UPGRADING WASTE STABILIZATION POND EFFLUENT BY INTERMITTENT SAND FILTRATION

BY

ENGR. GILBERT CHINYERE ANYADOH
B. Eng. (Hons) Civil, MNSE

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DECLARATION

I hereby declare that this thesis has been written by me under the close supervision of Dr. C. Okuofu and research work at the Ahmadu Bello University. It has not been accepted in any previous application for a higher degree.

All sources of information have been specifically acknowledged in the reference section.

Engr. G.C.Anyadoh

1995

CERTIFICATION

This thesis entitled Upgrading Waste Stabilization Pond Effluent by Intermittent Sand Filtration by G.C. Anyadoh meets the regulations governing the award of the degree of Master of Science of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

Dr. C. Okuofu Date: 26/4/96

Chairman, Supervisory Committee

Dr. L.I. Odigie. Date: 26/4/96

Member, Supervisory Committee

Dr. L.I. Odigie Date: 26/4/96

Head, Department of Water Resources

and Environmental Engineering

Dean, Postgraduate School Date: 29/4/98

DEDICATION

This thesis is dedicated to my wife Roselyn Chinyere Anyadoh and to my parents for their encouragement during the study.

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ABSTRACT

The feasibility of operating intermittent sand filters for upgrading the effluent parameters from waste stabilization pond was investigated. Samples of the effluent were colleeted from the outlet of the Waste Stabilization Pond of the Ahmadu Bello University Zaria (A.B.U.) and were subjected to sand filtration. The filter system, of which there were two, consisted of 150mm diameter perspex columns filled to a depth of 2.0 meters with sand obtained from the bed of Kubani River at A.B.U.. The sand had effective sizes of 0.25mm and 0.33mm, Uniformity Coefficient of 2.64 and 1.39 and porosity of of 0.435 and 0564 for filters 1 and 2 respectively. Both the samples and the corresponding effluent samples from the filters were collected and analysed for some physical, chemical and biological parameters.

The results show some reductions in the concentrations of suspended solids (SS), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), algae, helminths and water fleas. For a filter bed 2.0m deep consisting of sand with effective size 0.25mm, porosity of 0.435 and uniformity coefficient of 2.64, an average removal of 87.85%, 90.5% and 84.52% were obtained for S.S, BOD and COD respectively while complete removal of algae, helminths and water fleas were obtained at the same depth.

However, the concentrations of some metallic elements such as Bo, Mg, Ca and Cu whose original concentrations in effluent samples were low, did not show any appreciable reduction.

Also an increase in the numbers of faecal coliforms (MPN) in the filtrate was observed contrary to expectation.

However, this observation is not conclusive and is subject to further investigations.

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CHAPTER 1

INTRODUCTION

The importance of water to plants and animals is immeasurable. Water satisfies three essentials purposes of crops' requirements. These are: Support for continuous metabolic activity inside the plant tissues, regulations of body temperature and maintenance of thermal balance of plants at levels suitable for sustaining life. In man, it is important for continuity of life and numerous human activities taking cognisance of the dependence of man on plants and animals for food.

There are many possible uses of river water including domestic water supply, swimming, irrigation, waste water disposal, commercial fishing, industrial water supply, boating and other recreational activities. Also due to insufficient and/or irregular rainfall, the management of modern agricultural projects involves the investigatiion of cheap sources of water, like effluents from sewage treatment plants which would appear to be a suitable alternative source of water for such purposes. The protection and management of every available water resource for the use of man is therefore of great importance.

Sewage is the used water of a community and is made up primarily of about 80% of water. It is usually generated from residential areas, commercial and industrial establishments. Waste water generated outside the buildings include surface and storm water run-off. Usually, large proportions of waste water generated in communities find their way into ground and surface waters. Eventually a pollution course is set up which may adversely affect aquatic life.

In tropical developing countries water-related diseases account for a high proportion of all morbidity and mortality (WHO, 1971). In the light of the above, various types of waste water processes and disposal methods have been developed. A typical conventional treatment plant has four components. These include the primary devices such as screen and grit chambers (where floating and grit materials are removed), the secondary device such as sedimentation tank (where settleable solids are removed), the biological devices such as trickling filters, activated sludge process and waste stabilization ponds (where biological oxidation of organics takes place and final settlement of sludge), and the sludge digester (where sludge digestion takes place and final disposal of sludges). In some cases it may be necessary to add a tertiary device such as sand filtration to upgrade the effluent from the secondary device. The flow diagram for a conventional waste water treatment plant is shown in Fig. 1. Considering the low economic potentials of developing countries, a cheap but effective waste water treatment process is essential. Waste stabilization ponds (WSP) is a suitable type of waste water treatment for these countries.

High concentrations of algae are common in waste stabilization pond (WSP) effluent. They have the tendency to impair the quality of receiving waters. The dead ones cause dissolved Oxygen (DO) depletion during their oxidation while both dead and living ones may create odour and aesthetic problems in the receiving water. Consequently, the reusability of the WSP effluent without additional treatment is greatly reduced. Ferrara and Harleman (1981), Kilani and Ogunrombi (1984) and Bell and Allum (1986) discussed the methods of upgrading waste stabilization pond effluents. Some of these methods are sand filtration, chemical process, disinfection and algal harvesting. The use of sand as filter may be a viable alternative to the use of fish and chemical processes in upgrading the effluents.

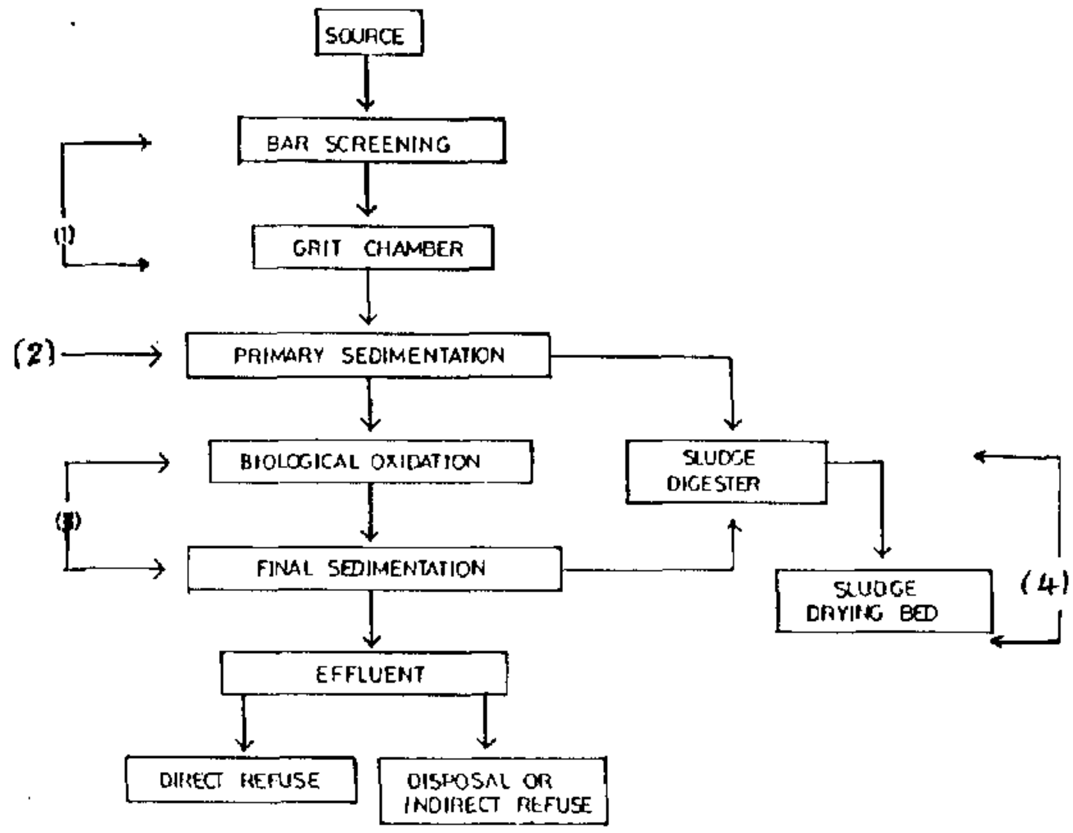


FIG. 1 FLOW DIAGRAM FOR A TYPICAL CONVENTIONAL WASTEWATER TREATMENT PLANT

1.2 Study Objective

At Ahmadu Bello University, Zaria (ABU), the discharge of waste stabilization pond effluent into the Kubani River is of great concern. It is observed that the villages which are located down stream of the effluent outfall utilise the water from the river for domestic, rearing of cattle and for irrigation purposes. It is also observed that in the dry season, there is no overflow from Kubani Dam to dilute the effluent discharged into the river. The direct use of the river water by the villagers without treatment poses a threat to the health of the people.

The general objective of this study, therefore, is to determine the use of intermittent sand filters for polishing the effluents from the stabilization ponds at ABU, Zaire, using sand from Kubani River down stream of the Kubani Dam. Some physical, chemical and biological parameters, of the WSP effluent and that of the sand filters will be measured and analysed. The physical parameters include the suspended solids, the chemical parameters include BOD, COD, heavy metals such as cadmium, copper and lead and other chemicals such as calcium magnesium and boron. The biological parameters include the faecal coliforms (MPN), helminth eggs/larvae counts, water fleas and algal counts.

CHAPTER 2

LITERATURE REVIEW

2.1 Polishing of Stablization Pond Effluents

Attempts have been made in various parts of the world to improve the quality of treatment plant effluents by different methods. White, (1973), Brinkhead and O'Brien (1973) attempted to upgrade the quality of similar effluents by disinfection. The United States Environmental Protection Agency (US.EPA 1974) also instituted a research programme aimed at establishing processes for improving the quality of waste treatment plant effluents. In consequence, therefore.

Lewis (1973) established guidelines for such research. These include:

(a) Processes for removing suspended solids at low cost.

(b) Design for the discharge of effluents on land.

(c) Methods of disinfection.

(d) Design of nutrient control technology.

(e) Utilization of sludge as cattle feed.

In the light of these, several investigators like Johnson et al. (1979) proposed several techniques for upgrading waste stabilization pond effluents. Among the processes so far used to polish pond effluents are disinfection, chemical coagulation, algae harvesting, polishing with fish and granular media filtration.

2.1.1 Disinfection of Lagoon Effluents

The organic composition of pond effluents ranges from basic food components - carbohydrates, fats and proteins to other organic nitrogen compounds. Johnson et al (1979) suggested the disinfection of Lagoon effluents in order to control the microbial populations. However, this cannot be easily accomplished because of the interaction of organic compounds with chlorine.

Dickman and Gochanaer (1978) studied the impact of sodium chloride on the microbiota of a small stream, and found that sodium choride (NACL) in excess of 1mg/L is poisonous to algae. Similar work was carried out earlier by Echelberger et at (1971) who monitored the effect of chlorine disinfection on algae laden waters. They discovered that 31.8% algal reduction was obtained without causing odour problems. Also, White (1973) observed that chlorine demand is increased when concentrations of algae commonly found in effluents are high. In the process of disinfection with chlorine, the break point chlorination technique is usually adopted but in lagoon effluent disinfection, the consequence of his technique is that large amounts of chlorine is consumed resulting in high cost of operations. Therefore the process of satisfying chlorine demand is an unjustified technique due to high recurrent expenditure.

Kott (1971) established a technique of short contact time where no serious case of chlorine demand will be experienced.

There are reports that the chlorination of waste waters with high concentrations of organic nitrogen and inorganic compounds may be accompanied by adverse effects (Tebbutt, 1977). The disadvantage centres on the production of substances that are toxic to man and aquatic life (Middle Brooks et al, 1982). Chlorine reacts with some dissolved organic compounds to produce halogenated organic compounds such as trihalomethanes which may be carcinogenic (Carry et al, 1989). The dissolved organic compound released from destroyed algae cells are oxidized by chlorine (Echelberger et at 1971).

2.1.2 Chemical Coagulation of Lagoon Effluents

Kilani (1983) reported high removal rates of algae in pond effluents treated with chemical coagulants. Although this investigation produced good practical results, he was of the opinion that the high cost of the chemicals is a limiting factor to the method for polishing waste water.

2.1.3 **Algae Harvesting Techniques**

Several techniques have been employed by investigators to reduce or eliminate completely, the concentration of algae in effluents from waste stabilization ponds. Some of these methods reported by Middle Brooks et at (1974) are coagulation and flocculation, dissolved air flotation and centrifugation. The adaptability of any particular process is a function of several factors among which are cost, operational procedures, frequency of maintenance and efficiency of the system. The average reduction efficiencies of these methods were reported to be as follows: Microstraining; 35%; coagulation and floculation; 85%; dissolved air flotation; 88%; centrifugation 73% and filtration, 50% (Middle Brook et at; 1974). The techniques that approach these requirements for polishing stabilization pond effluents are the sand filtration and fish polishing techniques.

2.1.4 **Sand Filtration**

In water treatment plants, sand filters are used in the removal of colloidal matter which exist at low concentrations in the raw water. There is also the possibility of obtaining high degree of treatment of pond effluents with sand filter since it possesses the capacity to eliminate fine particles from water.

Alka (1981) studied the performance characteristic of Kaduna River Sand as filter media and established that the sand is good for the reduction of BOD content of water samples. This was confirmed by Mohammed (1985). In recognition of the ability of sand to act as a filter researchers are investigating the viability of adopting direct high-rate filtration of low-turbidity waters which would eliminate the need for flocculation and sedimentation tanks. This technique of Rebhun, (1986), is called "contact flocculation filtration".

