxide	1000	35	
Caustic soda	2000	70	
Polyvinyl alcohol	750	28	
Starch (Meyz)	4200	1.40	
Resin Emulsion	27000	900	
Wetting Agents	250	8	
Hydrochloric Detergents	300	10	
Disinfecting Agent (bacterial)	150	5	
Acrylic Binder	70	2.3	
Carboxy. Methyl Cellulose	35	1.0	
Felcol	250	8	
Coating Lacquer	25	8	
Stripping chemical (SCR3)	-	-	stored in tank and replenished as required.
Turpentine	2000 litres	400	
Paraffin oil	15000 litres	3000	
<b>DYE STUFFS</b>			
Pigments	100	3	
Direct Dye stuff	1500	50	
Reactive Dyes	10	-	
Basic Dye stuff	10	-	
Disperse Dye stuff	15	-	
Sulphur Black	35	1	
Dye stuffs			Used only when special dyeing is required varies from 100 to 5000 litres indicated

TABLE 2

MONTHLY CONSUMPTION OF CHEMICAL MATERIALS AT THE THIKA UNITED TEXTILE MILL

ITEM	QUANTITY (kg)	AV. CONSUMPTION PER DAY (Kg)	REMARKS
Hydrogen Peroxide	1000	35	stored in tank and replenished as required.
Caustic soda	2000	70	
Polyvinyl alcohol	750	25	
Starch (Maize)	4200	1.40	
Resin Emulsion	27000	900	
Wetting Agents	250	8	
Synthetic Detergents	300	10	
Desizing Agent (Bacteria)	150	5	
Acrylic binder	70	2.3	
Carboxy, Methyl Cellulose	35	1.0	
Tallow	150	5	
Coating Lacquer	25	8	
Stripping chemical SCR31	-	-	
Turpentine	12000 litres	400	
Furnace oil	150000 litres	5000	

<u>DYESTUFFS</u>			
Pigments	100	3	used only when special Dyeing is required, varies from NIL to quantities indicated
Direct Dyestuff	1500	50	
Naphthol	10	-	
Reactive Dyes	10	-	
Vat. Dyestuffs	15	-	
Sulphur Black Dyestuffs	35	1	



CHAPTER 2

LITERATURE REVIEW

2.1 SOURCES AND CHARACTERISTICS OF COTTON TEXTILE WASTES

Miles et al (1938) report on the nature and sources of cotton textile wastes states that the wastes are composed of the natural impurities extracted from the fibres and the processing chemicals used in the factory. The processing of cloth from cotton fibres involves carding spinning, spooling, warping slashing and weaving or knitting after which the fabric is taken into the finishing mill. Except for slashing the rest are dry processes. In slashing, the thread is sized with starch to impart to it tensile strength and the smoothness necessary for the subsequent weaving operation. The sized goods contain about 15 per cent starch which is removed during the finishing process, starched goods are desized before wet processing to remove the natural impurities. In order to make the fabric white it is then subjected to the bleaching process. The bleaching of the fabric is followed by dyeing and mercerizing to give lustre to the cloth. The cloth is then printed, and sized once again to make it smooth and resistant to wear. These processes and operations contribute to the waste load that is



discharged into municipal sewers and sewerage treatment works or in to a water course. Some of these processes contribute more waste load than the others. The waste load depends on the stage treatment and chemicals used. Procopic (1955) carried out a survey on the major operations in cotton textile finishing and their related BOD loads from which Masselli and Burford(1956) have processed the flow chart below. (Table 3).

DEPARTMENT	PROCESS	BOD/1000 LB CLOTH	% OF TOTAL
Desizing		53	35
Scouring	Either Pressure kier first scour	53	16
	Pressure kier second scour	8	1
	Continuous scour	42	15
	Average	47	
	Sub total (scouring)		32
Dyeing		0.5-32	15-30
Printing	Color-shop wastes	12.0	7.0
	Wash after Printing with soap	17-30	17-30
	Wash after Printing with detergent	7	7
	Sub-total(Printing)		15-35
Bleaching	Hypochlorite bleach	8	3
	Peroxide Bleach	3	1
Mercerizing		6	1
Total		125-250	

TABLE 3

The chart indicates the BOD contributed by each process and the percentage of the total BOD load due to that process. After carrying out extensive work on cotton textile wastes Masselli et al (1959) observed that in a cotton mill the BOD load of the waste may be calculated using the following expression.

$$\begin{aligned} \text{Total lb BOD from mill} &= 0.067 \times \text{lb desized} \\ &+ 0.047 \times \text{lb Kiered} + 0.005 \times \text{lb bleached} + \\ &0.006 \times \text{lb mercerized} + 0.025 \times \text{lb. dyed and} \\ &\text{printed.} \end{aligned}$$

Total alkalinity load was observed to be equal to 1.7 times the BOD load. He also observed that the average BOD load will be equal to 15 per cent of the weight of cloth received for processing in a mill where cloth is desized, caustic scoured, bleached, mercerized, and dyed or printed. He further observed that desizing contributes 45 per cent of the total BOD and the scouring process contributes about 31 per cent of the total BOD load. Both these processes will contribute approximately 75 to 85 per cent of the total BOD load. Bleaching mercerizing dyeing or printing will contribute about 3 per cent, 4 per cent and 17 per cent respectively to the total BOD load. Brown's (1957) findings indicate that starch wastes constitute about 16 per cent of the total volume of waste produced,

53 per cent of the BOD, 36 per cent of the total solids and 6 per cent of the total alkalinity; caustic wastes constitute about 19 per cent of the total volume, 37 per cent of the BOD, 43 per cent of the total solids, and 60 per cent of the alkalinity. General waste which is composed of wastes from all other processes, that is washing, bleaching, dyeing, and finishing, constitutes 65 per cent of the total volume, 10 per cent of BOD, 21 per cent of the total solids and 34 per cent of the total alkalinity. Besselièvre (1952) notes that the wastes from a cotton textile mill not only emanate from the actual preparation of raw basic materials but also from the later steps of dyeing, finishing, printing etc. The nature of the waste will depend on the process used. The wastes may as such contain color, acids, alkalies, weighting agents, dirt, loose fibres etc.

A United States Public Health Publication No. 677 quoting the findings of the American Association of Textile Chemists and Colorists (1959) reports that apart from small volumes of waste from raw cotton dyeing and slasher wastes most of liquid wastes emanate from the processing of cloth. Fabrication of cloth therefore contributes little pollution load to the wastes. The slasher wastes contain a large amount starch,

washing, and leftover from the slasher operation. Desizing wastes contain a high organic content and include products resulting from the hydrolysis of starch and chemicals used for hydrolysis. Though the volume of wastes is low, desizing contributes a BOD load of up to 50 per cent of the total waste load. Use of alkali in the kiering process renders the wastes from this stage to be highly alkaline. The waste also contains high organic content. Fragments of cotton ball, sizing materials such as starch, caustic soda, and other materials are found in the kiering waste. Although kiering operations vary from mill to mill the BOD load contribution to the total waste may be up to 30 per cent. The bleaching process either using the hypochlorite or chlorine renders the waste alkaline. The waste also contains organic materials removed from the cotton. Peroxide bleaching makes the wastes have similar characteristics to those of kiering. The BOD contribution is normally low this being of up to 10 per cent of the total BOD load. The mercerizing stage also contributes a small percentage of the total BOD load. Dyeing operations contribute to large volumes of the total waste volumes. The nature of the waste will depend on the type of dye stuff used and its application on the cloth. The wastes are characterized by a low BOD contribution, high degree of color and may be

toxic. As these waste volumes are large the BOD load may be up to 35 per cent of the total load. Analysis of wastewaters originating from different processes and the related volumes by the American Association of Chemists and Colorists (1959) has been presented in Table 4.

Research work carried out by Souther R.H., (1955) on the sources of waste load from a textile mill notes that about 50 per cent of the total load is contributed by desizing. Acids and enzymes are used to hydrolyse starch. The process of scouring involves the use of caustic soda, soda ash, chlorine, Peroxides, silicates, sodium bisulphite, acids, detergents and penetrants. This process prepares the white cloth for finishing and contributes about 30 per cent of total waste load with natural cotton impurities making about 3% of the total load. Bleaching using chlorine or peroxide to remove the natural coloring matter contributes about 10 per cent of pollution load. In mercerizing the cloth is bathed in 20 per cent caustic soda. The BOD contribution from this process is at times nil but the process contributes to a high degree of alkalinity in the waste. Dyeing with its subsequent high degree of colour contributes to pollution load by about 20 to 40 per cent depending on the dyestuff used. During the finishing process the

TABLE 4 ANALYSIS OF WASTE WATERS ORIGINATING FROM COTTON TEXTILE MILLS.  
(adapted from American Association of Chemists and Colorist. 1959)

PROCESS	GALL. OF WASTE/100 LB (454 kg) OF GOODS	pH	TOTAL SOLIDS mg/l	5 DAY BOD AT 20°C. mg/l	POP. EQUIV. FOR 1000 LB OF GOODS.
<u>Fabrication of Cloth</u>					
Slashing (Sizing)	60-90	7.0-9.5	8200-22600	620-2500	2-30
<u>Processing of Cloth</u>					
Desizing	300-1000	-	16000-32000	1700-5200	90-100
Kiering	310-1700	10-13	7600-17400	680-2900	10-105
Scouring	2300-5100	-	-	50-110	8-18
Bleaching	300-14900	8.5-9.6	2300-14400	90-1700	30-90
Mercerizing	27900-36950	5.5-9.5	600-1900	45-65	60-80
<u>Dyeing</u>					
Direct	1700-6400	6.5-7.6	2200-1400	2200-600	25-75
Basic	1800-36000	6.0-7.5	500-800	100-200	100-400
Vats	1000-20000	5-10	1700-7400	125-1500	75-175
Sulphur	2900-25600	8-10	4200-14100	11-1800	14-1500
Developed	8900-25000	5-10	2900-8200	75-200	90-120
Naphltol	2300-16800	5-10	4500-10700	15-675	13-80
Aniline Black	15000-23000	-	6000-1200	40-55	40-60

cloth is subjected to processes which impart to it the desired feel or hand, the appearance, softness stiffness, smoothness, slickness and lustre of waterproofing property. Such chemicals as starches and dextrans natural or synthetic, waxes, synthetic resins, ammonium and zinc chlorides, softening agents, penetrants may be used but with variation as the need be. Waste volume is usually low, BOD is contributed by starch, gums, waxes and resins.

On Waste characteristics Souther notes that analysis of a composite sample from an integrated cotton textile plant contains starches, dextrans, alcohol, fatty acids, acetic acid, soaps, detergents, sodium hydroxide, carbonates, sulphides, sulphates, chlorides, dyes, pigments, carboxymethyl celluloses, gelatine dye carriers (phenol and benzoic acid) peroxides and chlorine bleach compounds. Other parameters analysed for gave the following results.

The pH 4-12  
The color will be that of the predominant dye.  
Total solids 1000 - 1600 mg/l  
BOD 200-1800  
Total alkalinity 300 - 900  
SS 30-300  
Chromium 0-25 ml  
Vol. of water per 1000 lbs of finished goods  
20,000 - 100,000 gal.

On the characteristics of individual wastes from the separate processes the following information has been supplied by the U.S. Public Health Service. An Industrial Waste Guide to the cotton Textile Industry (1959) gives similar analytical data to those given by the American Association of Textile Chemists and colorists (Table 4).

## 2.2 ABATEMENT OF POLLUTION LOAD:

Reduction of pollution load in a cotton textile mill can be achieved through improved operations and processes, substitution of high BOD load chemicals for low BOD chemicals as well as technological improvements. On control technology the United States Environmental Protection Agency (EPA) (1974) has recommended in plant methods for pollution control which include a water survey, major sources of waste, flow reduction, water reuse, waste segregation and substitution of process and materials. Out of plant control technology recommended by EPA (1974) for textile mill waste water management include screening, primary treatment, chemical coagulation followed by secondary biological treatment and finally chlorination. In a technology transfer publication by Metcalf and Eddy (1974) it is recommended that initially a survey of waste sources and strengths of textile wastes be carried out, followed by biological treatment which should be based on case histories of cotton



waste biological treatment and experience with granular activated carbon treatment as a methodical approach to reducing waste load and rendering up to date treatment to such wastes.

On waste reduction and prevention, Masselli et al (1959) has emphasized on some preliminary practices which should be implemented in a factory to reduce waste load. These include good house-keeping, closer process control, process chemical substitution and recovery. It is however emphasized that good housekeeping practices will only reduce the BOD by only 5 to 10 per cent. Closer control of kiering, sizing, and the amount of chemicals used in various other processes may reduce pollution load up to a maximum of 30 per cent. Nemerow (1971) supports the recommendations of Masselli and emphasizes that no treatment plant should be planned until serious consideration has been given to pollution reduction through chemical substitution. He notes that this would be possible in cotton and woolen textile mills.

In cotton mills Masselli (1959) recommends the following substitutions:

- (a) Substitution of low BOD synthetic detergents (0 to 20 per cent BOD) for soap (140 to 155 per cent). This will give a maximum reduction of approximately 35 per cent in plants where

soap is highly used. Synthetic detergents are however disadvantageous in that they persist in streams.

- (b) Substitution of steam ranges to oxidize dyes instead of using dichromate - acetic acid baths. This will achieve a BOD reduction of from 5 to 15 per cent.
- (c) A reduction in the use of caustic solution for kiering by 10 to 30 per cent will achieve a BOD reduction of 10 to 20 per cent.
- (d) Use of low BOD dispersing or emulsifying agents in place of high BOD agents gives a BOD reduction of 5 to 15 per cent.
- (e) In sizing the use of low-BOD sizes e.g. carboxymethyl celluloses, 3 per cent; hydroxymethyl cellulose, 3 per cent; Polyacrylic acid, 1 per cent, polyvinyl alcohol, 1 per cent; for high BOD, starch (50 to 70 per cent) will theoretically reduce the total BOD from a cotton mill by 40 to 90 per cent.
- (f) Replacement of acetic acid in dyeing with an inorganic salt such as ammonium sulphate or chloride ( 0 per cent).

The substitution of so called "no-BOD" compounds for the high BOD compounds, such as soluble sizes in place of starch may persist for long in a river, they may

find their way into water treatment works and interfere with the treatment process. This may lower the quality of domestic water supply. Masselli recommends the continued use of the no-BOD compounds and accord careful examination to water treatment and the immediate uses of water instead of using high-BOD sizes. Recovery of certain materials should be considered by all mills. Marsselli et al (1959) notes that about 200,000 tons of cotton impurities such as waxes, pectins alcohols etc are being dumped into sewers. Caustic soda and starch for slashing are recoverable chemicals which many mills are already recovering to ease the biological treatment of the remaining waste. The caustic soda found in contaminated kiering and mercerizing liquors can be recovered and purified through dialysis as reported by Nemerow et al (May 1955). However, this has not been found practicable due to presence of impurities such as colloidal and suspended matter in form of gums, pectins and hemicelluloses in the dilute kier liquors. On the recovery of starch, Masselli (1956) has calculated that 400,000 tons of glucose could be recovered yearly, purely from starch-desize from textile mills. He based his figure on the average addition of 10 to 15 per cent starch during the sizing process. Recovery of glucose would be both economical to the factory and would reduce the BOD load by about 45 to 94 per cent.

The industrial wastes from cotton textile mills can be reduced to minimal by taking such measures as good housekeeping, recovery and reuse of chemicals, substitution of process chemicals and process modification as recommended by Masselli (1959). Good housekeeping will avoid accidental spill of chemical baths and storage tanks as well as wastage of materials. This requires the training of managing and operating personnel because good housekeeping to succeed requires the cooperative effort of the personnel. Good house keeping if accompanied by strict control on chemicals used in kiering and sizing operations will reduce the pollution load by as much as 30 per cent. Carrigue and Jaurequi (1966) advocate considerable reduction in alkali pollution can be achieved through recovery and reuse of caustic soda in the processing. In many cotton mills caustic soda is reused for mercerizing plisse, printing, open boiling and cleaning operations. The washing of caustic soda treated fabrics should be done in as little water as possible to ensure that maximum caustic soda is in very little quantity of water and consequently can be reused without further treatment. When impurities have built in such a reused liquor to the extent of affecting the quality of the fabric, the solution should be filtered to remove suspended solids and then dialysed. Leatherland (1969) however emphasizes that recovery of

chemical material is generally not considered practicable with an exception of caustic soda. In place of recovery he advocates that special attention should be given to reducing the quantities of chemicals to the minimum necessary in the various unit operations and processes. Significant reductions in waste loads can be achieved only through the use of chemicals with low pollution effects in place of those with higher pollution effects. Substitution of carboxymethyl cellulose in place of starch for sizing operations, use of mineral acid or salt in place of acetic acid in dyeing operations, use of non-biodegradable detergents instead of soap, polyvinyl alcohol and polystyrene in place of starch in finishing as substituents will result in the reduction of BOD load to the extent of 10 to 50 per cent.

Process modification has also been found useful in reducing potential load from cotton textile manufacturing. Use of high speed continuous machinery combined or not with alternate process chemicals. Such sub-processes which reduce BOD by continuous operation, with waste potential reduction effectiveness compared to utilization of batch processes are scouring (21 per cent compared to boil off), bleaching (25 per cent) and dyeing (50 per cent). Use of low BOD chemicals especially use of synthetic detergents in wash after dyeing will reduce BOD by

50 to 80 per cent.

Porter (1973) predicts that increasing expensiveness in the treatment of water and wastewater will tend to make it desirable for reuse of water in the dyeing industry. This might turn to be economically feasible should the cost of treating wastewater or cost of water supply to a mill keep rising over the years to come. Souther (1955) recommends water conservation as an initial step in the reduction of pollution load from a cotton mill. He stresses that due to the increasing demand for water in such fields as agriculture, domestic, and industry, it will become necessary to conserve water resources by using less water. This will produce a smaller volume of concentrated waste which will be easier to handle during treatment. He further recommends recovery and reuse of material in the plant as a second step in abating pollution. As an in plant measure reduction of waste load can be achieved through use of reduced quantities of materials which in turn will reduce costs. Recycling and reusing of materials in a counter flow system especially of rinse water, reduction of process chemicals, which can be achieved through proper control of cloth processing, and recovery and reuse of caustic soda from mercerizing liquors process modification and substitution of chemicals are measures he emphasizes in in-plant reduction of waste loads.

Similar work carried out by Ganapati (1967) emphasizes on the same methods on pollution abatement from textile mills.

## 2.3 TREATMENT OF COTTON TEXTILE WASTES

### 2.3.1 PRE-TREATMENT PROCEDURES

Pre-treatment procedures in the treatment of textile waste involve segregation of wastes, equalization, screening and to some extent even pre-aeration. Segregation of the individual wastes from the different unit operations and process and their subsequent separate pretreatment is at times considered advantageous in that it reduces the waste volume treatment problem immensely. This however will depend on the character and nature of individual wastes, and the cost of separately sewerage and piping of the individual wastes to ensure separate treatment. Owing to the variation of flow and characteristics of wastes emanating from the various operations and processes equalization of wastes from a textile mill is definitely necessary where segregation of wastes and separate treatment is not required. Equalization of the waste will ensure that discharge of waste with such varying sanitary characteristics as pH, color, turbidity, alkalinity, BOD, SS, etc is uniform. It also ensures lowering of the concentration of contaminant effluents.

