THE EFFECTS ON NGONG RIVER BY EFFLUENTS FROM NAIROBI'S INDUSTRIAL AREA.

BY

OYAKE LEAH

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This is my original work and has not been presented for a degree in any other University for examination. The research was carried in the Chemistry Department, University of Nairobi.

LEAH OYAKE

This work has been submitted for examination with our approval as University Supervisors.

DR.H.N.NJENGA,
DEPARTMENT OF CHEMISTRY,
UNIVERSITY OF NAIROBI.

PROFESSOR G.N. KAMAU,
DEPARTMENT OF CHEMISTRY,
UNIVERSITY OF NAIROBI.

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CONTENTS

CHAPTER FOUR PAGE

CHAPTER FIVE

LIST OF TABLES. PAGE

LIST OF FIGURES.

LIST OF FIGURES PAGE

ABBREVIATIONS

PCB	Polychloro-biphinyl
pH	Hydrogen ion concentration
PE	Potential Difference
B.O.D	Biochemical Oxygen Demand
DDT	Dichloro-Dimethyl tetra acetate
C.O.D	Chemical Oxygen Demand
D.O	Dissolved Oxygen
W.H.O	World Health Organization
T.D.S	Total Dissolved Solids
E.D.T.A	Ethylenediamine TetraAcetate
NTU	Nephthalene-turbidometer Units
RNA	Ribo-nucleic acid

UNIT ABBREVIATIONS

μgml^{-1}	Microgramme per millilitre
mgl^{-1}	Milligramme per litre

ABSTRACT

The effects of industrial effluents on the quality of Ngong River water were studied. This river passes through the most industrialized part of Nairobi City. Effluents are discharged into the water body from the factories through drainages.

The study was carried out from December 1994 to June 1995, a period of seven months.

The study area was between Magoini, Fuata Nyayo slums and Outer Ring Road, a distance of 14 km. Water samples were collected at selected sampling points along the river and at the major drainages discharging effluents into the river. River samples were taken either immediately before or after drainage points.

The mean river temperatures varied between 21.33 to 21.57°C. The drainage samples had mean temperatures ranging from 22.83 to 25.12°C.

The mean river pH ranged between 6.9 and 9.0. These values were comparable with those obtained in a similar study carried out about ten years previously. This was an indication that pollution in Ngong River due to hydrogen ion concentration had not changed significantly during that period. In-fact there was a positive influence since the pH was high at the entry point but tended towards neutral downstream.

The drainages mean pH values were between 6.34 and 9.77.

The dissolved oxygen (D.O.) levels were low at the entry point and indicated upstream pollution. A seasonal effect was observed during the hot dry months of January and February which had mean D.O. values less than 2 mg/l while levels were above this value in the wet months. The mean B.O.D levels at entry and exit points were 222.9 and 168.6 mg/l respectively. This indicated a significant recovery downstream. The mean B.O.D for drainage samples were between 105.17 and 350.83 mg/l. Drainage D3 and D4 consistently discharged effluents with high B.O.D. Mean C.O.D values ranged between 722.14 and 1536.29 mg/l. A positive correlation between C.O.D and D.O. was observed. While all drainages had relatively high C.O.D levels, D3 in particular sometimes discharged waste waters with C.O.D values above 2000 mg/l. The mean suspended solids levels for the river and drainages ranged between 226.6 and 326.3 mg/l and 123.7 and 322 mg/l respectively. Wet months had lower averages than dry months.

The drainages had mean values of dissolved solids ranging between 468.8 and 1755 mg/l. These values were well above those recorded for river samples. The latter ranged from 377.71 to 651.43 mg/l. Chloride levels increased downstream. All the drainages and especially D3 and D4 discharged consistently high levels of chloride ranging from 96.3 to 239.8 mg/l.

The river mean levels were between 50.14 and 71.71 mg/l.

Turbidity values which ranged from 61.4 to 165 NTU decreased downstream. Most drainages had lower turbidity levels but drainage D4 had consistently high levels. The mean river nitrate and phosphate concentrations decreased downstream. The ranges were 0.99 to 1.83 mg/l and 0.84 to 2.9 mg/l respectively. With regard to corrosivity, Ngong River was also slightly polluted upstream. We obtained weight losses ranging from 9.43 to 10.34% with the higher mean recorded at R1.

Total hardness mean levels as calcium carbonate ranged between 152.28 and 180.14 mg/l. Generally the mean total hardness levels decreased downstream. The mean total hardness levels in the drainages showed no trend. Calcium hardness in the river samples (70.14 to 74.2 mg/l) was three and a half times higher than magnesium hardness. The drainages generally had lower calcium and magnesium hardness than the river. Drainage D3 had consistently high levels of calcium hardness.

With regard to metal pollution, the drainages had higher levels of chromium, lead, iron and zinc. Copper levels in both the river and the drainages were comparable. Manganese was higher in the river than in most drainages. Drainages D4 discharged high levels of chromium, iron and zinc.

Copper was highest at D3. The river point R4 was highly polluted with the above metals. Metal pollution was attributed to both the metal finishing and paint manufacturing activities around D3 and D4.

Discharges from the surrounding industries as well as from slum dwellers upstream of and around the study area were found to contribute significantly to organic pollution. The activities of the surrounding industries contribute to significant pollution of Ngong River particularly with respect to dissolved solids.

CHAPTER ONE

1.0 INTRODUCTION.

Environmental pollution has become a major concern in developed countries in recent years. There is an increasing awareness to minimize the amount of pollutants being discharged into the environment through various activities. Taking water as part of the environment, its pollution has been propagated by continuous growth in population and industrialization, both of which call for additional use of water and subsequent effluent discharge. This causes environmental degradation with serious health problems especially from toxic chemicals.

River pollution manifests itself in many ways. The layman measures the extent of pollution in rivers by the colour changes and suspended matter which floats on the rivers within the urban areas. Large concentration of human life in urban environment causes a lot of harm. In developing countries there is lack of facilities for urban drainage, water supply, solid waste and sewage pre-treatment [1]. Urban run off is typically highly polluted with pathogenic and organic substances that present public health threats especially during heavy rains.

Only about half of the urban population in Kenya has access to sewage disposal. Most of the existing collecting systems discharge directly into the receiving waters without any treatment. Garbage is often either dumped directly into the water bodies or thrown on roadsides or other equally unsuitable areas from where it is often washed into ponds or nearby rivers.

The notorious river pollution agent has been the industry which contributes about 80% of river pollution [2]. Chemical pollution due to the presence of organic or inorganic substances is in general, the commonest type of industrial pollution and one which can create a very critical situation in a river. Pollutants produced by other sources, like residential activities are organic and bio-degradable.

Organic pollution is due to the presence of proteins, fats, carbohydrates and other materials found in sewage and industrial wastes[3]. These carbohydrates, when discharged to the river give abundant food supply to the bacteria and fungi. The metabolic activities of these organisms deplete the dissolved oxygen through the biochemical reactions and the river is rendered anaerobic. The effect of organic contaminants on surface water and its use are becoming increasingly important.

Rapid industrialization and population growth in Nairobi have created major environmental problems. Pollution of rivers passing through the city has been of major concern to both the residents and the authorities [51].

Ngong river is an example of the rivers that are polluted as they pass through Nairobi City. Ngong River acquired its name from where it originates, the Ngong Hills. The river flows within the Nairobi City boundary a distance of about 28 km, 10 km of which is through the main industrial area where it collects various types of pollutants. Simultaneously the river also passes along slum areas which are bordering the river bank.

The study area was selected to coincide with where the effect of the industrial pollution in the river was apparent. This was between Magoini and Fuata Nyayo slums opposite Kenya Commercial Bank on Enterprise Road, and Outer Ring Road bridge , a distance of 14 km. Figure 1 shows the ten sampling points; five along the river and five at the major drains discharging into the river. The description of the sampling points are as follows:

River Point	Location.
R1	Adjacent to Magoini and Fuata Nyayo slums and Kenya Commercial Bank building on Enterprise Road.
R2	Near Kenya Wine Agencies adjacent to Express Kenya Ltd ; about 3 km from D1.
R3	At Enterprise Road bridge about 2 km from D2.
R4	On Lunga Lunga Road next to Lunga Lunga slums.
R5	At Outer Ring Road bridge about 4 km from R4.

Drainage Point	Location	Remarks
D1	1 km from R1 downstream	The drain is about 1 m diameter. Industries nearby include SmithKline Beecham

		and Glaxo Ltd.
D2	1 km from R2	The drain is about 0.5m diameter. It crosses Enterprise Road from Jilore Road. Sadolin Paints Ltd is among the industries near the drain.
D3	1/2km from R3 downstream, adjacent to Orbitsports before Enterprise Rd bridge	The drain is about 1 m diameter. Industries within include Orbitsports and Crown Paints Ltd. The effluent has varied colors.
D4	1/2 km before R4 along Pate Road from Lunga Lunga	The drain is about 1m in diameter. Industries within include Colgate Palmolive, Crown Berger, Patco Industries among others. The drain was discharging constantly throughout the study.

D5	About 2 km from R4, off Lunga Lunga Road.	The drain is about 0.5m diameter. Industries nearby include Aceknit and Kenpoly Ltd.The drain also takes effluent from surrounding slums.

It was difficult to keep regular sampling day times and monthly time intervals. Accessing the river sampling points was also difficult. They were established purposely for this study.

Due to the dynamics involved in urban rivers, particularly with reference to rapid industrial development and excessive population growth, there is urgent need to monitor the status of our urban rivers periodically, say at least once in two years [52]. This type of information is highly needed by government, local authorities and city dwellers.

The objectives of the present work were:

1) to come up with an up to date data on various parameters that would show the causes and the extent of Ngong River pollution.
2) to establish the effects of industrial discharges on the river pollution.
3) to investigate seasonal differences.

In order to achieve the above objective, the following parameters were analysed in both the river and the drainages, monthly from December 1994 to June 1995:

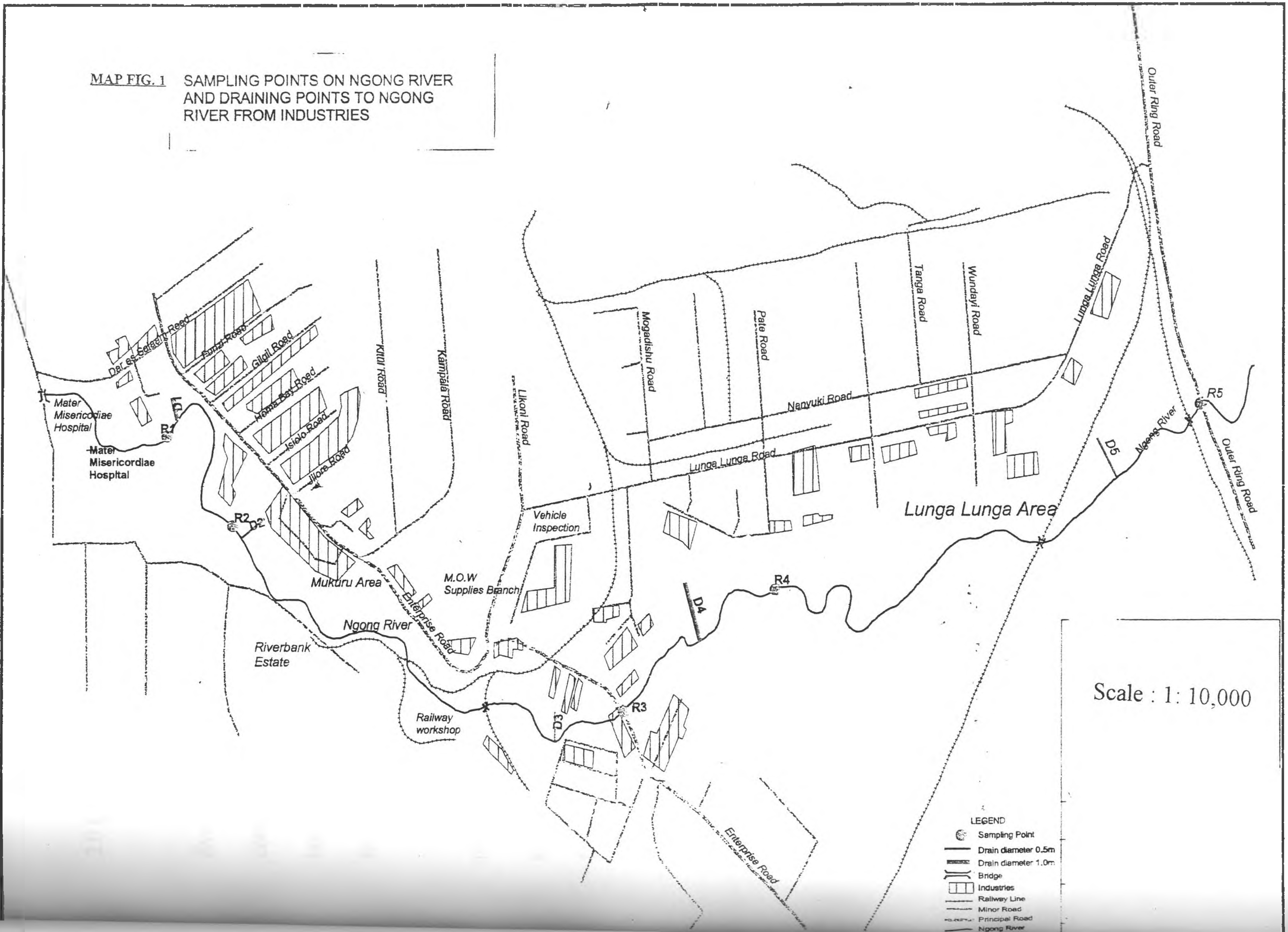
- Temperature
- Hydrogen - ion concentration (pH)
- Biochemical Oxygen Demand (B.O.D)
- Chemical Oxygen Demand (C.O.D)
- Dissolved Solids
- Suspended Solids.
- Chlorides.
- Turbidity
- Dissolved Oxygen
- Total hardness.
- Calcium & magnesium hardness
- Total phosphates (as P-PO4)
- Nitrates as N - NO3
- Corrosivity (as percentage).
- Metals: chromium, copper, iron, manganese, lead and zinc.

The study area and the individual sampling points are shown on the Map Fig. 1. All the large drainages were selected and river water samples were taken at convenient points close to the drainages. The details of the sampling procedure and the standard methods of analysis are given in Chapter Three.

The results were analysed in such a manner as to give indications of how each pollution parameter varied down the river.

The contribution to river pollution by each drain was also analysed. Seasonal variations and comparisons with other local river waters were noted. Reference was made to a study carried out about ten years earlier. Details of all the results obtained are presented in Chapter 4 and Appendix I. The results of this study would be useful to the Nairobi City Council with respect to tracking down and dealing with individual polluters and also in instituting measures to control organic pollution from surrounding slums.

MAP FIG. 1 SAMPLING POINTS ON NGONG RIVER AND DRAINING POINTS TO NGONG RIVER FROM INDUSTRIES



CHAPTER TWO

2.0 LITERATURE REVIEW

Pollution in the water bodies has become a major problem to deal with. Even the so called industrialized countries have found it hard to devise pollution control measures sufficient to restore the ecosystem, mainly because of the long lasting contamination with persistent toxic substances that continue to be released from complex pollution sources.

In North America, over a dozen species of Great Lakes mammals, birds, reptiles and fish are still suffering from high levels of contamination from persistent toxic substances like mercury, cadmium, lead, PCBs, DDT, dioxin, furans, hexachlorobenzene, chlorinated hydrocarbon pesticides and other man-made chemicals released from pulp/paper mills, petrochemical plants, steel mills, various manufacturing facilities, and agricultural activities [4].

These toxic substances are long-lived and can accumulate in living organisms. They are associated with very serious and complex reproductive and other health problems in fish and wildlife. Human beings have also been found to be adversely affected by persistent toxic substances introduced into the Great Lakes [5]. Problems noted include reproductive, metabolic, neurological and behavioural abnormalities. Other effects include immune system suppression and increased levels of breast and other cancers through bioaccumulation in food chains.

These man-made chemicals act like artificial hormones to disrupt the endocrine system [5]. In Michigan, persistent toxic substances have been associated with impaired growth, cognitive malfunctioning and behavioural disorders in children born to mothers who consume several Lake Michigan fish meals each month during pregnancy [6].

The impact of industrial pollution to the water bodies has also been greatly felt in developing countries. In Egypt, the impact of industrial pollution is evident in the decreased fish catch from the Nile, the lakes and from both the Mediterranean Sea and Red Sea. Degradation of water resources, deterioration of valuable recreational areas, severe operational problems in sewerage networks and treatment works and most important serious effects on public health and amenities available to the people have been on the increase. In a recent study [7] about 1,243 industrial plants and production units located within fifty-seven industries were identified as major sources of liquid pollution [7]. Paper, textile and food industries were the main contributors to the organic load in lakes and seas. Concentrations of trace metals were extremely high in tannery wastes, which were being discharged to the sea without prior treatment. High levels of some trace metals were also found in paper conversion, foundry, copper and electronic effluents [7].

In India seventy major industries and two hundred and fifty coal mines are spread around Asanul alone [8]. In terms of oxygen depletion, eight industrial units in Durgapur dump wastes equivalent to the sewerage from a city of one million people.