2.1.4.1 Composition of Sand Filters

There are two broad categories of sand filters - the slow sand filter and the rapid filter. While the slow filter has the advantage of producing high quality effluents, the low filtration rate constitutes a major constraint. Though the quality of effluent from rapid sand filters is lower than that of slow sand filters, it is more accommodating to high rate filtration, operational errors and back-wash. These qualities make it more acceptable for municipal treatment works.

Borchardt, (1961) used a sand bed of 24 inches (61cm) deep during his work on the filtration of algal suspensions with sand. But in general a 7.5cm layer of coarse sand having an effective size of between 0.8 and 2.0mm was placed between the filter sand and gravel to act as an interface and prevent the penetration of finer sand into the gravel layer. The level of water above the top of the bed may be between 0.9 and the head loss in a clean bed may be between 0.2 to 0.5m. the design head loss during operation may be about 3.0m with a free board of about 1m .

2.1.4.2 Hydraulics of Filtration

A porous medium comprises several tiny channels through which fluids can pass. Sand filter medium follows the theory of hydraulics of laminar flow through porous media. Several approximate theories have been formulated in this regard but that of Darcy (1856) is most widely accepted. Kozeny (1927) considered the provisions of Darcy - Weisbech equation as related to porous media. He derived an expression for voidage with the assumption that the media comprised separate small particles, flow is in one direction (x-direction) and that the passages are similar to capillary tubes. The expression was modified by Carman (1927) who maintained that the passages are sinusoidal. However, the expressions were derived with the assumption that the bed consists of particles of uniform size.

Rose, (1951), stated that the ratio of tube diameter to the sand size must be at least 50:1 as this helps to minimize the wall effects on the flow processes. Since the bed of the rapid sand filter is stratified as a result of back-washing, he developed an expression for the head loss through spherical or nearly spherical particles. He made allowance for the geometric mean size, shape factor, porosity and the depth of the bed in deriving the relationship between head loss through the bed and the rate of filtration. Further examination of this relationship (Rose, 1951), shows that the parameters can be manipulated to produce an efficient filter design with reference to specific waste waters.

2.1.4.3 **Quality of Filter Effluents**

The use of sand filters in water treatment has enjoyed wide acceptability. In the 19th century a slow sand filter was used in the United Kingdom while the rapid sand filter was developed in the United States between 1900 - 1910. Since then these filters have undergone several modifications but the basic principles of filtration are the same. the development of these filters has led to the adoption or promulgation of water acts which recommend sand filters in water treatment by several countries of the world.

Runji (1977) set up a pilot plant to study the use of sand filters in water treatment. Two types of media, the coarse and fine media were used in the study and results exposed the limitations of filters in water treatment process. The quality of the effluents did not satisfy International Drinking Water Standards as regards bacteria, turbidity and colour concentrations with the fine sand media. The results obtained with the coarse sand filter was even poorer. This suggests that sand filters may not be appropriate for the treatment of water for certain constituents such as bacteria because of their micro-sizes as compared with the pore sizes of the bed. Therefore the incorporation of treatment units to oxidise bacteria will prove more reliable than filtration.

Mohammed (1985) reported that a study conducted in Thailand on multiple granular media filtration gave substantial reduction of suspended materials of the water samples. Several media combinations were investigated and it was found that the use of sand below a bed of burnt-rice-hust have effluents of high quality. The major set back in this type of filter was the cleaning process where it was required to remove the top layer of burnt-rice-husk each time cleaning was carried out. The use of materials, which when adopted singly or in composite form with sand forms porous media with more satisfactory results than sand medium should be encouraged especially after appropriate economic considerations.

Rebhun (1966) investigated the relationship between flocs and polyelectrolytes in the flocculation process of water treatment, and found that flocculation with poly-electrolyte is characterized by a relatively narrow dose range and a high settling velocity. La Mer et al (1957) explained flocculation with the aid of synthetic polymers. They observed that the bridging between the polymers and the particles resulted in the formation of large and strong three-dimensional structures. Based on these explanations investigations were made into the use of poly-electrolytes as filtration aids. Adin and Rebhun (1974) investigated the use of poly-acrylamide in both conventional and multimedia filters and discovered that in extremely low doses, it resulted in stronger attachment to the grains of the bed and a lower turbidity of the filtrate at the same time. In one of the laboratory works by La Mer et la. (1957), two perspex tubes were used. The filter media comprised local sand effective diameters of 0.62 and 1.21 and uniformity coefficients of 1.21 and 1.17 respectively. At filtration rate of 5m/hr, polymer (poly-diallyde methyl ammonia halide) dose of 0.05 - 0.06 mg/l together with hydrolytic alum gave the best removal of turbidity. Most of these findings compare favourably with the results obtained by Adin and Rubhun (1974).

2.1.5 **Polishing Effluent with Fish.**

Fish is an important aquatic animal that contributes significantly to the maintenance of aquatic ecosystems. Antonio, (1986) reported that fish is useful in reducing vegetative growth in ponds and in controlling mosquitoes. Mosquito fish (Gambusia affinis) and the guppy (Pocilia reticulata) have been found to be effective in this regard because they feed on mosquito larvae and pupae (Diamant 1979). Bolarin, (1984) also used tilapia and Pelmoto-chromis spp. for bilhazia control Wrigley et al (1988) cultured a variety of fish in a pilot pond consisting of four 10m3 plastic oxidation ponds in series with an average depth of 1.0m. The fish Orechromis mossambicus, Cyprinus carpio and Cryprinus gariepinus, among others, were stocked in the ponds. Results show that O.mossambicus, C. carpio and C. gariepinus grew significantly in size. Also the analyses of effluent from the ponds for water quality showed that the concentrations of total suspended solids (TSS), chlorophyll-a (chla), NO3-N, MH3-N, PO4-P and COD reduced substantially. TSS and Chl-a concentration reduced by 54 and

53% respectively. Hypothamichthys molitrix were found to consume all sizes of phytoplankton (Smith, 1985). Also C. carpio feed on Zooplankton and bottom invertebrates while Clarias feed on snails, crustacea and worms among others. (Anthonio, 1986). Therefore the co-existence of fish species could be exploited in effective polishing of effluents from waste stabilization ponds.

Polishing of effluent has high economic advantages. The cost of maintenance is low since the nutrients required for the survival of fish is available in waste waters. Inspite of the existence of high numbers of micro-organisms were not isolated from fish fillets grown in waste waters (Slabbert et al, 1989). They were said to be safe for human consumption.

2.1.6 **Granular Media Filtration**

The use of granular media in upgrading the quality of sewage effluents could be effective for the removal of suspended matter especially algae from effluents (Mara et. al 1992).

Borchardt (1961) used sand of grain sizes ranging from 0.31mm to 0.524mm to filter water mixed with algal cultures of genera Scemedesmus, Ankistrodesmus and Anabaena SPP grown in batches. At flow rates Of 2.0gpm to 0.2gpm, a minimum algal removal efficiency ranging from 45% to 2% was recorded. Efficiencies of more than 80% were also recorded. This suggests that the granular media were effective in the removal of algae through filtration.

2.1.6.1 **Removal of Chemical Substances by Filtration**

Borchardt et. al (1961) introduced an iron floc into a mixture of algal culture and tap water and passed it through a sand filter. More than 80% changes in the concentration of iron in the effluent was observed. Stanley (1955) in a similar study used radiotracers to monitor the movement of iron in the filter medium. He noticed that iron penetrated through the filter bed. His work revealed that the removal efficiencies of filters with respect to chemical elements and algae might be a function of other variables other than the straining action of the filter. This study also indicated that iron is removed best at its iso-electric point. Additional support for this inferrence is the result of the works of Sanford and Gates (1956).

2.1.6.2 **Effectiveness of Sand Filter in BOD Removal**

It is essential that BOD reduction be effected in sewage effluents if they must be discharged into streams as is usually the case. Sand filters can be used in polishing sewage effluents with respect to BOD reduction (Johnson et al 1979). The studies carried out by Ontario Water Resources Commission (1978) on the treatment of effluents from activated sludge plants indicated that microstrainers give an average BOD reduction of 50%.

Analysis of effluents from waste stabilization Lagoons at Wardieburn Housing Estate by Bradley (1983) indicated that there was substantial influence of algae on BOD concentrations of effluents from the lagoon. It was observed that the BOD of centrifuged samples of secondary lagoon effluent varied from 5 to 2mg/l compared with a BOD range of 13 to 49 mg/l in non centrifuged samples. This gave an average percentage reduction range of 38 to 40%. Furthermore, additional observation revealed that algae contributed 50 to 62% of the final effluent BOD. Therefore algae removal which can be obtained through sand filtration (Mara et. al. 1992) should contribute effectively to BOD removal of Waste Stabilization pond effluent.

2.1.6.3 **Granular Activated Carbon Treatment of Effluents**

Eberhardt (1975) used ozone-activated carbon to upgrade effluents from a pilot plant at Bremen, West Germany. McGreary and Snaeyinlk (1977) in a review of the results obtained by Eberhardt (1975) reported that during the third year of operation of the pilot plant without regeneration or replacement of the carbon, removals of KMn04-COD were up to 30%. Since recurrent expenditure on this process can be kept low enough, it can be economically employed in upgrading waste stabilization pond effluents at a quaternary stage of treatment.

CHAPTER 3

MATERIALS AND METHODS

3.1 Materials

3.1.1 Filter Column

Two filter columns were used comprising 150mm diameter transparent perspex column fitted with control valves. A control valve was fixed at the base of the column while sampling points were located at 500mm interval along the length of the column (see Fig.2).

3.1.2 Filter Media

The filter medium was sand. It was obtained from the banks of Kubani River, down stream of Kubani Dam located at the main campus of Ahmadu Bello University, Zaria. Collection was made in December 1988 and transported to the Soil Mechanics Laboratory of Civil Engineering Department of the same institution where it was sieved with British sieve size No. 200 to eliminate slit, washed and dried under the sun. A typical set up of the filter media is shown in figure (2).

3.1.3 Source of Sample

The effluents from the Ahmadu Bello University waste stabilization ponds located at Samaru campus, Zaria were used. The treatment plant comprised two facultative ponds of about 200m x 80m x 2.0m each and four maturation ponds of about 50m x 10m x 1.5m each. The ponds outlet was a concrete channel 300mm in width with variable invert levels into which 150mm asbestos cement pipe carrying the treated waste water discharged.

This channel was the site for sample collection, (Fig. 5); Plates 1 and 2).

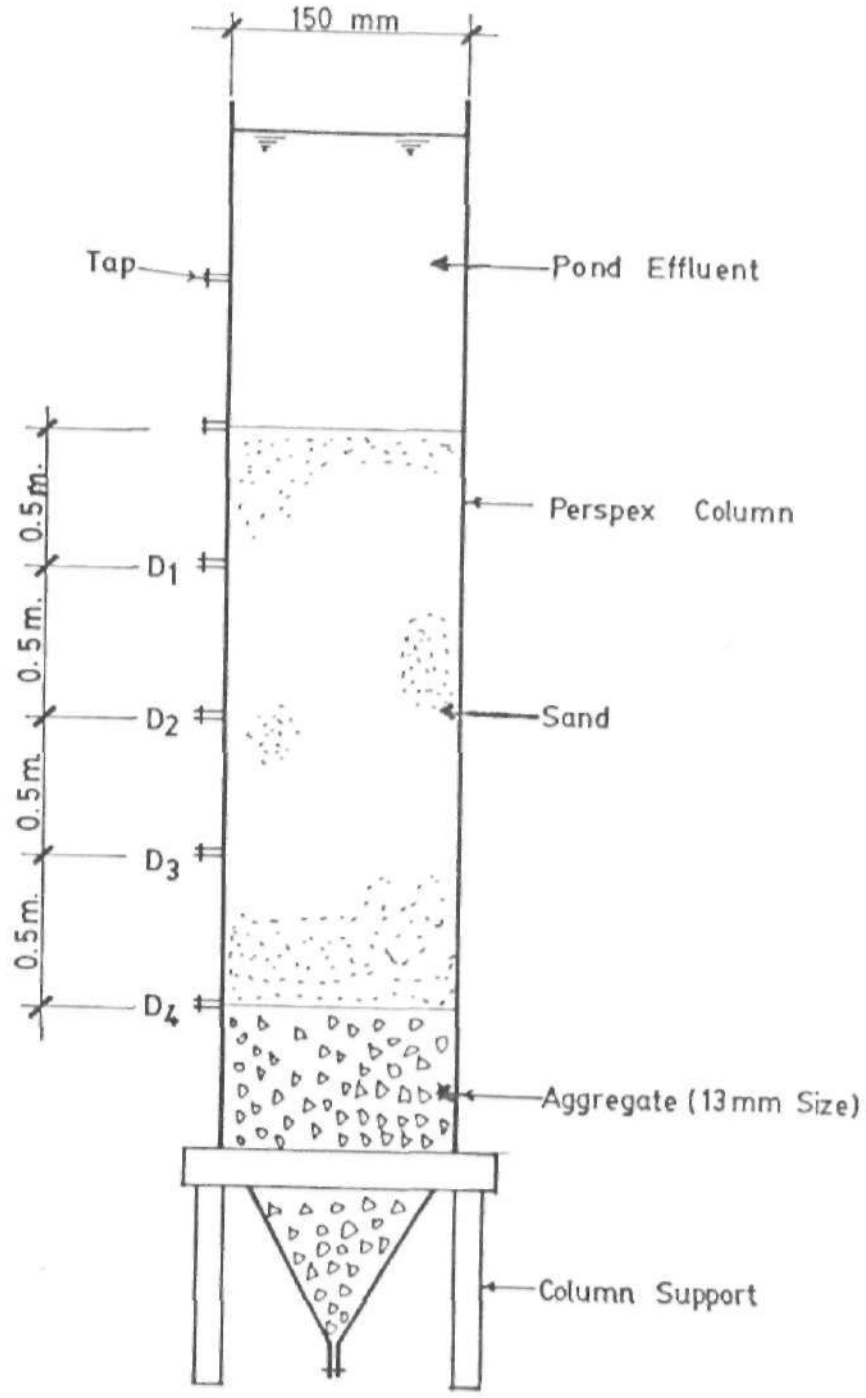


Fig. 2 A typical set up of Filters 1 and 2

3.1.4. **Equipment**

(a) **Spectrophotometer_**

A UNICAM Atomic Absorption Spectrophotometer (AAS) model SP9 located at the Food and Drug Administration and Control Kaduna was used to determine the concentrations of Cadmium and Iron. PYE UNICAM Lamps of model SP9were used. The ratings were 228.8NM, 15MA and 248.3NM, 15MA respectively, Perkin - Elmer make of AAS located at Nigerian National Petroleum Company (NNPC) Laboratory Kaduna model 200,200B was used to determine the concentrations of lead, calcium, magnesium and copper elements in the samples. The lamp ratings are 217NM and 4MA. 422.7NM and 3MA, 285.2NM and 4MA, 324,8NM and 4MA respectively. The non-availability of lamps required for the determination of various elements made it difficult to use only one make of the equipment.