Where a mill is working for a twenty four hour period, then a twenty four hour equalization will be required. This might necessitate the construction of two basins with a capacity to hold a 24 hour waste flow from the mill.

Pre-treatment by screening can be achieved by using bar screens or rotating disc screen. These devices will effect sufficiently the removal of objectionable coarse solids e.g. fibres and trash.

Neutralization is a major step which should be carried out before biological treatment of textile wastes. The wastes are usually highly alkaline and a reduction in pH is necessary as a prelude to efficient biological treatment. Addition of sulphuric acid, carbon dioxide and flue gas can be used to lower the pH of the wastes. Sulphuric acid and carbon dioxide stand as relatively expensive methods for lowering of pH of caustic solutions. Flue gas contains 12 to 14 per cent of carbon dioxide and can be used to lower the pH with relatively low operating costs. This is possible if a scrubber, blower and pipeline are installed. Lowering of pH of caustic wastes using flue gas has been investigated by King (1955) and Steel (1954). They found the use of flue to operate at reasonably low costs. Beaches (1956) had observed that certain dye wastes had a pH range of 2 to 11 and a sulphides concentration of 30 mg/l. While using flue gas



they were able to reduce the sulphides concentration by 98 per cent and lower the pH from 9 to 6.1. They used a fume scrubber operating on the aspirator principle to pass flue gas. Other workers who have worked on the reduction of pH using flue gas include Brown (1950), Curtis and Copson (1931), Jung (1934) and (1948) and Murdock (1951).

pH is controlling factor in biological treatment, and optimum BOD reductions can only be achieved when pH range is between 7 and 9. This pH range will depend on the character of the waste, the period of equalization and the degree of dilution especially with domestic sewage. Walter (1959) has observed that maximum BOD removals are achieved between a pH range of 8 to 9 in a trickling filter. However, BOD reductions also take place at any pH slightly below or above the pH range 7 to 9 but at pH levels above 11.5 little if any BOD reduction takes place.

Pre-treatment and neutralization are largely carried out as a prelude to cotton textile waste biological treatment. Toxic materials should also be removed before subjecting the waste to biological treatment. Biological treatment is usually carried out after pre-treatment and admixture with domestic sewage. Some of the more successful methods recommended for textile waste treatment

are activated sludge process, the dispersed growth aeration, the trickling filtration and to a less extent the lagoons. The trickling filter has been found to be more desirable in view of greater flexibility, lower operating costs and its ability to withstand and handle shock loads of wastes. The activated sludge process has been found to be more efficient in BOD reduction but has disadvantages in that it requires a longer detention period, a highly qualified supervision and large units to provide the required detention period. Dispersed growth aeration also gives a more acceptable effluent quality, and requires minimum maintenance and operation. A combination of trickling filtration and activated sludge has also been successfully used in treating textile mill waste and domestic sewage by Hazen (April 1957) and others. On the treatment of highly alkaline cotton klering liquor Pettet et al. (1959) discourages subjecting the liquor to anaerobic treatment. He encourages dilution by domestic sewage for aerobic treatment or evaporation and incineration. However, Busweel et al (1962) recommends anaerobic digestion for desizing wastes after their segregation as a means of reducing treatment plant costs. Through anaerobic digestion of these wastes 80 to 90 per cent COD reduction was achieved at loadings of 0.05 lb per day per cu.ft. Aerobic treatment of textile mill waste was carried out by Jones et al (May 1962). Using

contact stabilization and prolonged anaerobic stabilization processes, he was able to achieve successful results.

### 2.3.2 CHEMICAL TREATMENT

Use of chemicals for the removal of COD, BOD, suspended solids, and color is the most effective method for treatment of textile wastes (Nemerow, 1971). Most of chemicals used are inorganic coagulants such as alum, iron salts, lime, calcium chloride and sulphuric acid. To remove BOD and bleach the dyes, chlorinated copperas have been used to oxidise the dyes. In strongly alkaline liquours Mokrzycki and Stasiak (1959) have found that calcium chloride gave the best results in the removal of color. It has also been reported by Rao (1966) that the removal of fibres and suspended solids in cotton finishing wastes can be effectively done by using gypsum with lime. Coagulation followed by aeration and filtration through a gypsum bed for final treatment gives a very clear effluent. Lu've Yu and Antipova (1967) carried out chemical purification of wool washing waste waters using aluminium chloride  $AlCl_3$ , aluminium sulphate  $Al_2(SO_4)_3$  and magnesium oxide or delonite in combination with milk of lime at a pH of 12 to 12.4. The washing waste water contained

700 to 4,000 mg/l of chlorinated sulfonal and 330-1500 mg/l of grease. The resulting chemical treatment removed 100 per cent of grease and 80 to 90 per cent of surfonal which is a surface active agent. The solution was decanted, solids concentrated to 5 per cent and then vacuum filtered. The effluent pH was reduced before discharge into a stream. The method was found applicable to cotton mill textile wastes. Iida and Endo (1967) used iron salts in an attempt to precipitate both direct and acid dyes. The iron salts were ferric chloride and ferrous sulphate. Their study covered 18 direct dyes and 6 acid dyes. Both salts were found to give excellent results on the removal of direct dyes but not acid dyes. Ballnus (1967) advocated both the use of lime with the alum or ferrous sulphate during the treatment of various textile wastes. Deitrich (1967) used various electrolytes containing  $Al^{3+}$ ,  $Fe^{3+}$ ,  $Fe^{2+}$ ,  $Si^{4+}$  and  $Ca^{2+}$  to precipitate organic matter in cotton textile wastes. He found that mixtures of the electrolytes were more effective than electrolytes with  $Fe^{3+}$  alone. Chemical dosage at below 50 mg/l per litre was found to improve the drying ability of the sludge and reduced organic matter immensely. Weiner et al (1967) researched into the decolorization of waste water from a dye plant discharging its effluent into a stream. He used ferrous sulphate, and lime to treat the dye waste. He subjected the waste to

a skimming process, then treated it with chemicals, filtered, decolourized and then passed the effluent through activated carbon filter. The activated carbon was regenerated by heating. The method required two minutes of chemical mixing and a thirty minutes period for effective settling. Removals attained were in the range of 83 to 100 per cent.

Nemerow (1952) in several reports has recommended five ways through which cotton textile dye waste should be treated before it is discharged into a watercourse. The five ways include equalization, neutralization, proportioning, color removal and reduction of the oxygen demanding matter of the waste. On the removal of colour and oxygen demanding matter he carried treatment of textile waste using alum  $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$  and found that this coagulant apparently removed all the color from a sewage dye-waste mixture. Reduction of BOD load was achieved up to 63 per cent. The dosage of alum required varied with pH. At a pH of 8.3 dosage of alum required was 200 mg/l whereas at a pH of 7 the dosage was 140 mg/l. Chamberlain (March 1954) applied chlorine in the treatment of textile waste instead of coagulating the waste chemically. Chlorine applied was in form of chlorinated copperas to oxidize and bleach dyes and to remove BOD from sulphur dyes. Chlorine was apparently observed to act as an aid to coagulation.

Dosage of chlorine required was assessed to be in the range 100 to 200 mg/l. The chlorine action was found to be primarily that of oxidizing organic dyes to colorless end products. Ichikawa and Maeda (1968) researched into the treatment of industrial wastes and particularly sulphur dye wastes in Japan. They recommended the neutralization of wastes with waste stack gas and then oxidation to remove  $\text{Na}_2\text{S}$ . The dye was precipitated with  $\text{FeSO}_4$  or electrolytic treatment at 1 to 10 volts DC. In the electrolytic process the electrode was noted to be affected by fouling.

Pyron E. (1968) has described the practices used in the treatment of dyeing wastes and finishing wastes. To reduce pollution load he advised on the process of neutralization, flocculation decolorization with carbon and sedimentation. For textile finishing wastes he recommends the process involving equalization, skimming aeration and flocculation with alum and sodium silicate, sedimentation and decolorization with  $\text{CaCl}_2$ . Similar work was carried out by Otholf and Eckenfelder (1976) on finishing and printing wastes of various types of textile mills. They found that by using ferric sulphate or alum dosages of about 500 mg/l or lime dosages of 300 mg/l significant color removed was achieved up to 80 to 90 per cent. Use of lime

was found to offer the least expensive approach. Chemical precipitation followed by treatment of waste by either activated sludge process or continuous activated carbon treatment has been carried out on cotton textile dye and finishing wastes by Shelley et al (1976). Significant amount of color and COD removal by using lime or alum was achieved but lime was found to have a superior removal ability. The activated carbon system adsorbed additional total organic carbon (TOC) not removed through the chemical treatment.

Besselièvre (1952) strongly suggests that where biological treatment is not possible, textile waste should be treated through chemical precipitation to remove the main pollution load. On the chemical precipitation of various wastes from cotton mills he suggests the use of recommendations given by the United States of Connecticut. For cotton threading mills precipitation can be achieved by using copperas and lime, thus achieving a BOD reduction of about 60 per cent. For finishing cotton piece goods, where bleaching, kiering boiling, dyeing and printing are carried out, segregation of print wash followed by coagulation using copperas and lime and aeration of effluent will achieve a BOD reduction of about 65 per cent. Where finishing waste is to be treated from a processing producing

alkali and peroxide boil, mercerizing, printing, dyeing and finishing liquors, it is recommended that storage of waste in open air for a week, followed by coagulation using ferric sulphate with lime will give an effluent with a BOD reduction of about 65 per cent. He further recommends that print wastes should be incinerated.

Randall and King (1973) have reported that the combined chemical and biological treatment system consisting of an aerated lagoon and chemical coagulation was successful for treatment of concentrated finishing dyeing wastes. They observed that large lime dosages were required and an anionic polyelectrolyte to produce a rapidly settling floc. Asplough (1973) found that alum was more successful than other coagulants and that for high effectiveness in the removal of waste load, a combination of alum (150 to 250 mg/l), lime (10 mg/l) and a cationic polyelectrolyte or polymer (20 mg/l) should be used.

Apart from the use of common chemicals as coagulants, use of ozone and activated carbon has been widely researched on in the treatment of various kinds of textile wastes. Stuber (1973) used ozone for the treatment of various types of textile wastes. Ozone was found not only to provide the required disinfection of the waste but also to reduce bipheyls,



color, suspended solids and chemical oxygen demand. At low ozone concentrations the BOD and soluble organic carbon were found to increase but decreased at high ozone concentrations. Further research has been carried using ozone for treatment of dye waste by Snider et al (1971). They used a raw sample of dye waste containing commercial disperse dyes. The dyes used were Disperse Red 60, Foron Brill Red E-2BL and Eastman Fast Blue B-GLF No. 27. Their work proved that ozonation reduced the COD of the waste by a percentage ranging from a few to 30 per cent. They report that no significant decrease in total solids, dissolved or volatile solids was noted after ozonation. This they concluded was due to the oxidation of organic matter into  $\text{CO}_2$  and  $\text{H}_2\text{O}$  to no appreciable extent. Visible color was observed to decrease appreciably. The color reduction occurred within the dye waste even though the COD decrease was small either due to the selective attack by ozone or hydroxyl radicals on the dye waste molecule or breaking down of double bonds in the molecule thus rendering the waste colorless. They recommended ozonation as a final polishing agent for dye wastes to effect removal of dyes that are inert to conventional treatment because they assessed the operating cost of ozone treatment to be high.

DiGiano et al (1975) used three brands of

activated carbon for adsorption of two types of dispersed dyes and three types of basic dyes. The dyes used were representative of azo, anthraquinone, oxazine, methine and thiazine species. They observed that the adsorptive capacity of basic dyes was greater than the dispersed dyes, but the addition of a carrier to a dispersed dye increased its adsorptive capacity. Rock and Stevens (1975) having used a non-ionic polymeric adsorbent followed by an ion exchange resin found that the process represents an economical alternative to activated carbon treatment for dye waste streams. The polymeric adsorbent was found to reduce the bulk of soluble organics while the ion exchange resin removed the ionic dye components. The operating cost of treating dyes waste through this process for a flow of about 2000 m<sup>3</sup>/day and to achieve a 90 per cent was assessed to be very low. Thawar and Sleigh (1975) compared the operating cost and efficiency of reverse osmosis to that of activated carbon for treating dye house wastes. Use of reverse osmosis was noted to have a lower operating cost, achieved color removal and a reduction of over 95 per cent of dissolved solids, thus rendering the water suitable for re-use. Calvin and Edwards (1973) also used activated carbon to adsorb and filter out organic materials from cotton textile waste. Carbon was regenerated through biological means. Their plant consisted of three units. The first unit consisted of

an equalization basin with with a capacity of 25,000 gpd ( $100 \text{ m}^3/\text{day}$ ) and had a detention of 5 to 8 hours. Diffusers were used for mixing and oxygen supply. Effluent from first unit was discharged into a second unit in form of activated carbon reactor. To avoid clogging of the activated carbon columns, they were operated in the upward flow mode of operation. The carbon was noted to adsorb organics as well as filtration of suspended materials and color. The third unit consisted of activated carbon. This had a high sorption efficiency to reduce organic constituents remaining in the effluent from the second units. The effluent from the plant was noted to be of acceptable quality to streams.

Other attempts made using chemical precipitation of dye wastes include those of Pollock (1973) using flue gas in treating alkaline textile wastes. The flue gas used neutralized the waste. He added fly ash to remove the color but this was not effective. Kase and Linford (1975) studied the effectiveness of alum and polyelectrolyte separately and in combination in reducing color from two disperse dyes. The alum and cationic polyethylene amine polymers separately removed in excess of 90 per cent of Artisil-Blue-Green and Artisil Red dyes but through a synergistic effect high removal was achieved. In one special case (Anon, 1970) treatment of waste was carried out to the extent where all the waste

water was of such quality that it was recycled back into production use. The complete treatment involved extended aeration of the waste followed by chemical coagulation, filtration chlorination and incineration. Coburn (1950) carried out pilot plant studies on chemical treatment of cotton printing and finishing wastes. Treatment consisted of coagulation and sedimentation. Using an average of 1780 lb (850 kg) of alum per 1 mgd (3784 m<sup>3</sup>/day) he achieved reductions in BOD of up to 45.2 per cent, SS 37.2 per cent, alkalinity up to 43.5 per cent and turbidity of up to 42.8 per cent. The sludge produced was 4 per cent by volume and had a dry solids concentration of 1 per cent. Compaction of sludge for 24 hours reduced the sludge volume to 19,000 gallons.

Although chemical precipitation is one of the common methods for treatment of textile wastes in that it can be easily adapted to suit the variations in quality and quantity of wastes and is possibly the only method by which concentrated wastes can be successfully treated, it has its own limitations stemming from the high cost of chemicals and the difficulties arising in handling large volumes of sludge. Spivakova et al (1969) after researching on chemical treatment of textile effluents observed that the method could be of practical value if only the treated water could be put into use in the mill.

However, where high effluent qualities must be achieved before disposal into a water course or a municipal sewer or no alternative method of disposal exist, chemical treatment could be used. The plant facilities required for chemical treatment would then be equalization basins, chemical feeders with a chemical store, flash mixing equipment, settling tanks and sludge drying facilities such as beds or filters. Where properly applied, chemical coagulation will achieve a BOD reduction of 60 per cent, up to 90 per cent in suspended solids and 50 per cent in total dissolved solids according to the findings of Clemson University, Department of Textiles (1971).

#### BIOLOGICAL TREATMENT

##### 2.3.3 (A) TRICKLING FILTER TREATMENT OF TEXTILE WASTE.

Trickling Filter treatment has for a long time been used for treatment of cloth industrial and domestic wastes. It has the ability to cope with variations in flow and also shock loads of wastes, flexibility and also lower operating costs. Many attempts have also been made to treat textile waste in filters separately and also jointly with domestic waste. The following is a review carried out on the treatment of textile waste separately and jointly with domestic waste in trickling filters. Over the years by different researchers in an

attempt to control pollution of waste emanating from textile mills in many countries all over the world.

Walter (Dec. 1959) worked on effect of pH on the trickling filter performance using alkaline wastes from a textile mill. He noted that alkaline wastes have an effect on the biological filtration of the waste. He worked on a 40 per cent alkaline textile waste on trickling filters. Removal achieved was up to 60 per cent of applied BOD in the loading range of 3,000 to 6,000 lb per day per acre-foot. Highest removal were experienced in the pH ranges of 8 to 9. Removal was found to decrease with raise in pH from 11.0 to 12.0. The filter reduced the pH of applied wastes when in the range of 9.0 to 11.0. Above and below this range the filter was found to have little effect if any on the pH of the waste. It was also found that the percentage removal of BOD by the filter decreased as the alkalinity of the applied wastes increased. At an alkalinity of 3,000 mg/l the filter reduced the BOD by only about 33 per cent.

A combination of trickling filter and activated sludge was used successfully in treating a 40 to 60 per cent mixture of textile finishing mill waste and domestic waste by Hazen (April 1957). A research carried out in a laboratory by the sanitary engineering Division of the American Society of Civil Engineers (1955) illustrated that a high loading of 2.73 lbs

of BOD per cubic yard of stone and a relatively high pH of 10.5 could achieve a reduction percentage of up to 58 per cent in trickling filtration. The results reflect that it is feasible to treat biologically a highly alkaline-sewage mixture without prior neutralization. The paper further notes this procedure may reduce or lower efficiency of treatment but this could be countered by considerable savings in chemical costs to the municipalities and industries involved. The reduction in pH of the filter effluent from 10.5 to 9.1 will produce a higher degree of efficiency in the subsequent biological treatment steps, and as such the trickling filter may be used to advantage as "roughing" or preliminary biological treatment. Colour removal of up to 42.5 per cent was obtained in this process as a secondary result. Brown (1959) working on the effect of temperature and ventilation effect of temperature and ventilation on trickling filter operation treating cotton waste and domestic sewage, found that efficiency of a trickling filter on BOD removal was increased by about 10 per cent and eliminated odour through ventilation.

Neas G. (1960) reports from his treatment of viscose and rayon that treatment is simplified if waste is subjected to treatment through Imhoff tank, trickling filter and final settling. He recommends acid waste to be equalized, then blended

with alkaline waste followed by neutralization with slaked high calcium lime clarification in a circular upflow unit. The clarified waste was to be mixed with sanitary plant and sulfide filter effluent from a trickling filter before being passed through lagoons for final polishing before discharging into a water course. He however noted that sludge from the treatment process posed a problem in that it was not easily filterable.

Plastic Filter Media has been used by Chipperfield, P.N. (1967) for the treatment of Industrial and Domestic waste. Chipperfield found that due to the fluctuating high pH and chemical composition, biological treatment is hindered. He found the requirements to be treatment of effluent to about 200-250 mg/l BOD, to reduce sulphide concentration so as to enable the wastewater to be treated in a local treatment plant. The hydraulic load varied between  $\frac{1}{2}$  the minimum wetting rate and the minimum wetting rate. Sulphide removal was found to be as follows:-

<u>Rate of Treatment</u> ( m <sup>3</sup> )	<u>Sulphides</u>	
	<u>Inlet</u> (mg/l)	<u>Outlet</u>
910	8.5	0.76
1200	9.8	1.1
1800	14.0	2.0

The addition of nitrogen was necessary.