Ground water pollution has been observed in various industrial towns in the state of Punjab. The industrial units are discharging their effluent on the surface, which through seepage reaches the ground water reservoir. Budha Nala in Luthuania town is a river which runs through the town collecting domestic and industrial wastes. The results of samples collected from Budha Nala indicated that there was high degree of oxygen depletion and dissolved oxygen varies from 0.2 to 8.7 mg/l. In the industrial area of Luthuania town, water samples taken from hand pumps were found to have concentrations of trace elements ranging from 0.05 to 1.75 mg per litre chromium, 0.04 to 0.16 mg per litre copper, 0.05 to 0.17 mg per litre zinc and 0.71 to 4.0 mg per litre iron[9].

Klein [10] reviewed the toxic effects of heavy metals in the biosphere including a case in which industrial effluents produced 1-2 mg per litre concentration of copper in an English river and exterminated all animal life from 16 km downstream. The effect could be observed for 30 km below the discharge even after dilution to 0.1 mg per litre of copper.

In Nigeria, chromium salts produced from exhaust liquors during tanning and retanning contributed 3-100 mg per litre chromium in the effluent[11]. Chromium in some of its various oxidation states is toxic. Adverse effects by low concentrations of chromium on corn and sugar beets have been reported [12].

Work done on nitrates and nitrites concentration in surface waters, bore holes, and wells by Nyanzi[13] showed that nitrate concentrations varied depending on the type of water. In general, the nitrates and nitrites in various waters were in excess of the acceptable levels of 45 ppm for nitrates.

Thermal pollution is a critical water pollution factor. Fish and other living organisms in water can tolerate a relatively narrow range of temperature. Therefore water temperature is a prime factor in determining the distribution of the fish species in a given water environment[53]. When a rise in temperature occurs in a river polluted by organic matter, there is not only the decrease in the dissolved oxygen but also an increased rate of utilization of dissolved oxygen by biochemical reactions which usually proceed faster at high temperatures.
This gives the river bad odours and varied colours start appearing. The temperature of water is important to the aquatic life and it influences the microbial self purification of the river [10].

The measure of hydrogen ion, concentration (pH) gives the chemical condition which prevails in the river [14]. Owing to the variety of substances which occur naturally in the water, there are many compounds which contribute to the presence of hydrogen ions. In various kinds of open dynamic natural water systems, hydrogen ion concentration varies from 5.5 to 10.5. However, the surface waters of larger lakes undergo relatively insignificant changes in hydrogen ion concentration from season to season [15].

Most unpolluted waters exhibit pH values on the alkalinity side and the maintenance of a normal pH range is very important for the aquatic life in the river. Recent studies [36] have shown that waters having a pH range from 6.7 to 8.6 will generally support a good fish population and have no effect on processes like growth and reproduction.

The pH of water has a marked effect on the toxicity of substances commonly present in industrial wastes [3].

Normally the appearance of the water in a river changes seasonally. A river that flows through a city changes its appearance after a rainfall because of street run off, surface run off from industries and sewage overflows which adds into the river. The amount of suspended solids in the river water depend on the quality and quantity of discharged wastes and also on the processes occurring in the whole catchment and in the river bed itself [16]. The insoluble matter in suspension is one of the commonest forms of pollutants in sewage and in most industrial waste waters [17]. Suspended matter is largely organic in nature [18]. It has been found that fish can exist in rivers containing up to 75 ppm of suspended solids of various types [19]. It is therefore difficult to draw a cut-off line between harmful and harmless levels of suspended solid particles. Certain conditions of acidity may liberate metals in soluble form from the suspended matter contaminated by metallic compounds and this may lead to fish mortality. A high level of suspended matter in a river hinders the penetration of light through the river and light penetration can be reduced by 50% in muddy water and by about 75% in very turbid water composed of living and dead phytoplankton and zooplankton, silt, human sewage, animal excrement, portion of decaying plants and animals and a vast range of industrial wastes [19].

Phosphorus compounds of streams are derived from biological and chemical processes along the course of the stream. Small quantities of phosphorus are weathered from rock minerals and held in soils from where low concentrations leach into the ground water and eventually into streams.In water catchment areas which have been altered by human activity, phosphorus enters natural waters from a number of sources. Orthoposphates applied to agricultural land as fertilizers are held tightly by the soil. Small amounts enter the river in solution while large amounts are carried by eroded soil particles. Domestic sewage is another important contributor of phosphorus to rivers since primary and secondary treatment remove only about 20 to 30 % (about 2 mg/l) of the element. More than one-half of the total phosphorus in domestic waste water is contributed by detergents and is in a form known as condensed phosphate, which may be in solution or solid form. Sodium salts are derived from phosphoric acid as follows:

$$H_3PO_4 + Na_2CO_3 \xrightarrow{\text{heat}} Na_2HPO4 + CO_2 + H_2O$$

$$2H_3PO_4+2Na_2CO_3 \xrightarrow{\text{heat}} Na_4P_2O_7 + 2CO_2 + 3H_2O$$

$$Na_2HPO_4 + NaOH \xrightarrow{\text{heat}} Na_3PO_4 + H_2O$$

Storm water run off from urban areas also wash high concentrations of phosphorus wastes into rivers. Industrial sources of phosphorus effluent are highly variable, depending on the form of the enterprise. Phosphate mining and milling, the processing of agricultural and animal products, as well as some chemical industries such as detergent plants are major contributors[20].

Inputs of nitrogen generally originate from the same sources as phosphorus. There are a variety of nitrogen forms ranging from those incorporated into organic detritus, compounds of ammonia in the process of being degraded, nitrates which are fully oxidised and stable nitrogen compounds in most surface waters. Streams from forested catchments have nitrate concentrations of about 0.1 mg/litre and organic nitrogen contents of the same magnitude. Agricultural regions heavily fertilized with ammonium salts sometimes yield run off with nitrate concentrations exceeding 1.0 mg/l, and smaller amounts of organic nitrogen [21]. Nitrates are held loosely in soils and are easily leached out to the ground water. In heavily fertilized croplands and feedlots, the nitrate concentration of ground water can exceed 100 mg/l and this has been linked to methemoglobinemia ("blue baby syndrome") among infants drinking the water.[13]

Domestic sewage averages more than 20 mg/l of total nitrogen, whereas urban storm water averages more than 1.0 mg/l of total nitrogen. Industrial sources of nitrogen are at least as variable as those of phosphorus, with food processing and chemical industries, such as the manufacture of fertilizers and explosives being among the worst offenders. European standard for drinking water recommends a nitrate concentration of between 50 - 100 mg/l nitrogen as NO_3 as acceptable range [19].

Chloride in drinking water is generally regarded as relatively harmless if present in small amounts. The World Health Organisation has quoted 200 µg ml^{-1} as the level above which undesirable health effects may be noted. It occurs naturally in rainfall, and levels of 10 µg per ml are not uncommon in coastal regions [22].

Biochemical oxygen demand (B.O.D) is one of the most widely used chemical indicators of the water pollution. It is the amount of the oxygen required by the micro-organisms like bacteria to break down the decomposable organic matter in a waste water sample under aerobic conditions [22]. The B.O.D test is an imperial bioassay type procedure which measures the dissolved oxygen consumed by bacteria and other microbial life. The B.O.D standard test conditions are incubation at 20°C in the dark for a specified period of time, usually 5 days. The reduction in dissolved oxygen concentration during this time is a measure of the biochemical oxygen demand.

Another important parameter in water quality analysis, especially wastes from the industrial sector, is the chemical oxygen demand (C.O.D).Although not biochemical in nature, C.O.D test is included because of its close relationship to B.O.D test. Many organic compounds do not undergo biological decomposition fast enough to be taken into account by a 5 - day B.O.D. test; while others may never undergo biological decomposition hence the use of a strong oxidizing agent like potassium dichromate in the C.O.D test. Glucose (biologically degradable) and lignin (biologically resistant) are both oxidized completely. As a result, C.O.D values should be greater than B.O.D values and may be much greater when significant amounts of biologically resistant organic matter is present in a water sample. C.O.D test is a measure of oxygen equivalent of the organic matter content of a water sample susceptible to oxidation by a strong oxidant under specified conditions of oxidising agent, temperature and time. Potassium dichromate has been found to be the most practical oxidising agent due to its ability to generate abundant oxygen atoms.

Total dissolved solids (TDS) gives the total concentration of dissolved solids in a water sample. The following constitute dissolved solids: phosphates, nitrates, alkalis, some acids, sulphates, iron, magnesium and most of the inorganic pollutants.

TDS determination gives a quick assessment of the general water quality.

Since most dissolved solids impart the ability to conduct electricity to water, a more rapid determination of T.D.S is by measuring conductivity which is proportional to TDS. Rivers containing T.D.S. values below 50 ppm are considered "salt poor".

They contain a few nutrients to support a reasonable plant and animal population [10]. Streams in arid areas tend to have high concentrations though their total annual solute transport is low because of low runoffs.

The situation is the same in rivers passing through industrial areas whereby during dry seasons, the TDS concentration is very high as compared to rainy seasons when the flows are fast and there is no time for the solutes to settle.

Dissolved oxygen is essential to all forms of aquatic life including those organisms responsible for the self-purification processes in natural waters [21]. The oxygen content of natural waters varies with temperatures, salinity, turbulence, the photosynthetic activity of algal and plants and atmospheric pressure. The solubility of oxygen decreases as temperature and salinity increase. In fresh waters, the dissolved oxygen (DO) at sea level ranges from 15 mgl^{-1} at 0°C to 8 mgl^{-1} at 25°C [23]. Concentration in unpolluted waters are usually close to but less than 10 mgl^{-1}. DO can also be expressed in terms of percentage saturation and levels less than 80% saturation in drinking water are usually detected by consumers as a result of odour and taste.

Variation in DO occurs seasonally or even over 24 hour periods in relation to temperature and biological activity like photosynthesis and respiration. Biological respiration including, that related to decomposition process, reduces DO concentrations. Waste water discharges from industries high in organic matter and nutrients can lead to decrease in DO concentrations as a result of increased microbial activity occurring during the degradation of the organic matter. The measurement of DO can be used to indicate the degree of pollution by organic matter, the destruction of organic matter and true level of self-purification of the water.

In severe cases of reduced oxygen levels (whether natural or man made) anaerobic conditions can occur i.e., 0 mgl^{-1} of oxygen concentrations. Determination of DO is a fundamental part of water quality assessment since oxygen is involved in or influences nearly all chemical and biological processes within water bodies. Concentrations below 5 mgl^{-1} may adversely affect the functioning and survival of biological communities and below 2 mgl^{-1} may lead to the death of most fish.

Turbidity in water is an expression of the optical property of water that scatters light [24]. The scattering increases with suspended particulate matter which reduces light penetration and restricting photosynthesis by plants, it also reduces vision of animals. The presence of fine materials of colloidal, clay, or even silt size gives water a cloudy or opaque appearance.

Turbidity increases with but not as fast as suspended load concentration, it reduces the depth to which sunlight penetrates and thus alters the rate of photosynthesis and thus reducing the amount of lives which depends on light [25].

Hardness in natural water is mainly caused by calcium and magnesium ions. These ions are mainly present in water as sulphates, chlorides and bicarbonates.

In most natural waters hardness is almost entirely due to bicarbonates mainly calcium bicarbonate and to a lesser degree magnesium bicarbonate [26]. The presence of compounds like calcium chloride and magnesium sulphate depends primarily on the geology of the land around the water body and also one cannot rule out pollution from industries as a possible cause of hardness.

Hardness in water is undesirable for many reasons, most of which are economical. Calcium and magnesium ions in water reacts with soap to form curds which hinder effective washing. Further, when these ions are present as bicarbonates they precipitate out when the water is heated, forming the familiar tea kettle scale and the costly boiler.

Corrosion is defined as the deterioration of material (or its properties) because of a reaction with its environment. Water is termed corrosive when it has some characteristics which affects the occurrence and corrosion of a material in it [27]. The characteristics of water that affects rate of corrosion can be classified into three categories i.e., physical, chemical and biological. In most cases corrosion is caused by a complex interaction among several factors [28]. Flow velocity and temperature are the two main physical characteristics of water that affects its corrosivity. High velocity waters combined with other corrosive characteristics can rapidly deteriorate the materials used to or the water piping system.

Low velocities also causes tuberculation and pitting especially in iron pipes and on aerators made of iron as well as promoting biological growth. Temperature effects are complex and depend on water chemistry and type of construction material present in the system. The rate of all chemical reactions including corrosion reactions in water increases with increase in temperature.

Temperature significantly affects the dissolution of calcium carbonate. Less calcium carbonate dissolves at high temperature leaving $CaCO_3$ to precipitate out to form a protective coating which reduces the corrosion of the material in system. Chemically the factors that affect corrosion are so closely related that a change in one changes the other. The most importance of this relationship is between pH carbon dioxide and alkalinity. The important corrosion effect results from pH and pH is affected by a change in CO_2. Since H+ is one of the major substances that accept the electrons given up by a metal when it corrodes, pH is an important factor to measure.

At pH values below 5, iron and copper corrode rapidly and uniformly while at pH values higher than 9 they are protected. pH also affects the solubility of protective films. Dissolved oxygen is also another important and most common corrosive agent. In many cases it is the substance that accepts the electron given up by the corroding metal as shown below in the case of iron.

$$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$$

$$\underline{\qquad\qquad Fe \rightarrow Fe^{2+} + 2e^-}$$

$$4Fe^{2+} + 3O_2 + 6H_2O \rightarrow 4Fe(OH)_3$$

When total dissolved solids level is high in water conductivity and corrosion rate increases, while magnesium and calcium precipitate out of hard water forming protective film on the system material thus reducing corrosion. Chlorides and sulphates when in high levels increase corrosion of copper and iron. Natural colour and organic matter usually decrease corrosion.

Heavy metals and trace elements are natural constituents of the aquatic environment and they also play a very important role in biological systems of any living matter. The elements are divided into two groups, namely the essential elements and the non-essential ones. The essential elements are known to maintain living organisms and the non-essential ones are not known to be having any biological function in living organisms. The non-essential elements are characterized by severe toxicological effects at very low levels [29]. Among the elements known to be essential for animal life include copper, iodine, iron, zinc, manganese, molybdenum, cobalt, selenium, chromium, nickel, tin, silicon, fluorine and vanadium [30].

Toxicity refers to the potential of a given substance to cause harm in living organisms and the extent of damage it has on a particular organism.

Generally all metals are toxic if taken or administered in excessive amounts.

The toxicity of heavy metals is as a result of their binding to the active sites of important enzymes in the cells and to some ligands in the membrane cells thereby interfering with normal cell functions.

Heavy metals are mainly considered toxic in their soluble ionic forms. In hard waters, toxicity of heavy metals is known to be reduced [31]. Natural concentrations of heavy metals in water bodies are considered to be very low possibly due to high reactivity of metals in solution, as they may be removed by many physicochemical and biochemical processes to the biotic phase.

In surface waters, the concentration of various elements may be increased beyond their natural levels due to the very many activities taking place on the environment surrounding the water. Domestic, agricultural, industrial and other waste releases have been the major causes of increased levels of elements in natural waters. These heavy metals are mainly present in water as soluble or bound to particulate. The trace heavy metals which are absorbed to suspended matter or dissolved in the water may accumulate to a level where they become hazardous to health, when they become available to man directly or via the food chains. Trace metals also affect living organisms in the receiving water [32]. The accumulation of the heavy metals both in the aquatic and interrestial environments can cause adverse alteration in the structural and functional systems in the biota.

Chromium is one of the few chemically inert trace element and this accounts for its extensive use as an electroplated, protective coating in metal plating. It is an essential trace element acting as the glucose tolerance factor and it is also found in small quantities in the RNA of a few organisms.[5].

Chromium being used in metallurgy, finds its way into the surface waters through metal finishing processes such as electroplating, pickling and bright dipping. Uncontrolled emissions have great potential for contaminating the fresh waters with the relatively toxic form, Cr(+6) [30]. Chromium (+6) are from the additive in circulating cooling waters, laundry chemicals and animal glue manufacture. Other sources of chromium (+3) include liquid waste discharges from leather tanning and textile dyeing.

In natural waters chromium (+3) is the most stable and important oxidation state since it forms a large number of relatively kinetically inert complexes which can be isolated as solids.

Municipal waste waters release considerable amounts of chromium into the rivers which create a sharp drop in the concentration of dissolved oxygen content with hydrogen sulphide production.

Total chromium levels in raw water are usually 10 mg/litre or less. Rarely do levels exceed 25 g/litre except in highly contaminated situations. There is a tendency for the naturally occurring high levels of chromium to be associated with waters of the greatest hardness [33]. Deficiency of chromium leads to diabetes melitis.

Copper in the environment is widely distributed in the free state and also as sulphide, arsenide, chlorides and carbonates. Copper exhibits a wide variation in its properties such as spectral, magnetic, duplexing capacity and oxidation state.

Sources of copper are as varied as its properties. It is found in metal plating, industrial and domestic wastes, mining and mineral leaching. Copper is an essential trace element not very toxic to animals but toxic to plants and algae at moderate levels.

Several copper-containing proteins have been identified in biological systems. Oxygen binding haemocyanin, cytochrome oxidase, tyrosinase, lactase and Ceruplasmin, a blue protein in mammalian serum which accounts for over 95% of the circulating copper in mammals are examples of these[11].