A Hitachi Atomic Absorption Spectrophotometer Model 10 located at Petrochemical Laboratory Kaduna was used in the determination of boron concentration in the samples. The lamp rating was 249.8NM wave - length and 18MA current.

(b) **Incubators and Refrigerators**

Two Gallen kamp cooled CO2 incubators were used for the determination of 5-day BOD and for bacteriological analysis. Refrigerators of Lec and Ambassador 650 makes were used for storage and preservation of samples.

(c) **Reflux Apparatus_**

COD was determined in accordance with the standard methods by the reflux process using reflux apparatus by Gallenkamp.

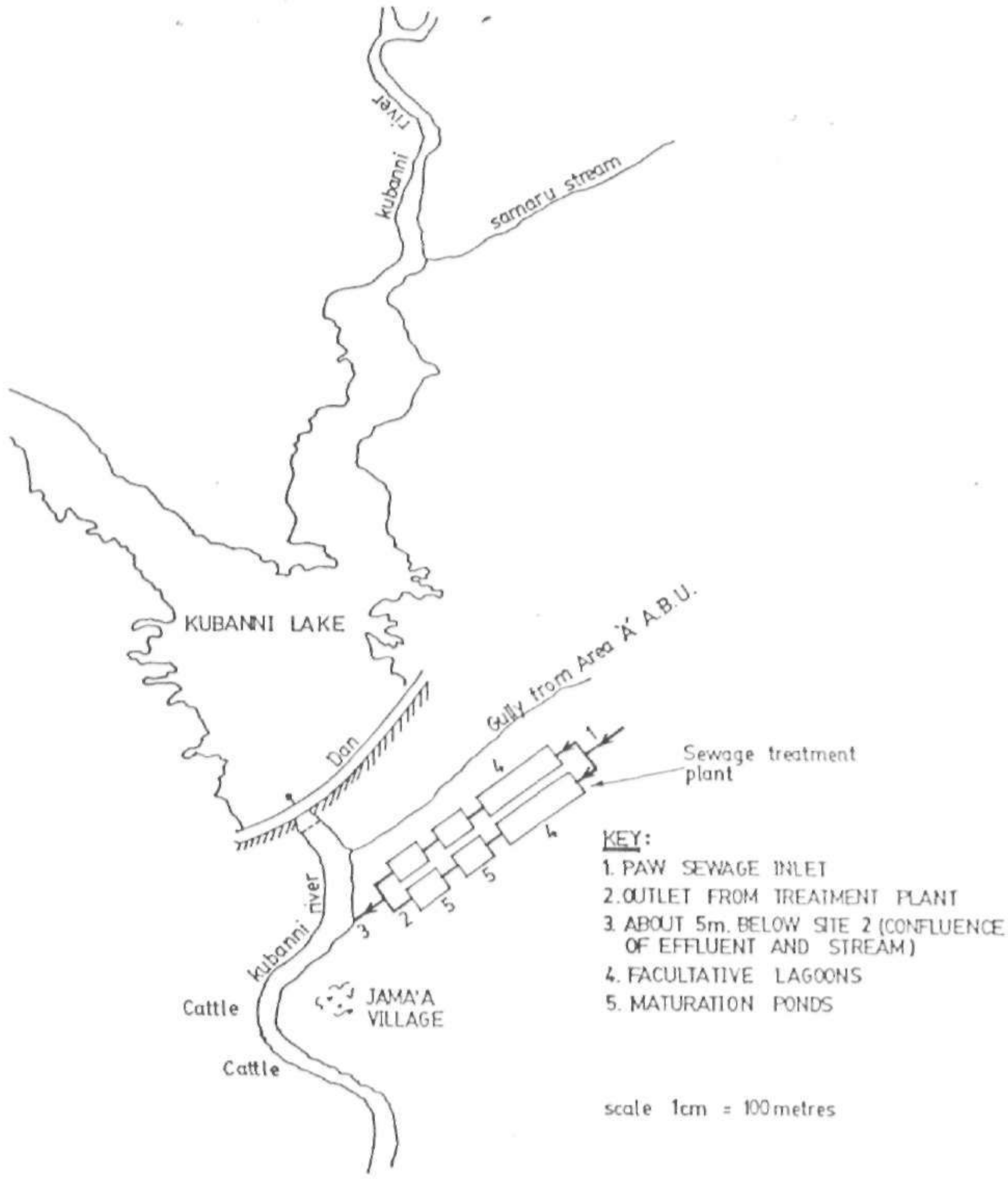


FIG 3 General locations map of Influent and Effluent Courses (Adapted from Okuofu C. (1978). M.Sc. Thesis)

(d) **Scale**

All weighing was carried out by means of a Mettler P160 chemical balance. This equipment is capable of weighing up to 700 grams of substance with an accuracy of $\pm$ 0.001 gram.

(e) **Microscopy**

An Olympics model KHC - 2246 microscope was used for counting helminth eggs, larvae and water fleas.

(f) **Glass ware**

The following glassware were used:

burettes, pipettes, reflux flasks, conical flasks, measuring flasks, Durham tubes and test tubes.

(g) **Autoclave**

A Griffin and George Ltd "portable" autoclave was used for sterilizing all glassware and media

3.2 Methods

3.2.1 <u>Sample Collection</u>

Grab samples were collected from the effluent channel of the maturation pond of the waste stabilization pond at Ahmadu Bello University, Zaria on various days between 9.00 a.m and 1.30 p.m. during the dry season. The samples were collected from 2nd February 1989, to 30th April 1989. The duration of sample collection and transportation to laboratory was about 20 minutes and filtration started as soon as the samples arrived at the laboratory. The samples were analysed for some physical parameter, suspended solids; chemical parameters, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Cadmium (Cd), Lead (Pb), Iron (Fe), Calcium (Ca), Magnesium (Mg), Copper (Cu), and Boron (Bo) and biological parameters, algae, helminths, water and fleas faecal coliform.

3.2.2 Analysis of sand.

Sieve analysis was carried out and the result obtained are shown in figs. 3 and 4. The sand had effective sizes of 0.25mm and 0.33mm; uniformity coefficient of 2.64 and 1.39 and porosity of 0.435 and 0.564 for Filter 1 and Filter 2 respectively. The effective size (D10) was obtained as the maximum partlcle size of the smallest 10 percent of the particle size distribution while the uniformity coefficient was the ratio of the maximum particle size of the smallest 60 percent (D60) to the effective size (Smith, 1978). The porosity (n) of the soil sample was determined as the ratio of volume of voids to total volume of sample. These effective sizes and porosities are within the range recommended for a slow sand filter and the filters are expected to operate as such. Each filter was filled with sand to a depth of 2.0 meters.

3.2.3 Analysis of water sample

Analysis of the samples for the different parameters were carried out as soon as the samples were collected except for the determination of metallic elements concentrations whose samples were stored in a refrigerator pending analysis. The analysis of samples were carried out in the following locations;

a **Suspended Solids**

Samples analysis for suspended solids (SS) was carried out in the Water Resources and Environmental Engineering Laboratory of Ahmadu Bello University, Zaria by the filter method.

b **BOD and COD**

Both BOD and COD of the samples were analysed at the Water Resource and Environmental Laboratory of Ahmadu Bello University, Zaria by Winkler and Reflux methods respectively.

c **Metals**

Atomic Absorption Spectrophotometer (AAS) was used in the determination of the concentration of metals in the samples. PYE UNICAM AAS was used to analyse the

Fig4 FILTER 1

PARTICLE SIZE DESTRIBUTION

D_{10}^{A} = 0.25mm uniformity coef = $\frac{0.66}{0.25}$ = 2.64

D_{10}^{B} = 0.33mm " " = $\frac{0.46}{0.33}$ = 1.3[illegible]

PRETREATMENT DETAILS..........................

LOCATION Nº .... BORE HOLE Nº .... SAMPLE Nº ....

DATE OF TEST .... DESCRIPTION ....

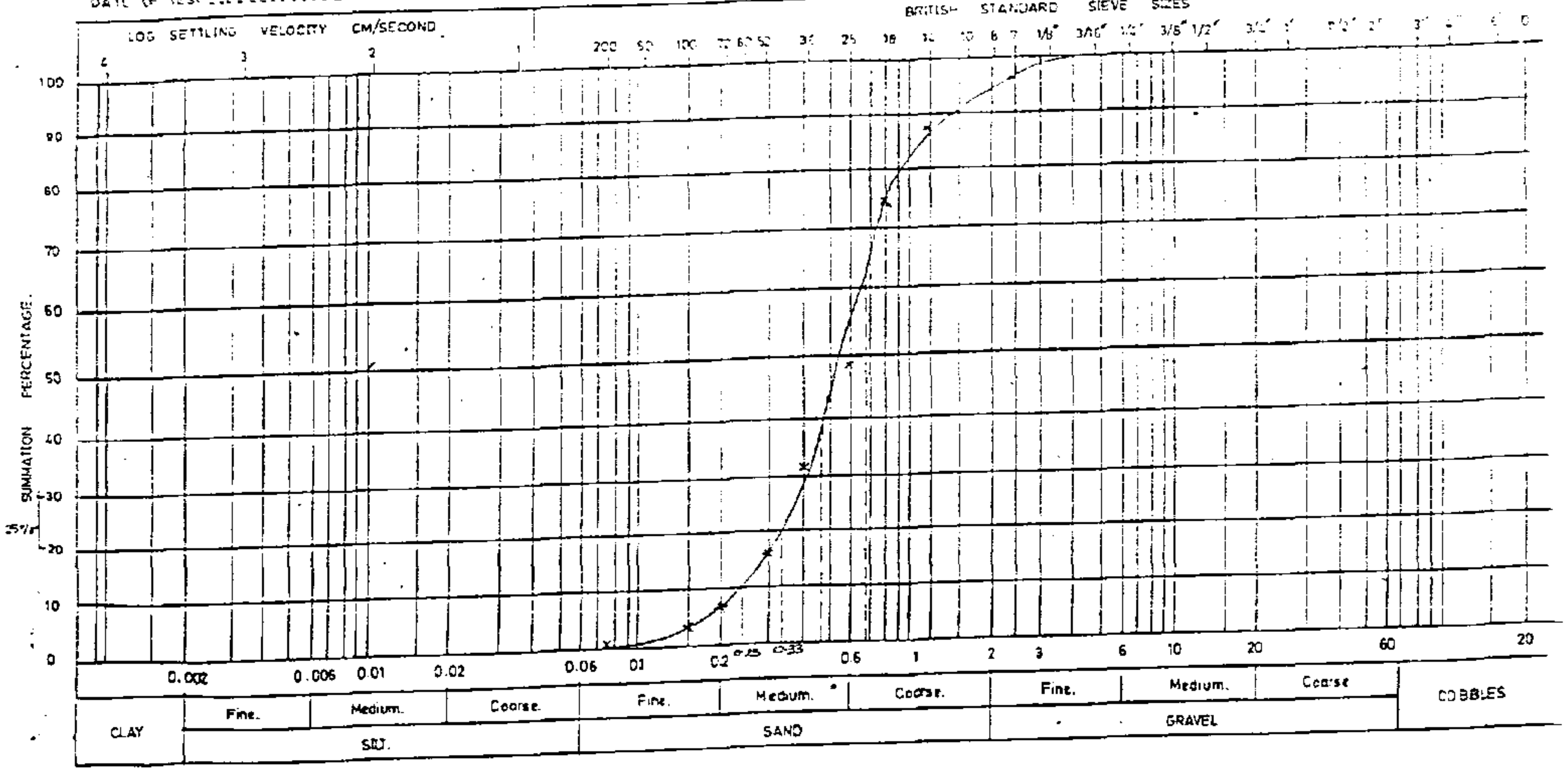
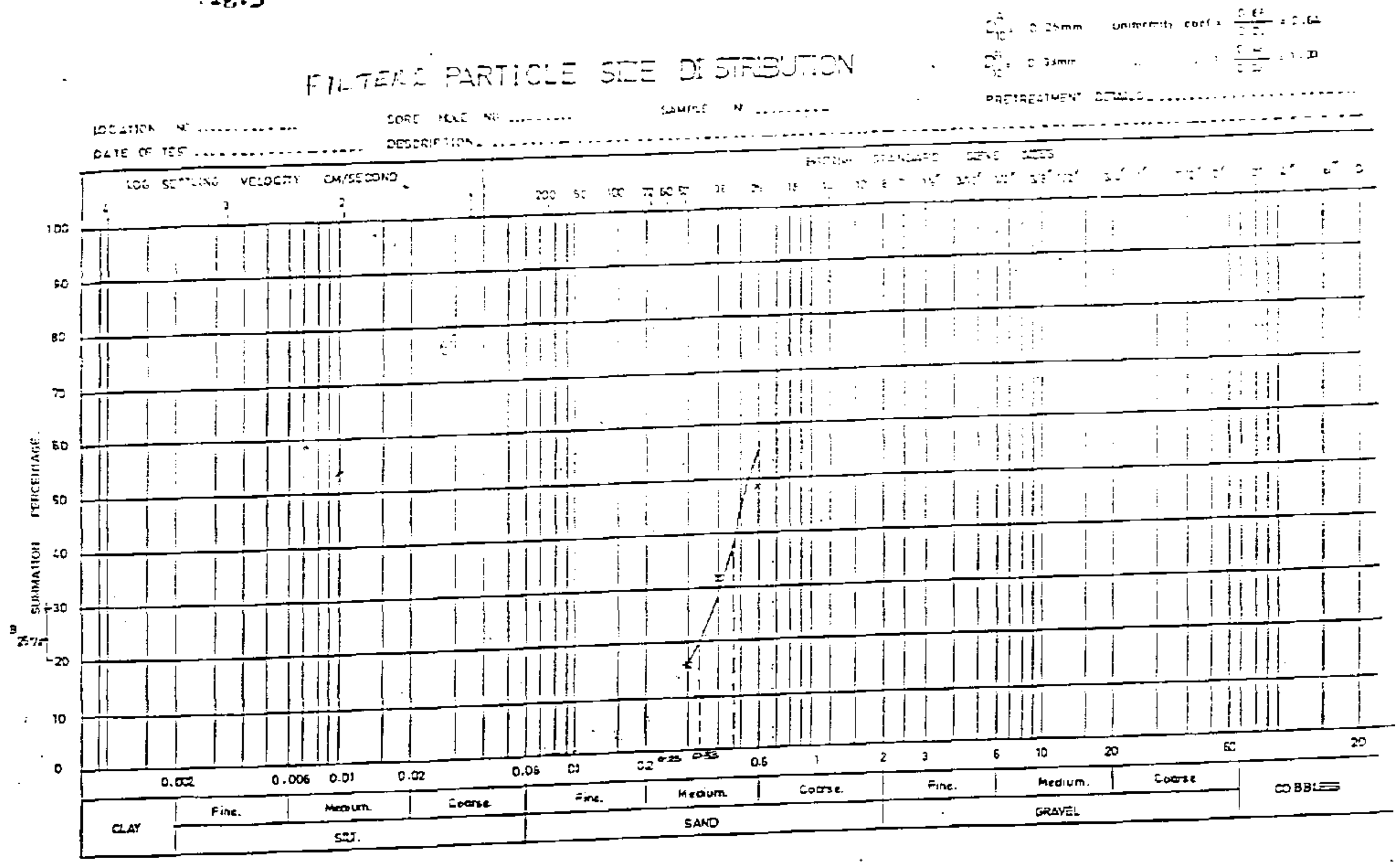