In another laboratory experiment a man-made (Synthetic) polymer manufacturing waste was used where roughing was required before discharge of waste in to a local domestic sewer. Investigations revealed that after treatment through activated sludge process and plastic media filters, the latter was opted for because of the lower running cost and ease of control. A single stage pilot plant was found to give a 65<sup>+</sup> percent removal of BOD with an influent load of 2,800 mg and an effluent of 800 mg/l at 74 lb/day/1000 cu ft. (5.86 m/day/m) (180 g/day/m<sup>3</sup>) and a 50 per cent removal of BOD when the influent is 2800 mg/l and effluent 1400 mg/l at a flow rate of 148 lb/day per 1000 cu.ft. (2,360 g/day/m<sup>3</sup>)

TABLE 5

FLOW	BOD LOAD		% REMOVAL
	INFLUENT	EFFLUENT	BOD
m/day/m <sup>3</sup>			
5.86	2800 mg/l	800 mg/l	65%
11.603	2800	1400 mg/l	50%

Askew M.W. (1967) used a two stage trickling filter using flocor as a medium in the treatment of textile wastes from synthetic resin manufacture. The synthetic waste was found to be easier to handle. Removal of phenol from the waste was achieved up to 95 per

cent in the first stage as against 58 to 64 per cent removal of BOD in the second stage. Deighton K.A. (1968) on treatment of kier liquor emphasized on the treatment of cotton kier liquor mixed with domestic wastewater and then subjected to a two stage biological treatment process involving activated sludge and then a trickling filter. He found that a combination of these gave a satisfactory effluent.

Brown J.L. (1971) using biological treatment system designed for 55,000 Kg. BOD per day and with a complete segregation of all wastes, (domestic, starch, rinse, finishing, caustic and dye wastes from a cotton mill) emphasizes that each of these types of wastes should be subjected to any one of the following types of treatment i.e. primary sedimentation, two stage trickling filters, sedimentation chlorination, neutralization, activated sludge and sedimentation then wet oxidation. He used trickling filters which were deep enclosed and covered, with a waste water recirculation ratio of 7:1 and forced air recirculation of from 5 to 10:1.

Souther and Alsphaughn (1955) notes that trickling filtration is becoming fast obsolete and is being replaced by prolonged bioaeration treatment. The bioaeration treatment can achieve efficiencies as high as 99 per cent with lower costs than the trickling filter. Using trickling filtration with plastic filter

removal of up to 50 per cent has been achieved but he also, notes that to achieve 90 per cent removal of the pollution load, oxidation ponds or lagoons can be added. Combined treatment of sewage and textile waste in trickling filtration has been found to effect an average of almost 75 per cent BOD removal. High efficiency can be achieved through recirculation or by treating the waste through two stages of filters in series. Trickling filtration has also been used to reduce the high alkalinity of textile waste of pH 12 or above prior to activated sludge process by Souther et al (1955). Waste water flow of up to 30 mgd can be treated in a filter space of 1 acre. Sludge from the settled effluent is disposed into digesters in the usual sludge disposal procedures.

Coburn (1950) using high rate trickling filter for short time and a recirculation ratio of 4 to 1 indicates that more than 50 per cent of SS and over 60 per cent BOD reduction can be achieved. He stresses that fortification of the waste by nitrogen and phosphorous is necessary for biological treatment. For combined treatment the textile waste should be conditioned with sulphuric acid ( $H_2SO_4$ ) prior to application to filter.

### 2.3.3 (B) ACTIVATED SLUDGE PROCESS

The use of activated sludge process for treating cotton textile waste in admixture with domestic sewage has been reported to be more successful than trickling filtration especially in color removal. This being a biological treatment process, pretreatment is normally carried out before discharge of the waste into an activated sludge treatment plant. Pretreatment should involve use of coagulants such as ferric chloride and lime, adjustment of pH, sedimentation and removal of toxic materials such as sulphur dyes prior to admixture with sewage for activated sludge process treatment.

Lauria and Willis (1966) have carried out pilot plant studies on the combined treatment of textile waste and domestic sewage in an activated sludge process. Their pilot plant was capable of handling 80 per cent of textile waste and 20 per cent of sewage waste mixture which was completely mixed in an activated sludge process. 90 per cent removal of BOD was achieved. By using the extended aeration process study they were able to find a basis for a full scale plant design with surface aerators for treating textile wastes. Kashiwaya (1965) after carrying out pilot plant studies of treating textile waste in an activated sludge process

reported that this could be effectively achieved by conventional activated sludge process or contact stabilization. Deighton (1968) restricted his investigations to the treatment of kier liquor in admixture with sewage. The treatment process consisted of a two stage biological method using activated sludge and then a trickling filter. The combination was observed to give a satisfactory effluent. Nemerow (1952) found that the activated sludge process treatment gave a greater BOD reduction than trickling filtration, but entails large units to provide large detention periods of 12 to 48 hours and a high degree of supervision. He emphasizes on adjustment of the pH as a controlling factor in the efficiency of the biological treatment. He obtained maximum BOD reductions when the pH is in the range 7 to 9. Bright (1969) reviewed an activated sludge process treating 35,000 m<sup>3</sup> per day of waste. The plant had a 45 day aeration using eighteen 75 kw. mechanical aerators and included clarifiers and sludge reaeration. Over 90 per cent BOD reduction was achieved in the plant effluent. Sludge was disposed through sludge irrigation. Little (1969) observes that where biological treatment of bleaching and dye house wastes is to be treated by the activated sludge process, sedimentation is not a necessity.

Brown (1971) worked on a biological system

designed for 55,000 Kg/day and had complete segregation of domestic, starch, rinse, finishing caustic and general dye wastes. He subjected each type of waste to treatment involving primary sedimentation, two stage trickling filtration, sedimentation, preaeration, chlorination, neutralization, activated sludge, sedimentation and finally wet oxidation processes. The trickling filters he used were deep enclosed and covered and were using a waste water recirculation ratio of 7:1 and forced air recirculation of from 5 to 10. The resulting effluent was noted to be of high quality. Masselli et al (1973) followed the waste treatment from a textile mill and put on emphasis on the activated sludge process for treatment of textile wastes. Adams (1976) studied case histories of textile plants treating wastewater in activated sludge systems in which powdered activated carbon was added. The method was found to give an improved over all removal of biochemical oxygen demand, chemical oxygen demand, adsorbed dyes, reduced foam, improved solids separation and levelled plant performance during periods of varying flows and contaminant levels. Molva, et al (1970) obtained a high degree of purification of the wastes from a goods dyeing and finishing plant. His treatment included a dispersed growth aerator, carbon filtration and biological regeneration of carbon. BOD reduction up to 95 per

cent was achieved, color reduction up to 80 per cent and 70 per cent reduction in nitrogen and phosphorous. The effluent thus obtained after treatment could, if finally polished through sand beds filtration, be reused in the plant. A Multistage system for textile waste treatment has been described by Dietrich (1970). This couples both biological and mechanical treatment.

Rhame (1970) has described an extended aeration process which he used for the treatment of alkaline textile wastes from cotton finishing mills. The plant produced an effluent load which had a 95 per cent BOD removal compared to the influent load. Extended aeration, chemical coagulation, filtration, chlorination and incineration of sludge has been jointly used to treat complete textile waste from a screen printing plant in fieldherst, Slokedale, N. Carolina in U.S. (Anon 1970) The effluent produced was recycled back into production use. The extended aeration system has been singled out as holding great possibilities for future textile waste treatment.

In a biological purification process of production effluent from cotton heachery plant Zawadzki (1967) carried activated sludge process treatment in a pilot plant to which nitrogen and phosphorous were added as nutrients. This resulted

in a BOD reduction of up to 85 to 90 per cent. The resulting effluent was observed to be clean enough for reuse in rinsing raw cotton after bleaching. In Grenzech, Germany, the treatment of a combined flow of 14,000 m<sup>3</sup> per day was undertaken by Ciba-Greigy (Anon 1976). The industrial waste was subjected initially to adjustment of pH by acid or alkaline flocculation and sedimentation followed by equalization in a basin with a flow capacity of 13,000 m<sup>3</sup>. The industrial waste was then mixed with Municipal waste water for combined treatment in an activated sludge process. The treatment was noted to be successful. The sludge from the pre-treatment of the cotton mill waste was dewatered and then incinerated. Evaluation of the efficiency of industrial waste treatment versus joint municipal and industrial treatment was carried out by Guertin et al (Oct. 1975). The waste was from a mill which cards spins, weaves, knits, and finishes fabric. The bench scale extended aeration studies showed 88 per cent reduction by separate treatment and 86 per cent by joint treatment.

Banerjii et al (January 1968) studied the removal mechanism of starch by the activated sludge process, as a method of reducing pollution from a cotton textile plant. He reported that colloidal substances can be treated satisfactorily through contact stabilization. Starch, was initially



removed by adsorption into the sludge. With a high initial sludge concentration, a large percentage of colloidal material in the waste can be removed over a short contact period. He concluded that the removal of starch in an acclimated activated sludge system follows first order kinetics during the initial aeration period. The starch removal rate constant is dependent on food to microorganism ratio (F/M) and not on the initial sludge concentration. The rate constant of total COD removal he observed to be dependent on the initial MLSS and not on F/M ratio. Banerjii also found that temperature affects on the removal rate of starch-COD and total COD. In aerobic systems no accumulation of starch break down products other than carbohydrates in the medium was found but in anaerobiosis of acclimated sludge no effect is noted on starch as long there is complete mixing of contents. There is very much retarded total COD and starch carbohydrate removal, and limited growth in anaerobic systems. Banerjii's works becomes very important in the textile field because of the widespread use of large quantities of starch in the sizing processes.

A United States Public Health report (1959) noted that treatment of industrial wastes through activated sludge process has been found to effect removals of up to 95 per cent of the BOD. This resulting in a clear stable effluent from normal

cotton textile wastes. The biosorption, contact aeration, step aeration are processes which are less subject to upsets, more economical and equally efficient for joint treatment of mixtures of sewage and domestic sewage. Such treatment methods as prolonged aeration, extended aeration, total oxidation, endogeneous respiration with increased aeration periods are being more extensively used for treating textile wastes because of their simplicity, low construction and operating costs. The process involves aerating seeded wastes from 12 to 72 hours until organic matter is totally oxidized and then letting it settle where detention exceeds one to three days equalization is not necessary. Mechanical agitation methods or diffused air method can be advantageously used because of their higher efficiency and economy during aeration. The performance of this method is excellent without pretreatment. By using this method in the treatment of a mixture of 7 per cent municipal sewage and 93 per cent strong mill waste with sulphur dye remarkable results were achieved. The influent waste had a pH of 12, a BOD load of 1400 mg/l and chromium concentration of 25 mg/l. After treatment the effluent was found to have a BOD of 11 mg/l. Efficiency was over 93 per cent and Ridgway (1963) observed that to achieve those efficiencies no equalization, primary treatment or sludge digestion

is necessary.

Extensive work has been done by Porter et al (1976) while investigating the biodegradability of textile chemicals such as polyvinyl alcohol, textile finishes and dyes, hydrocarbon solvents in an activated sludge process. He observed that many of these chemicals are slowly biodegradable and continue to use oxygen even after a detention period of 30 day in an activated sludge process. Having found that the 5 day BOD test is not an accurate measure for the measurement of organic waste in textile wastes he suggested that this method be coupled with the COD method to obtain accurate results. He noted that removal of polyvinyl alcohol (PVA) in an activated sludge process depends on the mixed liquor suspended solids (MLSS). In one case where MLSS was 5,800 mg/l, 94 per cent removal of PVA was achieved in an activated sludge process. As MLSS drops to 2,300 mg/l the removal achieved dropped to 75 per cent. He notes that many waste treatment works operate at a much lower MLSS level and there will be a lower percentage removal of PVA. He therefore recommends specific treatment of those compounds which are not easily biodegradable.

On dyes he recommends that inert dyes be removed through adsorption on MLSS if concentration is high. This should be accompanied by a long

retention period. A short retention period for pigment dyes makes them pass through the waste treatment plant unaffected. He further found that for dyes such as vat black 25, vat violet II, reactive red 21, disperse yellow 144, reactive blue 31, disperse yellow 139, disperse red 68 and direct blue 80, which he need for his experimental work were resistant to biodegradation and were showing little color change even after 30 days. He further recommends that chemical treatment for removal of dyes from textile wastes, although adsorption on activated sludge can also be used. In an activated sludge process plant, a careful monitored control is necessary for optimum biological treatment. Porter's findings support the long term aeration for biological treatment. Long term aeration allow more time for biological treatment. Long term aeration allow more time for biological degradation and also protects the system from shock loading. pH and temperature variations are also minimized.

### 2.3.3 (C) WASTE STABILIZATION PONDS

Definition Classification: Waste stabilization ponds are man-made impoundments on the surface of the earth, of controlled dimensions and are used for the treatment of domestic and industrial wastes. The three classes of wastestabilization ponds are

facultative, maturation and anaerobic. The facultative ponds combine aerobic and anaerobic conditions. At the bottom of the lagoon where heavier solids settle to form a sludge layer anaerobic digestion takes place. Aerobic digestion takes place on the soluble fraction of the waste. Mara (1975) gives the following equation for biological aerobic digestion of waste.

Waste + Oxygen bacteria oxidized waste +

New Bacteria. Oxygen is supplied by algae through the photosynthetic process of algae. Algae production of oxygen is in turn controlled by the availability of incident solar radiation. More oxygen is therefore produced in shallow lagoons than in deep lagoons of the same volume. To maintain a predominantly aerobic condition in a pond the pond depth of facultative lagoons must be less than 1.5m in hot regions (Mara 1975). The pond depth must however exceed 1 m to prevent the emergence of vegetation. The general appearance of facultative lagoons is dark green with a high algae proliferation. Reduction of BOD of up to 80-90% can be achieved.

Maturation ponds are wholly aerobic and are used as a secondary stage to facultative lagoons for the purpose of destroying pathogenic bacteria, virus, cysts and ova of intestinal parasites. Effluents from these ponds are comparable with

those obtainable by chlorination of sand filtered effluents in terms of E.coli (Stander and Meiring, 1962). Mara (1975) recommends two maturation lagoons in series for the effluent to be biologically acceptable with a BOD of less than 25 mg/l in a river which is used downstream as source of domestic water. The ponds are usually dark green in appearance and measure 1.0 to 1.5 m in depth and are supersaturated with oxygen.

Anaerobic lagoons are pretreatment units which have a high solids concentration and a BOD of more than 400-500 mg/l. They have long retention times, and are characterized by odour production, absence of algae, dark colouration, red or purple colour due to the presence of anaerobic purple phototrophic bacteria. They require desludging after a period of 3.5 years.

#### Mode of Operation of Stabilization Ponds

A major consideration in the operation is BOD reduction. In such cases it is common practice to use either a combination of anaerobic and facultative stabilization ponds or facultative pond independently (Gloyna, 1971). Where it is found important to reduce numbers of pathogenic bacteria then series connected ponds can be used. This may include anaerobic facultative and maturation ponds.

Series design is usually found where organic

load is great and where it is necessary to reduce the coliform count. Parallel systems can be used where flexibility of operation is desirable. Recirculation helps to increase oxygen in the system by bringing back the oxygen rich effluent to the part of the system where oxygen is required.

Industrial wastes which usually contain large amounts of solids and occasionally toxic or coloured substances require special treatment.

Detention time and temperature control the biological process in waste stabilization ponds. Effluent and influent flow rates should be equal.

In various parts of the world waste stabilization ponds have been put into increasing use in the treatment of raw and partially treated wastes. In South Africa the maturation ponds have been incorporated to become an integral part in waste water treatment systems. (Van Ech. 1961). In Israel where great importance is attached to the treatment of wastewaters in Stabilization ponds, attention is being made to recharge groundwater with waste water and plans have been developed for the use of this method for a city with a population of over one million. Part of the design recommendations include use of both anaerobic and facultative ponds as reported by Amramy (1965). The effluent from the ponds would be spread in basins and reclaimed by withdrawing the water through wells. Gloyna (1971)

reports that in the United States of America, waste stabilization ponds are used to receive effluents from overloaded biological treatment units. The ponds are designed to improve effluents of activated sludge plants, biological filters, anaerobic or facultative ponds. The water prepared thus is reused to reduce BOD loading. Askew et al (1965) reported that in Santee, California, effluent from activated sludge treatment plant was detained in a waste stabilization pond for 30 days after which the water was dosed with 5mg of chlorine and then allowed to percolate through a natural sand and gravel formation 3-4 m thick. The water was collected 25 km in reactional lakes. The activated sludge effluent was found to contain one or more of 13 different types of viruses, whereas only 25 per cent of stabilization pond effluent samples were found to contain viruses.

Samples from the lakes were found to contain no viruses. Shaw (1962) report indicates that where nightsoil or wastes from conservancy tanks is to be treated in stabilization ponds, the ponds will remain aerobic if the loading does not exceed the contribution from 3,000 - 5,000 persons per hectare per day and if minimum depth is about 1 m. He further stressed that losses due to evaporation and seepage must be compensated for if this type of waste pond is to continue operating. Treatment of wastes in farm ponds



has been reported by Bay (1962). In the State of Missouri (U.S.A.) he reports that there are over 200 ponds for the treatment of hog wastes.

#### Advantages of Lagoons

Treatment of waste using stabilization ponds has been reported to have many advantages over conventional treatment works. Mara (1975) reports that where sufficient land is available, lagoons may be the most suitable process for waste water treatment. He gives the following reasons:-

(a) The ponds are capable of achieving any required degree of purification in BOD and coliform reduction.

(b) Stabilization ponds have proved to effect the removal of pathogens in a superior level to that of other waste treatment methods.

(c) Stabilization ponds are able to withstand both organic and shock loads.

(d) Through the process of precipitation, absorption and sedimentation, lagoons are capable of removing toxic compounds present in industrial wastes.

(e) It is much cheaper, simpler and economical to operate and maintain lagoons.

(f) Design of the ponds facilitates flexibility in a manner which can allow the degree of waste treatment to be simply altered.

(g) Land put into waste stabilization purposes can in future be reclaimed for other uses should it be necessary.

(h) The high degree of algal proliferation which is a source of protein in facultative and maturation ponds can be exploited for fish farming.

#### WASTE STABILIZATION POND DESIGN METHODS

Current procedures for the design of waste stabilization ponds have the main objective of treatment of wastes clearly defined. The current procedures of design are those of Marais and Shaw, Gloyna's procedure, . The Indian surface method and the load per unit area method.

Marais and Shaw (1961) modified procedure for the design of sewerage lagoons assumes the first order kinetics for the 5 day BOD removal in a completely mixed lagoon. For the removal of BOD they have given the following equation

$$Le = \frac{Li}{1+kt} \quad (1)$$

where  $Le$  is the effluent  $BD_5$  in mg/l

$Li$  is the influent  $BOD_5$  in mg/l

$t$  is the retention time in days

$k$  is the facultative lagoon constant per day.