In aquatic environments, copper can exist as particulate colloid and soluble forms and its speciation in natural waters is determined by the physico-chemistry, hydrodynamic characteristics and the biological state of water.

Human exposure to copper is through food. Copper deficiency may cause anaemia and Menke's disease (a genetic disorder) whose symptoms are cerebral degeneration, depigmentation of skin and hair and steely hair.

Copper toxicity also has got its side effects. Copper accumulates in the liver and brain to high concentrations resulting into Wilson's disease which is an inherited autosomal recessive disorder. The clinical disorders of copper toxicity are nausea, vomiting and intravascular haemolysis with resistant juorndice and acute renal failure [34].The toxicity of copper to algae and bacteria is utilized in controlling algal bloom by use of bordeaux mixture which is a fungicide as well as an algacide.

Iron is one of the major constituents of the lithosphere and comprises approximately 5 per cent, being concentrated mainly in the mafic series of magmatic rocks. The geochemistry of iron is very complex in the terrestrial environment and is largely determined by easy change of its valence states in response to the physicochemical conditions [4]. Some of the sources of iron are corroded metal, industrial wastes, acid mine drainage, low PE water in contact with iron minerals.

Iron is essential to all organisms, it exists in the animal body mainly in complex forms bound to protein (hemo proteins), as heme compounds (haemoglobin or myoglobin), as heme enzymes (mitochondrial and microsomal cytochrome, catalase and peroxidase), or as non-heme compounds such as flavin iron, enzymes, transferrin, and ferritin. Iron plays a vital role in animal metabolism mainly confined to the process of cellular respiration, as a component of haemoglobin, myoglobin and cytochrome. Iron is one of the least toxic of the essential trace elements. Its toxicity is characterized by reduced feed intake lowered daily gain, diarrhoea, hypothermia and metabolic acidosis [5].

Severe cases of iron toxicity leads to haemolytic anaemia. In plants, iron deficiency leads to intervenial chlorosis of young organs and in human, it leads to myocardiac inflammation and acute inflammation.

Manganese is one of the most abundant elements in the earth's crust. Its sources are mining, industrial waste, acid mine drainage and microbial action on manganese minerals at low potentials. Manganese and its compounds are used in making steel alloys and in the production of non-ferrous alloys such as bronze for machinery requiring high tensile strength and in alloys with copper and nickel in electrical industry. It is also used as an oxidizing agent in the chemical industry and also in medicine as germicide and antiseptics.

Manganese is an essential element and occurs in all living organisms. It finds its way to human being through water, air and food, with food being the major source. In humans, manganese is incorporated in the enzyme, arginase, concerned with urea formation. Manganese is also used in the formation of glycoproteins and in general carbohydrate metabolism. Dismutation of superoxide from the body is by the aid of manganese.

Manganese is least toxic to humans and there are no clear cut cases of symptoms of manganese toxicity except for cases of prolonged exposure which results in acute hepatitis and myocardiac infarctin. Manganese is toxic to plants at high levels and it stains materials (bathroom fixtures and clothing).

Lead is an element which is a natural constituent of the environment. It is relatively abundant and occurs in association with copper and zinc in their polymetallic ores. Lead is a highly toxic metal. It is widely distributed in the environment because of its use in the motor vehicle industry as an anti-knock. Lead occurs in water in the (+2) oxidation state and arises from a number of industrial and mining sources.

Lead is one of the oldest metals known to man and since medieval times it has been used in piping, building materials, paints, type metal and castings. In more recent times, lead has been used mainly in storage batteries, metal products, chemicals and pigments. In chemicals, tetraethyl lead constitutes an antiknock agent in gasoline. The production of non leaded gasoline for use in automobiles with emission control devices has sharply reduced the use of tetraethyl lead in gasoline since 1972. Combustion oil and gasoline accounts for 50 % of all anthropogenic emissions and thus form a major component of the global cycle of lead.[31]. Automobile exhaust accounts for about 50 % of the total organic lead absorbed by humans. Concentrations of soluble lead in uncontaminated fresh waters are generally less or equal 3μg per litre (Forstner and Wittman 1979).

However, much higher levels occur near highways and cities due to combustion of gasoline. In aquatic plants, high lead residues are often accumulated in plants inhabiting polluted waters. In fish, there is often little accumulation of lead in marine and freshwater species, consequently lead is not a threat to fisheries resources except in cases of extreme pollution.

In biological systems toxicity of lead is based on the fact that it replaces the sulphdryl (SH) groups on the enzyme, rendering the enzyme inactive. It also inhibits the synthesis of heme and the utilization of iron in the body resulting into anaemia cases [35].

Sources of Zinc are industrial waste, metal plating and plumbing. Zinc oxides are used in the plant industry, rubber, chemical industry and agriculture. Zinc being used in different manufacturing, is a common pollutant in industrial effluent.

Zinc is an essential element that is important to life as principal vitamins [33]. Zinc is an essential element in many metalloenzymes [11]. Zinc was found to act as a co-factor in a variety of enzymes like arginase, carbonic anhydrase, alcoholic dehydrogenase and other zinc activate enzymes. It is also important in wound healing. At high levels zinc is toxic to plants so it is a major component of sewerage sludge which limits disposal of sludge to agricultural land.

Human main intake of zinc is through foodstuff like fish, shellfish, meat products, legumes and whole grain.

Although zinc is essential element needed at micro-nutrient concentrations, excessive intake of zinc leads to parakeratosis, dehydration and profound weaknesses. Zinc deficiency leads to leukaemia, cirrhosis, infectious diseases, -and other genetic disorders like sickle cell disease [34]. The World Health Organisation has recommended daily dietary zinc intake from 6 mg (infants) to 27 mg (lactating mothers).

Analysis of water from seven Kenyan lakes for heavy metal concentration gave data that compared satisfactorily to the drinking water standards as given by World Health Organisation (WHO) [50].

CHAPTER THREE

3.0 ANALYTICAL TECHNIQUES AND METHODOLOGY

3.1 SAMPLING

Water samples were taken at the identified sampling points as shown in Figure 1. A day before each sampling, the polyethylene sample containers were thoroughly washed with water, soaked in chromic acid (a mixture of sulphuric acid and potassium dichromate) and then rinsed with distilled water. The volume of samples taken and the pre-treatment procedure depended on the type of analysis planned. Samples for elemental analysis were collected in 250 ml plastic bottles and their pH were reduced to about 2 with nitric acid (Aristar).

This low pH was meant to prevent any metabolic processes which might cause changes in the sample's chemical composition and also reduce adsorption of metals on the surface of the containers. For phosphate and corrosivity tests, the samples were collected in 500 ml plastic containers. Containers for samples meant for phosphate analysis were not at any time washed with phosphate containing detergents. For all other tests, samples were collected in 1 litre plastic containers. The samples were then transported to the laboratory immediately and stored in the refrigerator.

3.2 ANALYTICAL TECHNIQUES AND METHODOLOGY

3.2.1 Temperature: Temperature was determined on site using a mercury thermometer which was read to an accuracy of ± 0.05°C. The thermometer was immersed into the sample contained in a 5 litre sample bottle.

3.2.2 Hydrogen ion Concentration: pH was determined in the laboratory using a reference glass electrode.

3.2.3 Dissolved Oxygen: This was determined on site using a digital dissolved oxygen meter.

3.2.4 BioChemical Oxygen Demand (B.O.D) The B.O.D test was done in the laboratory. Two solutions were drawn from each sample and prepared as described below. The initial dissolved oxygen was determined using one of the solutions. The other set was incubated at 20°C for 5 days in darkness after which the amount of dissolved oxygen remaining in the incubated sample was measured. The difference between the initial dissolved oxygen in each sample and the final dissolved oxygen after incubation gave the amount of oxygen required for oxidizing the organic matter in the sample.

The following stock solutions were used for B.O.D. determination:-

(a) Ferric chloride: 0.25 g $FeCl_3.6H_2O$ was dissolved in 1 litre distilled water.

(b) Calcium chloride: 11.0 g $CaCl_2$ was dissolved in distilled water and made up to 1 litre with distilled water.

(c) Magnesium sulphate : 10.0 g $MgSO_2.7H_2O$ was dissolved in distilled water and made up to 1 litre.

(d) Phosphate buffer stock solution: 34 g potassium dihydrogen phosphate (KH_2PO_4) was dissolved in 500 ml distilled water. Then 175 ml 1 N sodium hydroxide solution was added and this gave a pH of 7.2. To this solution, ammonium sulphate $(NH_4)_2SO_4$ was added and diluted to 1 litre.

To a litre of distilled water, 0.5 ml of solution (a), 2.5 ml of solution (c) and 1.25 ml of solution (d) were added in an aspirator bottle and aerated for 45 minutes. The sample pH was adjusted to about 7 with standard acid or alkali solutions using a pH meter. It was placed in 1 litre volumetric flask and topped with distilled water.

The 250 ml B.O.D bottles to be used were rinsed with hydrochloric acid and thoroughly with distilled water. They were filled in duplicates with the diluted samples in the volumetric flasks. A blank made up of dilution water was also prepared in duplicate. One diluted sample in the B.O.D bottle and one blank sample were water-sealed and then incubated for 5 days in the dark at 20 degrees centigrade. The dissolved oxygen concentrations in the remaining diluted sample and blank were then determined.

After 5 days the stopper of the B.O.D. bottle was removed and in quick succession, 0.7 ml of N-free concentrated sulphuric acid followed by 1 ml of N/80 $KMnO_4$ solution were added.

The mixture was shaken and allowed to stand for 20 minutes. It developed a pink colour which was removed by adding 0.5 ml potassium oxalate. After 5-10 minutes, more potassium oxalate solution was added, 1 ml manganous sulphate and 3 ml alkali iodide were also added.

100 ml of the incubated sample treated as explained above was titrated with N/80 sodium thiosulphate solution using starch as indicator.

After a complete reaction, the following equation is expected :-

(CH_2O), the consumption of oxygen in water by degradation of organic matter

$(CH_2O)_n + 3/2\ {}_nO_2 \rightarrow nCO_2 + nH_2O$

Calculation

Formula (1): B.O.D. = $(x-y)(a+1)$ when the two blank samples had the same D.O.

Formula (2): B.O.D. $= \frac{(x-y)-(az)a}{a+1} + 1$ ppm with blank difference

when the two blank samples had different D.O. values.

where:
x = initial D.O
y = final D.O.
a = volume of diluting water used in 1 litre.
z = blank difference.

3.2.5 Chemical Oxygen Demand (C.O.D)

This is a measure of oxygen equivalent of the organic matter content of a water sample susceptible to oxidation by a strong oxidant. This test was done in the laboratory by taking 20 ml sample or diluting the samples to 20 ml, then refluxing for 2 hours.

In this study, concentrated sulphuric acid with silver sulphate was used. After refluxing the samples were cooled and titrated against ferrous ammonium sulphate using ferroin indicator.

This can be represented by the following chemical equation :-

$K_2Cr_2O_7 + 4H_2SO_4 \rightarrow K_2SO_4 + Cr(SO_4)_3 + 4H_2O + 3O^{\cdot}$

The oxygen atom is then taken up by the organic matter.

Experimental Procedure

To about 0.4 g $HgSO_4$ placed in a refluxing flask, 20 ml of sample or sample diluted to 20 ml with distilled water and 10 ml standard potassium dichromate solution were added.

The condenser was then connected to the flask and 15 ml concentrated sulphuric acid was added to the contents in the flask through the condenser opening.

The mixture was then refluxed for 2 hours, cooled and the condenser washed down into the mixture with distilled water. The mixture was then diluted to about 80 ml with distilled water and cooled to room temperature. The resulting mixture was then titrated against standard ferrous ammonium sulphate solution

using ferroin indicator. A blank consisting of 20 ml distilled water was treated in the same way as the samples.

Calculation

C.O.D. (mg per litre) = 8000M (A - B) per ml sample where:

A = ml titrant used for the blank.

B = ml titrant used for the sample.

M = molarity of the titrant.

3.2.6 Suspended Solids

The determination of suspended solids is one of the most important tests for sewage and industrial effluents. The removal of matter suspended solids in raw sewage or industrial waste, is indeed one of the indications of the efficiency of settling tanks.

In this study, 100 ml sample was filtered through asbestos glass fibre filter and the filter dried at 103°C.

An asbestos fibre filter was dried in the oven at 103 to 105°C for 1 hour and then stored in a desiccator. It was weighed just before use, mounted onto a suction pump and a known volume of the sample filtered through the filter was carefully removed and dried in the oven at 103°C till a constant weight was achieved. It was cooled in a desiccator and then weighed. The difference between the weight of the dry filter containing filter residue and the empty filter gave the amount of suspended solids in the volume of a sample.

3.2.7 Dissolved Solids

The sample was shaken well and filtered through a diatomaceous earth filter. 100 ml was placed in a crucible which was previously washed and dried at 103°C in an oven to a constant weight. The crucible was cooled in a desiccator before weighing. The difference in weight of the crucible gave the amount of dissolved solids in a given volume of sample.

Calculation

Dissolved solids, mg / litre = g dissolved solids x 10^6 per ml.sample

3.2.8 Chlorides

In chloride determination, the Volhard method was used. The following reagents were used:

a) 0.0282 N silver nitrate solution.

b) Potassium chromate solution indicator.

Calculation

Chloride as Cl^{-1} ppm = 35450N(A - B)/ ml.sample.

where: A = ml of titrant used in sample.
B = ml of titrant used in blank.
N = Normality of titrant.

3.2.9 Nitrates

The brucine method was used in this study and compared to the Lovibond comparator method [26].

Fresh standard nitrate solution was prepared from the stock solution by diluting 10 ml stock solution to 1000 ml. Various concentrations were made ranging from 0.1 to 2 mg per litre sodium nitrate for calibration curve. 10 ml water sample or diluted to 10 ml was placed in a reaction tube and 2 ml NaCl added while swirling. 10 ml sulphuric acid solution was then added and the mixture swirled before cooling. A 'blank' consisting of distilled water was also treated as above.

The reaction tubes were then placed in a cold water bath inside a fume cupboard and 0.5 ml brucine sulphanilic acid solution added as swirling continued.

The reaction tubes were then transferred into a well stirred boiling water bath at a temperature above 95°C for 20 minutes after which the tubes were again transferred back into the cold water bath until thermal equilibrium was reached. PERKIN ELMER 35 Spectrophotometer was used in this study and calibrated using the "blank" and the standard solutions at 410 nm after which direct readings of the samples for nitrates were taken.

3.2.10 Total Phosphates: Total phosphates was determined based on colometric methods. In this case, an orthophosphate yellow complex was developed and determined.

The method embodied two general procedural steps:-

(i) Conversion of the phosphorus form of interest to dissolved orthophosphate.

(ii) Colorimetric determination of dissolved orthophosphate.

The perchloric acid method, which was time consuming was used since in procedure (i) most of the samples were industrial effluent which are termed as difficult samples.

100 ml sample was filtered and put in a 400 ml clean beaker. The sample was then taken into a fume cupboard and concentrated to about 50 mls by heating. The sample was then cooled and 5 ml concentrated nitric acid was added together with 1 ml perchloric acid. A few boiling chips were added and the beaker was covered with a watch glass. The solution was concentrated by heating to dryness until the fumes turned from brown to colourless. The rate of heating was controlled in order to minimize loss of liquid through splashing which was brought about by the escaping fumes.

The sample was then cooled and 20 ml distilled water was added and this mixture was brought to boiling in a few minutes . The sample solution was filtered into a 25 ml volumetric flask and then topped, to the mark with distilled water. From this volumetric flask, 10 ml was taken out and put into a 50 ml volumetric flask. To this solution was added 5 ml vanado-molybdate reagent and the mixture made to the 50 ml mark with distilled water. A blank consisting of distilled water was prepared in the same way as the samples.

Different concentration of phosphate standards were prepared by diluting the phosphate stock solution to the desired volumes and treated in the same way as the samples. The standards were allowed to stand for 10 minutes for the colour to develop.

The Pye-Unicam SP-150 spectrophotometer was then calibrated using the "blank" and the standards at 450 nm. The absorbance of each sample solution was taken and later used for the calculation of the actual concentrations of phosphates in the original water samples as P - PO_4.

Calculation

Actual concentration of P - PO_4 or mg Phosphorus per litre=mg P(in 50 ml final volume)×1000/ml.sample read directly.

or concentration in mg/litre = Absorbance/mean slope.

Slope was calculated by: Absorbance ÷ concentration of the standard solutions.

3.2.11 Corrosion

The corrosion tests for the water samples collected were determined by the method of cutting of pieces of iron sheets and dipping in water samples. Pieces of iron sheets were cut into almost uniformly sizes, weighed and immersed in water samples for a period of time.

Experimental procedure:

The pieces of iron sheet were cleaned with acetone then weighed. Each of the weighed pieces was put in a 400 ml beaker and 300 ml of water sample was added . The iron sheet piece was left in the sample for a week then it was removed and dipped in a mixture of stannous chloride and 3M HCl solution.

This solution removed corrosion products. The sheet was then cleaned with a zero number sand paper, cleaned thoroughly with acetone after which it was weighed again.

Calculation

% corrosivity = 100 (W1 - W2) / W1

where W1 = weight of iron sheet before immersing into sample.

W2 = weight of iron sheet after immersing into sample.

3.2.12 Turbidity:

The test was done in the laboratory within 24 hours of sampling. The test was done by using a turbidimeter. This instrument was calibrated using standards that were selected based on how the sample appeared.