Fig.5


FILTERED PARTICLE SIZE DISTRIBUTION
LOCATION No
DATE OF TEST
BORE HOLE No
DESCRIPTION
SAMPLE No
PRETREATMENT DETAILS
LOG SETTLING VELOCITY CM/SECOND
BRITISH STANDARD SIEVE SIZES
SUMMATION PERCENTAGE
0
10
20
30
40
50
60
70
80
90
100
0.002
0.006
0.01
0.02
0.06
0.6
1
2
3
6
10
20
CLAY
Fine.
Medium.
Coarse.
SILT.
SAND
GRAVEL
COBBLES

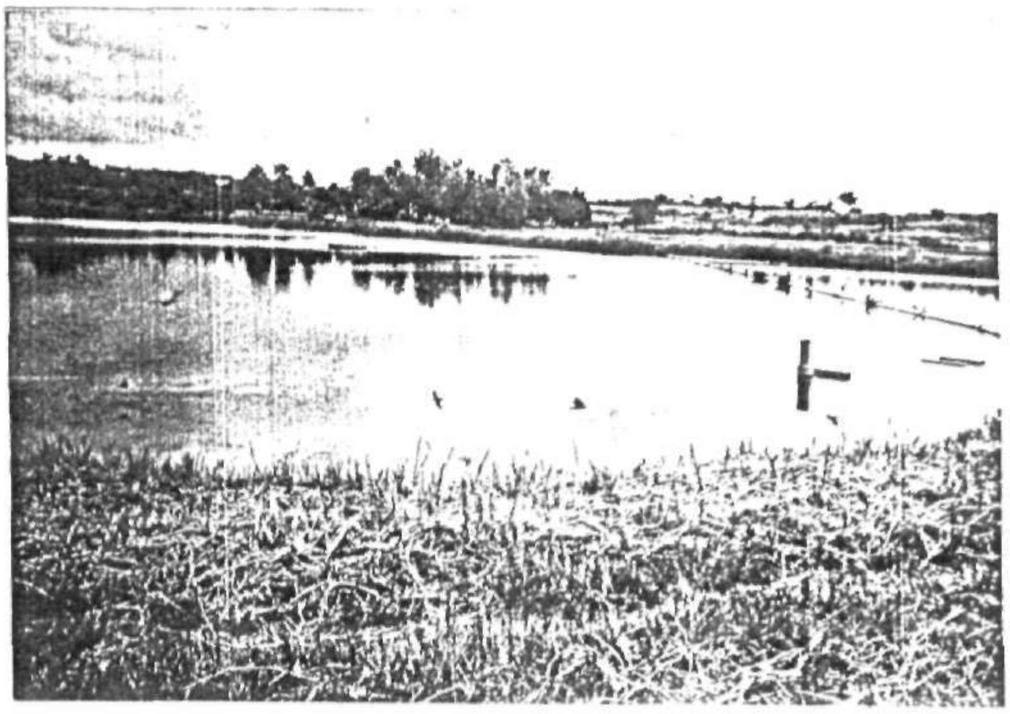


PLATE 1: A SECTION OF ABU STABILIZATION POND

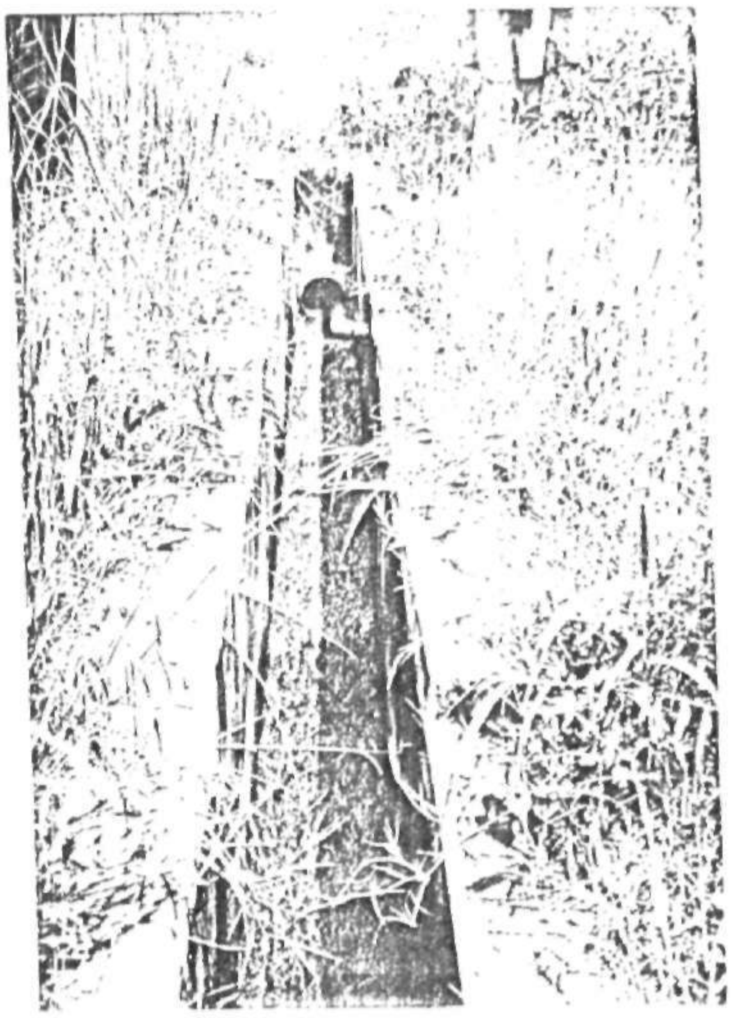


PLATE 2: EFFLUENT DISCHARGE CHANNEL OF THE STABILIZATION POND

samples for cadmium and iron while Perkin Elmer make of AAS was used to determine the concentrations of lead, calcium, magnesium and copper elements in the samples. Hitachi make of AAS was used to analyse samples for boron concentration in samples as described in section 3.1.4.

d **Algae**

Algae concentration in samples were determined by the use of Spectrophotometer in Water Resources and Environmental Engineering Departmental Laboratory by observing the chlorophyll-a concentration in mg/m3.

e. **Helminth and Water Fleas**

Helminth eggs/larvae and water fleas counts were determined in the Helminthology Departmental Laboratory, Faculty of veterinary Medicine Ahmadu Bello University, Zaria, using the microscopy method. This is the standard method adopted in the laboratory for observing the concentration of these parameter in water samples.

f. **Faecal Coliforms**

The determination of the Most Probable Number (NPN) of faecal coliforms was done through serial dilution process. It was carried out in the Water Resources and Environmental Engineering Laboratory of Ahmadu Bello University, Zaria.

3.2.4 **Filtration of Samples**

Figures 6 shows the arrangement during filtration process. A total of six filtration runs were made for each filter and the duration of each run varied between 2 minutes and 5 minutes within which the filtration rate was steady and samples were collected. At the end of each run, a thick layer of sediments formed at the surface of the sand, blocking the pores and making further filtration, difficult. Before the next run was taking, the surface layer of blocked by sediments was scrapped and flushed with clean water. The filter was also drained before the next run. Backwash was tried with little or no result because the whole sand floated and would have lost with backwash water.

Filtration rates ranged from 0.3 to 0.44 m3/d (0.196 x 10-4 to 0.282 x 10-4 l/cm^2/S). The filtrates collected at depth 2.0 meters of the filter bed were analysed for

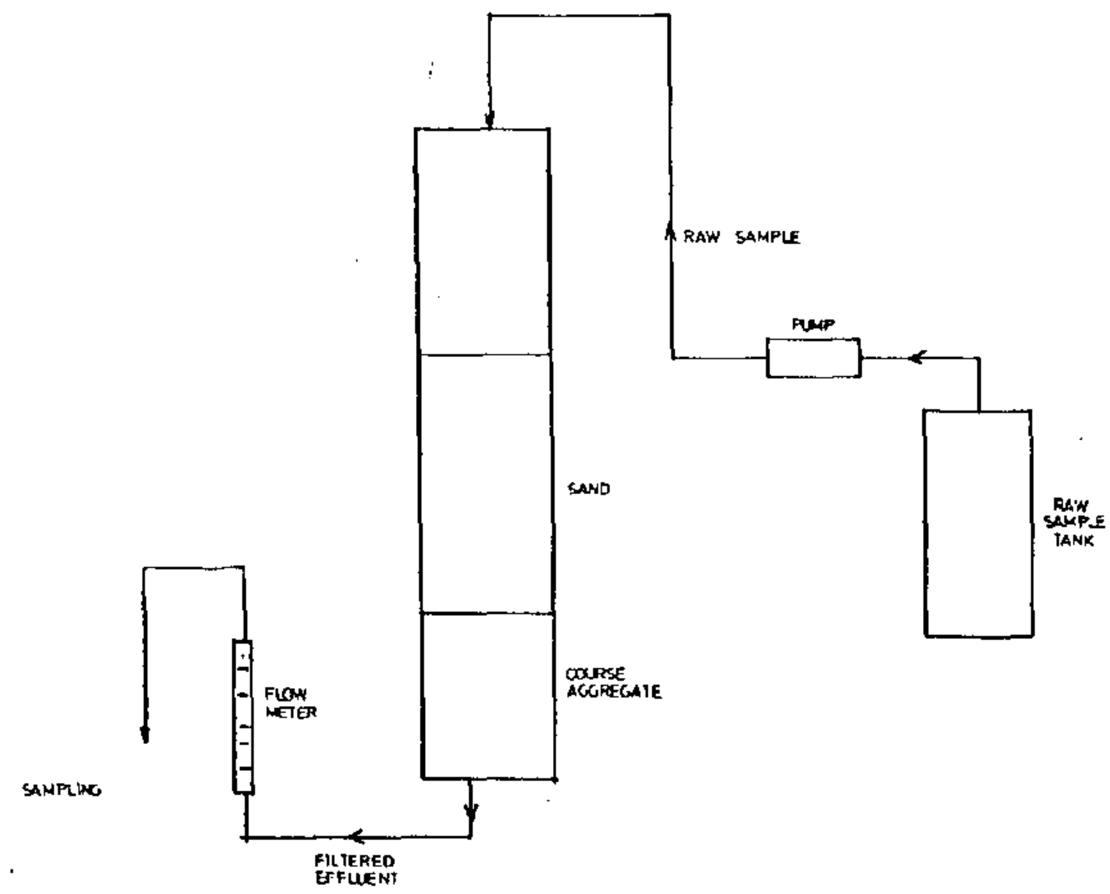


FIG 6 SCHEMATIC FLOW ARRANGEMENT OF POLISHING SYSTEM

the physical, chemical and bacteriological parameters as for the raw samples. In addition, filtrates were collected at depths D1,D2 and D3 (intervals of 0.5m) to study the removal of suspended solids and algae with depth of filter.