For aerobic lagoons they reported that the maximum

value of  $L_e$  is related to depth. Equation 1 was modified to equation 2 after field investigations of ponds in Zambia, Rhodesia, U.S.A. and South Africa.

$$L_e = \frac{1000}{2D \times 8} \quad (2)$$

where  $D$  = Lagoon Depth.

Meiring et al (1968) later reduced the value of 1000 in equation 2 to 600 which reduced equation 2 to design equation 3.

$$\frac{L_i}{1+kt} = \frac{600}{2D+8} \quad (3)$$

Marais (1970) considered the reduction to 600 as too high and consequently changed this to 700. For design purposes he puts the value of  $k$  as  $0.17 \text{ day}^{-1}$ . Marais (1966) allowed the value of  $k$  to vary with temperature as in equation 4.

$$kT = 1.2 (1.085)^{35-T} \quad (4)$$

where  $T$  is any temperature in  $^{\circ}\text{C}$ .

He made the assumption that the value of  $k$  at any temperature  $T$  was related to the value of  $k$  at  $35^{\circ}\text{C}$  which he found to be  $1.2 \text{ day}^{-1}$ :

Mara (1975) however says that the Marais and Shaw equation (1961) has got two shortcomings. Firstly the field variation of  $k$  with temperature cannot be deduced wholly from analysis of laboratory

models. Secondly, that no field data could be so accurate as to justify a decrease in  $L_e$  of 1 to 2 mg/l for a decrease in depth of 100 cm.

#### Gloyna's Procedure

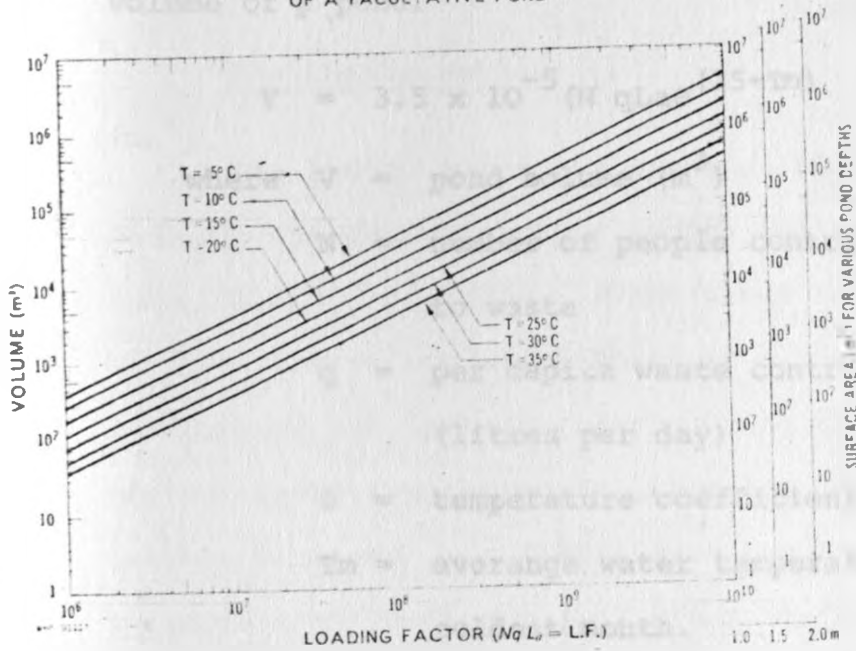
In their model laboratory ponds and from field study of stabilization ponds Herman and Gloyna (1958) advanced a theory that related pond volume to temperature, organic waste concentration, influent volume, and toxicity. They laid importance on the influence of temperature on detention time for fixed BOD reduction. At a temperature of  $35^{\circ}\text{C}$  they found that a 90 per cent BOD reduction could be obtained in a detention time of 3.5 days from data obtained in their laboratory scale experiments. They state that the required volume of a facultative pond can be estimated with the aid of Fig. 2. The loading (LF) can be computed by multiplying the number of persons contributing waste (N) by the per capita contribution in litres per day (q) and the BOD  $L_a$ . If the temperature of the coldest month of the year could be found, a reasonable design can be developed using fig. 2. This can be achieved by drawing a vertical line from the calculated factor to the selected temperature thus finding the required volume in  $\text{m}^3$  which can be read off the left ordinate and the required surface area on the right ordinate.

FIG. 2

PROCESS DESIGN PROCEDURES

65

FIG. 13. GRAPH FOR CALCULATING THE REQUIRED VOLUME AND SURFACE AREA OF A FACULTATIVE POND \*



\* Pond depth = 1 m. Influent volume must be sufficient to maintain liquid depth.  
 T = average water temperature of coldest month (°C)

( ADAPTED FROM GLOYNA 1971)

Suwannakarn and Gloyna (1964) observed that temperature is the only most important single consideration for domestic sewage but light intensity, wind, total dissolved solids and other factors may influence the pond volume. Herman and Gloyna (1958) came up with the following equation for calculating the required volume of a pond.

$$V = 3.5 \times 10^{-5} (N qLa^{\theta})^{(35-T_m)}$$

where  $V$  = pond volume ( $m^3$ )

$N$  = number of people contributing to waste

$q$  = per capita waste contribution (litres per day)

$\theta$  = temperature coefficient = 1.085

$T_m$  = average water temperature for the coldest month.

For wastes containing more than 500 mg/l of sulphate ion, Gloyna and Espino (1969) recommend that surface area must be increased. This also applies to industrial wastes which are not readily biodegradable and are toxic to algae or may reduce the chlorophyll content as reported by Huang and Gloyna (1968) and Thirumuthi and Gloyna (1965).

Gloyna (1958) states that appropriate depth should be determined after considering the type of waste to be treated, the environmental conditions

and safety factors required. The pond depth should not be less than 1 m deep as this will allow growth of emergent vegetation and development of odours in hot seasons. He recommended depths in excess of 1.5m to cater for sludge storage and facilitate excess capacity for cold weather.

#### The Indian Method

The Indian Method is based on the suggestions made by the Central Public Health Engineering Institute (CPHERI) of India. CIPHERI bases the design of facultative ponds for domestic wastes on a loading of 336 kg/ha per day. Using this loading and an operating depth of 1.22 m for domestic waste waters Dave and Jain (1967) have reported a BOD reduction of 70-85 per cent after studying 8 ponds. The method recommends use of 2 ponds to facilitate servicing and cleaning. For a flow which exceeds 2,250,00 litres per day CIPHERI recommends use of multi-parallel units of ponds.

Another design method for aerobic ponds which was originated by Oswald and Gotaa's (1957) and reported by Arcierala et al (1969) consists of loading the pond with a load consistent with the production of oxygen through the algal photosynthetic process. The method takes into account such factors as oxygen production conversion of solar energy,

temperature and latitude.

These two approaches for aerobic pond design are understood to provide reasonably similar results as reported by Gloyna (1971).

Load per Unit Area Method

This method states that generalization can be made with regard to the acceptable organic load of a facultative waste stabilization pond. The table No. 6 shows BOD loading values which have been used successfully in various geographical areas, based on load per unit area method.

TABLE 6 GENERAL BOD LOADING PER UNIT AREA PER DAY UNDER VARIOUS CLIMATIC CONDITIONS.  
(adapted from Gloyna 1971)

SURFACE LOADING Kg BOD/ ha/day <sup>5</sup>	POPULATION PER ha	DETENTION TIME DAYS	ENVIRONMENTAL CONDITIONS
Less than 10	Less than 20	More than 200	Frigid zones, with seasonal ice cover, Uniformly low water temperatures and variable cloud cover.
10-50	200-1000	200-100	Cold seasonal climate with seasonal ice cover and summer temperatures for short season.
50-150	1000-3000	100-33	Temperate to semi- tropical, occasional ice cover, no prolo- nged cloud cover.
150-300	3000-7000	33-17	Tropical, uniformly distributed sunshine and temperatures, and no seasonal cloud cover



This methods recommends the distribution of settleable solids through use of multiple inlets and deeper ponds of 1.5 to 2 m. Operation of the entire pond system is dependent on volumetric loading, BOD per unit area and the concentration of organic matter in the waste water. Where water content is low, this method recommends that water be added to maintain sufficient liquid over the settled solids or have the ponds designed to function without overflow. Fisher et al (1968) and Horn, (1965) have reported that due to extremes in seasonal temperatures, inadequate surface area, uneven distribution of settleable solids, and inadequate depth unpleasant odours may occur.

#### 2.3.4 STABILIZATION POND IN COTTON TEXTILE WASTES TREATMENT

The use of oxidation ponds, lagoons and stabilization ponds for treatment of cotton textile wastes offers the most economical method for reduction of BOD. This method of treatment is best suited to warm sunny climates and where ample land is available. The waste is allowed to flow into shallow lagoons usually not more than 1.3 metres deep. If the wastes have no significant color a depth 1.2

metres is usually recommended but should the waste be containing a high concentration of dyes then it becomes necessary to limit the depth of utmost 0.9 metres. Detention period recommended is for 30 days for textile waste with a BOD loading in the range of 55-100 kg/ha per day. The pond should be maintained aerobic by keeping it shallow or recirculating the effluent (Coburn, 1955).

Gurnham (1955) recommends lagooning with aeration of textile wastes after biotreatment as a process of which serves as a polishing step and accomplishes maximum removal of pollution load usually to over 95 per cent. He recommends oxidation ponds with or without aeration as the most effective types of lagooning. Loading should be 55 kg per hectre per day where aeration is not provided, but this may be raised to 100 kg per hectre per day where aeration is not provided. With aeration a detention time of 3 to 10 days is required, this again depending on the amount of degree of aeration provided. He recommends oxidation ponds because they offer the cheapest method of treatment with low construction and maintenance costs compared to the other treatment methods although a long retention period of 30 days is required.

Murray et al (March 1973) treated wastes from a plant which carried out sewing and finishing cotton threads in aerated basins. The waste consisted of dyeing, mercerizing and bleaching liquors. Pretreat-

ment involved equalization and settling in a basin with a flow detention period of about one week. Treatment was undertaken in two aeration basins with a flow detention period of approximately 4.5 days. The settling and stabilization basins had a detention period of 1.5 days. Recirculation was provided for from the second pond basin to the first. The results of influent BOD ranged from 225 mg/l to about 70 mg/l and the effluent BOD was about 12 mg/l to 8 mg/l thus achieving a BOD reduction of 94 to 85 per cent. The pH of the influent ranged from 10.2 to 9.1. Other workers who have attempted to look into the treatment of cotton textile wastes in lagoons are Williams and Hutto (1962). Anon (1966) showed the ability of aerated lagoons to handle shock loads and support suspended solids concentration of up to 10,000 mg/l. Using mechanical aerators 37,9000 m<sup>3</sup> per day of bleachery waste could be treated through an extended aeration plant. The mechanical aerators had a horse power of 127.5 h.p. and 62-65 per cent BOD removal was achieved at a pH of 12.0.

#### 2.3.4 OTHER METHODS OF COTTON TEXTILE WASTE TREATMENT AND DISPOSAL

Apart from biological treatment and chemical precipitation other varying methods have been used in the treatment and disposal of cotton textile wastes.

Methods so far tested upon include biofiltration, ion exchange processes, ultrafiltration and radiation as treatment methods and irrigation as a disposal method. Using hyperfiltration on cotton textile waste Brandon (1973) found that 87 per cent of the water was recoverable and re-usable in the mill. Color removal achieved was up to 99 per cent. A report on Progress and Problems in controlling Pollutions (Anon 1975) highlighted that in one case where hyperfiltration was used for treatment of dyeing water, it was possible to reuse this water for commercial dyeings for over eighteen times. Porter (1973) has discussed reverse osmosis, adsorption and chemical coagulation as the three possible methods of treating textile wastes. He argues that reverse osmosis could probably be the most applicable method because through its use process chemicals can be isolated and recovered.

Radiation has been used by Case et al (1973) in the treatment of dyeing wastes. By subjecting dyeing wastes to gamma radiation he noted low temperature oxidation process was induced which led to color removal.

Disposal of textile waste through soil irrigation has been investigated by Kustermann and Reploh (1966). In their investigations they used textile waste containing chromium and found that the chromium concentration in the wastewater must not exceed 0.5 mg/l and the amount of irrigation water

must not exceed 2000 m<sup>3</sup>/ha. High alkalinity must be neutralized to avoid reducing filtration rates in the soil by dissolving humus substances. pH control could be adjusted through the use of sulphuric acid (H<sub>2</sub>SO<sub>4</sub>). Further work on disposal of textile waste has been carried out by Stroka and Reineke (1973). They noted that the success of the process depends on the reduction of volumes of water used in textile processing and an adequate pretreatment of the waste before disposal onto land. Oden (1967) treated a small factory waste from a dye and process by letting it pass into a small surge tank and then into trenches containing limestone and sand. The trenches were covered with building paper or fertilizer bags and a 15-20 cm layer of soil. The effluent seeped through the trenches and surrounding ground to the nearest waterway. Removal of color was 100 per cent. Disposal through soil irrigation could as such be practiced where pretreatment of the waste is carried out, to reduce alkalinity as well as lowering pH, where ample land is available and infiltration rates are high.

### 2.3.5 POLLUTION EFFECTS OF TEXTILE WASTE

The effects of direct discharge of raw cotton textile wastes into a river course are varied and could have long term or short term effects depending on the constituents of the waste. The wastes may deplete dissolved oxygen, change the pH of water thus rendering it alkaline or acidic, or add toxic matter to animal, plant or aquatic animals. Intensity of these effects will depend on the concentrations of the various pollutants on the waste and more so on the dilution factor of the waste. Part of the waste may exert an immediate oxygen demand in the stream. Such compounds as sulphides and reduced dyes will exert this immediate oxygen demand. Benthic deposits resulting from sedimentation of organic waste on to the river beds will exert a long term oxygen demand. Both the immediate and long term demands will affect the self purification capacity of the stream. Should the demand be considerable it will also affect the stream life. Suspended, colloidal and dissolved solids in the wastes may through the neutralization process be precipitated thus causing increased turbidity, and benthic deposits which will interfere with food for fish as well as their spawning grounds. Oil and grease will form floating scum on the stream surface. Color, though it may not be harmful may interfere with the recreational uses of the river this being objectionable to many people.

Bad odour resulting from decomposition of wastes undergoing anaerobic biodegradation and evolving hydrogen sulphide e.g. from sulphur compounds is also objectionable. Toxic substances if in high concentrations may inhibit biological activity in the stream and particularly fish life. Alkalinity or acidity resulting from direct discharges of textile wastes from mills will also interfere with the water purification process in water treatment works.

### CHAPTER 3

#### CHARACTERIZATION OF WASTES FROM

#### THIKA UNITED TEXTILE MILL

##### 3.1 MATERIALS AND EXPERIMENTAL PROCEDURE

Waste water samples were collected from the various departments of the United Textile Mill where wet processing of cloth is carried out. These departments where water is used include sizing, scouring, bleaching, dyeing and finishing. In collecting the samples from the various processing units plastic cans were placed at the outflow sewer of each unit during periods when the mill was in full operation.

Waste water quantities were calculated by measuring periods in seconds necessary to fill a ten litre plastic container. The volumes were then computed to give the waste water discharge per 12 hours, this being the period during which the mill operates per day. No flow measurements meters are installed at the factory for measuring the daily water consumption. Composite samples were also collected at the main effluent channel. The sampling consisted of sampling for 12 hours at



intervals of one hour.

### 3.2 ANALYTICAL METHODS

All samples collected were analysed for pH, COD, BOD, and SS. The scouring wastes were analysed for alkalinity.

COD: The test was carried out as described in the Standard Methods (1971), experimental method 220. Apparatus were available in the laboratory to reflux a maximum of nine samples at the same.

BOD: Bod tests were carried out in accordance with Standard Methods. The Winkler titration method involving incubation of samples for 5 days at 20°C was used for all BOD analysis.

pH: A direct vibret pH meter Model 3920 was used in measuring the hydrogen ion concentration of all samples.

DO: The dissolved oxygen concentration was done using the Winkler Method. This was done also according to Standard Methods (1971), experimental Method 218B.

SS: The measurements were also done according to Standard Methods (1971).

3.3 OBJECTIVE:

The experiments were done to achieve the following objectives:-

- 1) To establish the characteristics of wastes from the United Textile Mill at Thika.
2. To establish the potential pollutional load discharged from the factory.

3.4 EXPERIMENTAL RESULTS

The results of analysis of samples collected from the various stages of wet processing of cloth at Thika United Textile Mill are as shown on Table 7.1, 7.2 and 7.3. The samples were collected on different dates. Table 7.4 shows the average values for pH, BOD COD and SS for the analytical data of Tables 7.1 to 7.3. Table 7.4 also indicates the calculated volumes of waste waters discharged per day from each of the wet processing operations. The percentage BOD contributions for each of the waste waters has also been calculated on daily basis as is shown in Table 7.4.

Table 8 shows the data obtained from analysis of 3 composite samples collected at the main effluent channel. The composite samples were collected on the respective dates during which the sampling of wet processing of cloth was done. The analytical data was then

averaged and this is shown on the same Table.

SANITARY CHARACTERISTICS OF WET PROCESSING  
WASTES SAMPLED FROM THIKA UNITED TEXTILE MILL

TABLE 7.1 SAMPLING DATE 4/1/78

PROCESS	pH	5-DAY 20°C BOD mg/l	COD mg/l	SS mg/l
Sizing	7.3	2300	3800	5360
Scouring	12.3	4900	8030	24350
Bleaching	6.9	100	460	480
Dyeing and Printing	7.5	2500	4800	1600

Scouring wastes: Alkalinity 2660 mg/l

TABLE 7.2 SAMPLING DATE 20/2/78

PROCESS	pH	5-DAY 20°C BOD mg/l	COD mg/l	SS mg/l
Sizing	7.2	1460	3150	3300
Scouring	11.8	6400	10000	28600
Bleaching	8.7	490	900	1440
Dyeing and Printing	6.8	2340	4440	1560

SCOURING WASTES: ALKALINITY = 2120 mg/l

TABLE 7.3 SAMPLING DATE 11/11/77

PROCESS	pH	5-DAY 20°C BOD (mg/l)	COD mg/l	SS mg/l
Sizing	7.8	1760	3770	4030
Scouring	11.5	3750	7270	18460
Bleaching	9.0	360	730	1060
Dyeing and Printing	7.5	2120	4310	2400

Scouring Wastes: Alkalinity = 2300 mg/l

TABLE 7.4 AVERAGE VALUES FOR WATER DATA .

7.1, 7.2, and 7.3 WITH THE AVERAGE

WASTE WATER VOLUMES & BOD CONTRIBUTIONS

PER DAY.