The sample was put in a turbidimeter bottle and after calibrating the instrument, the bottle was inserted into the instrument and readings taken in NTU units.

3.2.13 Total hardness:

The test was performed in the laboratory by titration method.

To a 100 ml sample in a conical flask, 1 ml of buffer solution was added followed by one total hardness indicator tablet which was and made to dissolve. The resulting solution was then titrated with E.D.T.A. solution with continuous mixing. The end point was marked with a colour change from red to blue.

Calculation

Total hardness as $CaCO_3$ = $1000V_2/V_1$ mg/litre

where: V_1 = ml sample

V_2 = ml N/50 E.D.T.A.

3.2.14 Calcium Hardness

50 ml sample was measured, boiled to drive off carbon dioxide then cooled 2 ml Normal NaOH and one calcium hardness indicator tablet (Calmagite) were then added. After the tablet was dissolved, the solution was titrated against magnesium chloride free N/50 E.D.T.A.

Calculation

Calcium hardness = $\frac{1000\ V_2}{V_1}$ mg / litre $CaCO_3$ or $20V_2$ mg/litre $CaCO_3$

where V_1 = ml sample

V_2 = ml N/50 E.D.T.A.

3.2.15 Magnesium Hardness

This was calculated using the difference between total hardness and calcium hardness as follows:

Magnesium hardness = (Total hardness - Calcium hardness) / 4.12

3.2.16 Elemental Analysis

Concentrated nitric acid (Aristar) was used to digest the samples because it could reduce interference by organic matter and also convert metal associated with particulates to a form that could be determined by atomic absorption spectrometry. The AA-680 atomic absorption spectrophotometer equipped with a micro-computer CRT display and graphic printer was used. Direct air-acetylene flame was employed.

i) Chromium: 0.1923 g CrO_3 was dissolved in water and when dissolution was complete, 10 ml concentrated HNO_3 was added. The solution was diluted to 1000 ml in a volumetric flask to give a concentration of 100µg Cr /ml.

ii) Copper: 0.1 g copper metal was dissolved in 2 ml concentrated HNO_3 . A further 10 ml concentrated HNO_3 was added and the solution diluted to 1000 ml with water to a concentration of 100 µg Cu /ml.

iii) Iron: 0.1 g iron wire was dissolved in a mixture of 10 ml HCl and HNO_3 , the 3 ml concentrated HNO_3 was added and a further 5 ml concentrated HNO3 and diluted to 1000 ml with water to give a concentration of 1000 µg Fe /ml.

iv) Manganese : 0.1 g manganese metal was dissolved in 10 ml concentrated HNO_3. This solution was then diluted to 100 ml with water to give a concentration of 100 µg Mn /ml.

v) Lead: 0.1598 g lead nitrate, Pb (NO_3) was dissolved in a minimum amount of concentrated HNO_3 after which 10 ml concentrated HNO_3 was added. This solution was then diluted to 1000 ml with water to give a concentration of 100 µg Pb /ml.

vi) Zinc : 0.1 g zinc metal was dissolved in 20 ml HCl and diluted to 1000 ml with water to give a concentration of 100 µg Zn /ml.

Samples, as explained earlier were filtered into 100 ml conical flasks. Different concentrations were made from the stock solutions for the calibration curve ranging from 1 ppm to 6 ppm in the case of Cr, Cu, Fe, Mn and Pb.

Zinc calibration standard solutions were made from 0.5 ppm to 3 ppm. With the exception of chromium standard solution, the above standard solutions were made by pippeting the required volumes into 100 ml volumetric flasks then making it upto the mark with deionized water. For the chromium standard solutions, 5 ml NH_4 Cl solution was pippeted in every flask before the required volumes were made to the mark with deionized water. This was to change other oxidation states of chromium to oxidation states which did not create a lot of interferences in the analysis.

A blank composed of deionized water was then aspirated into the AA-680 spectrophotometer and its absorbance recorded on the CRT display. The procedure was repeated with standard solutions starting from the low to the high concentrations.

A linear calibration curve was obtained. Samples were then aspirated and their absorbances and concentrations were recorded and printed on the graphic printer. The calibration curves for the various elements are shown in Fig 3.1 to Fig 3.6.

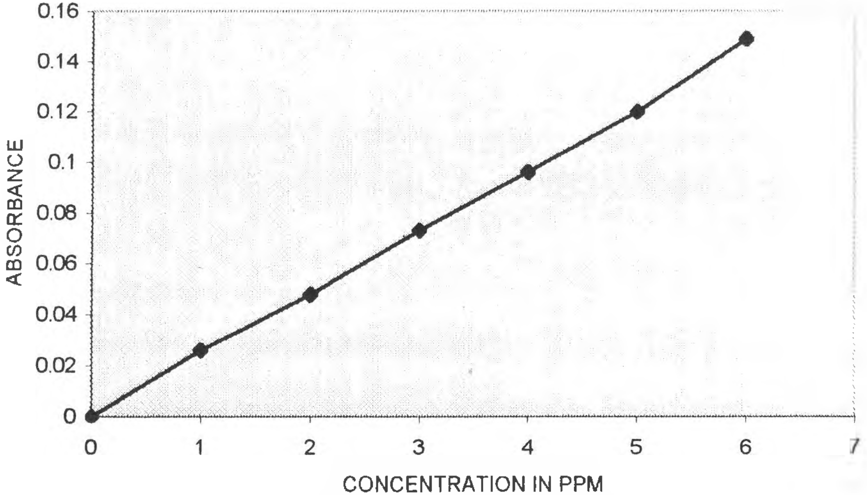


FIG 3.1 STANDARD CALIBRATION CURVE FOR CHROMIUM

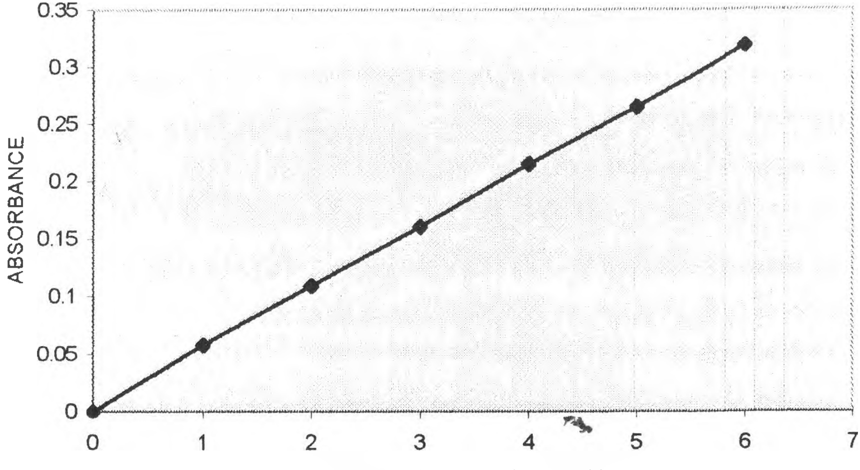


FIG 3.2 STANDARD CALIBRATION CURVE FOR COPPER

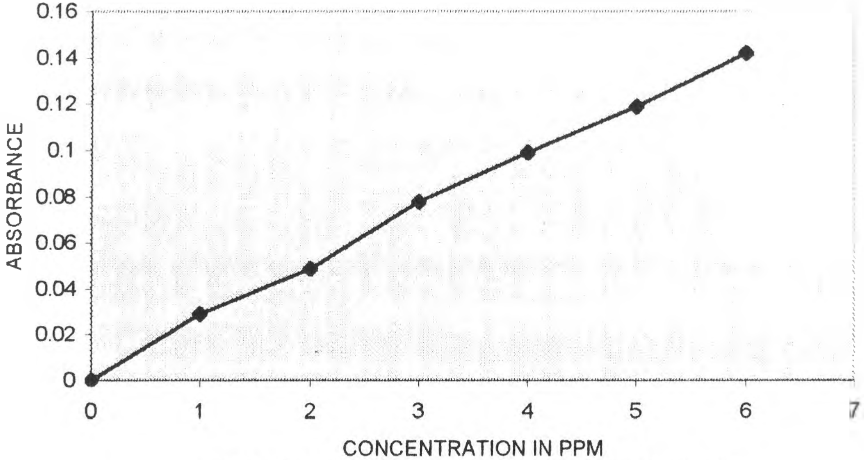


FIG 3.3 STANDARD CALIBRATION CURVE FOR IRON.

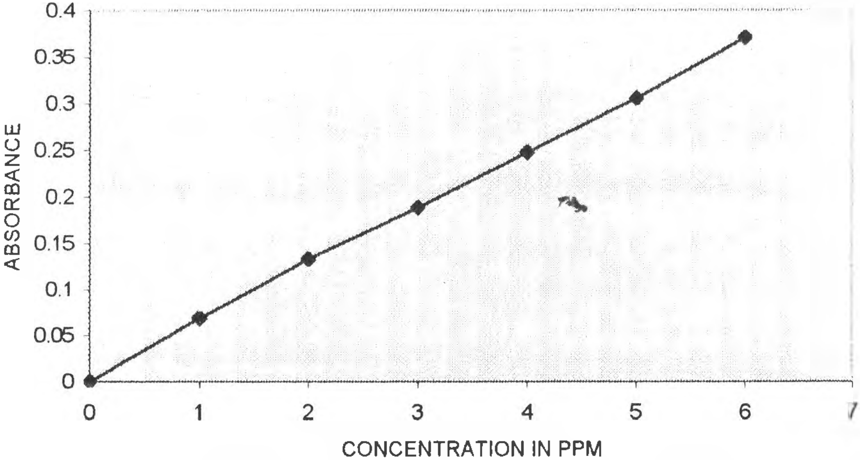


FIG 3.4 STANDARD CALIBRATION CURVE FOR MANGANESE

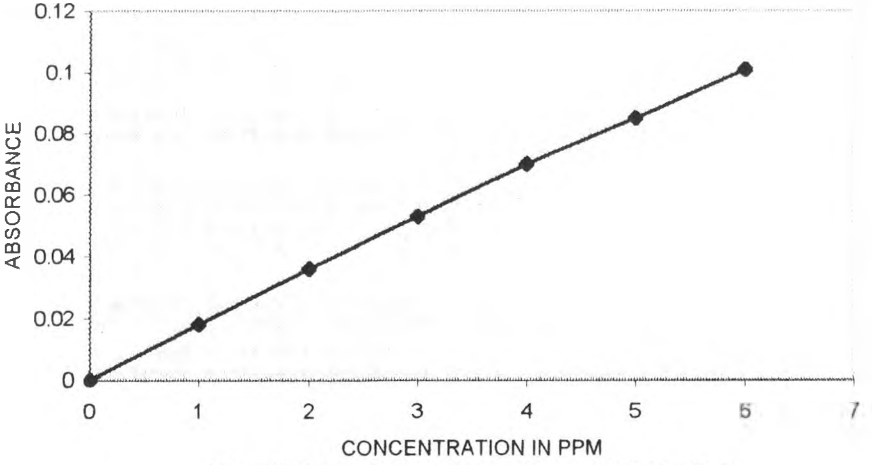


FIG 3.5 STANDARD CALIBRATION CURVE FOR LEAD

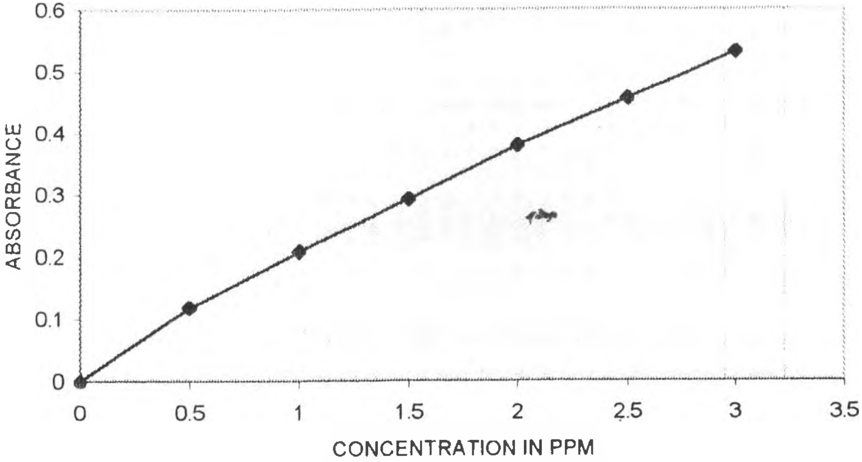


FIG 3.6 STANDARD CALIBRATION CURVE FOR ZINC

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Mean Pollution levels.

For each sampling point, the mean for each physico-chemical parameter for the whole study period was calculated. This information is presented in Tables 4.1.8 and 4.1.9 for the river and drainages respectively.

4.1.1 Temperature.

The river mean temperature ranged between 21.33 to 21.57°C. The river entered the study area with a mean temperature of 21.56°C at R1 and as it flowed downstream, there was a decrease in temperature to 21.33°C at R5. Fig 4.1.1 , Page 56. The mean river temperatures were within the acceptable levels of 25°C [36] and so there is no form of thermal pollution.

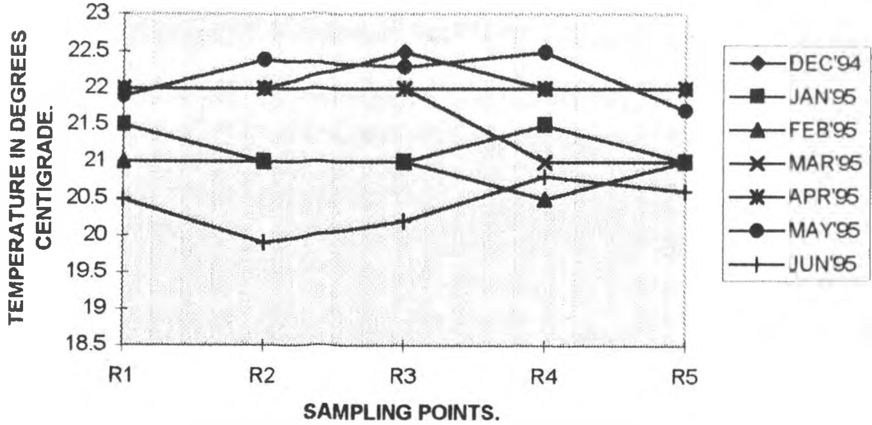


FIG. 4.1.1 TEMPERATURE LEVELS IN NGONG RIVER.

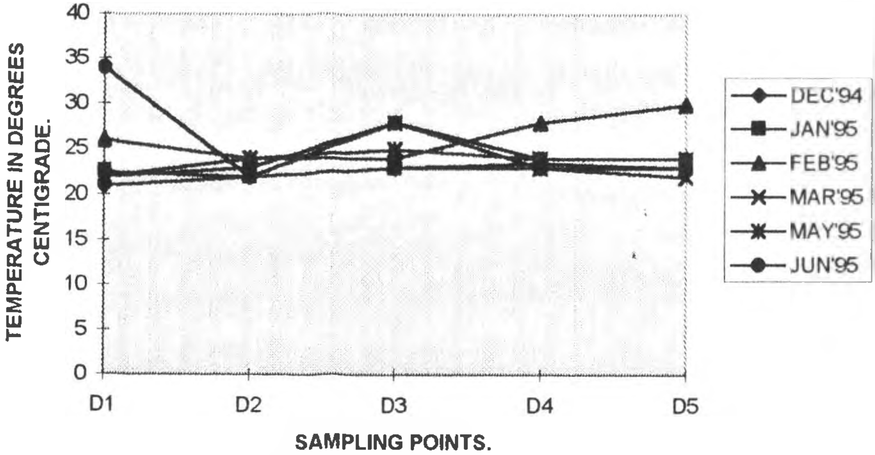


FIG. 4.1.1.1 TEMPERATURE OF DRAINAGE SAMPLES.

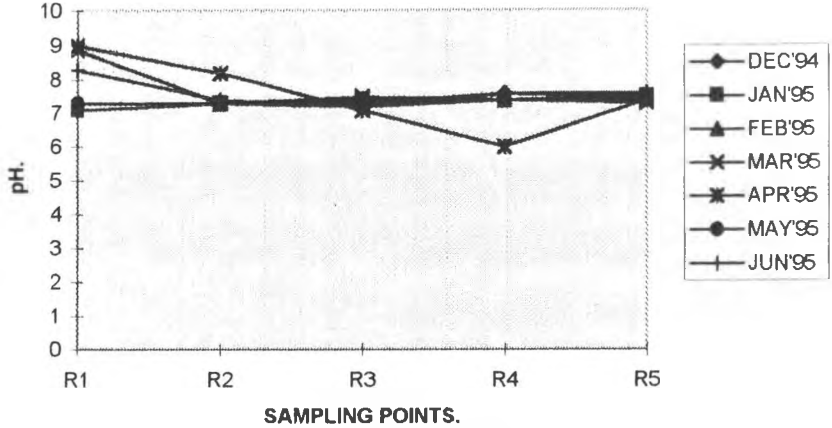


FIG. 4.1.2 pH LEVELS IN NGONG RIVER.