CHAPTER 4

RESULTS

The results obtained for the physical, chemical and biological analysis of samples from both the Waste Stabilization Pond (WSP) effluents (herein referred to as **influent** to the filters) and the filtrates are presented in this chapter.

4.1 Characteristics of sand

The sand had effective sizes of 0.25mm and 0.33mm; uniformity coefficient of 2.64 and 1.39 and porosity of 0.435 and 0.564 for Filter 1 and Filter 2 respectively. The effective size (D10) was obtained as the maximum particle size of the smallest 10 percent of the particle size distribution while the uniformity coefficient was the ratio of the maximum particle size of the smallest 60 percent (D10) to the effective size (Smith, 1978). The porosity (n) of the soil sample was determine as the ratio of volume of voids to total volume of sample. These effective sizes and porosities are within the range recommended for a slow sand filter and the filters are expected to operate as such.

4.2 Characteristics of Samples

Table 1 shows the range of concentrations of samples constituents monitored. Table 2 shows the average concentrations of parameters while Table 3 shows the percentage removal of the parameters. The characteristics of the filter influent and effluent were determined as follows;

(a) Suspended Solids.

Figure 7 shows the suspended solid (SS) removal with depth of filter bed. The result indicates that a removal of 87.85% of suspended solids was achieved using a filter bed of 2.0 meters consisting sand whose effective size is 0.25mm, porosity of 0.435 and uniformity coefficient of 2.64. It is observed that the bulk of removal was achieved at a depth of 1.0 meter of sand.

(b) **BOD and COD**

It was observed that the removal of BOD and COD of the waste water and filtrate samples was more in Filter 1 containing sand of an effective size of 0.25mm than Filter 2 containing sand of an effective size of 0.33mm. The average percentage removal of BOD are 90.5 % and 84.08% for Filters 1 and 2 respectively. The average filter influent BOD was about 58mg/l and the average effluents from the filters were about 6mg/l and 10mg/l respectively. Also the average percentage COD removal are 84.5% and 64.3% for filters 1and 2 respectively. While the measured average BOD concentration of WSP effluent (influent to the filters) was about 58mg/l the average COD was about 361mg/l (i.e. a ratio of about 1:6). Figure 8 and 9 show the variations in the removal efficiencies of BOD and COD with number of runs. Figure 10 gives the correlation between BOD and COD concentration in the filtrate of Filter 1 while figure 11 gives a graphical comparison between the filter 1 influent and effluent BOD - COD correlations.

(c) **Metals**

Tables 1, 2 and 3 show the concentrations of the heavy metals in the WSP effluent used. The average concentrations were 0.01mg/l, 2.56 mg/l and 0.03 mg/l for cadmium, iron and copper respectively while lead was not detected. After filtration, the average concentration of iron was reduced to about 1.74 mg/l while cadmium and copper were not affected. Other chemicals shown on tables 1,2 and 3 are calcium, magnesium and boron which were observed present in both the WSP effluent and filtered effluents.

(d) **Algae**

Figure 12 shows the algae removal with depth of filter bed. The raw data are presented in appendix A. The algae removal measured as chlorophyll-a (mg/m3) was

Table 1: **Characteristics of Wastewater Samples before and after filtration (mg/l)**

Parameter	Influent Concentration (Co)	Effluent	
		Filter 1	Filter 2
Suspended Solids	240-400	10-130	N.D
BOD	35.0-71.0	0.4-10.60	1.20-16.9
COD	121.4-810.95	19.42-126.26	43.62-291.6
Cd	0.00-0.01	0.00-0.01	0.00-0.01
Pb	0.00	0.00	0.00
Fe	2.26-3.01	1.51-1.9	1.24-2.21
Ca	7.05-9.81	5.93-9.13	5.12-9.3
Mg	8.59-9.81	4.64-5.41	4.86-7.10
Cu	0.01-0.05	0.01-0.01	0.01-0.05
Bo	0.05-0.16	0.04-0.14	0.04-0.16
Chlorophy-a(mg/m^3)	40.05-60.08	0.0-13.35	N.D
Helminth Eggs/Larvae/ 100ml	0.00-10	0	0
Water Fleas/100ml	20-590	0	0
Faecal Coliform		$1.3x10^5$	
(MPN)/100ml	$4x10^4$-$2.2x10^5$	$2.7x10^5$	N.D

N.D = Not determined.

Table 2: Average concentrations of Wastewater Characteristics (mg/1)

Parameter	Influent Concentration (Co)	Effluent	
		Filter 1	Filter 2
Suspended Solids	300.00	42.50	N.D
BOD	360.49	52.92	129.63
Cd	0.01	0.01	0.01
Pb	0.00	0.00	0.00
Fe	2.56	1.74	1.72
Ca	8.57	7.24	7.19
Mg	9.07	4.94	6.2
Cu	0.03	0.03	0.03
Bo	0.09	0.07	0.07
Chlorophy-a(mg/m^3)	51.73	8.35	N.D
Helminth Eggs/Larvae/ 100ml	3.75	0	0
Water Fleas/100ml	185	0	0
Faecal Coliform (MPN)/100ml	9.5×10^4		N.D

Table 3: **Percentage Reduction of Parameters.**

Parameter			Effluent	
	Range	Average	Range	Average
SS at D4	70.0-95.8	87.85	NL	N.D
BOD	82.50-98.9	90.50	72.10-96.60	84.08
COD	84.10-85.10	84.52	63.90-64.07	64.30
Cd	0.00	0.00	0.00	0.00
Pb	-	-	-	-
Fe	24.0-44.0	31.67	23.0-44.0	31.33
Ca	2.44-28.62	15.33	2.0-29.0	14.50
Mg	8.59-9.51	45.57	23.34-71.71	42.90
Cu	0-50.0	19.60	0-25.0	8.40
Bo	14.6-25.0	12.01	0-20	4.80
Chlorophil-a D4	100	100	-	-
Helminth Eggs/Larvae	100	100	100	100
Water Fleas	100	100	100	100
Faecal Coliform	-	-	-	-

* Increased concentration of Faecal/Coliform.

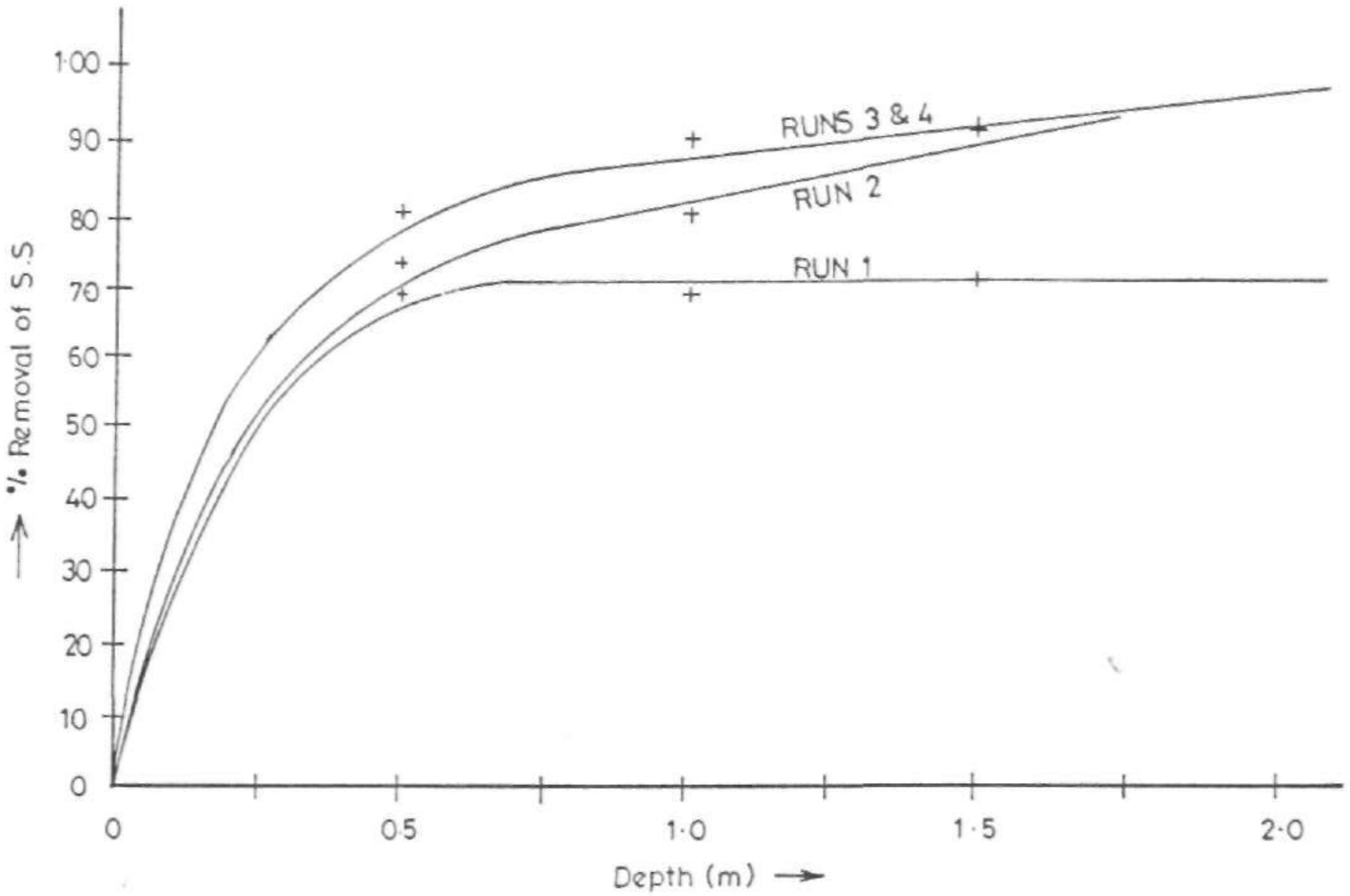
observed to have an average filter 1 effluent value of 8.35 mg/l while the WSP waste water value was 51.73 mg/m3 on the average.

(e) **Helminth and Water Fleas**

Helminth eggs/larvae and water fleas were observed in WSP effluent samples. The average counts were 3.75 eggs/larvae per 100ml and 185 Nos/100ml of samples for helminths and water fleas respectively. After filtration, non of these parameters were found in the filtrates of both filters 1 and 2 as shown in tables 1, 2 and 3.

(f) **Faecal Coliform**

The coliform count (MPN/100ml) determined by serial dilution in both the WSP effluent and filtrate is shown in tables 1 and 2. The average count in filter influent (WSP effluent)was observed to be 9.5 x 10 4 MPN/ 100ml while that of the filtrate was 2.03 x 105 MPN/1001 for filter 1.



Fig· 7 Percentage Removal in Filter 1. of suspended solids with depth of Sand

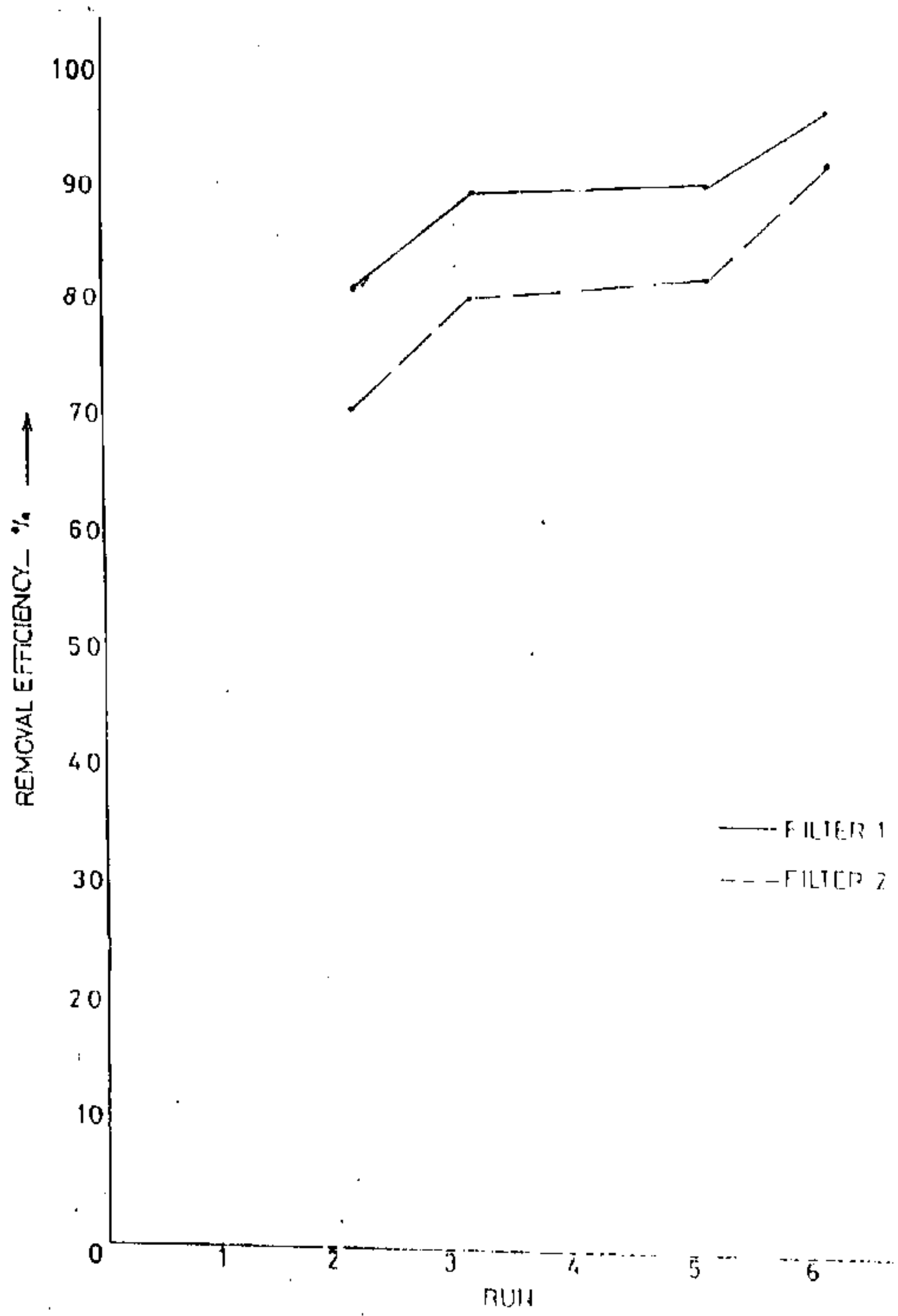


Fig.8 Variations in B.O.D removal efficiency of sample

Degree of Removal increased with the number of runs (ie filters becomes more efficient with number of runs)