PROCESS	pH	5-DAY 20°C BOD mg/l	COD mg/l	SS mg/l	WASTE WATER VOLUMES/ DAY (m <sup>3</sup> )	% BOD CONTRIBUTION PER DAY
Sizing	7.4	1840	3573	4230	16.52	3.35
Scouring	11.85	5015	8447	23803	111.6	62.10
Bleach- ing	8.2	317	703	993	238.0	8.4
Dyeing & Print- ing	7.25	2320	4503	1520	102.0	26.2

ALKALINITY: COURING WASTES 236 mg/l

TABLE 8: CHARACTERISTICS OF COMPOSITE SAMPLES

SAMPLE NO.	1	2	3	AVERAGE
pH	8.5	6.4	12.5	9.1
COD mg/l	3080	1040	1840	2947
SS mg/l	60	85	33	60
5-Day 20°C BOD (mg/l)	1240	448	758	815

AVERAGE ALKALINITY 415 mg/l

## CHAPTER 4

### JOINT TREATMENT OF COTTON TEXTILE AND DOMESTIC WASTES IN STABILIZATION PONDS

#### 4.1 EXPERIMENTAL PROCEDURES AND MATERIALS

##### 4.1.1 MODEL PONDS AND LOCATION:

Six model ponds were used in this experiment. The ponds were constructed from perspex sheeting of 5 mm thickness. The Joints of the ponds were sealed using chloroform (Fig. 3). The overall dimensions for 5 ponds were the same: 900 mm x 540 mm x 150 mm. The sixth pond was made available from previous work on stabilization ponds. Its dimensions were the same on length and width but with a height of 180 mm. The ponds were located in a spacious building with two roofing translucent sheets. One of the walls was made of glass doors. These two conditions facilitated sufficient lighting in the building. The model ponds were supported on two Handy Gauze racks constructed for this purpose. The racks were of the dimensions 2000 mm x 1000 mm and were elevated to 500 mm above the floor level. The ponds were denoted as P1, P2, P3, P4, P5 and P6.

#### 4.1.2 SOURCE OF WASTE WATER SAMPLES:

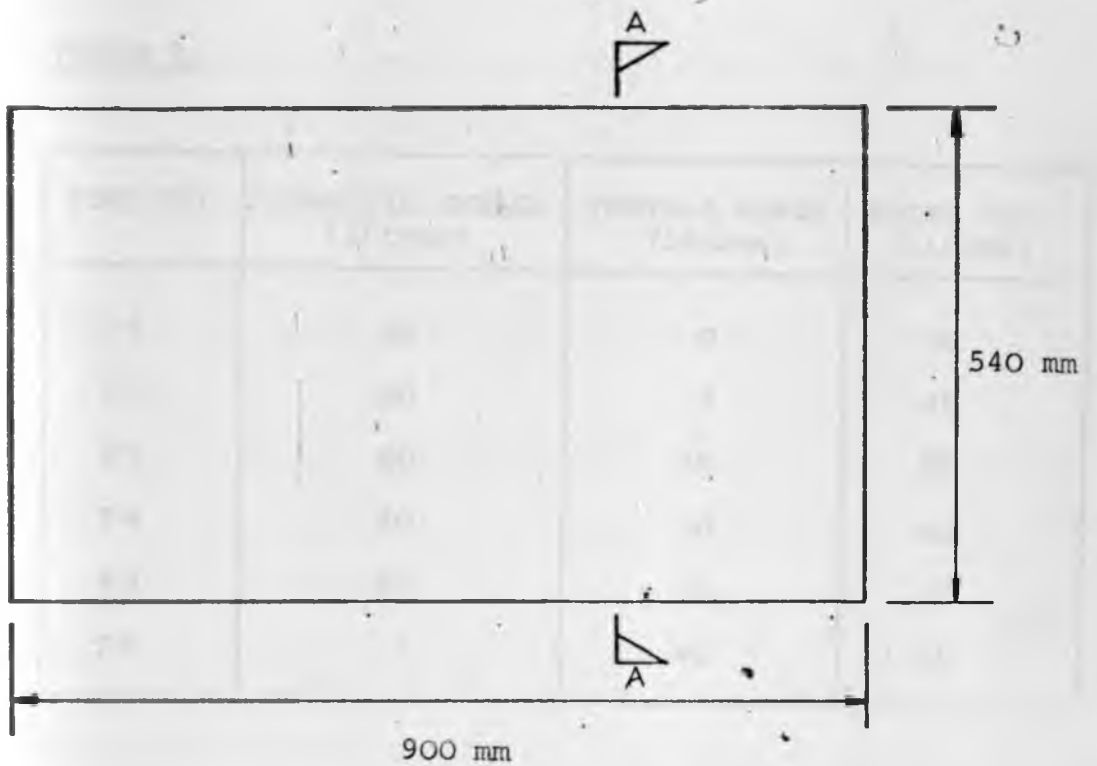
Domestic waste water used for this experiment was obtained from Langata-St. Aquinas Seminary Stabilization ponds. The waste water had to be obtained from here because the ponds are solely used for domestic sewage treatment. Sampling was done at the effluent channel of the primary pond.

Cotton textile waste was obtained from the United Textile Mill at Thika. A composite sample for the experiment was obtained by sampling at intervals of one hour for twelve hours.

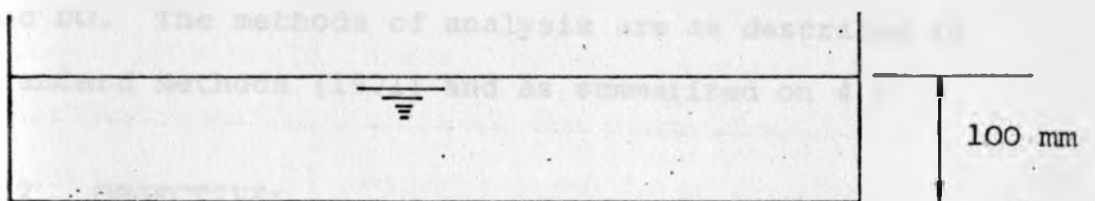
#### 4.1.3 PROCEDURE

Model ponds P1 to P5 were each loaded with 40 litres of the stabilized domestic sewage. Pond P1 was chosen as the control pond. The ponds P2 to P6 were loaded with 5, 10, 20, 40, litres of cotton textile waste to give concentrations of 12.5, 25, 50, 75 and 100 per cent textile waste content (Table 9). Pond P6 contained only textile waste and no domestic sewage.

The contents of each pond were thoroughly mixed before sampling. Sampling of waste from each pond was done along the diagonals of each pond and at a depth of 3 cm from the water surface. The sampling intervals were of three days after the first seven days after loading. The experiment was carried out on batch process basis and lasted for thirty days.



PLAN



SECTION THROUGH AA

FIG. 3 POND PLAN



TABLE 9.

POND NO.	DOMESTIC SEWAGE (litres)	TEXTILE WASTE (litres)	TOTAL VOL. (litres)
P1	40	0	40
P2	40	5	45
P3	40	10	50
P4	40	20	60
P5	40	30	70
P6	0	40	40

Room temperature was between 17 and 19°C during this period. The room temperature was taken to be the temperature of the ponds.

#### 4.1.4 ANALYTICAL METHODS

All samples collected were analysed for COD, pH, and DO. The methods of analysis are as described in Standard Methods (1971) and as summarized on 4.2.

#### 4.2 OBJECTIVE:

The experiments were done to achieve the following objectives:-

1. To establish what proportions of cotton textile waste and domestic sewage (volume by volume) can be treated together jointly in stabili-

zation ponds without adversely affecting the efficiency of the pond.

2. To establish what adverse effects may arise from overloading a domestic sewage stabilization pond with textile wastes.

#### 4.3 EXPERIMENTAL RESULTS:

##### General Appearance:

Pond P1 remained relatively green compared to the other ponds during the experimental period. Ponds P2 to P6 showed an increasing intensity in colour. This was dependent on the volume of textile waste added to each pond. Algae could be detected visually in ponds P2 to P5 but again this was noted to be in a decreasing order as the concentration of textile wastes increased. No algae could be observed in pond P6 which contained only textile waste. Chironomid larvae, aphanids, euglena and flagelles were detectable in the ponds after observing the pond contents visually or through a microscope. The ponds remained relatively aerobic and showed no signs of frothing or forming a scum layer during the experimental period. In all ponds sludge was found to have settled at the bottom. All the ponds formed a suitable breeding ground for mosquitoes. Mosquito larvae were observed to be highly prevalent at the water air interface of each pond. Table 9,

10, 11, 12, 13 and 14 are presented to show the conditions of waste water characteristics collected from ponds P1, P2, P3, P4, P5, and P6 respectively.

Graphical presentations of the waste characteristics is depicted in figures 3 and 4.

TABLE 10: POND P1 (CONTROL POND)

DATE	DETENTION TIME (DAYS)	DO (mg/l)	COD (mg/l)	pH
26/10/77	0	5.1	188	7.8
3/11/77	7	6.5	135	7.95
6/11/77	11	6.9	101	8.3
8/11/77	13	7.3	83	8.45
11/11/77	16	7.5	68	8.65
14/11/77	19	7.8	60	8.8
16/11/77	21	8.1	50	8.9
18/11/77	23	8.4	45	9.1
22/11/77	27	8.6	42	9.1
25/11/77	30	8.6	38	9.1

TABLE 11 POND P2

DATE	DETENTION TIME (DAYS)	DO (mg/l)	COD (mg/l)	pH
26/10/77	0	4.4	308	7.6
2/11/77	7	4.6	263	7.8
6/11/77	11	4.9	200	8.0
8/11/77	13	5.1	168	8.1
11/11/77	16	5.5	125	8.1
14/11/77	19	5.9	112	8.3
16/11/77	21	6.2	93	8.5
18/11/77	23	6.5	80	8.5
22/11/77	27	6.8	66	8.6
25/11/77	30	7.4	60	8.7

TABLE 12: POND P3

DATE	DETENTION TIME (DAYS)	DO (mg/l)	COD (mg/l)	pH
26/10/77	0	2.7	383	7.45
2/11/77	7	3.2	345	7.50
6/11/77	11	3.5	292	7.60
8/11/77	13	4.2	255	7.75
11/11/77	16	4.6	200	7.8
14/11/77	19	5.1	180	7.9
16/11/77	21	5.4	148	8.2
18/11/77	23	6.0	123	8.35
22/11/77	27	6.5	100	8.5
25/11/77	30	6.7	82	8.55

TABLE 13 POND P4

DATE	DETENTION TIME (DAYS)	DO (mg/l)	COD (mg/l)	pH
26/10/77	0	0	517	7.2
2/11/77	7	0	465	7.35
6/11/77	11	0	412	7.35
8/11/77	13	2.0	364	7.5
11/11/77	16	2.6	300	7.7
14/11/77	19	3.2	267	7.7
16/11/77	21	3.4	225	7.8
18/11/77	23	3.7	200	7.8
22/11/77	27	4.2	165	7.85
25/11/77	30	4.6	130	8.05

TABLE 14 POND P5

DATE	DETENTION TIME (DAYS)	DO (mg/l)	COD (mg/l)	pH
26/10/77	0	0	660	7.05
2/11/77	7	0	611	7.1
6/11/77	11	0	550	7.1
8/11/77	13	0.9	499	7.3
11/11/77	16	1.1	442	7.5
14/11/77	19	1.35	401	7.5
16/11/77	21	1.8	346	7.7
18/11/77	23	2.1	324	7.9
22/11/77	27	3.2	274	7.9
25/11/77	30	3.4	246	8.05

TABLE 15 POND 6

DATE	DETENTION TIME (DAYS)	DO (mg/l)	COD (mg/l)	pH
26/10/77	0	0	757	6.7
2/11/77	7	0	716	7.05
6/11/77	11	0	675	7.1
8/11/77	13	0.1	645	7.3
11/11/77	16	0.6	600	7.3
14/11/77	19	0.9	561	7.4
16/11/77	21	1.2	521	7.4
18/11/77	23	1.65	488	7.5
22/11/77	27	2.5	241	7.55
25/11/77	30	2.7	383	7.60

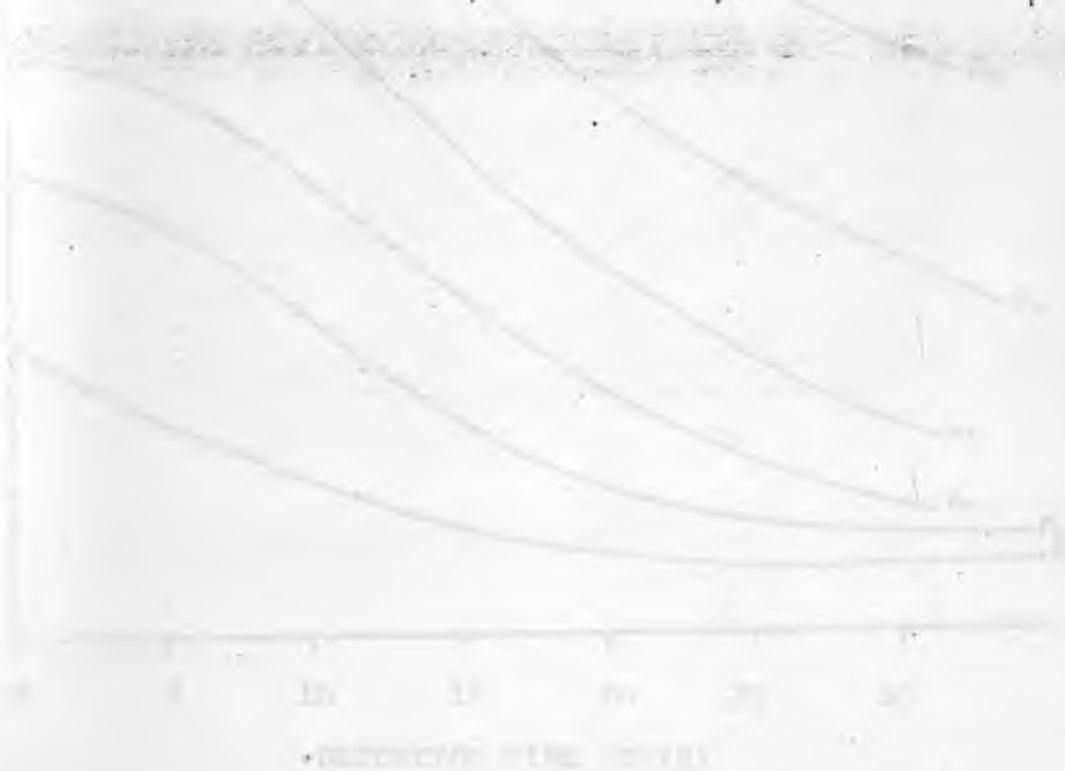




FIGURE 4. CHEMICAL OXYGEN DEMAND AS A FUNCTION OF DETENTION TIME.

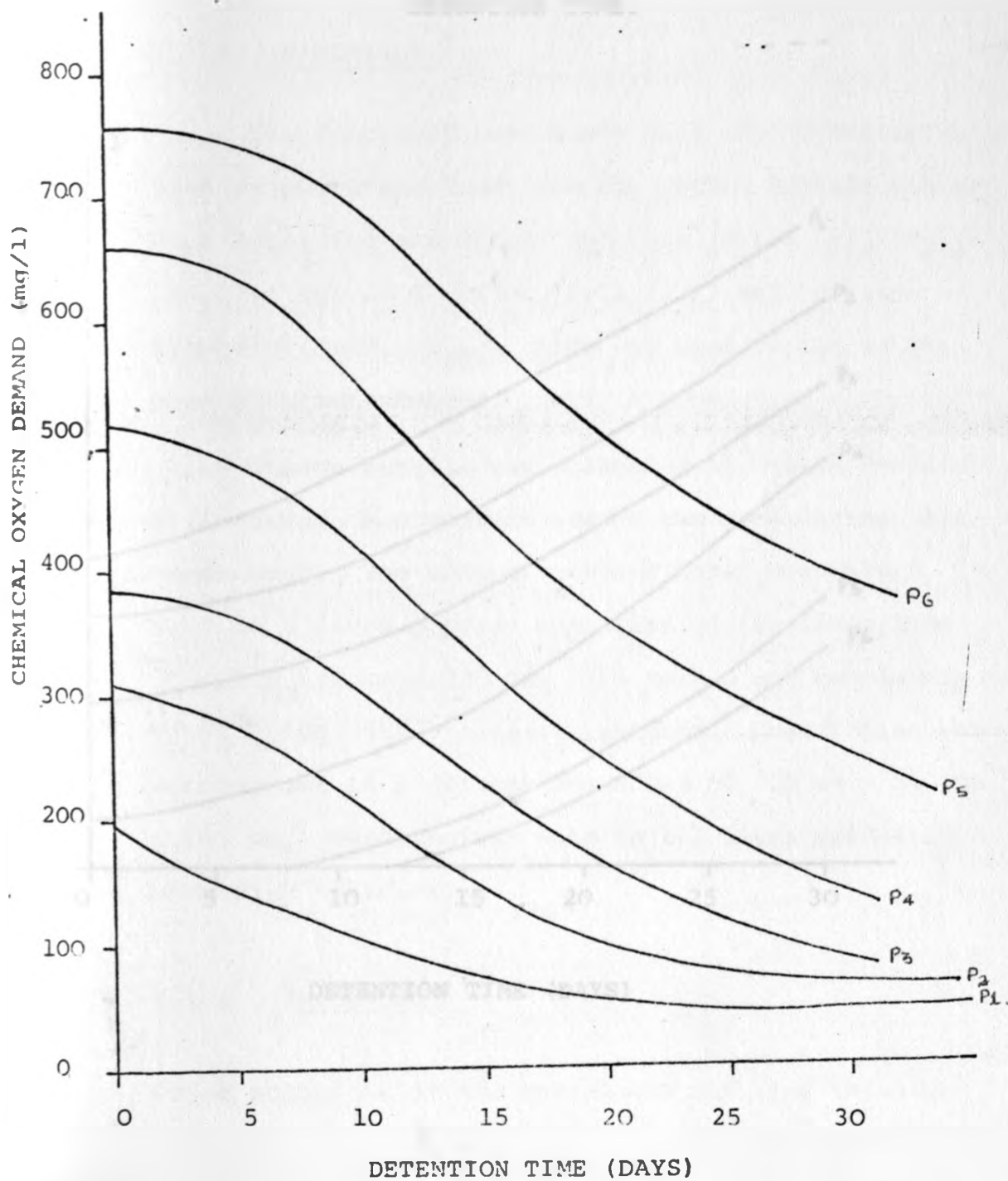
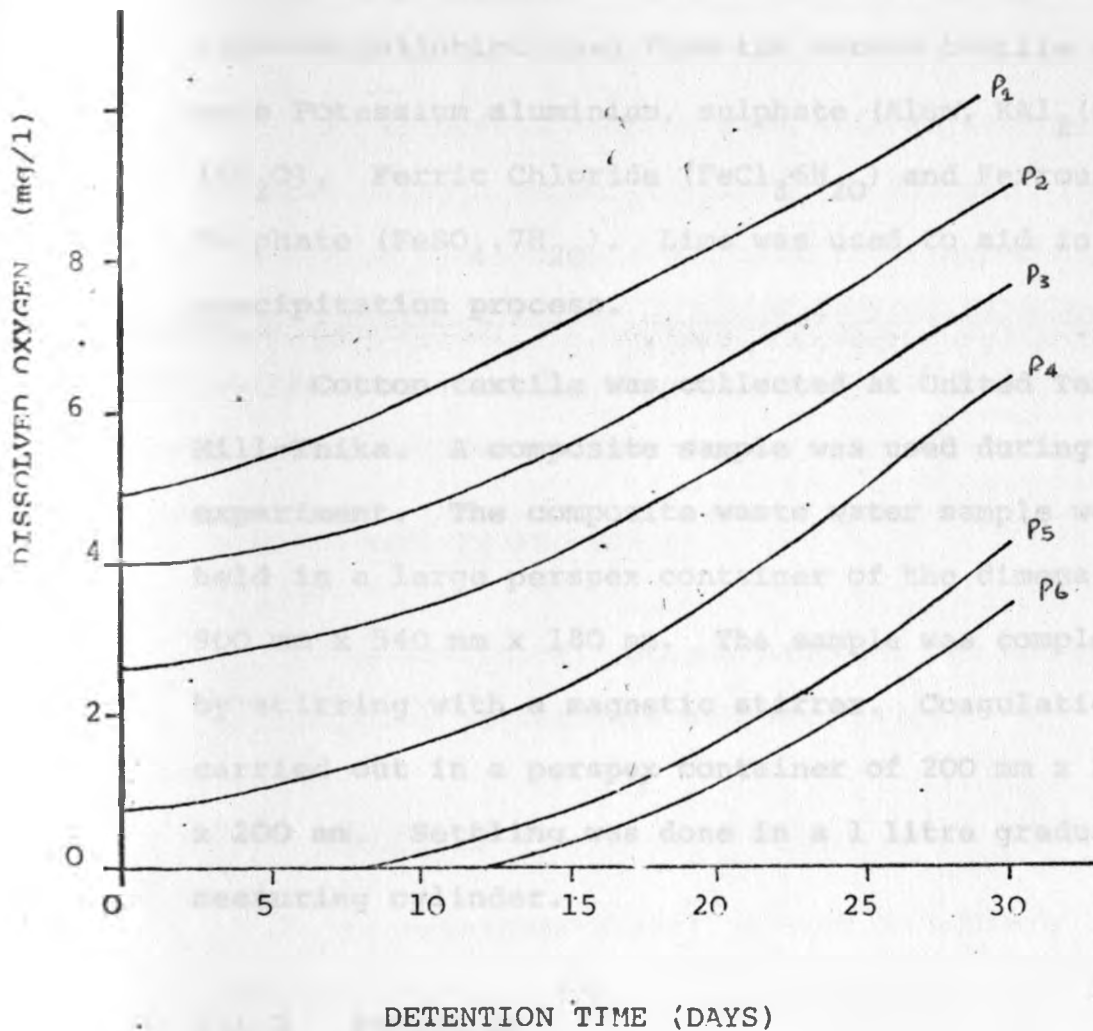