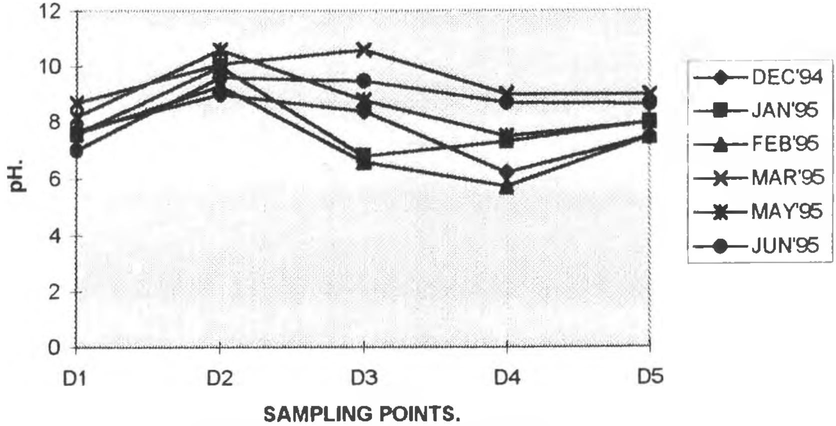


FIG. 4.1.2.1 pH VALUES OF DRAINAGE SAMPLES.

4.1.1 Seasonal Changes.

In order to examine the seasonal changes of Ngong River temperatures, the monthly mean temperatures were compared with corresponding atmospheric monthly mean temperatures for Nairobi [37]. This comparison is shown in table 4.1 below.

Table 4.1 Ngong River mean temperatures and atmospheric mean temperatures for the period December 1994 to June 1995.

Month	% Relative Humidity	Atmospheric Mean Temperature ^{0}C	Ngong River Mean Temperature ^{0}C ± 0.05°C
Dec.1994	64.50	19.30	22.25
Jan .1995	55.50	19.55	21.25
Feb.1995	54.00	20.20	20.75
Mar.1995	65.00	20.75	21.50
Apr.1995	69.50	20.20	22.00
May.1995	70.50	18.90	21.10
Jun .1995	68.00	17.40	20.35

In Figure 4.1, Ngong River and atmospheric mean temperatures have been plotted. The atmospheric mean temperature kept rising from the month of December reaching a maximum in March then dropped gradually until the month of June.

Throughout the study period, the river mean temperatures were always above the atmospheric mean temperatures as not expected. The seasonal changes of atmospheric and river temperatures seem to be out of phase with each other i.e., when one is a maximum the other is a minimum. These deviations were a minimum during the hot weather and a maximum during the rainy weather.

The results were compared to those obtained by Odipo[3] in 1986. This comparison is shown in Tables 4.2 below and Figure 4.2.

Table 4.2 Comparison of Ngong River mean temperatures for the periods 1985/1986 and 1994/1995.

Month	This study (1994/95), ^{0}C ± 0.05°C	Odipo,(1985/86), ^{0}C
Dec.1995	22.25	22.60
Jan.1995	21.25	22.75
Feb.1995	20.75	22.70
Mar.1995	21.50	23.20
Apr.1995	22.00	19.90
May.1995	22.10	20.36
Jun.1995	20.35	21.65

Generally, Odipo recorded a higher mean temperature of 21.88^{0}C as compared to our mean value of 21.48^{0}C. The slight difference could be due to environmental, seasonal and climatic changes over the months and years. Ngong River temperatures are still below the levels which can be considered lethal. The temperature changes throughout the study period and area also showed that Ngong River's natural capacity to deal with the current volume of industrial discharge has not been exceeded.

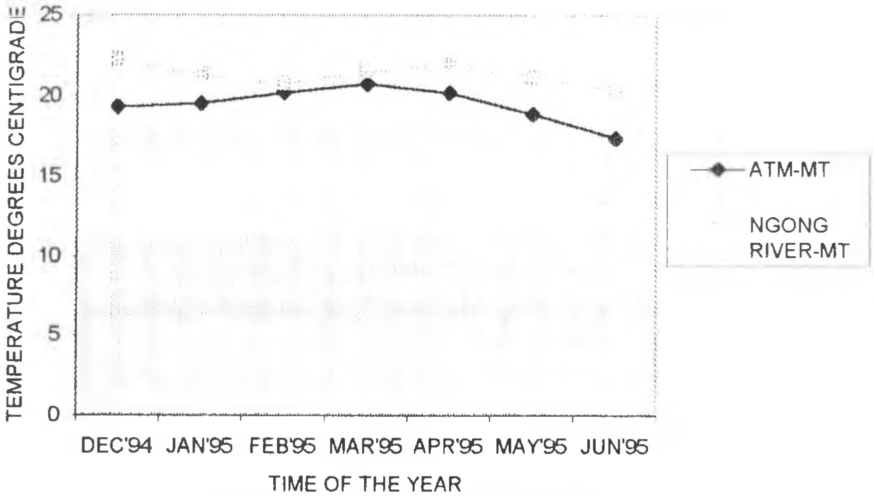


FIG 4.1 COMPARISON OF NGONG RIVER WITH ATM. MONTHLY MEAN TEMP.

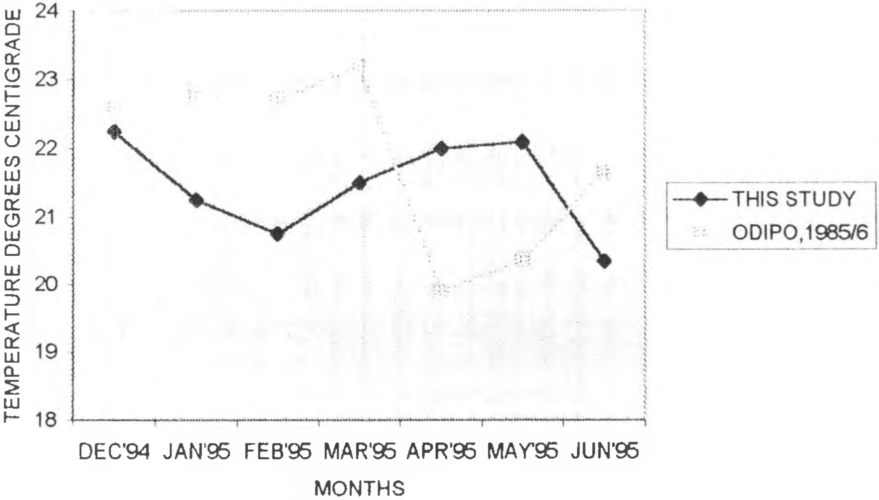


FIG 4.2 COMPARISON OF ATM. MEAN TEAM FOR THIS STUDY AND ODIPO'S,1985/6

Comparison of Ngong River mean temperature with that of river waters in Kerio valley area illustrate the influence of geographical location. The latter waters had a mean temperature of 23^0 C in 1993 [38].

4.1.1.1 Effects of effluents on river temperatures.

The stretch of Ngong River studied was approximately 14 km. It was observed that the river entered the study area at a mean temperature of 21.56^0 C. The group mean temperatures for the sampling points R2, R3, R4 and R5 during the study period was 21.46^0C. Thus as the river traversed the main industrial area of Nairobi, its temperature decreased by about 0.1^0C. This was in spite of the group mean of drainage sampling points D2, D3, D4 and D5 having a mean temperature of 24.46^0C. The mean temperatures for the entry point R1 and exit point R5 were more or less the same implying a high rate of recovery and that the changes were both local and temporary.

Normalization of river temperatures is attributed to heat exchange between the river and the atmosphere. Overall, the mean drainage temperatures were higher than the mean river temperatures. Used water is almost always at higher temperature than water in natural water course.

Since the sampling from the river and the drainages were not done simultaneously and that most industrial activities in Nairobi are discontinuous, one could not expect a correlation between the temperatures in individual drainage points and those for the neighbouring river sampling points.

Temperature in each drainage were also independent of those in other drainages and it has been shown that their effects on the river were local and not cumulative.

4.1.2 pH of Ngong River Waters.

Ngong River entered the study area with a mean pH value of 7.9 at R1. This is on the alkalinity side. As the river moved downstream, the mean pH value decreased to a value of 7.39 at R4 then slightly picked up to a value of 7.44 at R5. (Fig 4.1.2.) Page 52. Thus overall, the river pH decreased downstream towards neutral.

For any kind of open dynamic natural water system, the pH varies from 5.5 to 10.5[39]. Thus the changes within the study area are still in the ranges considered to be generally safe for fish growth and reproduction[15]. For most unpolluted waters, the pH is generally on the alkalinity side. Acids and alkalis not only promote corrosion if discharged into a stream, but they can also be lethal to plant and animal life if they cause the pH to be too far removed from neutral [40].

Generally, the mean pH changes were minimal as the values ranged between 7.29 at R3 and 7.90 at R1, ranges which could be described as local and normal.

4.1.2.1 **Effect of Effluents on rivers pH.**

During the study period, the mean pH of the drainages ranged between 6.34 and 9.77. The majority of the drains had alkaline pH. (Tables 4.2.1.1 to 4.2.6.1 in the Appendix I).

There are two possible explanations. One possibility could be that the primary waste from certain industries is alkaline and is not neutralized before discharge. Alternatively, industries with primary acidic waste may be over neutralizing their waste waters resulting in alkaline effluent.

The mean drainage pH values were within the recommended levels of between 6.0 and 9.0 which is important for fish reproduction [41]. Except once in December 1994 when the values for D2 was 5.7. Thus there is still no serious acidity or alkalinity problems in Ngong River contributed by the current industrial and domestic activities, unless one considers the effect at the point of discharge. Rather we observed a positive effect where inlet alkaline pH of the river decreased towards neutral pH.

The pH ranges obtained in this study were comparable to the values obtained by Odipo in 1985/86 of between 6.8 to 7.6[3].

This implies that the pollution due to hydrogen ion concentration has not changed much after ten years and the river is not significantly polluted in this aspect.

4.1.3 **Dissolved Oxygen .**

The river entered the study area with a low mean level of dissolved oxygen (D.O) of 2.0 mg/l at R1 indicating that the river was quite polluted upstream.
The low levels of dissolved oxygen in most of the sampling areas were also marked by bad odours due to the anaerobic conditions which prevailed.
The general low levels of dissolved oxygen (see Tables 4.1.1 to 4.1.7 in the Appendix I) was due to high levels of B.O.D and C.O.D. The low D.O levels were also probably due to low river turbulence, since the river is narrow and sluggish.

Ngong River is highly polluted by organic matter as indicated by these low levels of dissolved oxygen. This form of pollution could adversely affect the functioning and survival of aquatic biological communities. As shown in Fig 4.1.1 to 4.1.3, there is a very clear seasonal effect. The hot months of December, January and February all had mean D.O. values of less than 2 mg/l. The rainy months of April, May and June recorded mean dissolved oxygen levels above 2.0 mg/l. This could be due to dilution and high turbulence during these rainy months. Dilution and turbulence reduces organic B.O.D and C.O.D pollution and also enhances the addition of oxygen into the water.

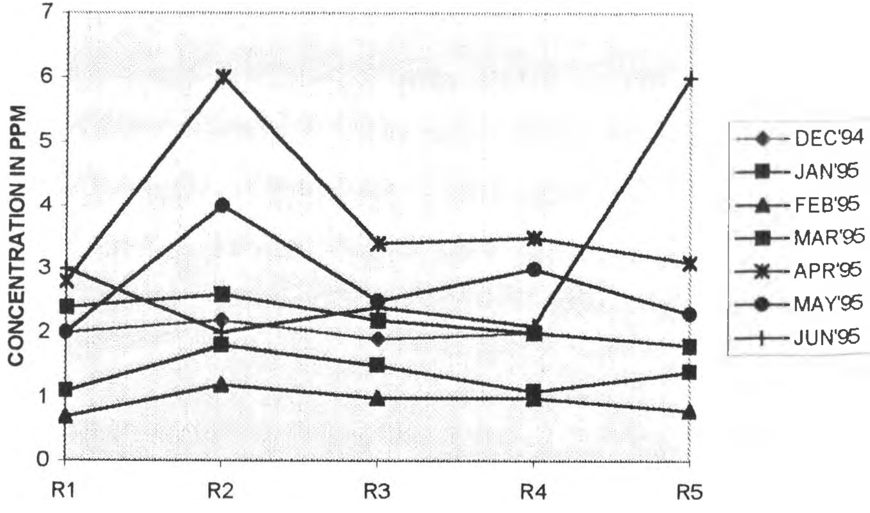


FIG 4.1.3 D.O. LEVELS IN NGONG RIVER.

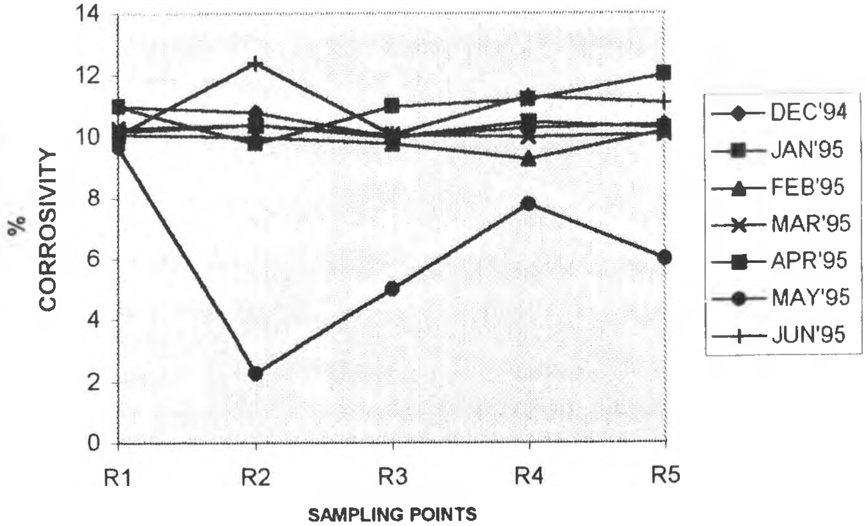


FIG 4.1.4 CORROSIVITY LEVELS IN NGONG RIVER

4.1.4 Corrosivity.

When " non-noble" metals are exposed to water at room temperature, there is a tendency for them to dissolve. This kind of reaction results into weight loss or corrosion.

At room temperature the progress of electrochemical corrosion is determined by a number of factors foremost of which is the aggressive nature and concentration of any oxidizing reactants present [42]. In contrast corrosion at elevated temperatures is determined not only by the conducting properties of surface films formed by the process, but also by kinetic factors such as bulk diffusion and electron transfer reactions, all of which take place more rapidly at elevated temperatures.

Throughout the study period, the mean corrosivity of Ngong River waters ranged between 9.43 to 10.34%. The highest mean percentage was recorded at R1 which showed upstream pollution. From the percent corrosivity figures, one could see that there was the effect of dilution during the rainy month of May with very low percentage values. The values in May were different from the rest of the months, which could be due to the massive wash of the heavy rains during that month. The mean percentage corrosivity did not differ very much from one point to the other and also from one month to the other showing that the activities leading to the waters being corrosive were not cumulative but were local.

There was very little turbulence in Ngong River during the study period as supported by the fact that the mean percentage values were almost the same (Tables 4.1.1 to 4.1.7 in Appendix I). The mean monthly changes in the pH of the industrial effluents are represented in (Tables 4.1.1.1 to 4.1.6.1).

The pH of 6.34 – 9.77 obtained is circum-neutral, an indication that not much of the effluents could have been acidic.

4.1.5 B.O.D.

The B.O.D values at the entry point of the study area were already high. This suggested upstream pollution, most probably from the densely populated Kibera slum area.

The recommended maximum safe B.O.D value for industrial discharge is less than 20 mg/l [41]. Except for the 10 mg/l recorded at R5 in June, none of the other values obtained met this condition.

The mean B.O.D. recorded at the exit point R5 was 168.6 mg/l which when compared with the inlet mean of 222.9 mg/l indicated a slight recovery in organic pollution. This could be due to a dilution effect by less industrial effluent with less organic load. The monthly mean for drainage samples ranged between 105.2 to 354 mg/l with most areas below 200 mg/l. Ngong River B.O.D. values obtained were higher than the global averages [43], and were about twenty times in excess of the maximum permissible level for drinking water of 3.0 mg/l[38].

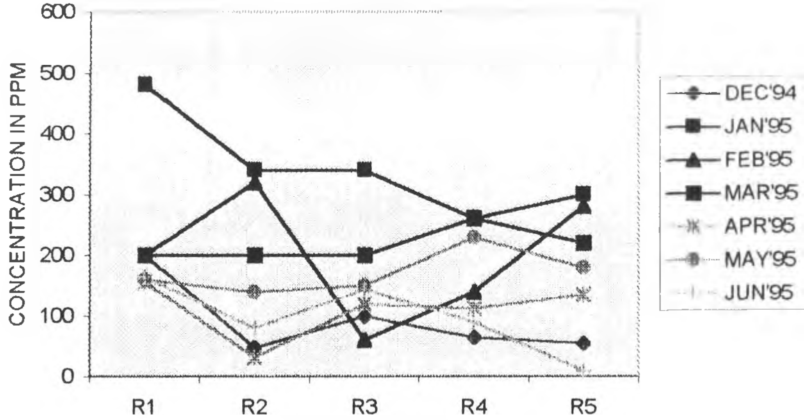
Expensive treatment would be required to make Ngong River water safe as domestic and or industrial water with regard to B.O.D . The values were comparable to the B.O.D values of surface waters receiving effluents from the industrial area of Thika town with mean B.O.D in the period October 1990 to August 1992 177 mg/l [43]. This might indicate a widespread culture in Kenya of discharging untreated industrial effluent directly into water bodies.