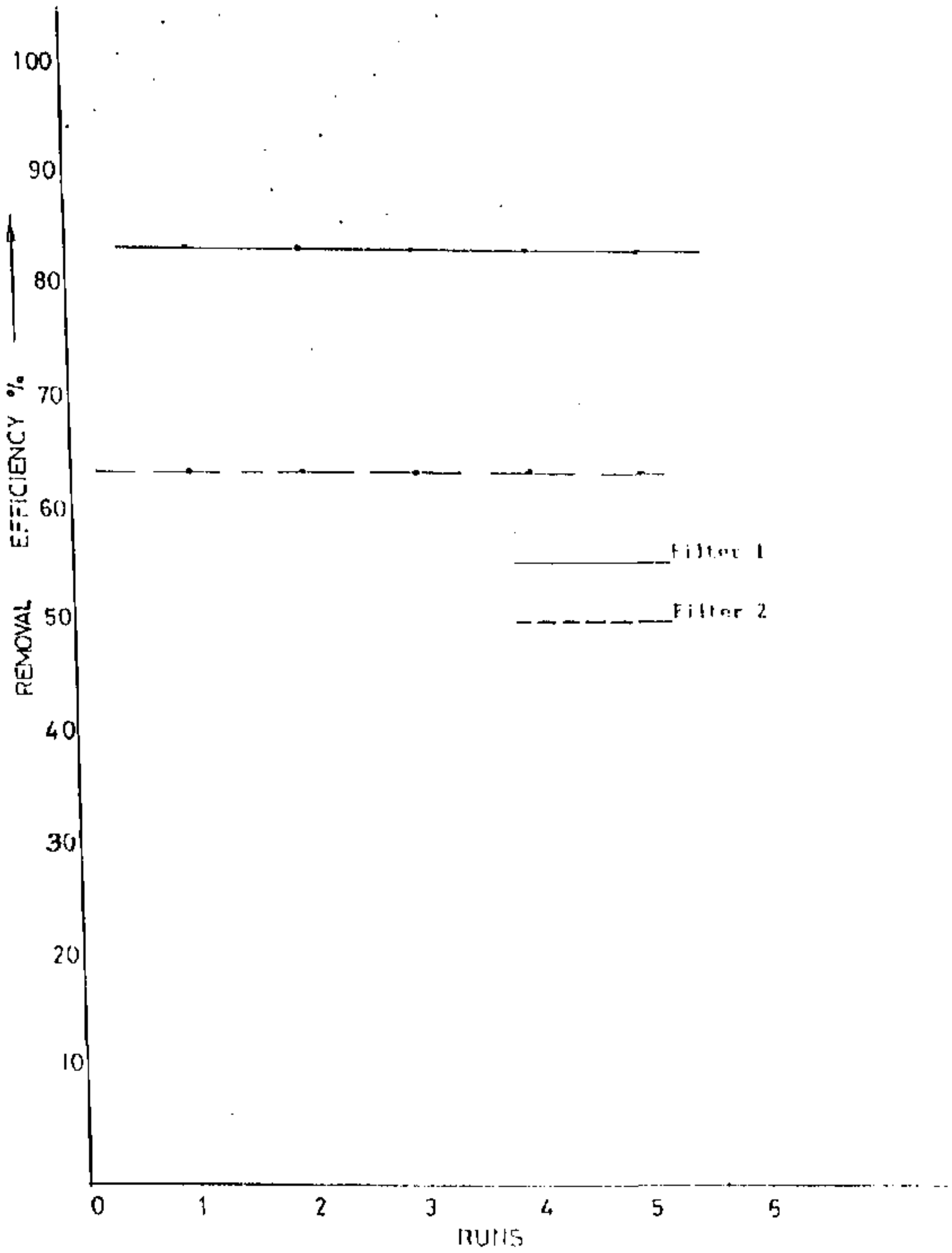


Fig 9 Variations in COD removal efficiency

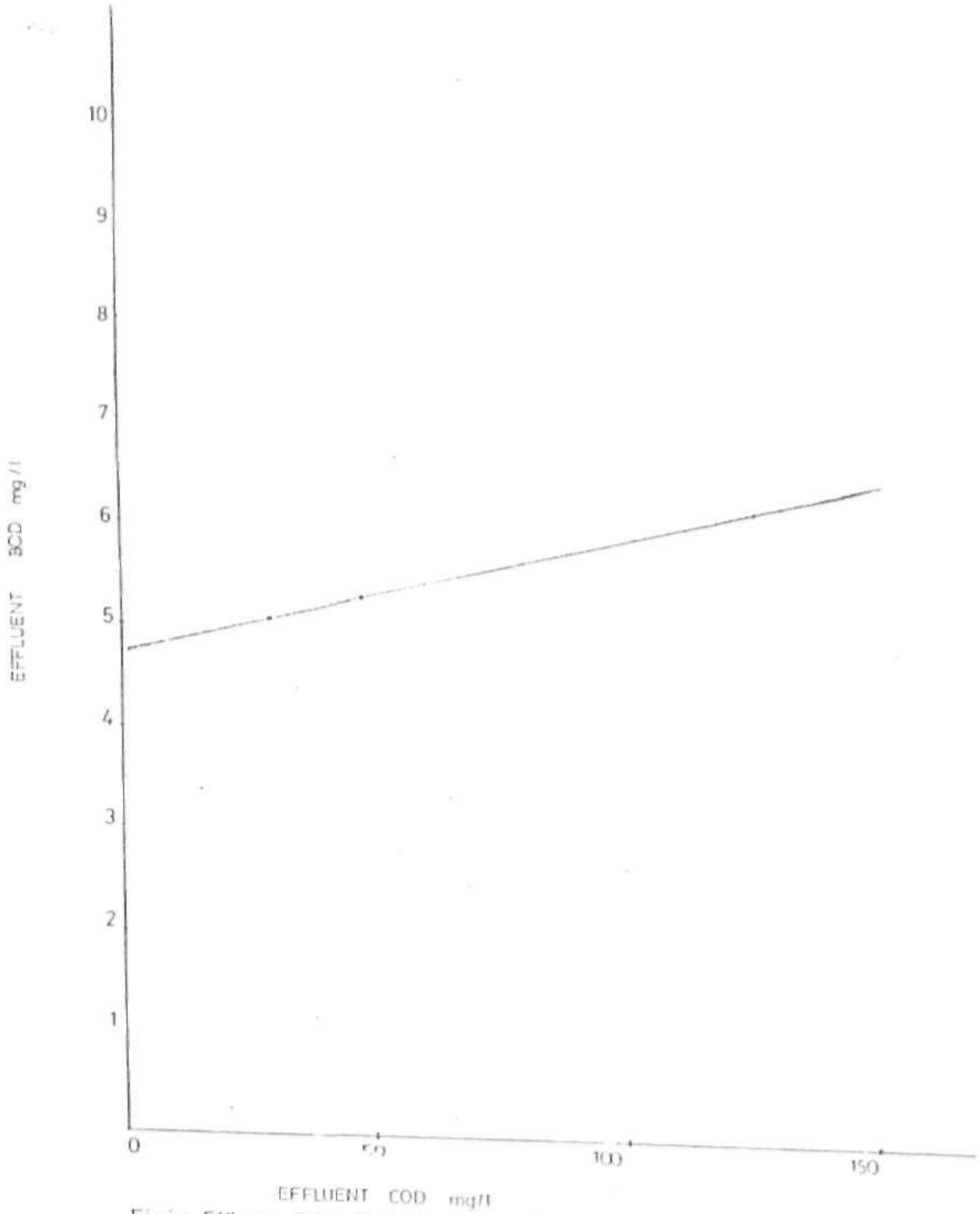


Fig 10 Effluent BOD-COD Correlation (FILTER 1)