FIGURE 5: DISSOLVED OXYGEN AS FUNCTION OF DETENTION TIME.



## CHAPTER 5

### TREATMENT OF COTTON TEXTILE WASTES USING

### ORGANIC COAGULANTS

#### 5.1 EXPERIMENTAL PROCEDURE AND METHOD

##### 5.1.1 MATERIALS:

The inorganic coagulants used in the precipitation of pollution load from the cotton textile wastes were Potassium aluminium, sulphate (Alum,  $KAl_2(SO_4)_3 \cdot 16H_2O$ ), Ferric Chloride ( $FeCl_3 \cdot 6H_2O$ ) and Ferrous Sulphate ( $FeSO_4 \cdot 7H_2O$ ). Lime was used to aid in the precipitation process.

Cotton textile was collected at United Textile Mill-Thika. A composite sample was used during this experiment. The composite waste water sample was held in a large perspex container of the dimensions 900 mm x 540 mm x 180 mm. The sample was completely mixed by stirring with a magnetic stirrer. Coagulation was carried out in a perspex container of 200 mm x 200 mm x 200 mm. Settling was done in a 1 litre graduated measuring cylinder.

##### 5.1.2 PROCEDURE

Stock solutions of the coagulants and lime solution were prepared by dissolving 5 gms of each chemical

in a litre of distilled water. These solutions had each a concentration of 5000 mg/l. In each coagulation process one litre of the cotton textile waste sample was used. Varying concentrations of each coagulant ranging from 100 to 1000 mg/l were added to different samples. Lime dosage of 250 mg/l was used for each experimental sample. The concentration of lime needed for precipitation was arrived at by adding varying concentration of the solution to a litre of waste water containing 100 mg/l of a coagulant.

Experimental samples were stirred for ten minutes using a magnetic stirrer at 40 rpm. The coagulated waste sample was then transferred to 1 litre graduated measuring cylinder to settle for thirty minutes. The supernatant was then decanted and analysed for COD and pH.

### 5.1.3 ANALYTICAL METHODS

The analytical methods used for COD and pH are as described in standard methods (1971).

### 5.2 OBJECTIVE

The experiments were carried to achieve the following objectives.

1. To establish the more effective coagulant in the removal of waste load from cotton textile wastes.

2. To establish the optimum dosage of the most effective coagulant required for precipitation of pollutional load from the waste.
3. To establish the economic possibility of treating textile waste through chemical precipitation as opposed to biological treatment in Thika Municipal Stabilization Ponds.

### 5.3 EXPERIMENTAL RESULTS:

#### GENERAL OBSERVATION:

After using the coagulants for the removal of waste load it was observed that no precipitation can be effected in the absence of lime solution. Lime dosage was required upto the amount 250 mg/l to bring about effective precipitation. In the absence of lime solution the flocs were observed to float at the surface of the liquid.

Use of coagulants was noted to effect the complete removal of colour from the waste water. However doses below 250 mg/l of each coagulant were observed to be not sufficient for the complete removal of color. Sludge volume was observed to increase with dosage upto the optimum dosage of the coagulant. The flocs were observed to settle very fast. Flocs were observed to be weak and through excessive agitation

the floc structure was easily disrupted.

Data obtained from experiments carried out using varying dosages of alum, ferric chloride and ferrous sulphate with lime at varying concentrations are presented in Table 15, 16, and 17 respectively. The prices used for the chemicals are based on the current chemical prices in Kenya shillings. Graphical presentations of the results are shown in figures 6 and 7.

Chemical	Concentration (mg/L)	pH	Settling Time (min)	Floc Structure	Cost (KSh)
Alum	10	7.5	15	Weak	100
Alum	20	7.5	30	Medium	200
Alum	30	7.5	45	Strong	300
Ferric Chloride	10	7.5	15	Weak	150
Ferric Chloride	20	7.5	30	Medium	300
Ferric Chloride	30	7.5	45	Strong	450
Ferrous Sulphate	10	7.5	15	Weak	120
Ferrous Sulphate	20	7.5	30	Medium	240
Ferrous Sulphate	30	7.5	45	Strong	360

TABLE 16 COAGULANT  $Fe_3, 6H_2O + 250 \text{ mg/l}$  of LIME

DOSAGE (mg/l)	0	100	200	300	400	500	600	700	800	900	1000
pH	8.5	10.75	9.9	9.1	8.95	8.75	7.75	7.5	7.3	7.25	7.2
COD (mg/l)	1840	1600	1300	1070	880	720	626	534	460	405	368
COD Removal	-	240	540	770	960	1120	1214	1306	1380	1435	1472
% COD Removal	-	13	29.3	41.8	52.2	60.9	67.4	72.8	75	75	80
Treatment cost/m <sup>3</sup> (KShs)	-	2.20	4.40	6.65	8.85	11.10	13.30	15.50	17.70	19.90	22.15

TABLE 17: COAGULANT:  $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$  + 250 mg/l LIME SOLUTION

DOSAGE (mg/l)	0	100	200	300	400	500	600	700	800	900	1000
pH	8.5	10.2	9.65	8.8	8.45	7.9	7.7	7.3	7.65	6.8	6.45
COD (mg/l)	1840	1670	1510	1320	1190	1110	1062	901	834	815	773
COD Removal	-	170	330	520	650	730	837	938	1006	1025	1067
% COD Removal	-	9.2	17.9	28.3	35.3	39.7	45.5	51.0	54.7	55.7	58
T.Cost/m <sup>3</sup> (KShs)	-	2.10	4.25	6.35	8.50	10.60	12.75	14.85	17.00	19.15	21.25



TABLE 18: COAGULANT  $KAL_2(SO_4)_3 \cdot 16H_2O$  + 250 mg/l OF LIME

DOSAGE (mg/l)	0	100	200	300	400	500	600	700	800	900	1000
pH	8.5	11.5	10.9	10.20	9.3	8.7	7.0	6.4	6.15	5.9	5.6
COD (mg/l)	1840	1450	1100	850	640	490	310	200	150	90	60
COD Removal	-	390	740	990	1200	1350	1540	1640	1690	1750	1780
% COD Removal	-	21.2	40.2	53.8	65.2	73.4	83.7	89.0	91.8	95.1	96.7
Treatment Cost per m <sup>3</sup> (KShs)	-	1.65	3.35	5.00	6.70	8.35	10.0	11.70	13.40	15.10	16.75

FIGURE 6 PERCENTAGE REMOVAL OF COD AS A FUNCTION OF COAGULANT DOSAGE

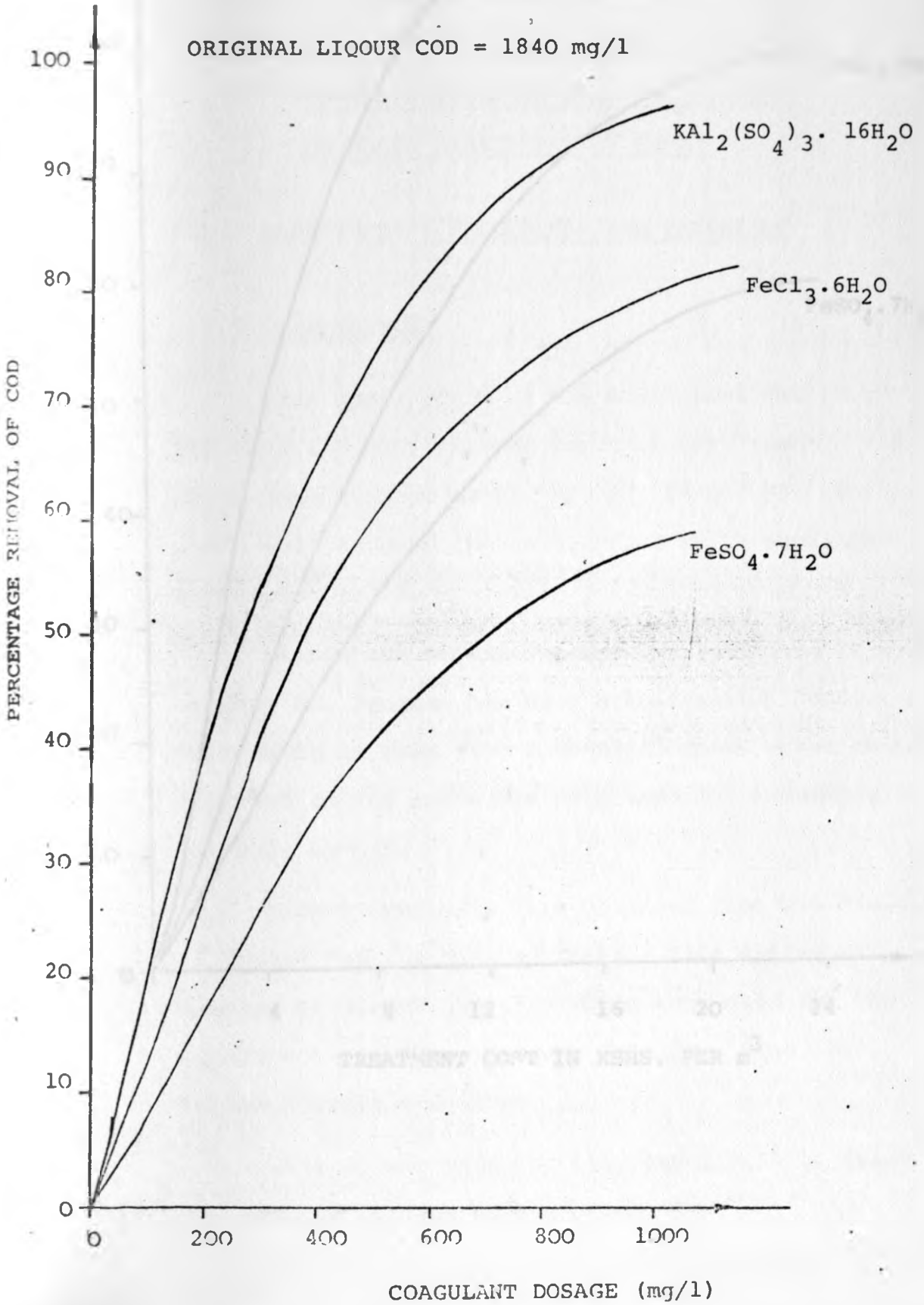
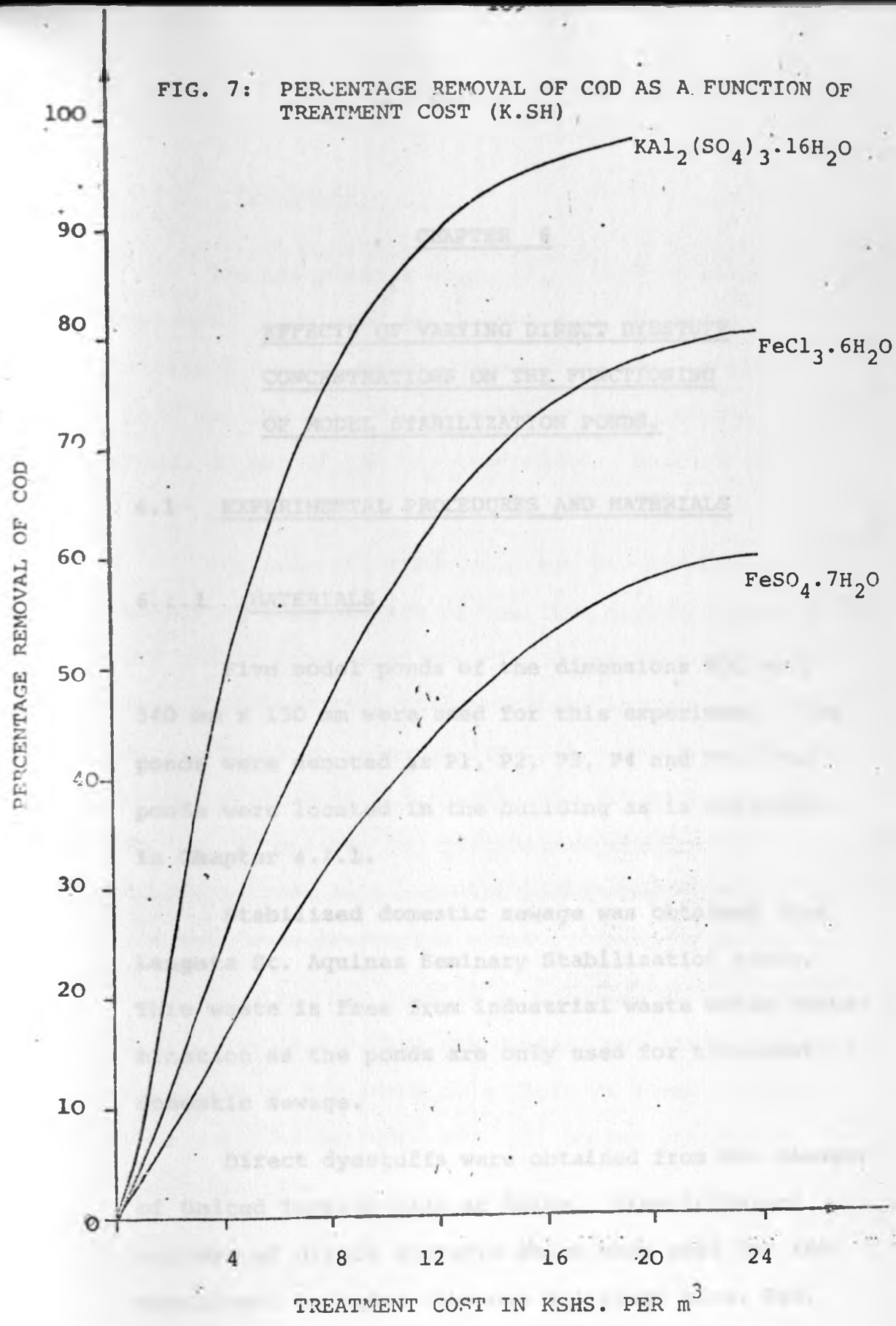


FIG. 7: PERCENTAGE REMOVAL OF COD AS A FUNCTION OF TREATMENT COST (K.SH)



CHAPTER 6

EFFECTS OF VARYING DIRECT DYESTUFF  
CONCENTRATIONS ON THE FUNCTIONING  
OF MODEL STABILIZATION PONDS.

6.1 EXPERIMENTAL PROCEDURES AND MATERIALS

6.1.1 MATERIALS

Five model ponds of the dimensions 900 mm x 540 mm x 150 mm were used for this experiment. The ponds were denoted as P1, P2, P3, P4 and P5. The ponds were located in the building as is explained in Chapter 4.1.1.

Stabilized domestic sewage was obtained from Langata St. Aquinas Seminary Stabilization ponds. This waste is free from industrial waste water contamination as the ponds are only used for treatment of domestic sewage.

Direct dyestuffs were obtained from the Manager of United Textile Mill at Thika. Five different colours of direct dyestuffs which were used for the experiment included Cibacone Brilliant Blue; Red, Yellow, Purple and Brown.

Glucose was used for this experiment to raise the organic loading of the ponds.

### 6.1.2 PROCEDURE:

The experiments were all carried on batch process. Each pond was loaded with 40 litres of stabilized waste water. The water level in each pond was 100 mm. To raise the organic loading in each pond, 50 gms of glucose were added. Pond P1 was taken as the control.

The dyestuff stock solution was prepared by measuring 1 gm of each of the five direct dyestuffs and mixing them together. The dyestuff mixture was then dissolved in 1 litre of distilled water to make a stock solution of 500 mg/l. To give dyestuff concentrations of 2.5, 5.0, 10, and 15 mg/l in ponds P2, P3, P4 and P5, 25, 50, 100 and 150 mls of the dyestuff stock solution were added respectively. The contents were thoroughly mixed.

Sampling was done at an interval of three days for thirty days. This was carried out along the diagonals of the ponds at a depth of 3 cm. Samples were analysed for COD, BOD, pH, DO and chlorophyll 'a' concentration.

### 6.1.3 ANALYSIS OF SAMPLES

All samples were analysed for COD, BOD pH and DO as described in Standard Methods (1971) Chlorophyll 'a' analysis was done after extraction with 90 per cent Acetone. Filtering was done using Whatman filter

paper No. 41. Chlorophyll 'a' concentration was determined by running samples in a Perkin-Elmer Spectrophotometer, Coleman 55 Digital, at a wavelength of 665. Filter 3 was used for the Near Infrared range (615-900 nm). 90 per cent acetone was used as the standard.