Seasonal changes were observed with the wet months showing low B.O.D values and vice-versa in the case of dry months. January had consistently high B.O.D values. Surface run-off evidently reduces organic pollution in Ngong River, hence the low B.O.D values resulting from dilution during the rainy season.

4.1.5.1 Effect of Effluents on B.O.D. levels.

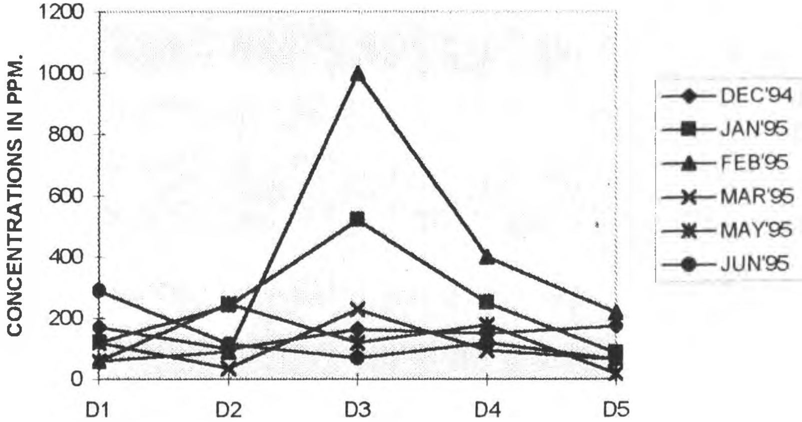
The same trend was observed in drainage samples. The levels recorded ranged between 10 and 480 mg/l. Drains D3 and D4 consistently discharged effluents with high B.O.D values.

Looking at the tables in Appendix I, there is no clear relationship between B.O.D and D.O. This could be due to other factors also contributing to the depletion of the dissolved oxygen. One solution to the B.O.D. problem would be to instal aerators to reduce some level of toxicity of some elements in water i.e. the manganese and iron can be oxidized through aeration thus reducing their toxicity in element form.



SAMPLING POINTS

FIG. 4.1.5 B.O.D. LEVELS IN NGONG RIVER.



DRAINAGE POINTS.

FIG. 4.1.5.1 B.O.D. VALUES OF DRAINAGE SAMPLES.

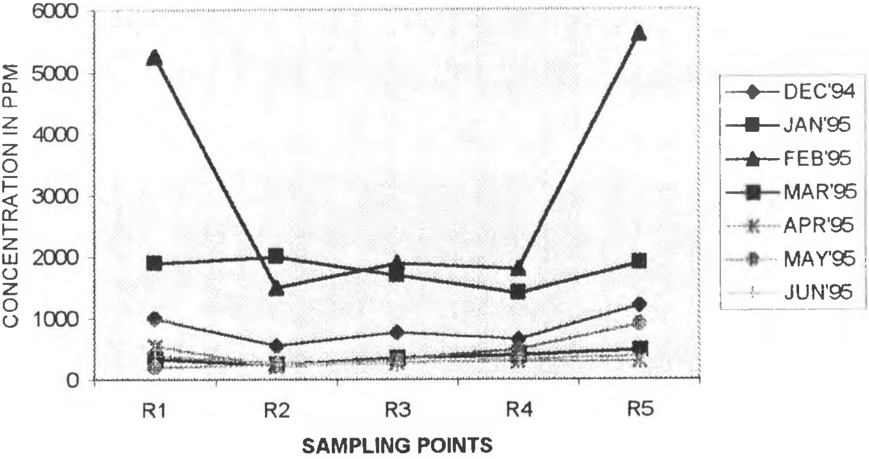


FIG. 4.1.6 C.O.D LEVELS IN NGONG RIVER.

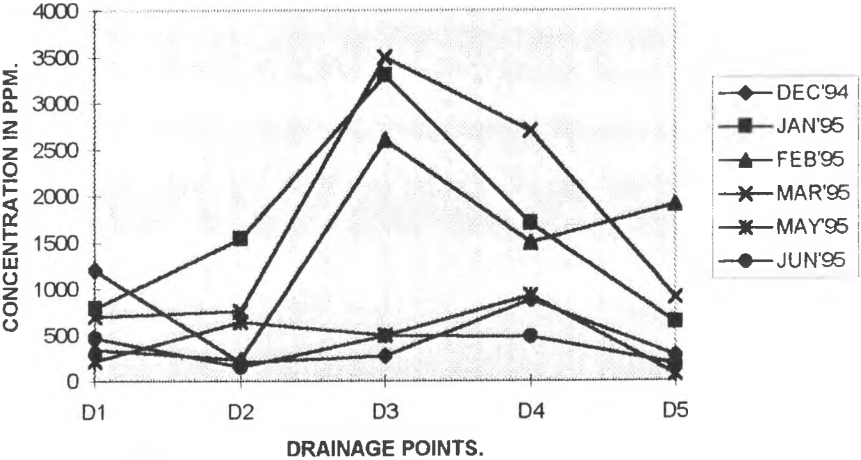


FIG. 4.1.6.1 C.O.D. LEVELS OF DRAINAGE SAMPLES.

By aerating water, there is ease of contact of air and water, thus enabling the micro-organisms in the water to break down the organic matter thereby reducing the B.O.D. Some elements in the water such as manganese and iron may also be oxidized hence reducing their toxicity.

4.1.6 C.O.D.

Referring to Fig 4.2.6 for C.O.D levels in Ngong River and neglecting the two erratic data at R1 and R5 for February, the C.O.D values for the month did not vary much down the river. They were mostly between 500 and 2000 mg/l.

In 1985/86 Odipo recorded a maximum value of 2500 mg/l. The 5260 mg/l and 5600 mg/l recorded in February at R1 and R5 respectively cannot be justifiably used to conclude that C.O.D levels have increased over ten years, but significant to the industrial practices.

We observed seasonal changes marked by consistently low levels of C.O.D. in the months of March, April, May and June apparently due to the dilution effect of the long rains. C.O.D levels were around 500 mg/l. December had about 1000 mg/l indicating reduced dilution effect of the short rains . January and February had as much as four times higher C.O.D values than the wet months. From the data given in Appendix I there is an indication of C.O.D being related to D.O. The months of January and February with high C.O.D levels also recorded D.O. levels between 0.7 to 1.8 mg/l which is an inverse relationship.

4.1.6.1 Effect of Industrial effluents on C.O.D levels.

Except for the month of March, the seasonal changes observed in Ngong River samples were also observed in the drainage samples. The drainage waste water was apparently also diluted by surface runoff during the wet months.

The drainage D3 discharged waste waters with the highest mean value of 1776.7 mg/l. Attention should therefore be focused on this drainage system in order to establish the culprits. D4 with C.O.D. values ranging from 483 to 2700 mg/l also attracted our attention. The same observation was made from B.O.D results .

4.1.7 Suspended Solids.

The mean suspended solids recorded ranged from 226.6 to 284.3 mg/l except at R3 where a mean value of 326.3 mg/l was observed. These values were well above the international average for fresh water of 150 mg/l [43]. During the wet months, there were lower averages than during the dry months. This seems to indicate that a lot of suspended matter in River Ngong emanates from manufacturing activities rather than from heaped garbage which eventually gets washed into the river when it rains. In most cases high suspended solids also corresponded with high B.O.D. levels showing a good correlation between B.O.D and the suspended matter.

4.1.7.1 Effect of Industrial Effluent on Suspended Solid levels.

The drainages had mean values from 123.7 to 322 mg/l. These were above the discharge levels mandated by the Nairobi City Council of not more than 30 mg/l but they are within the range of mean values recorded for river samples [44].

The trend for seasonal changes was similar to that for the river. There were very low levels during the wet months and very high levels during the dry months with the exception of D5 in December where a value of 10 mg/l was recorded.

4.1.8 Dissolved Solids.

Ngong River entered the study area with a mean dissolved solid level of 651.4 mg/l. The 484.3 mg/l recorded at R5 showed some level of recovery.

Generally, the dissolved solid levels were high during dry months and moderately low during rainy months. This was attributed to dilution during rainy months and increased concentration due to evaporation during dry months. The dissolved solid levels were observed to increase as suspended solids concentration decreased.

This could be as a result of materials being taken out of suspension by sedimentation and ending up as deposits at the bottom of the river.

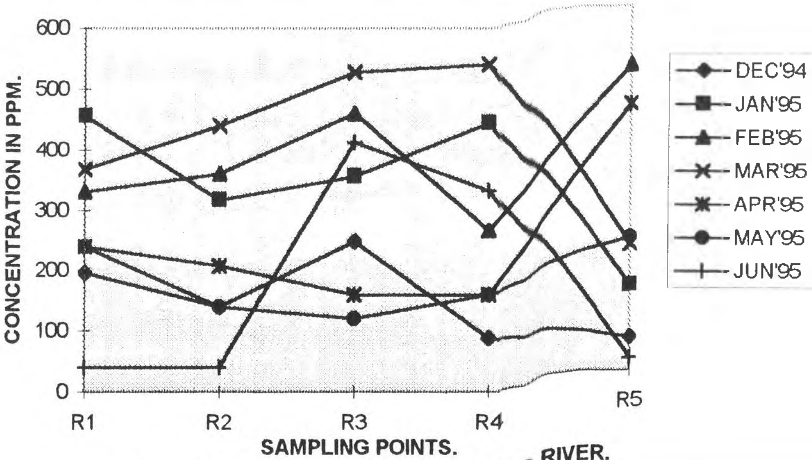


FIG. 4.1.7 SUSPENDED SOLIDS IN NGONG RIVER.

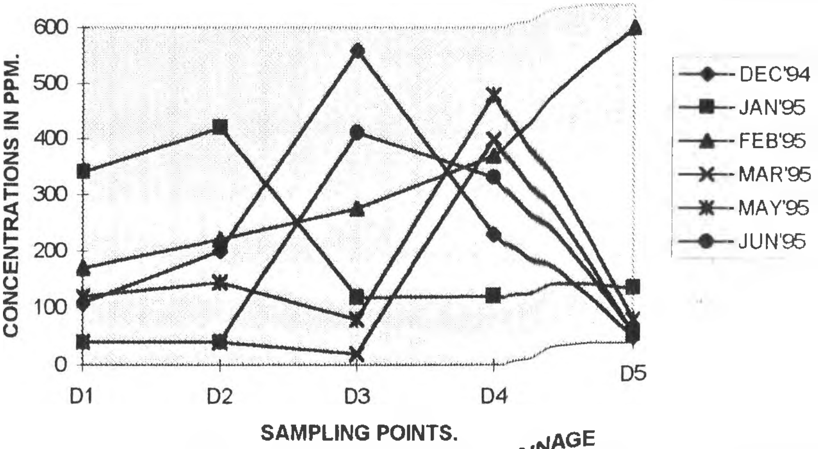


FIG. 4.1.7.1 SUSPENDED SOLIDS OF DRAINAGE SAMPLES.

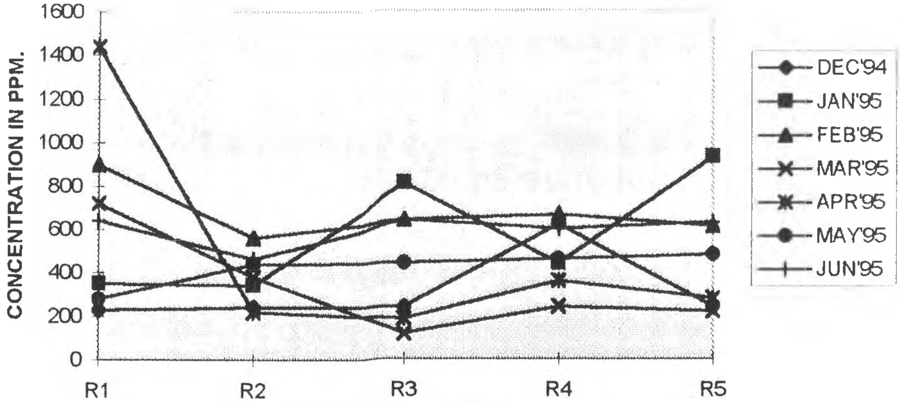


FIG. 4.1.8 DISSOLVED SOLIDS IN NGONG RIVER.

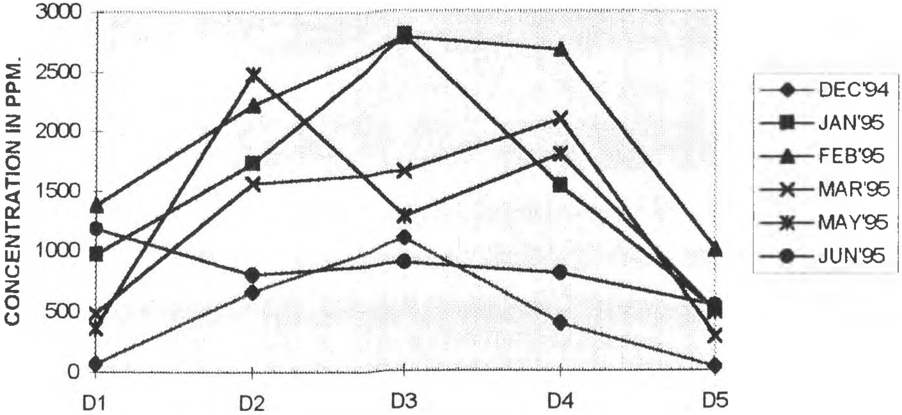


FIG. 4.1.8.1 DISSOLVED SOLIDS OF DRAINAGE SAMPLES.

The dissolved solids mean levels recorded in the various stations were all below the maximum permissible level in drinking water of 1000 mg/l, but were above the international average for fresh water of not more than 100 mg/l[43].

The Ngong River dissolved solids levels were well above those recorded for the Thika area. This indicated a massive use of dissolved salts in the neighbouring industries.

There was an observed relationship between the dissolved solids and ions such as chlorides and nitrates as can be seen from the results tables in Appendix I. When the dissolved solids were high, both the chlorides and nitrates were also high.

4.1.8.1 Effect of Industrial effluent on dissolved solids levels.

The drainages had mean values of dissolved solids ranging between 468.8 and 1755 mg/l with three of the mean values above 1000 mg/l. These values were above those recorded for river samples. This indicated pollution contribution by the surrounding manufacturing industries. The levels were well above the maximum permissible level of 500 mg/l in drinking water [38].

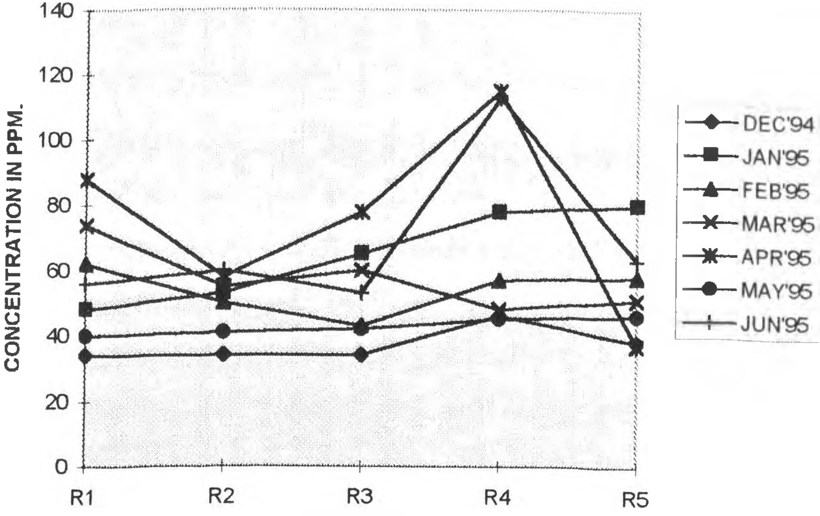


FIG. 4.1.9 CHLORIDE LEVELS IN NGONG RIVER.

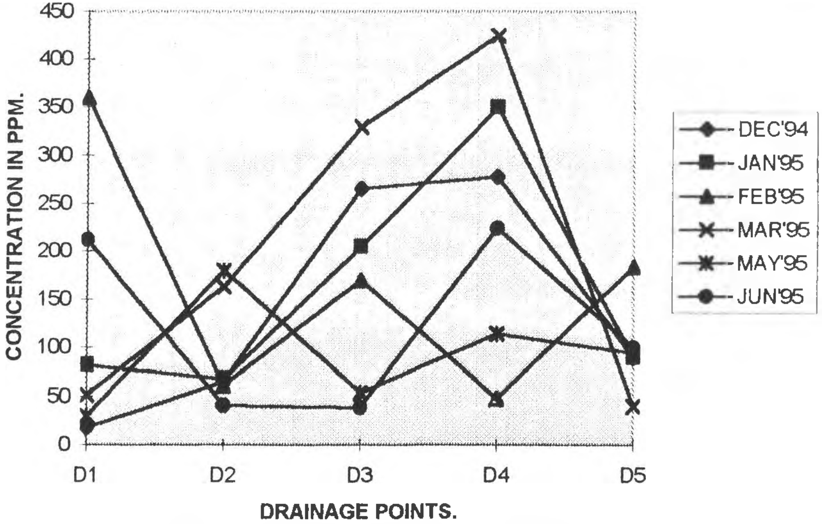


FIG. 4.1.9.1 CHLORIDE LEVELS OF DRAINAGE SAMPLES.