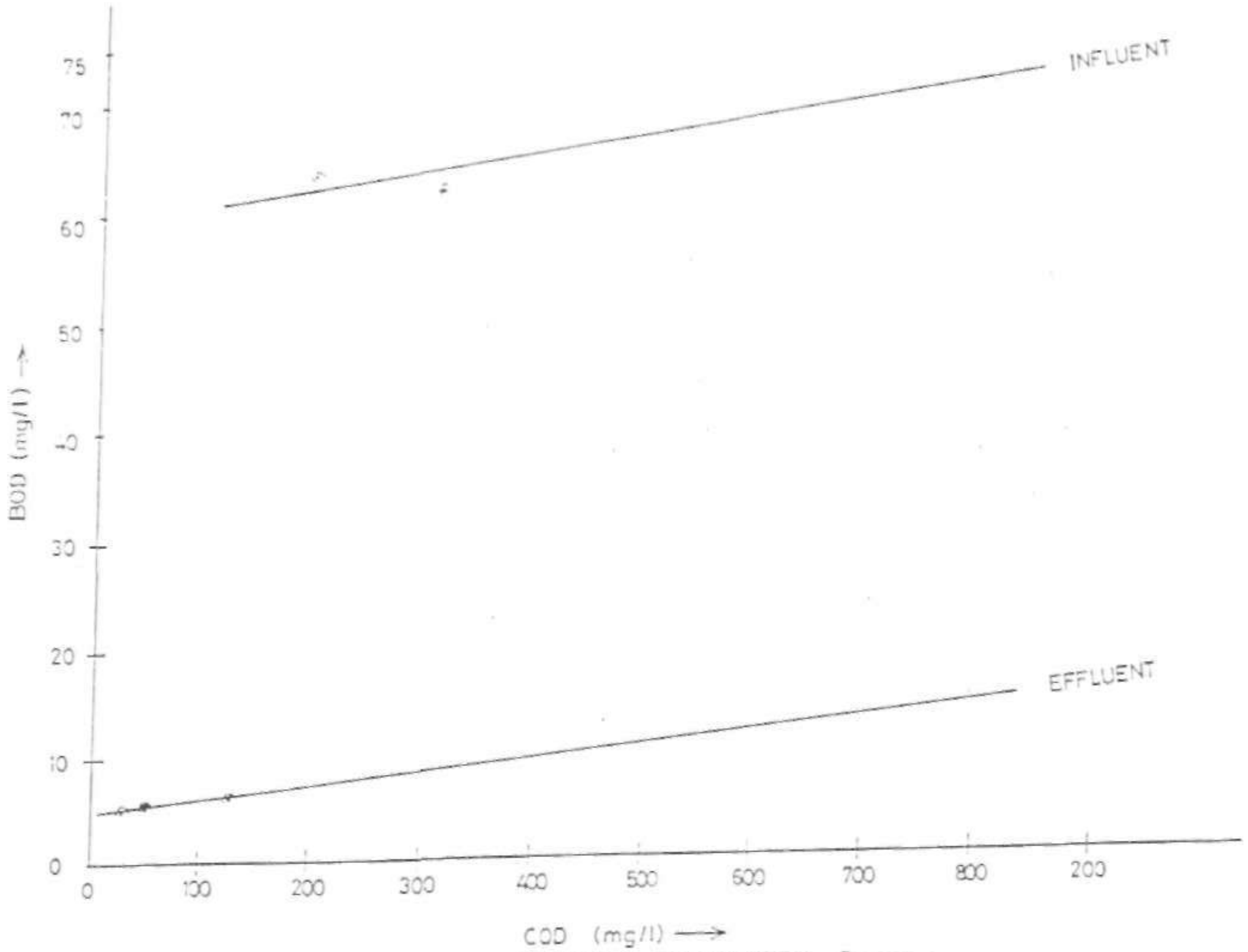


Fig 11

BOD/COD CORRELATION FILTER 1

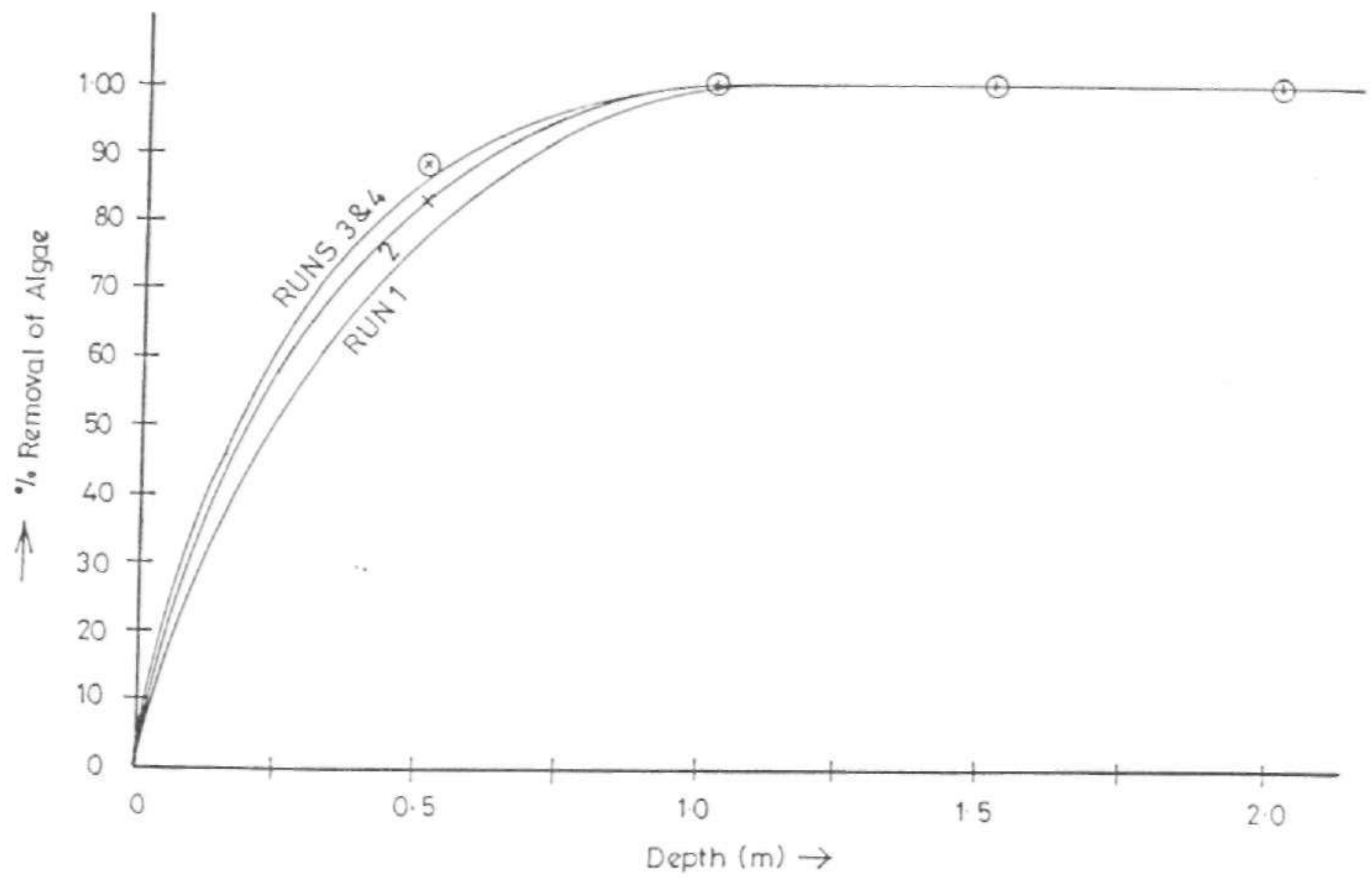


Fig. 12. Percentage Removal in Filter 1 of Algae with depth of Sand

CHAPTER 5

DISCUSSION OF RESULTS

The results obtained in this study are discussed under three sub-headings. These include the physical, chemical and Biological parameters.

5.1 Physical Parameters

5.1.1 Suspended Solids

It is generally recognized that the removal of impurities through a bed of sand is a combination of physical and chemical processes. The factors responsible are identified as the straining action taking place at the furface of the filter bed, adsorption or electrokinetic force, biological activity which depends on the concentrations of the organics present in the water, coagulation inside the filter bed, sedimentation inside the filter bed and also the effective size and porosity of the filter media.

Algae constitute a high proportion of the suspended solids in the WSP effluent used in the present study. Considering their sizes relative to the porosity and effective sizes of the sand used, it is believed that straining action and adsorption phenomenon were the primary factors in the removal of most of the suspended solids. Table 1, 2 and 3 show the average concentration of suspended solids in both the WSP effluent and the filtrate sample. Fige 7 also shows the percentage removal with depth of filter.

5.2 Chemical Parameters

Tables 1 and 2 show the concentrations of the chemical parameters measured. These include the Biochemical Oxygen Demand (BOD), the Chemical Oxygen Demand (COD), Heavy metal and other chemicals. Table 3 shows the percentage removal of these parameters after filtration.

5.2.1 **Biochemical Oxygen Demand (BOD)**

Dead algae cells, dissolved and colloidal decomposable and non-decomposable matters are expected to contribute to the organic loading from the WSP effluent. It had been reported that about 0.1mg chlorophyll is equivalent to 3mg BOD (Mara et al 1992). The removal of organics by the filter bed is expected to be by both the straining action and adsorption phenomenon. Suspended organic matter which were too large to pass through the pores of the sand bed would be retained on the surface of the bed. Organic colloids; would be removed by adsorption due to electro-kinetic forces existing between the sand particles and the colloids. The filtered effluent will not pose a serious threat in terms of BOD if discharged into a river.

5.2.2 **Chemical Oxygen Demand (COD)**

It is observed that the bulk of the organic matter in the WSP effluent used are not biologically degradable as shown by the COD results. The COD removal by filter 1 compares favourably with the average removal of 86% obtained with activated carbon filtration reported by Carry et al (1989). The mechanism of removal by sand filtration is expected to be straining action, adsorption phenomenon and by sedimentation within the pores of the filter bed.

Although a high percentage removal of 84.5% is achieved by filter 1, the residual COD concentration of about 56mm/1 in the filtrate is still far above 10mg/1 recommended for potable river water (WHO, 1971), However, a substantial reduction in exertion on chlorine is expected if disinfection of the filtrate is necessary (Echelberger, et al. Also the filtrate may qualify for irrigation purposes.

5.2.3 **Heavy Metals (Cadmium, Lead, Iron and Copper)**

The metallic waste, cadmium (Cd), Lead 8Pb), iron (fe) and copper (Cu) collectively referred to as "Heavy Metals" are of serious concern when discharged into a receiving water because of their toxic properties and other adverse effects on the aquatic biota. At toxic levels (above the maxium allowable level of 0.01 mg/l) cadmium has been reported to cause gastronterstinal disturbances, renal dysfunction and lung impairments in man and animal (Thompson and Wagstaff, 1978). Lead is a commulative body poison. Injection of water containing small quantities of lead may give rise to symptoms of lead poison with serious effect on liver, cardiovascular and reproductive systems in man and animal. As far as it is known, humans suffer no harmful effects from drinking water containing iron. But when water containing ferrous iron is exposed to air the ferrous iron may be oxidized to ferric iron causing the water to be turbid and highly aesthetically unacceptable. Also, iron interferes with laundering operations, introduce objectionable stain to plumbing fixtures and support the growth of iron-bacteria which may cause difficulties in the distribution system. Iron also introduces taste to water which may be detectable at very low concentrations. Cadmium and copper were not affected probably due to their initial very low concentrations in the WSP effluents. The measured concentrations of the heavy metals satisfy the International Standards and may qualify the filtered effluent as irrigation water. The removal of iron may be probably due to the formation of ferric iron due to oxidation of ferrous iron which precipitates and removed by straining action or by adsorption on the surface of the filter media or by sedimentation within the pores of the sand.

5.2.4 Other Chemicals (Calcium, Magnesium and Boron)

Calcium and Magnesium salts are the most frequent causes of hardness in water and they may affect the scale - forming and corrosive properties of the water. The determination of Boron in water, industrial wastes and sewage effluents is important in agriculture. Boron in excess of 2.0mg/l in irrigation water is deleterious to certain plants. There is also evidence that some plants may be adversely affect by concentrations as low as 1.0mg/l (or even less in commercial green houses) (Anodere 1982).

It is observed that the concentrations of these chemicals are low and will not constitute any problem if the filtered effluent is discharged into a receiving water. Also the filtrates may qualify as irrigation waters as far as the parameters are concerned.

5.3 Biological Parameters

Tables 1 and 2 show the concentrations of biological parameters measured. These include algae, helminths, water fleas and faecal coliforms. Table 3 shows the percentage removal of these parameters after filtration.

The removal of biological parameters by sand filters is expected to be mainly by the smaller pore sizes of sand. The electrokinetic forces existing between the fine particles and the sand is expected to have contributed to some degree to the reduction of the parameters. However, these conditions may not have applied strictly to all the items measured especially the faecal coliforms as shown in subsequent subsections.

5.3.1 Algae

As discussed under subsection 5.1.1, algae constitute the bulk of the suspended solids in the WSP effluent. The discharge of the algae - laden effluent into a body of water is undesirable and should be controlled. The dead algae cells are organic in nature and will normally be degraded by bacteria under aerobic and anaerobic conditions. Both the dead and living algae cause odour and taste problems and may constitute aesthetic nuissance in the water to be used for recreation. Also the cost of treatment of such water for domestic purposes may be prohibitive.

It has been established and confirmed in this study that sand filtration is effective in algal removal, from the WSP effluents. The results of the present study show that an average removal of 84% (as measured by chlorophyll-a) was achieved at 0.5m depth of sand of effective size of 0.25mm and porosity of 0.435.

Complete removal was achieved at a depth of 1.0m (figure 8).

This removal was by straining action at the surface of the filter and also by adsorption phenomenon. Further removal may have been achieved by biological activities within the filter media.

5.3.2 **Helminths and Water Fleas**

Sand filtration is generally observed to be one of the most effective means of removing helminth ova and water fleas. Removal of about 100% have been recorded for ova of Ascaries and hookworm (Cream, 1953) It was observed that the influent waste water to the filter beds contained an average counts for Helminths eggs/larvae and water fleas of 4 and 185/100ml respectively. However, 100% removals were obtained after filtration. The removal of both eggs and larvae of helminths and water fleas is believed to be as a result of the straining action of the sand filter and the adsorption mechanism on the deposited particles.

Purified sewage effluents free from helminths are of considerable agricultural importance when used for irrigation purposes. Therefore, the quality of effluent obtained in this study with respect to helminths and water fleas removal has qualified it for use as irrigation water.

5.3.3 **Faecal Coliform**

The removal of bacteria from water through sand filtration is often associated with conventional treatment of water for domestic consumption. One would also expect that sand filtration will be effective in bacterial removal from sewage effluents. However, most of the available literature on upgrading sewage effluent are silent on bacterial removal. For example in the works of Bell and Allum (1986), Pescod and Alka (1984) and Noll et al, (1986) where sand filters were employed for tertiary treatment of sewage effluents, emphasis were focused on SS and BOD reduction rather than bacterial removal. Filtration processes were complimented by disinfection especially with chlorine. Reverse-osmosis has been suggested as an alternative method for removing bacteria from WSP effluents followed by the use of lime.

In the present study, contrary to expectation, it was observed that the bacterial counts increased rather than decrease after sand filtration. This observation may be attributed to a number of factors such as the nature and composition of the sewage effluent, porosity and the effective sizes of the sand used relative to the bacterial size. Sewage would normally contain viable bacteria which would thrive under favourable environmental conditions. The sewage effluent may provide such an environment and the rate of bacterial growth may be faster than their die-off rate. And because of the bacterial size relative to the effective size of the sand media, the excess bacteria would pass through the pore of the sand with the filtrate. In a related study involving ozone-activated carbon filtration, Bell and Allum (1986) observed that total bacterial counts increased in the filtrate. It should be emphasized that the results of the present study is by no means conclusive. More research work is needed using different finer sizes of sand media.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

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

1. Sand filtration as a tertiary sewage treatment device is capable of upgrading the quality of the Waste Stabilization Pond Effluent with respect to some physical, chemical and biological parameters like the suspended solids (S.S), Biochemical Oxygen Demand (BOD) the Chemical Oxygen Demand (COD), metallic elements, algae, helminth eggs/larvae and water fleas.

2. Straining action of the filter media, adsorption of materials on the filter media surface, and trapping of impurities within the pores of the filter media are some of the factors believed to be responsible for the removal of the impurities during filtration.

3. A sand filter medium with effective size of 0.35mm, porosity of 0.435 and uniformity coefficient of 2.64 was found to perform better than a sand filter medial with effective size of 0.33mm, porosity of 0.564 and uniformity coefficient 1.39.

4. For the more effective filter described above operating at a depth of 2.0 meters and at hydraulic loading of $20m^3/m^2/day$, and average removal of 87.85%, 90.5% and 84.52% were achieved for SS, BOD and COD respectively while complete removal of algae, helminth eggs/larvae and water fleas was achieved.

5. Concentrations of heavy metals such as cadmium, lead, copper and iron and other chemicals such as Boron, magnesium are low in both the WSP effluents and filtrates.

6. Contrary to expectation, Faecal coliforms were observed to increase in the filtrate. The nutrients necessary for bacterial growth may be sufficiently present in the WSP effluent and these may encourage the growth of the Faecal coliforms the size of

which may be so small to pass through the pores of the sand media used. This observation is subject to further investigations.

7. The concentrations of the measured parameters (except for the Faecal coliforms) satisfy the International Standard. The filtered WSP effluent may be discharged into a receiving body of water or may qualify as irrigation water after some controlled chlorination to reduce the concentration of coliform bacteria.

6.2 Recommendations

The conclusions above are based on a short term investigation with only two types of sand, single stage hydraulic loading and filtration columns. They may not apply strictly to large installations. It is therefore recommended that:

1. Several grades of sand may be used to establish the removal efficiencies with effective sizes, uniformity coefficient and porosity.

2. Multistage intermittent/continuous flow filtration may be investigated to establish flow relationships with the removal efficiencies.