#### 6.2 OBJECTIVE:

The experiments were done with the following objective:-

- (1) To establish what effects direct dyes in varying concentrations may have on domestic sewage stabilization ponds.
- (2) To establish as to whether it would be necessary to remove direct dyes from cotton textile waste before discharge of the wastes into Thika Municipal stabilization ponds.

#### 6.3 EXPERIMENTAL RESULTS:

##### GENERAL APPEARANCE

In ponds P2, P3, P4 and P5 the colour intensity increased with increased dye concentrations. The control pond P1 remained relatively green. A scum layer was formed on the surface of each pond during the first seven days. This scum layer resulted from the anaerobic biodegradation of glucose.

Table 18, 19, 20, 21, and 22 are presented to show the data obtained from the analysis of pond samples for a detention period of thirty days. The graphical presentation of the data is shown in figures 12, 13, 14, 15 and 16.

TABLE 19 POND P1

DATE	DETENTION TIME (DAYS)	pH	DO (mg/l)	COD mg/l	BOD mg/l	CHLOROPHYLL 'a' mg/l
23/2/78	0	4.75	0	880	480	2683
24/2/78	1	5.0	0	880	480	2113
27/2/78	4	6.4	0	840	450	975
1/3/78	7	7.0	0	728	430	754
4/3/78	10	7.8	0.5	479	315	1048
7/3/78	13	7.8	1.2	384	294	2332
11/3/78	17	7.8	1.9	351	268	1654
13/3/78	19	7.9	2.5	327	224	834
16/3/78	22	7.9	2.8	288	186	2085
18/3/78	24	8.1	3.2	257	147	661
20/3/78	26	8.1	3.7	208	106	872
23/3/78	29	8.3	3.9	182	85	1374

TABLE 20 POND P2

DATE	DETENTION TIME (DAYS)	pH	DO mg/l	COD mg/l	BOD mg/l	CHLOROPHYLL 'a' mg/l
23/2/78	0	4.6	0	840	480	2961
24/2/78	1	5.1	0	784	478	1412
27/2/78	4	5.3	0	720	446	525
1/3/78	7	5.5	0	684	418	424
4/3/78	10	6.2	0.2	487	390	336
7/3/78	13	7.2	0.9	376	370	2179
11/3/78	17	7.45	1.7	3.16	220	616
13/3/78	19	7.6	2.2	284	179	583
16/3/78	22	7.75	2.5	267	151	525
18/3/78	24	7.8	3.1	234	132	586
20/3/78	26	8.2	3.2	211	120	328
23/3/78	29	8.3	3.8	164	108	969



TABLE 21 POND P3

DATE	DETENTION TIME (DAYS)	pH	DO mg/l	COD mg/l	BOD mg/l	CHLOROPHYLL 'a'
23/2/78	0	5.3	0	886	480	2683
24/2/78	1	5.5	0	864	440	1106
27/2/78	4	6.7	0	850	386	533
1/3/78	7	7.05	0	840	350	487
4/3/78	10	6.8	0.3	516	290	400
7/3/78	13	7.1	1.5	376	260	1937
11/3/78	17	7.20	2.3	281	230	636
13/3/78	19	7.8	2.6	256	187	439
16/3/78	22	7.8	3.1	244	156	870
18/3/78	24	8.2	3.4	226	140	389
20/3/78	26	8.35	3.6	188	126	391
23/3/78	29	8.5	3.8	168	115	341

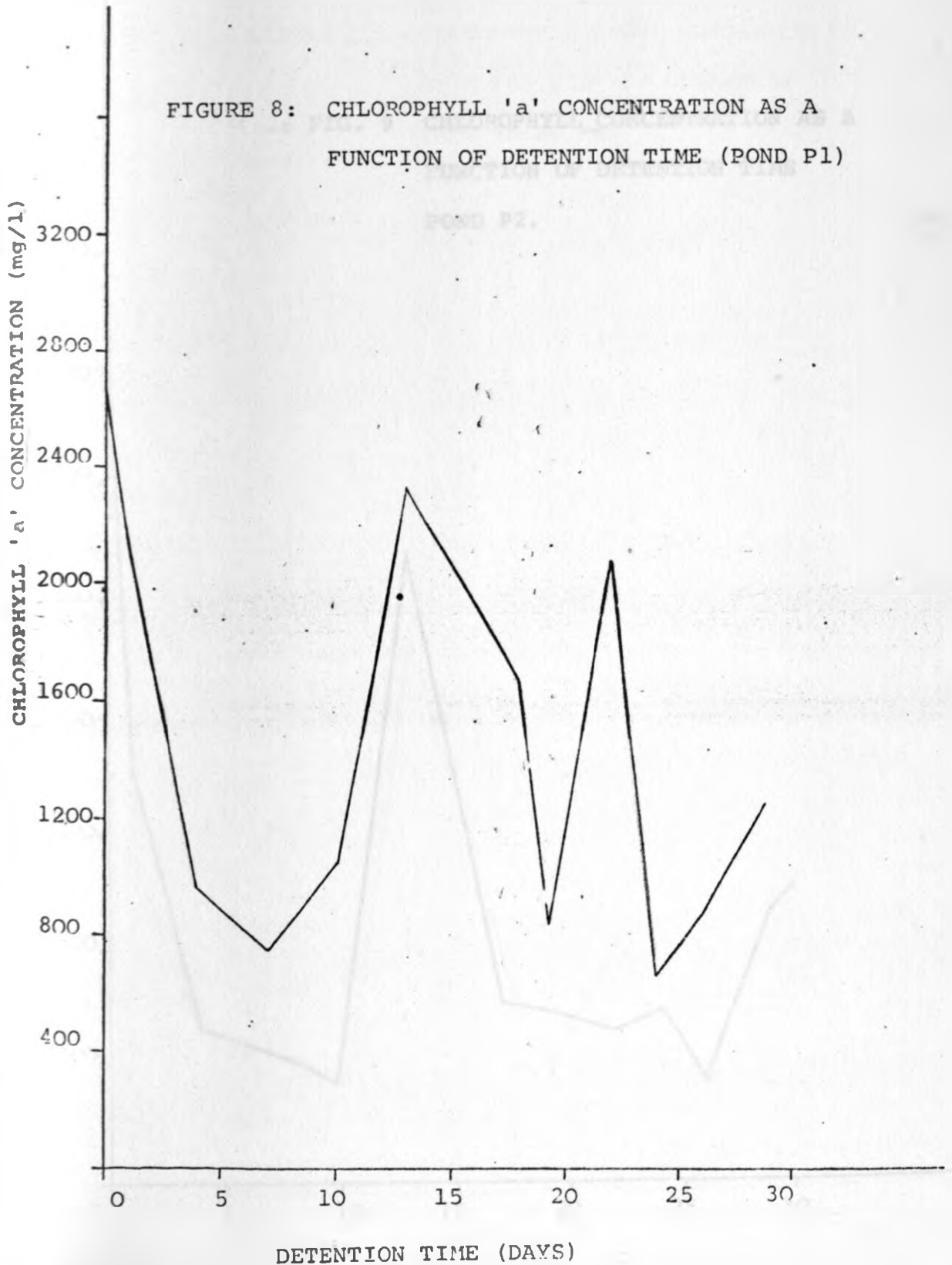
TABLE 22 POND P4

DATE	DETENTION TIME (DAYS)	pH	DO mg/l	COD mg/l	BOD mg/l	CHLOROPHYLL 'a'
23/2/78	0	5.0	0	880	482	2683
24/2/78	1	5.45	0	864	476	1490
27/2/78	4	6.6	0	840	408	1040
1/3/78	7	7.0	0	688	340	436
4/3/78	10	7.4	0.25	616	322	233
7/3/78	13	7.8	1.0	458	304	1601
11/3/78	17	7.8	1.6	376	280	678
13/3/78	19	7.95	1.8	314	250	564
16/3/78	22	8.2	2.40	329	184	931
18/3/78	24	8.4	2.8	288	158	340
20/3/78	26	8.6	3.2	257	130	1476
23/3/78	29	8.6	3.6	188	118	380

TABLE 23 POND P5

DATE	DETENTION TIME (DAYS)	pH	DO mg/l	COD mg/l	BOD mg/l	CHLOROPHYLL 'a' mg/l
23/2/78	0	5.25	0	880	487	2683
24/2/78	1	5.6	0	878	476	1367
27/2/78	4	6.65	0	740	452	583
1/3/78	7	7.15	0	688	320	560
4/3/78	10	7.6	0.2	471	308	542
7/3/78	13	7.8	0.8	380	300	1178
11/3/78	17	7.9	1.2	342	258	633
13/3/78	19	8.0	1.9	307	200	355
16/3/78	22	8.1	2.6	252	190	783
18/3/78	24	8.3	2.9	227	164	335
20/3/78	26	8.3	3.3	204	150	283
23/3/78	29	8.5	3.7	186	132	187

FIGURE 8: CHLOROPHYLL 'a' CONCENTRATION AS A  
FUNCTION OF DETENTION TIME (POND P1)



(a) → FIG. 9 CHLOROPHYLL CONCENTRATION AS A  
FUNCTION OF DETENTION TIME  
POND P2.

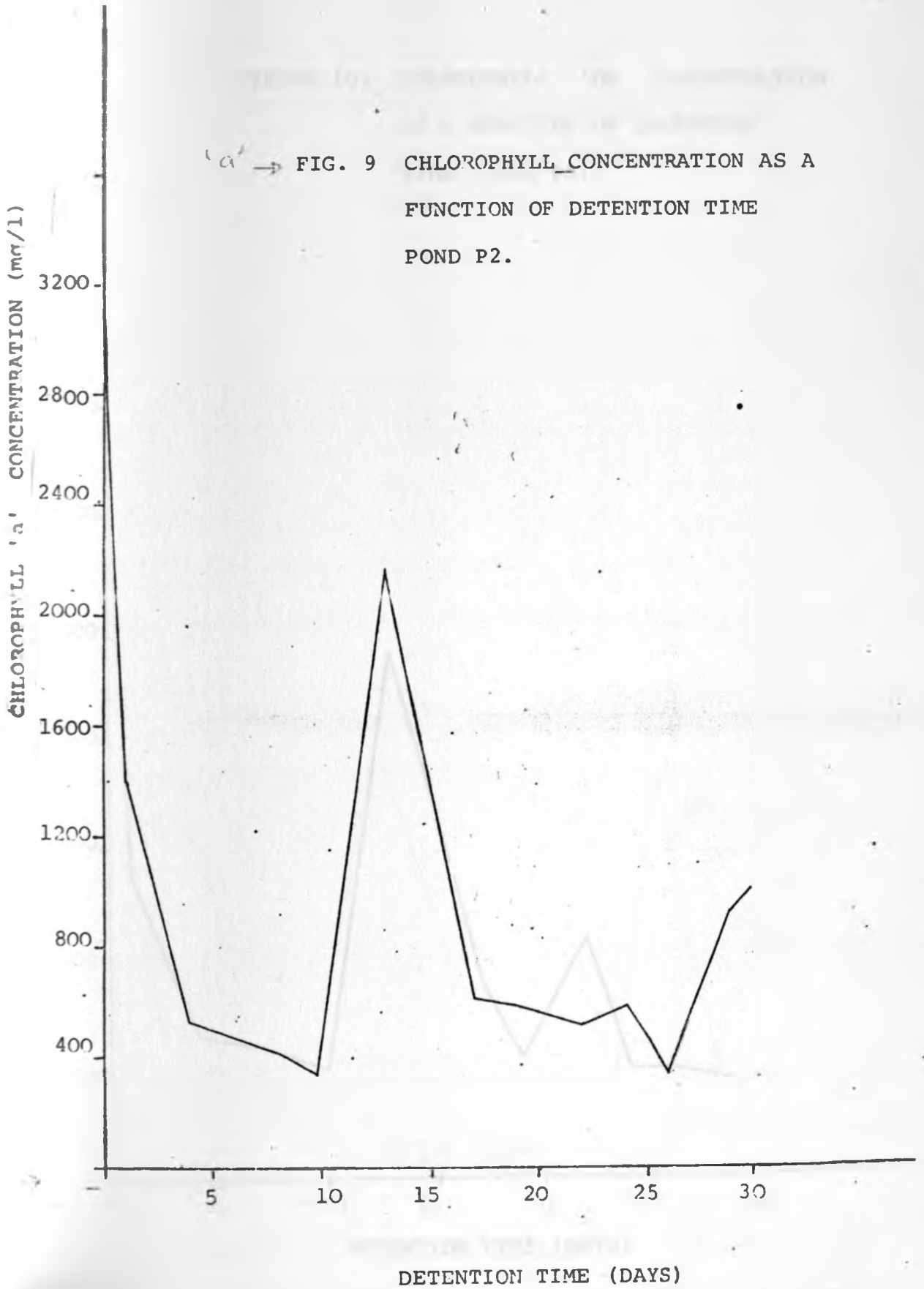


FIGURE 10: CHLOROPHYLL 'a' CONCENTRATION  
AS A FUNCTION OF DETENTION  
TIME (POND P3)

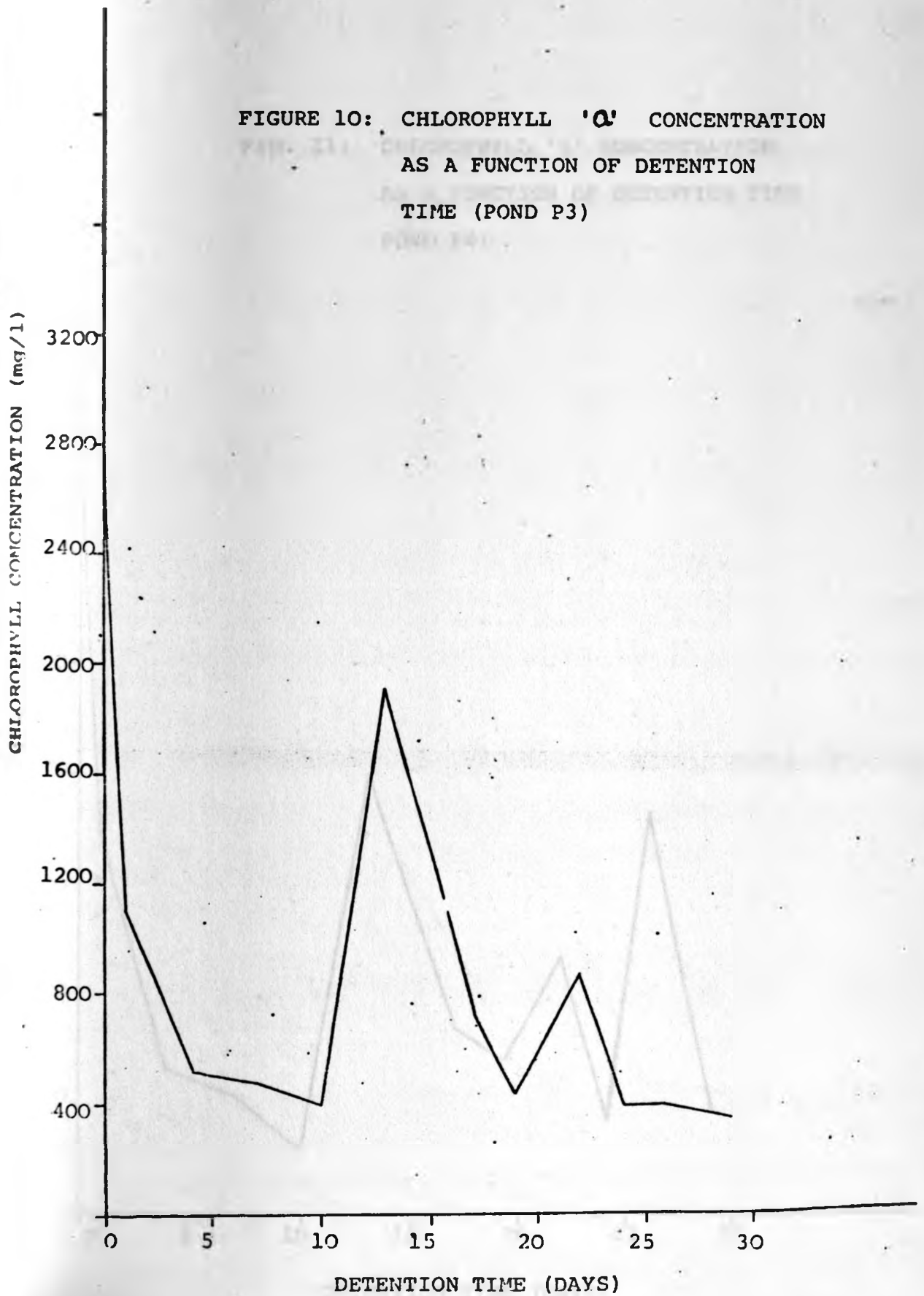


FIG. 11: CHLOROPHYLL 'a' CONCENTRATION  
AS A FUNCTION OF DETENTION TIME  
POND P4)