4.1.9 Chloride Levels.

As the river traversed downstream, there was a good recovery in the mean chloride level because at R5 the mean value was 53.3 mg/l as compared with 57.3 at R1.

The levels were still within the maximum permissible level in drinking water of 250 mg/l, since the highest value recorded for the river was 115 mg/l at R4. Ngong River mean values ranged between 50.1 and 71.7 mg/l which suggested a good maintenance of chloride levels in the river.

There seems to be no seasonal changes but generally, April had the highest levels of chloride for all the sampling points except at R5 where the lowest level was recorded. In natural waters, chloride occur in varying concentrations. Natural unpolluted waters may contain as low as 10-20 mg/l chloride [45].

4.1.9.1 Effect of Industrial effluent on chloride levels.

The drainages recorded high levels of chloride which apparently led to the rise in chloride levels in the river between R2 and R5. This observation suggests the use of chlorides in the industries along the study area especially those discharging effluents at D3 and D4.

4.1.10 Nitrate Levels.

Nitrates in natural surface waters are normally below 5 mg/l since they are readily taken up by plants. The presence of high levels of nitrates indicates contamination [46]. The mean nitrate levels ranged between 0.99 to 1.83 mg/l at R5 and R1 respectively. Irrespective of some higher values observed between these points, especially in April, the river seemed to have recovered from nitrate pollution downstream. This could be due to breakdown of nitrates in anaerobic processes due to decreased dissolved oxygen. In 1985/86, Odipo[3] observered levels ranging between 0.1 to 1.61 mg/l along the course of the river. There seemed to be an increase in nitrate levels since then.

The mean nitrate levels were all above the international average for fresh water of 0.1 mg/l but were below the minimum permissible level in drinking water of 10 mg/l[40]. When compared to those of Kerio Valley waters with mean averages ranging between 0.04 to 0.06 mg/l, Ngong River had higher nitrate pollution.

4.1.11 Dissolved Phosphates.

At the entrance point to the study area, a mean phosphate level of 2.9 mg/l was recorded. As the river traversed downstream, a decreasing trend in phosphate levels was observed with a mean level of 0.84 mg/l at R5.

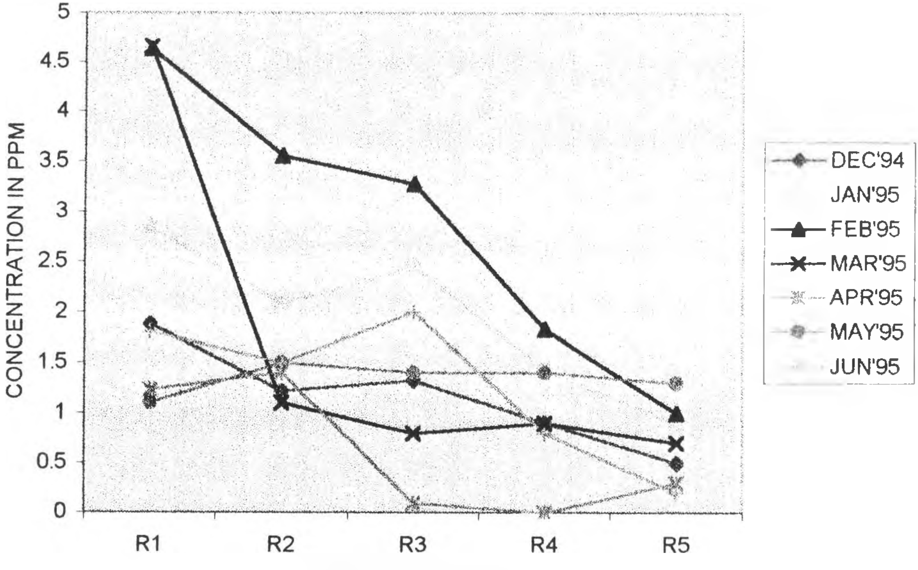


FIG. 4.1.10 NITRATE LEVELS IN NGONG RIVER.

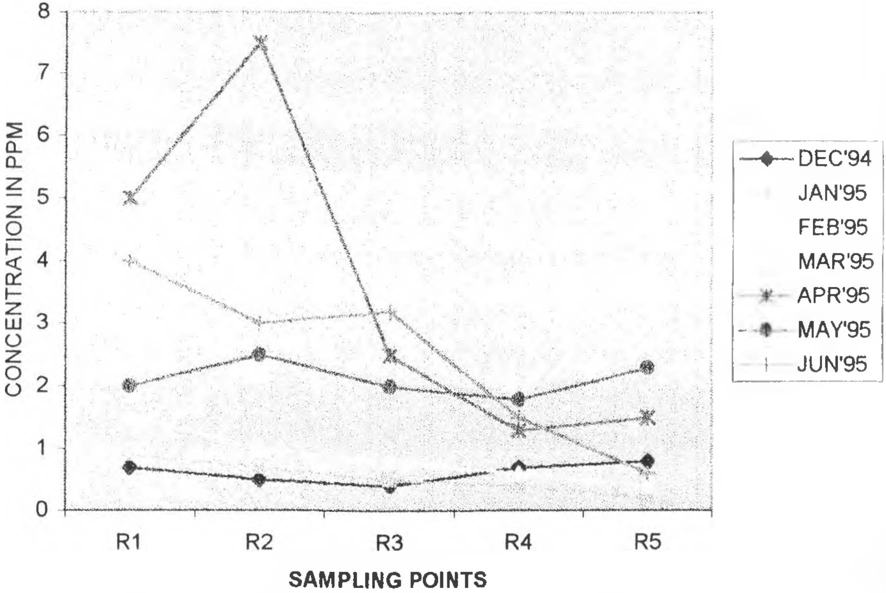


FIG. 4.1.11 PHOSPHATE LEVELS IN NGONG RIVER.

This showed a good recovery in phosphate levels in the river but it could also mean some kind of anaerobic processes going on due to high levels of pollution. The high levels of phosphates recorded at R1 could be from detergent residues in the sewerage from upstream Kibera slum area.

4.1.12 Turbidity.

Turbidity in water not only depend on the concentration of suspended matter, but also on its type [47].

Ngong River turbidity mean values ranged between 61.4 and 165 NTU. The mean turbidity was observed to decrease downstream with R5 having a value of 83.6 units. The high values recorded at R1 indicated that the water was turbid from upstream probably due to clay, silt or other suspended matter. Downstream, the low values of less than 100 units showed that there was a slight improvement. This could probably be due to the settling of suspended solids or dilution by industrial discharges.

The values recorded at all the sampling points throughout the study period were much above the maximum permissible level of 5 NTU in drinking water [38]. The levels compared well with waters of Kerio Valley with mean range of 94 to 255 NTU.

Generally, the turbidity values were high in the month of May, suggesting a dilution effect.

4.1.12.1 The Effect of Industrial Effluent on Turbidity Levels.

There was no direct influence of the discharges on the river as some of the drainages recorded very low values of turbidity compared to the river samples. For almost all the sampling months, drainage D4 had the highest turbidity levels and this could mean that the discharges from D4 had high levels of suspended matter.

4.1.13 Total Hardness .

Hardness in water is mainly due to calcium, magnesium and partly iron ions. Calcium and magnesium ions are the major contributors of hardness in water. Calcium bicarbonate is formed as follows:

$CaCO_3 + CO_2 + H_2O \rightarrow Ca^{2+} + 2HCO_3^-$

4.1.14 Calcium Hardness.

At the entry point to the study area a mean value of 70.14 mg/l was recorded. Calcium hardness rose to a slightly higher value of 74.29 mg/l at R5. Generally, high levels of calcium hardness were observed during the rainy month of April. This could be due to a lot of rock washings in the underlying area of the river. The mean values of calcium hardness were mostly below the maximum permissible level in drinking water of 500 mg/l[38]

4.1.14.1 Effect of Effluent discharge on Calcium hardness levels.

The drains had mean calcium hardness ranging between 33 and 138.5 mg/l during the study period. Values for D3 were generally higher than for those for the other drains. This indicated discharge of waste water containing calcium hardness into that drain. The increased level observed down the river could be attributed to discharge from industries in the neighbourhood of this drain.

Generally most means were within 50 to 100 ppm range. They were observed to be lower than the river values but there was a cumulative effect.

4.1.15 Magnesium hardness .

The mean magnesium hardness levels ranged between 20.8 and 26.3 mg/l with the exit point R5 having the higher value.

Throughout the study period there was no extreme mean value which could suggest usage of magnesium compounds by neighbouring industries.

Mean magnesium hardness were always lower than the mean calcium hardness implying that most of the hardness was due to calcium ions.

4.1.15.1 Effect of effluent discharges on magnesium hardness levels.

The draining had mean magnesium hardness ranging between 9.48 and 27.6 mg/l throughout the study period. The levels were generally low except for D1 and D4 which had mean values above 26 mg/l.

Generally the drainages recorded lower mean values compared to the river. This trend was similar to the one observed for calcium hardness.

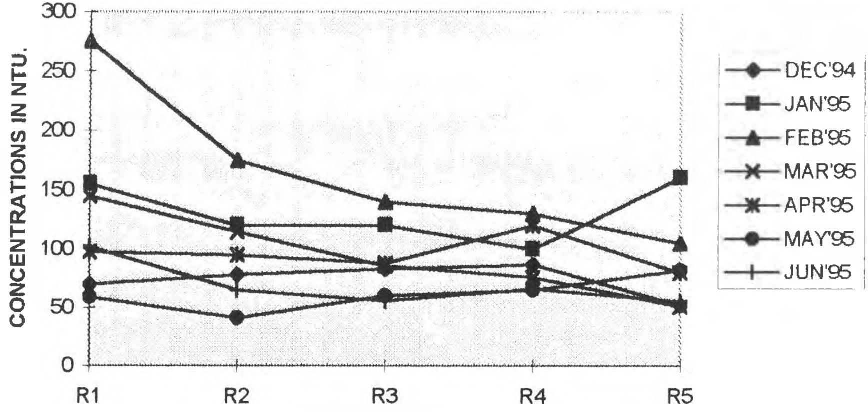
4.1.16 Chromium:

At R1, a mean value of 0.006 mg/l chromium was recorded. The levels increased down the river with the exit point R5 recording a mean value of 0.019 mg/l. R4 had the highest mean value of 0.039 mg/l throughout the study period. The mean levels of chromium ranged between 0.004 - 0.039 mg/l . These levels were above the international average for fresh water of 0.0001 mg/l[43] but were still within the limits of maximum permissible level in drinking water of 0.05 mg/l [48].

The values were low when compared to the waters of Kerio Valley whose arithmetic means ranged between 0.03 and 0.11 mg/l[38].

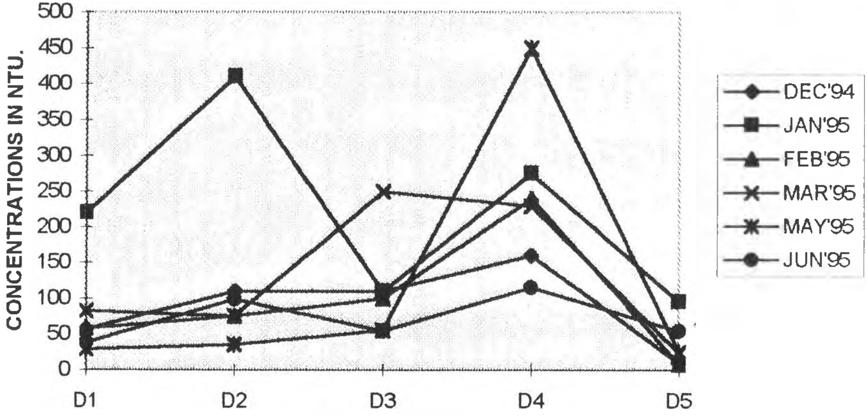
4.1.16.1 Effect of Industrial effluent on Chromium Levels.

Waste water discharged into the river had levels ranging between 0.015 and 0.925 mg/l chromium throughout the study period. The highest mean level was recorded at D4. This indicated the possibility that a metal finishing industry was discharging into that drainage. It was therefore no coincidence that high levels of chromium were observed in river samples obtained at R4.



SAMPLING POINTS.

FIG. 4.1.12 TURBIDITY LEVELS IN NGONG RIVER.



SAMPLING POINTS.

FIG. 4.1.12.1 TURBIDITY OF DRAINAGE SAMPLES.

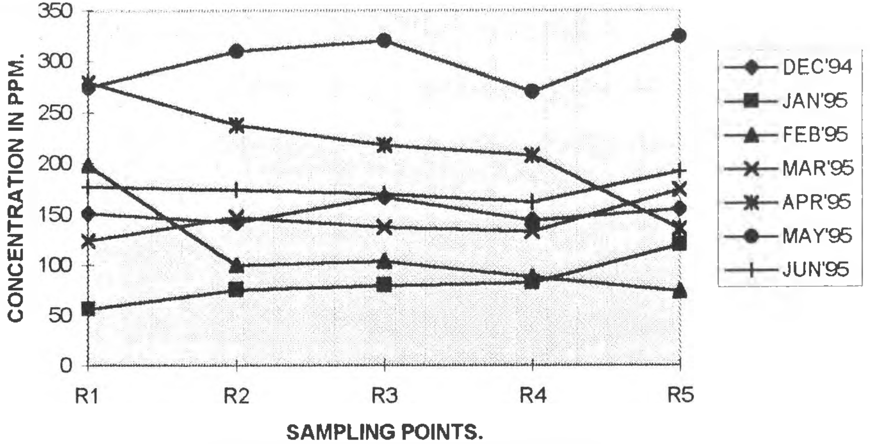


FIG. 4.1.13 TOTAL HARDNESS IN NGONG RIVER.

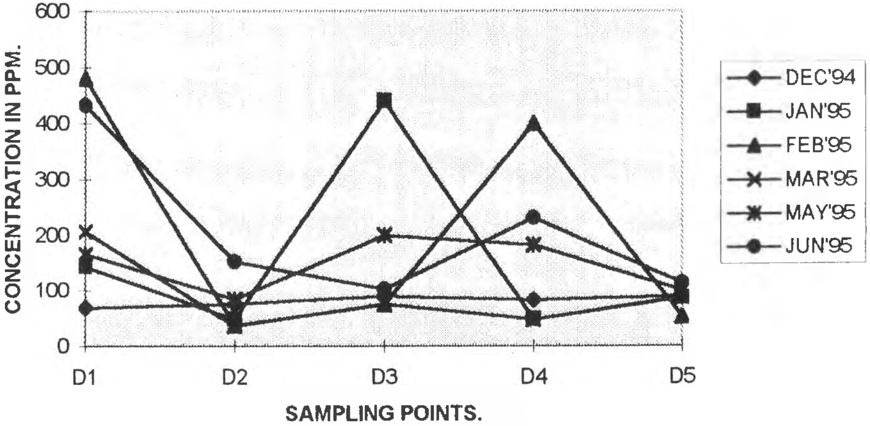
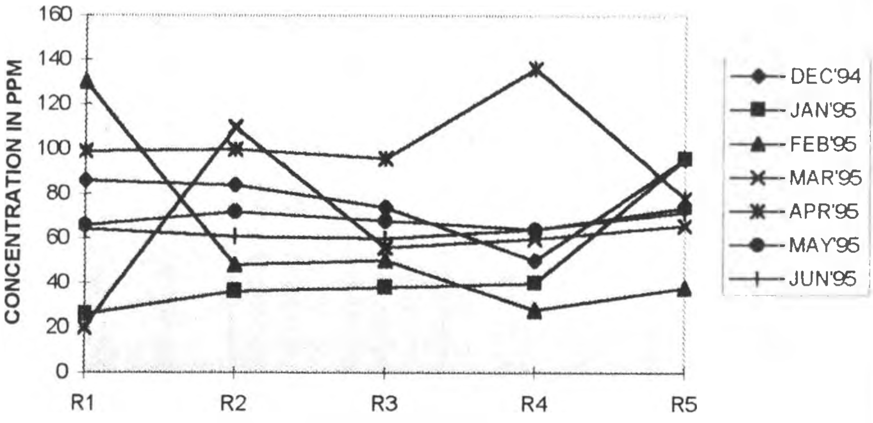
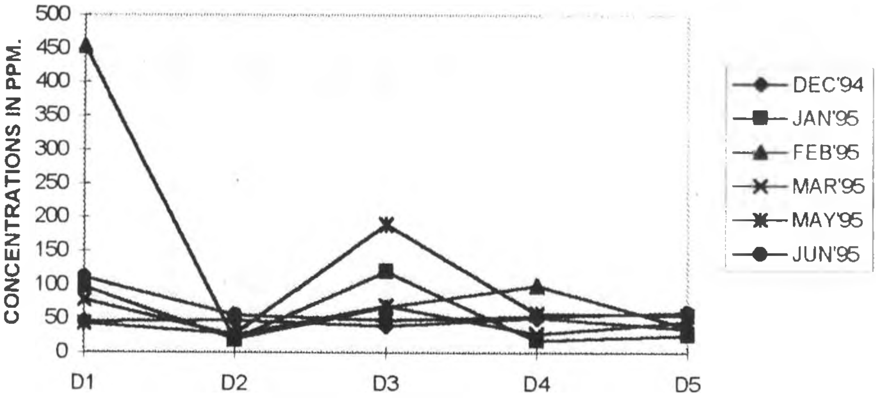


FIG. 4.1.13.1 TOTAL HARDNESS OF DRAINAGE SAMPLES.