3. Pilot models adjacent to existing WSP may be constructed and tested under the field conditions.

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APPENDIX A. TABLES

APPENDIX A1 TABLES

TABLES A - 1 CHEMICAL PARAMETERS OF FILTER 1 (mg/1)

RUN	BOD		COD		SUSPENDED SOLIDS				
	INFLUENT	EFFLUENT	INFLUENT	EFFLUENT	INFLUENT	EFFLUENT			
						D1	D2	D3	D4
1	53.0	7.0	ND	ND	400	130	130	120	120
2	60.5	10.6	ND	ND	240	70	50	30	10
3	71.0	6.2	810.95	126.26	280	60	30	30	20
4	62.5	5.3	310.50	48.25	280	30	30	30	20
5	64.0	5.1	199.10	29.76					
6	35.0	0.4	ND	ND					
7	ND	ND	121.40	19.42					

ND = Not Determined

D = Depth of Filter Medium

D1 = 0.5m D2 = 1.0m

D3 = 1.5m **D4** = 2.0m

TABLE A - 2 METALLIC CHEMICAL PARAMETERS OF FILTER 1 (mg/1)

RUN	CADMIUM		LEAD		IRON		CALCIUM		MAGNESIUM		COOPER		BORON	
	INFL	EFFL	INFL	EFFL	INFL	EFFL	INFL	EFFL	INF	EFFL	INFL	EFFL	INFL	EFFL
1.	0.01	0.01	0	0	2.41	1.51	9.81	8.61	8.64	4.81	0.02	0.01	0.09	0.05
2.	0.01	0	0	0	3.01	1.69	9.54	6.81	9.51	5.01	0.03	0.02	0.08	0.06
3.	0.01	0.01	0	0	2.67	1.84	9.42	9.13	8.59	4.64	0.04	0.03	0.05	0.04
4.	0.01	0	0	0	2.26	1.67	7.05	6.84	9.05	4.95	0.05	0.04	0.05	0.06
5.	0	0	0	0	2.51	1.81	8.13	5.93	9.51	5.41	0.04	0.03	0.08	0.06
6.	0.01	0.01	0	0	2.51	1.9	7.45	6.14	9.14	4.81	0.01	0.01	0.16	0.14

TABLE A - 3 BIOLOGICAL PARAMETERS OF FILTER 1

RUN	CHLOROPHYLL-a mg/m^2					HELMINTHS /100ml		WATER FLEAS /100ml		FAECAL COLIFORM Bactt./100ml	
	INFL	EFFLUENT				INFL	EFFL	INFL	EFFL	INFL	EFFL
		D1	D2	D3	D4						
1.	60.08	13.35	0	0	0	0	0	20	0	$4x10^4$	$22x10^4$
2.	40.05	6.68	0	0	0	10	0	80	0	$22x10^4$	$27x10^4$
3.	53.4	6.68	0	0	0	5	0	50	0	$4x10^4$	$13x10^4$
4.	53.4	6.68	0	0	0	0	0	590	0	$8x10^4$	$19x10^4$

TABLE A - 4 PROPORTION OF EFFLUENT TO INFLUENT PARAMETERS OF FILTER 1 c/co

RUN	BOD	COD	SS at D4	Cd	Pb	Fe	Ca	Mg	Cu	Bo	HELMINTH	WATERFLEA	FC	CHORO-a at D4
1.	0.132	-	0.03	1	0	0.63	0.88	0.56	0.5	0.56	0	0	55	0
2.	0.175	-	0.04	0	0	0.56	0.71	0.53	0.67	0.75	0	0	1.23	0
3.	0.087	0.156	0.07	1	0	0.69	0.97	0.54	0.75	0.8	0	0	3.25	0
4.	0.085	0.155	0.07	0	0	0.74	0.97	0.55	0.8	0.86	0	0	2.38	0
5.	0.08	0.149		0	0	0.72	0.73	0.57	0.75	0.75	0	0		
6.	0.011	-		1	0	0.76	0.82	0.53	1.0	0.88	0	0		
7.	-	0.159												

TABLE A - 5 PERCENTAGE REMOVAL OF PARAMETERS OF FILTER 1 (%)

RUN	BOD	COD	SS	Cd	Pb	Fe	Ca	Mg	Cu	Bo	HELMINTH	WATERFLEA	FC	CHORO-a	
			D4											D1	D4
1.	86.8	-	70.0	-	-	37.34	12.23	44.33	50.0	44	100	100	-450	100	77.78
2.	82.5	-	95.8	-	-	43.85	28.62	47.37	33	25	100	100	-23	100	83.32
3.	91.3	84.4	92.8	-	-	31.09	3.08	45.98	-	20	100	100	-225	100	87.49
4.	91.5	84.5	92.3	-	-	26.11	2.98	45.3	0	14	100	100	-135	100	87.49
5.	92	85.1		-	-	27.89	27.06	43.11	25	25	100	100			
6.	98.9	ND		-	-	**24.30**	17.58	47.37	75	12.5	100	100			
7.	ND	84.1													

TABLE A - 6 CHEMICAL PARAMETERS OF FILTER (mg/l)

RUN	1 BOD		1 COD	
	INFL	EFFL	INFL	EFFL
1.	53.0	7.2	ND	ND
2.	60.5	16.9	ND	ND
3.	71.0	12.5	810.95	291.6
4.	62.5	10.5	310.5	111.63
5.	35.0	10.45	199.1	71.87
6.	35.0	1.2	ND	ND
7.	ND	ND	121.4	43.40

TABLE A - 7 METALLIC CHEMICAL PARAMETERS OF FILTER 2 (mg/1)

RUN	CADMIUM		LEAD		IRON		CALCIUM		MAGNESIUM		COOPER		BORON	
	INFL	EFFL	INFL	EFFL	INFL	EFFL	INFL	EFFL	INF	EFFL	INFL	EFFL	INFL	EFFL
1.	0.01	0.01	0	0	2.41	1.24	9.81	5.12	8.64	4.86	0.02	0.01	0.09	0.06
2.	0.01	0.01	0	0	3.01	2.21	9.54	7.13	9.51	6.7	0.03	0.03	0.08	0.06
3.	0.01	0.01	0	0	2.67	1.84	9.42	9.3	8.59	6.43	0.04	0.03	0.05	0.04
4.	0.01	0.01	0	0	2.26	1.28	7.05	6.84	9.05	6.29	0.05	0.05	0.07	0.06
5.	0	0	0	0	2.51	1.83	8.13	7.97	9.51	7.10	0.04	0.04	0.08	0.06
6.	0.01	0.01	0	0	2.51	1.92	7.45	6.8	9.14	5.93	0.01	0.01	0.16	0.16

TABLE A - 8 BIOLOGICAL PARAMETERS OF FILTER 2

RUN	HELMINTHS (/100ml)		WATER FLEAS (/100ml)	
	INFLUENT	EFFLUENT	INFLUENT	EFFLUENT
1.	0	0	20	0
2.	10	0	80	0
3.	5	0	50	0
4.	0	0	590	0

TABLE A - 9 PROPORTION OF EFFLUENT TO INFLUENT PARAMETERS OF FILTER 2

RUN	BOD	COD	Cd	Pb	Fe	Ca	Mg	Cu	Bq	HELMINTH	WATERFLEA
1.	0.136	-	1	0	0.51	0.52	0.56	0.5	0.67	0	0
2.	0.279	-	1	0	0.73	0.75	0.7	1.0	0.75	0	0
3.	0.176	0.36	1	0	0.69	0.99	0.75	0.75	0.8	0	0
4.	0.168	0.36	1	0	0.57	0.97	0.70	1.0	0.86	0	0
5.	0.163	0.361	0	0	0.73	0.98	0.75	1.0	0.75	0	0
6.	0.034	ND	1	0	0.76	0.91	0.65	1.0	1.0	0	0
7.	ND	0.357									

TABLE A - 10 PERFORMANCE REMOVAL OF PARAMETERS IN FILTER 2 (%)

RUN	BOD	COD	Cd	Pb	Fe	Ca	Mg	Cu	Bo	HELMINTH	WATERFLEA
1.	86.41	-	-	-	48.55	47.81	43.75	50	33.33	100	100
2.	72.1	-	-	-	26.58	25.26	29.55	0	25.0	100	100
3.	82.4	64.07	-	-	31.09	1.3	25.15	25.0	20.0	100	100
4.	83.7	64.05	-	-	43.36	3.0	30.50	0	14.29	100	100
5.	83.7	63.9	-	-	27.09	2.0	25.34	0	25.0	100	100
6.	96.57	ND	-	-	23.51	8.72	35.12	0	0	100	100
7.	ND	64.06									

TABLE A-11

Test Data Sheet 301 Sieve Analysis on KUBANNI RIVER SAND

Gross mass of soil $(M)_o$ 300 grs.

Sieve Number	Mass of Soil Retained(g)	Eraction Retained	Commulative Fraction Retained	Fraction Passing %
7	12.00	12.00	12.00	95.82
14	26.40	26.40	38.40	86.65
18	38.50	38.50	76.90	73.27
25	70.80	70.80	147.70	48.66
36	57.80	57.80	195.50	32.05
52	48.00	48.00	243.50	15.36
72	26.80	26.80	270.30	06.05
100	6.00	6.00	276.30	03.96
200	9.40	9.40	285.70	00.69
200	2.00	2.00	287.70	00.00

Table A-12. Average Suspended Solids Removal with Depth (%)

	Depth of Sand			
RUN	0.5m(D1)	1.0m(D2)	1.5m(D3)	2.0m(D4)
1	67.5	67.5	70.0	70.0
2	70.8	70.2	87.5	95.8
3	78.6	89.3	89.3	92.9
4	78.6	89.3	89.3	92.9

Table A-13. Average Algae Removal with Depth

			Depth of Sand	
RUN	0.5m(D1)	1.0m(D2)	1.5mD3	2.0mD4
1	77.8	100	100	100
2	83.3	100	100	100
3	87.5	100	100	100
4	87.5	100	100	100

APPENDIX B TABLE STANARDS FOR WATER

TABLE B-1

Standards for River Water Quality for Polable use given Natural Treatment

Colour	Limiting Value 300 Preferred level mg/l	Hazen Units Max. Level mg/l
Total dissolved solids	500	1500
Tron	0.5	5
Manganese (as suming ammonia 0.5 mg/1)	1.0	5
Copper	1.0	1.5
Zinc	5	15
Magnesium plus sedium sulphate	500	1000
Detergents ABS	-	1.0
Nitrate as NOs	-	45
Fluoride	-	1.5
Phenolic compounds	-	0.002
Arsenic	-	0.05
Cadmium	-	0.01
Chromium	-	0.05
Cyanide	-	0.20
Lead	-	0.10
Selenium	-	0.01
Chemical oxygen demand (COD)	- 10 mg/I	
Biochemical oxygen demand (BOD)	6	
Total nitrogen eveluding nitrate	1	
Ammonia	0.5	
Organic pollutants Grease	0.5	
Coliforms	1	
for disinfection only	MPN/100 ml	
for conventional treatment of coagulation filtration and disinfection	0-10 50 5.000	
for extensive treatment	5 000-50 000	
to be avoided	50 000	

TABLE B -2

Drinking Water Standards: World Health Organization 1971

Characteristic	Units	Preferred	Maximum
Colour	Hazen	5	50
Turbidity	Units	0	25
Total solids	mg/1	500	1500
PH		7,0,8.5	6,5,9.2
Amonic delegents	mg/1	02	1.0
Mineral oil	mg/1	001	0.3
Phenolic compounds	mg/1	0.001	0.002
Total hardness	mg/1 CaCOs	100	500
Calcium	mg/1	75	200
Chloride	mg/1	200	600
Copper	mg/1 Cu	0.05	1.5
Iron	mg/1 Fe	0.1	1.0
Fluoride	mg/1 F	-	0.8-1.7
Magnesium (sulphate-250 mg/1)	mg/1 Mg	30	150
Manganese	mg/1 Mn	0.05	0.5
Sulphate	mg/1 So	200	400
Zinc	mg/1 Zn	55	15
Arsenic	mg/1 As	-	0.05
Cadmium	mg/1 Cd	-	0.01
Cyanide	mg/1 CN	-	0.05
Lead	mg/1 Pb	-	0.1
Mercury (total)	mg/1 Hg	-	0.001
Selenium	mg/1 Se	-	0.01
Nitrate	mg/1 NOs	-	45

95 per cent of samples throughout the year should contain less than one coliform per 100 ml and not exceed 10 coliforms per 100 ml.

Source: International Standards for Drinking Water, world Health Organization 1971

TABLE B-3

GUIDES FOR EVALUATING THE QUALITY OF WATER USED FOR IRRIGATION
(Calif. State Water Quality Control Board, 1963).

Quality Factor	Threshold Concentration	Limiting Concentrations
Coliform Organisms, MPN per 100ml	1000	*
Total dissolved solids (TDS), mg/l	500	1500
Electrical conductivity, umhos cm	750	2250
Range of PH	7.0-8.5	6.0-9.0
Soduim adsorption ratio (SAR)	6.0	15
Residual Sodium carbonate (RSC) neq	1,25	2,5
Arsenic, mg/liter	1.0	5.0
Boron, mg/liter	0.5	2.0
Chloride, mg/liter	1000	350
Sulfate, mg/liter	2000	1000
Copper, mg/liter	0.1	1.0

* Aside from fruits and vegetables which are likely to be eaten raw, no limits can be specified for such crops, the threshold concentration would be limiting.

TABLE B -4

CHARACTERIST¢ICS OF WATER AND WASTEWATERS

B. European Standards + (in addition to or modifying the above)

Upper limit of concentration		Approximate level above which trouble may arise		
Lead	0.1	Flurode	1.5	Flurososis
Arsenic	0.2	Nitrate	50	Methaemoglobinaemia
Selenium	0.05	Copper	0.05	Taste and stain
Chromium (6+)	0.05	Iron	0.1	
Cadmium	0.05	Zinc	5.0	Taste
Cyanide	0.01	Magnesium	30	If 250 mg/1 sulphate hardness
			125	if less than 250 mg/1 sulphate hardness Taste
		Sulphate	250	Gastro-intestinal irritation
		Chloride	350	Taste
		Ammonia	0.5	Biological growths
		Phenolic substances (as phenol	0.001	Taste

Concentrations in mg/l except where noted.

+ European Standards for Drinking - Water, WHO, Geneva, 1961.