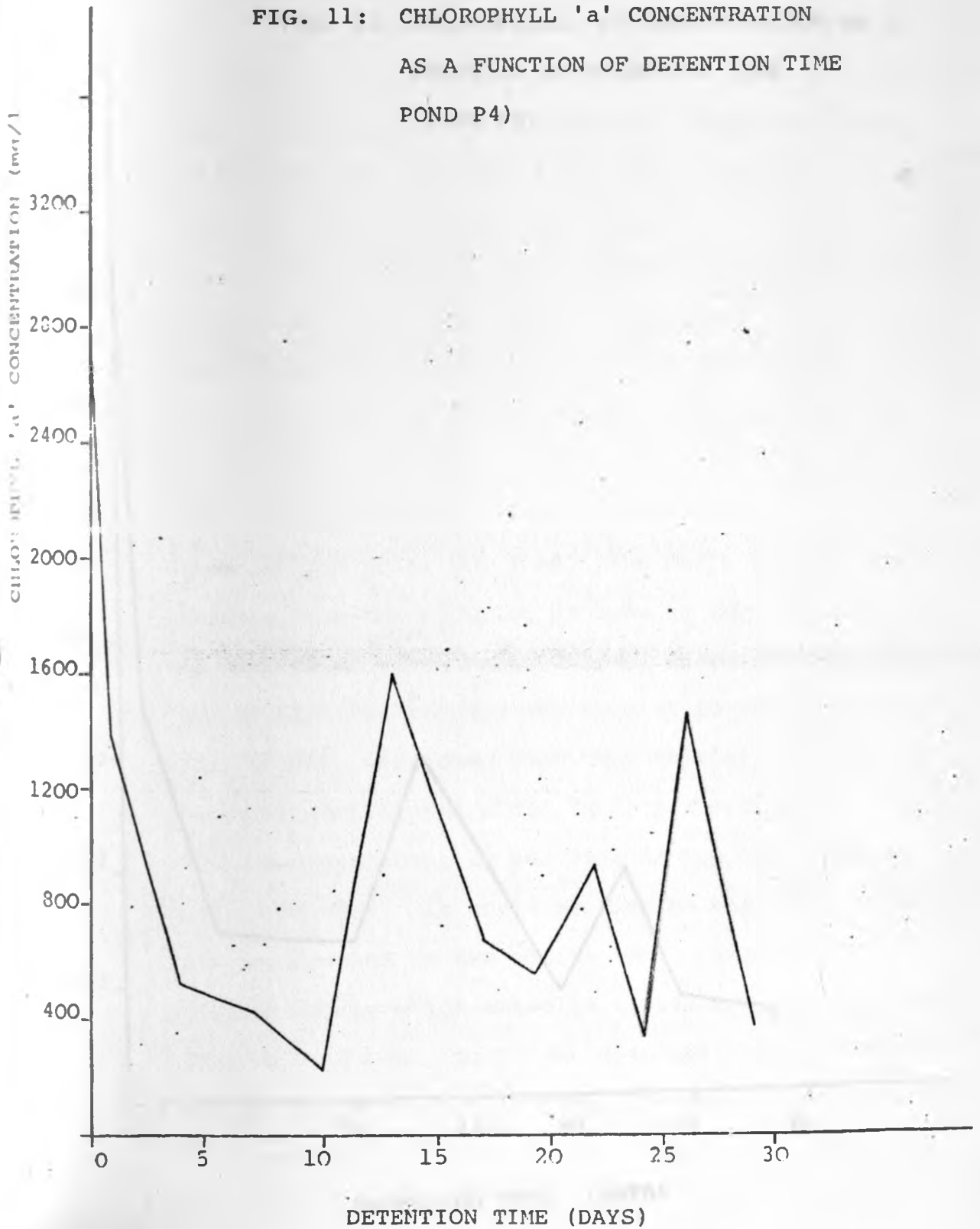
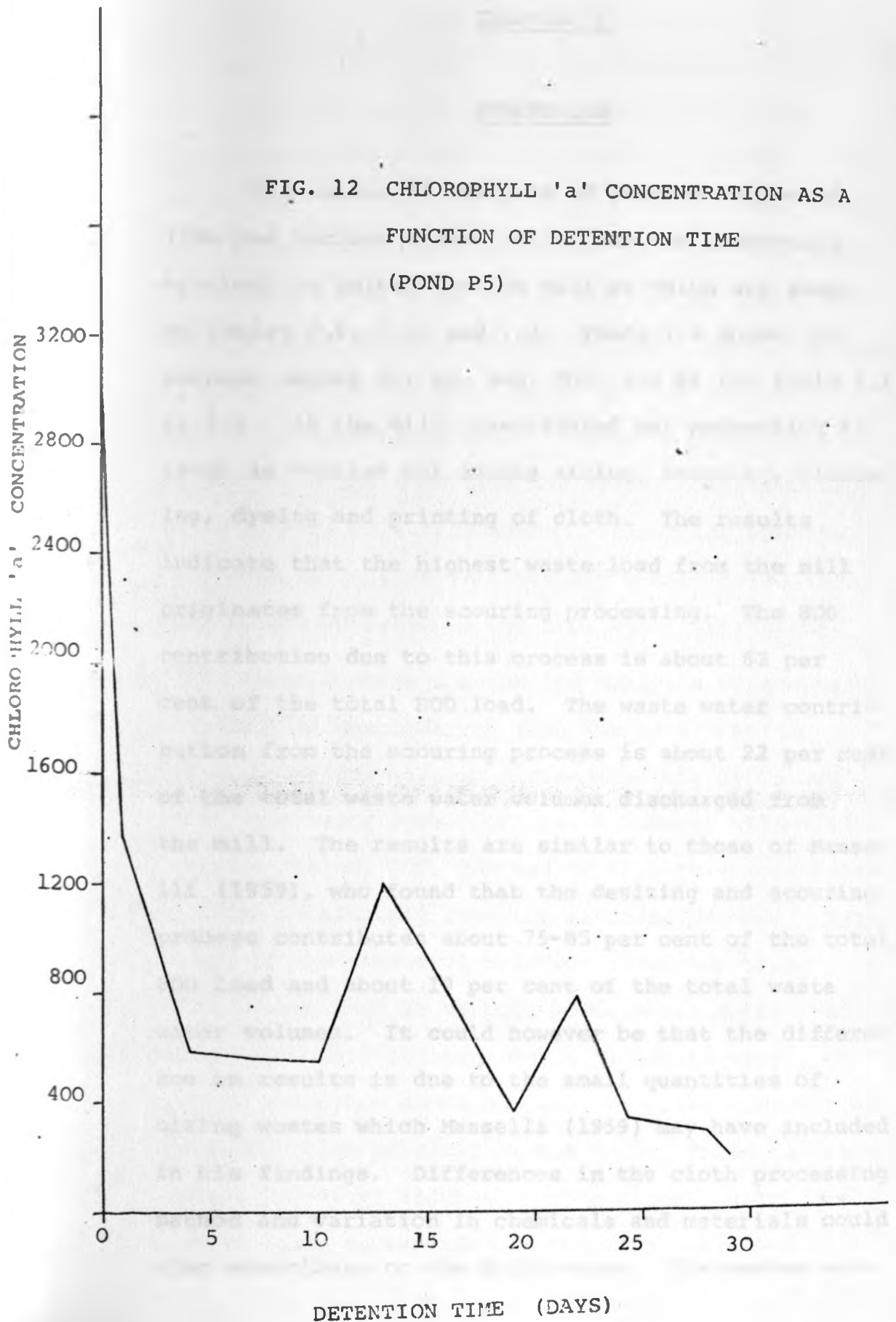


FIG. 12 CHLOROPHYLL 'a' CONCENTRATION AS A  
FUNCTION OF DETENTION TIME  
(POND P5)





## CHAPTER 7

### DISCUSSION

The values of analysis of samples collected from the various stages during the wet processing of cloth at United Textile Mill at Thika are shown on Tables 7.1, 7.2, and 7.3. Table 7.4 shows the average values for pH, BOD, COD, and SS for Table 7.1 to 7.3. At the mill investigated wet processing of cloth is carried out during sizing, scouring, bleaching, dyeing and printing of cloth. The results indicate that the highest waste load from the mill originates from the scouring processing. The BOD contribution due to this process is about 62 per cent of the total BOD load. The waste water contribution from the scouring process is about 22 per cent of the total waste water volumes discharged from the mill. The results are similar to those of Masselli (1959), who found that the desizing and scouring process contributes about 75-85 per cent of the total BOD load and about 19 per cent of the total waste water volumes. It could however be that the difference in results is due to the small quantities of sizing wastes which Masselli (1959) may have included in his findings. Differences in the cloth processing method and variation in chemicals and materials could also contribute to the differences. The wastes were

also found to have a total alkalinity in excess of 2,000 mg/l. This is contributed by the left-over of caustic soda used in the scouring baths. The high BOD contribution is due to starch and other impurities removed during the scouring process. The dyeing and printing processes also contribute greatly to the total BOD load from the mill. This has been calculated to be about 26 per cent of the total BOD load. Waste waters are used immensely for the dyeing and printing processes. The sizing and bleaching operations contribute about 3 and 8 per cent respectively. The waste load from the sizing operation is due to left overs of sizing agents. Bleaching operations use large quantities of water and their wastes are very dilute compared to those of other operations.

Table 8 shows data on the analysis of composite samples. It was observed from the data that the mixing up of the various wastes from the different cloth processing operations has a general effect of lowering the pH, COD, BOD and SS of such strong liquors as those originating from the scouring process. This is due to the effect of dilution resulting from waste waters used in various processes. Apart from those parameters analysed for a composite sample may contain all other chemicals and materials used during the fabrication of cloth at the mill. These include starch, polyvinyl alcohol, carboxymethyl cellulose, caustic soda, turpentine, resins, synthetic and

wetting agents, hydrogen peroxide, tallow, oil and grease and such different types of dyes as pigments, vat, naphthol, sulphur, reactive and direct dyes. The quantities of each of these reagents used in the Mill and found in the waste water discharging from the factory, will depend on how much of each is left over and washed out of the cloth after printing.

Figure 3 shows the curves relating to the performance of six model stabilization ponds P1, P2, P3, P4, P5 and P6. The figure represents the graphical presentation of the chemical oxygen demand as a function of detention time of the model ponds P1 to P6. Curve P1 of Figure 3 shows the digestion of waste in the control pond. As the pond was loaded only with domestic sewage no lag phase is observable from the curve. This is so because the bacteria were already acclimatized to the medium. Curve P2 to P6 show a lag phase of about 5 days during which little if any digestion of waste took place. The bacteria in the medium, were getting acclimatized to the domestic sewage textile waste mixture. After this lag phase of five days, a gradual increase in the rate of digestion is evident in all the ponds.

After a detention period of thirty days waste in model P1 to P4 are observed to attain stabilization state. This is observed from the curves of Fig. 3 as the curves tend to attain a parallelism to the horizontal axis. This may be due to the deficiency

of enough nutrients in the medium to sustain a growing bacteria population. This is followed by death of bacteria and subsequently in the reduction in the rate of digestion. This is evident also from the slow decrease in COD values in ponds P1 to P4, towards the end of the detention period. It is observed that the higher the loading the higher the curve is above the horizontal axis, and the more the duration required for the waste to stabilize fully. In curves P5 and P6 it is observed that even after a detention period of thirty days, the oxidizable matter is still very high. The rate of digestion is also high, this being so due to the highest nutrient content on which the bacteria population is relying on. The wastes in these two ponds would as such require a detention period in excess of thirty days to stabilize, and be dischargable to a receiving stream or support aquatic animal life.

The dissolved oxygen as a function of chemical oxygen demand for model ponds P1 to P6 is depicted graphically on Figure 4. For ponds P1 to P4 the curves indicate that a dissolved oxygen concentration of at least 0.9 mg/l is present in the ponds all along the detention period. It is also observed that as the loading increased the dissolved oxygen decreased accordingly. A dissolved oxygen concentration of 5.1 mg/l was present in the control pond P1, but with increased loading there followed subsequent decrease up to pond

P6 where zero DO content was observed at the start of the experiment. This was attributed to the increased pond loading, with the consequent requirement of increased oxygen utilization for organic waste oxidation by bacteria. Curves P5 and P6 in Figure 4 represent the performance of ponds P5 and P6 where textile wastes constituted 75 and 100 per cent cotton textile wastes respectively. The ponds were observed as is apparent from the curves to have maintained a zero dissolved oxygen for at least 7 days. This was taken to be a state of anaerobicity, due to oxygen depletion in the ponds. The dissolved oxygen increased in the pond P5 and P6 but even after thirty days the dissolved oxygen was observed to be below 5 mg/l. It was inferred that these two curves represent a state whereby oxidizable matter was still high in the ponds, and for the waste to stabilize a longer detention period would be necessary.

From Figures 3 and 4 it can be deduced that where textile wastes and domestic sewage are treated jointly in lagoons the textile waste should be less than 75 per cent by volume in proportion to the domestic sewage. For admixtures of textile waste in domestic sewage exceeding 75 per cent textile wastes anaerobic conditions will initially occur followed by a slow recovery towards aerobic conditions. During this anaerobic phase, the microorganisms in the ecosystem which depend on oxygen for their respiratory purposes will die off due to oxygen depletion. Even after

30 days admixtures in such proportions will not have achieved an oxygen content enough to support the respiratory purposes for aquatic animals such as fish. Okun (1967) stresses that where fish are to survive the dissolved oxygen content should be 5 mg/l at a minimum. Since the experimental findings tend to show that textile wastes in domestic sewage in the proportions of 75 per cent or over with domestic sewage in lagoons will not support animal life, then it might be necessary to pretreat such textile wastes in an attempt to reduce its pollutional load before discharge into a lagoon. Such pretreatment may involve use of inorganic chemicals to precipitate the waste load.

Data on experimental work carried out on the removal of waste load using chemical precipitation has been presented in Tables 16, 17 and 18. It was observed during these experiments that use of a coagulant alone does not bring about precipitation in the waste. However, when lime dosage of 250 mg/l was used in a litre of waste water, in addition to the coagulant dosage, precipitation resulted. Use of coagulant alone led to the formation of flocs which floated or formed a scum at the top of the clear solution.

From Fig. 6 it was observed that an increase in the dosage of a coagulant per litre of waste water contributed to an increased reduction in the COD of the

waste. This however does not have a linear relationship, and varies from one coagulant to another. It is however evident from the curves that potassium aluminium sulphate (alum) is more superior to either ferric chloride or ferrous sulphate. Ferric chloride is in turn superior to ferrous sulphate.

For potassium aluminium sulphate the optimum dosage is between 200 and 350 mg/l for a waste with a pH of 9.3. Nemerow (1952) found that at a pH of 8.3 the alum dosage to effect 63 per cent BOD removal was 200 mg/l, but this varies with pH. Asp-laugh (1973) found that for effective removal a dosage of alum between 150 to 250 mg/l and lime are required. Coburn (1950) found an alum dosage of 126mg/l. From the findings in this experiment a dosage of 350 mg/l would give a COD removal of 60 per cent. The variation from the findings of Nemerow (1952) Asp-laugh (1973) and Coburn (1950) may be due to the difference in pH and other sanitary characteristics of the waste.

On the cost effectiveness, it is evident from Fig. 7 that alum is preferential to the other two coagulants. However, alum and ferric chloride seem to be both economical to use but with a small variation in the cost and their effectiveness. This is in line with the findings of Christoe (1977).

As it would not be economically worthwhile to



remove the waste load by as much as 90 per cent unless the water is to be re-used in the mill, a reduction of waste load by about 60 per cent might be acceptable and would require a dosage of 400 mg/l and a final effluent COD of 640 mg/l. The COD value of 640mg/l could be considered acceptable where the textile waste is to be jointly treated with domestic waste as was observed in Fig. 4, curve P4, where the textile waste to domestic wastes are in the ratio of 1 is to 2. However, the cost incurred to treat the 500 m<sup>3</sup> of waste originating from the factory would be enormous. This has been calculated to require 200 Kg of alum at a cost of KShs. 3300 per day, running cost. Column (1950) had found that 810 Kg. of alum were required to treat 3.75 million litres of cotton textile waste per day and to reduce BOD load by 43.5 per cent. This reduces to 108 Kg. for 500 m<sup>3</sup> and a cost of KSh.1780 p.m. day. The cost figures show variation but this could be due to the degree of pollutional load removal. In either case it can be deduced that chemical precipitation is not economically favourable to the running of the factory. However, for the preservation of environment, measures requiring pre-treatment should be undertaken. This would reduce the waste load as well as remove dyes from the waste.

Experimental results obtained from investigations on effects of direct dyes on model lagoons treating



domestic wastes are presented on Tables 19 to 23. Direct dyes contribute to over 90 per cent of all dyes used at Thika United Textile Mill and consequently contribute to the highest percentage of all dye wastes discharged from the mill. The data shows that variations in pH, Do, COD, and BOD, are negligible in all the ponds P1 to P5. It can therefore be inferred that direct dyes in varying concentrations do not adversely affect the efficiency of domestic waste treatment in lagoons in as far as these parameters are concerned.

Figures 12, 13, 14, 15 and 16 are the graphical presentations of chlorophyll 'a' as a function of detention time in ponds P1 to P5. In all the ponds a sharp decrease in chlorophyll 'a' concentration was observed during the first seven days of anaerobic digestion. This general decrease may be due to the death of algae in the ponds during the anaerobic phase. After this period a sharp increase in chlorophyll 'a' concentration in all ponds was observed. This was attributed to the revival of algae which were about to die off towards the end of the anaerobic phase. Fluctuations of chlorophyll 'a' concentrations are observed in all the ponds during the subsequent period of the 17th to the 29th day. The fluctuations of chlorophyll 'a' concentrations were attributed to variation in the light intensity incident on the ponds. As the pilot plant building

was lighted by two translucent sheets at the roof it was observed that, depending on the position of the sun, there were periods when the incident light on the ponds was at higher intensity than at other times. This variation of light intensity incident on the ponds, could have affected the position of algae in the ponds. It could be that at low light intensity the algae mat could sink deeper than the 3 cm sampling depth and thus affect the concentration of chlorophyll 'a' concentration of a sample collected at such periods. During periods of increased incident light intensity the algae could float at the surface of the pond, and subsequently increase chlorophyll 'a' concentration of samples collected.

On the effects of varying concentrations of direct dyes on the functioning of stabilization ponds treating domestic sewage it can be deduced that as far as DO, pH, COD and BOD are concerned no significant differences are observable. Parameters analysed for, show a certain degree of similarity in all the ponds. However, analysis of chlorophyll 'a' concentration for the control pond P1 shows (fig. 12) a higher concentration than in ponds P2, P3, P4 and P5 which contained 2.5, 5.0, 10 and 15 mg/l of direct dyes. Pond P5 which had a direct dye concentration of 15 mg/l has a lower chlorophyll 'a' concentration than all the other ponds (Fig. 16). Taking all other factors to be the same

it can be deduced that direct dyes have effects on algae in a model pond, but this becomes more evident when the dye concentration exceeds about 10 mg/l.

The stabilization ponds at Thika Municipality were designed for a population of about 60,000 people. Facilities for future expansion exist. Out of this population only about 10,000 people are connected to sewers. The domestic sewage discharged into the sewers is about 1.5million litres per day with another 6.5 million litres of industrial waste waters. The two clothing mills at Thika discharge about 1.5 million litres of textile waste. If this volume of textile waste is discharged into Thika Municipal sewage treatment works, then pre-treatment in form of precipitation with alum should be undertaken in order to remove dyes and part of the organic load before discharge of the waste into the treatment works.

## CHAPTER 8

### CONCLUSIONS AND RECOMMENDATIONS

These conclusions and recommendations are based on pilot plant batch treatment process as opposed to a continuous process which is normally used.

1. In the joint treatment of cotton textile wastes with domestic sewage in lagoons, the volumes of textile wastes to domestic sewage should be less than 75 per cent, if the pond detention period is limited to thirty days.
2. For a textile waste domestic sewage mixture, with textile waste volume to domestic sewage volume being in the range of 75 to 100 per cent a detention period in excess of thirty days should be allowed for.
3. In using chemical precipitation, alum with lime is more effective in removing pollution load from cotton textile wastes than ferric chloride or ferrous sulphate. These three inorganic coagulants are reasonably effective in the removal of color. The coagulants should always be used with lime to raise the pH so that precipitation may occur.
4. The optimum dosage of alum is in the range 200 to 350 mg/l at a pH of 8.3.

5. Alum is more economical to use than ferrous sulphate or ferric chloride during chemical precipitation.
6. Direct dyes have deleterious effects on chlorophyll 'a' production in a lagoon when a concentration in excess of 10 mg/l is present.

The following recommendations have been suggested before combined treatment.

1. Screening of and equalization of waste.  
Equalization tank should hold the waste at least for 1 day. Capacity of tank should be over 500 m<sup>3</sup>.
2. Neutralization of waste using flue gas or lime is necessary to protect the sewers and as a prelude to biological treatment
3. Coagulation using alum is recommended in order to remove dyes and organic load from the wastes. A settling tank is therefore necessary.

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