SAMPLING POINTS.

FIG. 4.1.14 CALCIUM HARDNESS IN NGONG RIVER.



SAMPLING POINTS.

FIG. 4.1.14.1 CALCIUM HARDNESS OF DRAINAGE SAMPLES.

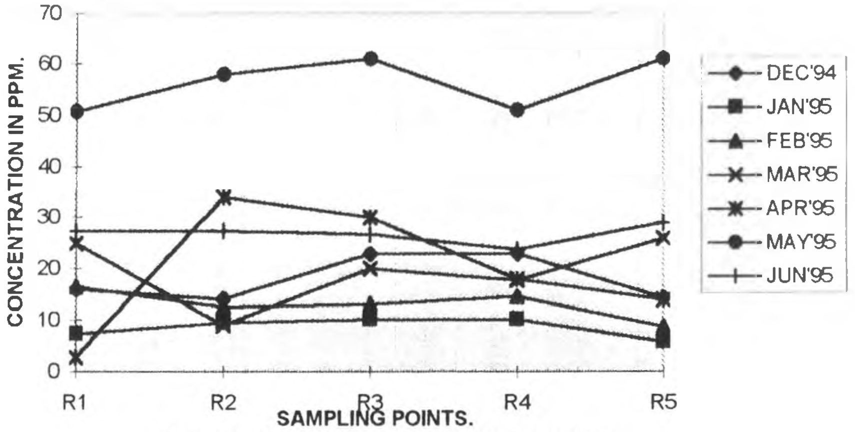


FIG. 4.1.15 MAGNESIUM HARDNESS IN NGONG RIVER.

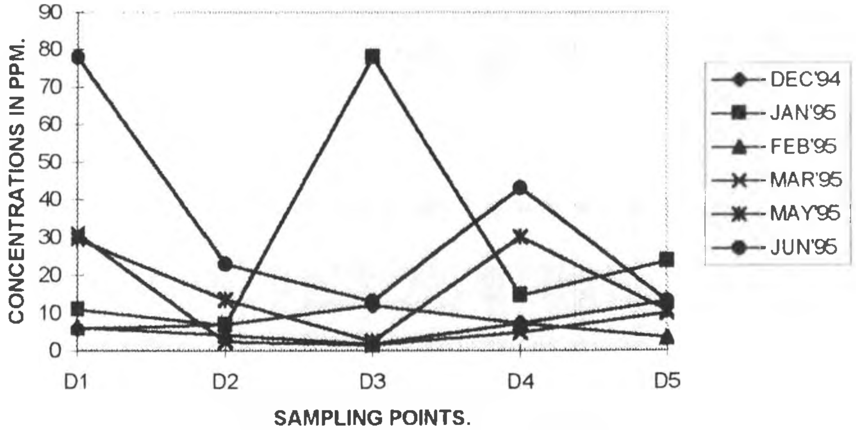


FIG. 4.1.15.1 MAGNESIUM HARDNESS OF DRAINAGE SAMPLE.

Generally higher chromium levels were observed in drainage samples compared to the river samples which suggested use of chromium in the surrounding industries. The mandated discharge levels of 0.001 mg/l were not being met. The Nairobi City Council advises industrialists to construct pre-treatment facilities to reduce levels of waste products before discharging into near-by water bodies or into sewer lines.

4.1.17 Soluble Copper.

Copper in the aquatic environment can exist in particulate colloid and soluble form. The speciation of copper in natural waters is determined by the physico-chemistry, hydrodynamic characteristics and biological state of the water.

During this study , soluble copper mean levels were found to range between 0.017 and 0.027 mg/l at R1 and R5 respectively. The levels did not fluctuate much after R1 and were around 0.021 and 0.024 mg/l. There was therefore a certain measure of recovery down the river.

High levels of copper of about 0.1 mg/l had previously been shown to be dangerous to animal lives [34]. Copper concentrations in Ngong River are still low and within the maximum permissible level of 1 mg/l in drinking water [49]. However, they are much above the international average for fresh water of 0.0014 mg/l.

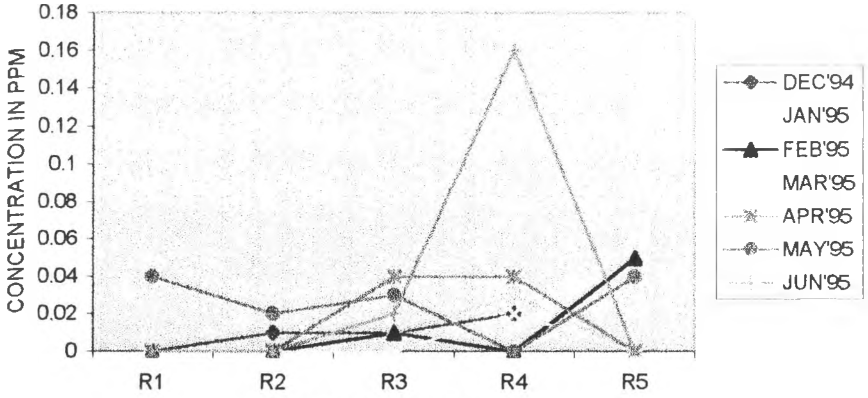


FIG. 4.1.16 CHROMIUM LEVELS IN NGONG RIVER

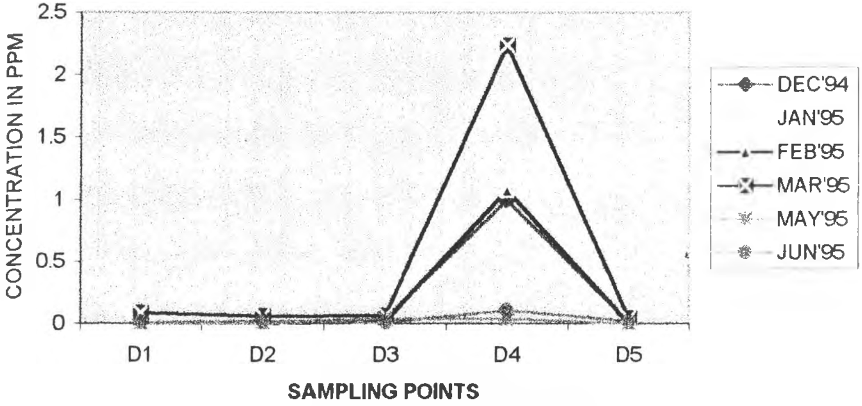


FIG. 4.1.16.1 CHROMIUM LEVELS OF DRAINAGE SAMPLES

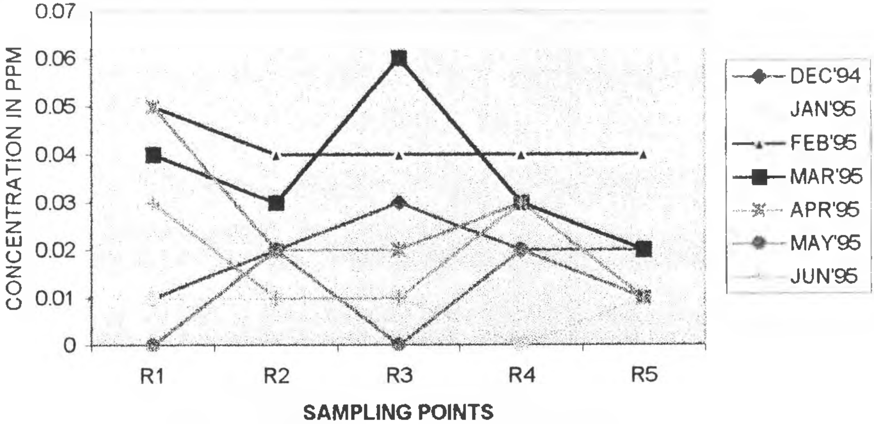


FIG. 4.1.17 COPPER LEVELS IN NGONG RIVER

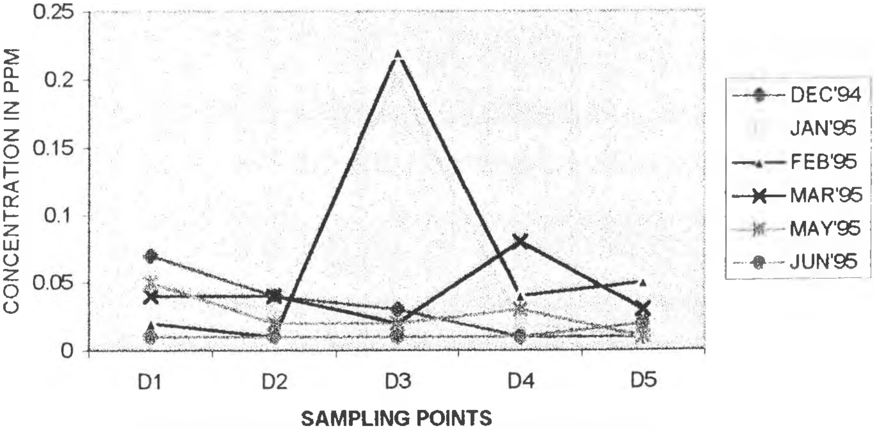


FIG. 4.1.17.1 COPPER LEVELS OF DRAINAGE SAMPLES

The levels are comparable to those of other river waters in Kenya. The waters of Kerio Valley had mean values of 0.002 to 0.003 mg/l [38].Waters around Thika town were observed to have 0.001 mg/l copper.[43]

4.1.17.1 Effect of industrial effluent on copper levels.

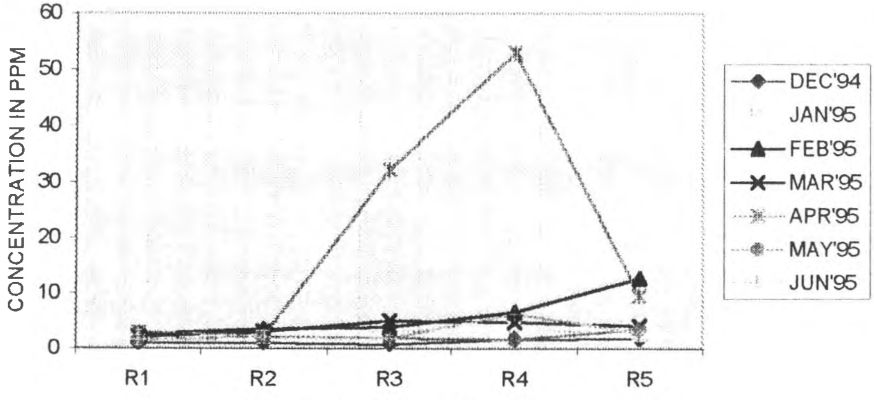
The mean copper levels in the drainages were comparable to those of river samples except for D3 which recorded a mean level of 0.142 mgl^{-1}. There could be a copper finishing industry discharging effluent into drainage D3. This actually did not have much influence on the river copper levels which ranged between 0.017 to 0.027 mgl^{-1}.

4.1.18 Soluble Iron.

Iron is a major constituent of the lithosphere and plays an essential role in all organisms . It is one of the least toxic of the metals [5].

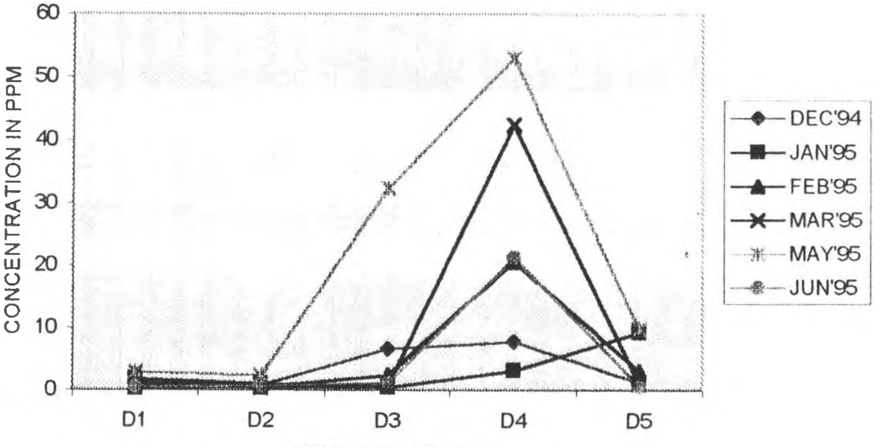
The study showed that the river was generally polluted with iron. The mean levels ranged between 2.00 to 11.16 mg/l (Tables 4.1.1 to 4.1.7).

The iron mean levels were all above the maximum international permissible average level in drinking and fresh water of 0.3 and 0.05 mg/l respectively. The standard set for drinking or domestic water (0.3 mg/l) is meant to prevent objectionable tastes or laundry staining and is of aesthetic rather than of toxicological significance. However, iron at high concentrations is toxic to livestock because it interferes with phosphorus metabolism[45].



SAMPLING POINTS

FIG. 4.1.18 IRON LEVELS IN NGONG RIVER



SAMPLING POINTS

FIG. 4.1.18.1 IRON LEVELS OF DRAINAGE SAMPLES

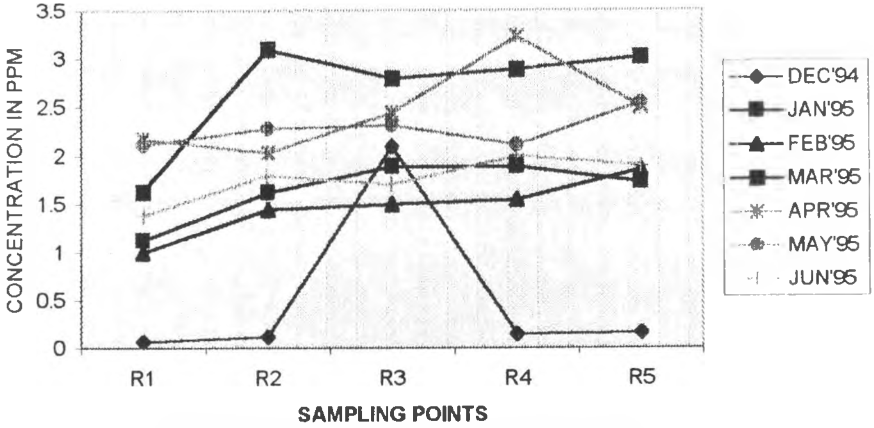


FIG. 4.1.19 MANGANESE LEVELS IN NGONG RIVER

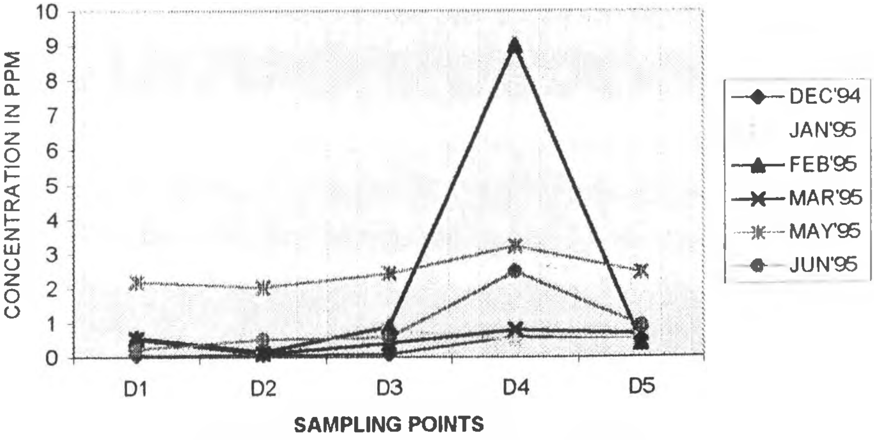


FIG. 4.1.19.1 MANGANESE LEVELS OF DRAINAGE SAMPLES

The high levels of iron in the study area could be attributed to industrial wastes from metallurgical industries in the neighbourhood . The trend in chromium levels was similar indicating metal-working and finishing industries as sources.

4.1.18.1 Effect of Effluent Discharge on soluble Iron levels.

The drainages mean values ranging between 1.00 to 14.12 mg/l had a very big effect on the river. The highest mean value was recorded at D4. The highest mean value for the river of 11.16 mg/l at R4 is a reflection of pollution from drainage D4. The levels at R3 were also influenced by discharges from the drainage D3. The values were 7.06 mg/l and 7.24 mg/l respectively.

4.1.19 Manganese Levels.

Manganese is one of the most abundant elements in the earth's crust and finds its way to human beings through water, air and food.

Along the study area , manganese mean levels in the river ranged between 1.36 to 2.11 mg/l (Table 4.1.1 to 4.1.7).

At R1 a low mean level of manganese was recorded. The mean levels increased down the river but with little variations from one sampling point to another. The levels were beyond the maximum permissible levels in drinking water and international average for fresh water of 0.1 and 0.001 mg/l respectively. The levels were higher than those recorded in some other river waters in Kenya [38], [43]. This indicated some kind of industrial activity involving the use of manganese.

4.1.19.1 Effect of Effluent discharge on Manganese levels.

The mean values from drainages ranged from between 0.503 and 2.773 mg/l, the latter having been observed at D4. Generally the values were lower than those of the river samples. Therefore, there seemed to be no significant influence from the drainages studied on the river.

4.1.20 Soluble Lead .

It is a highly toxic metal. It arises from a number of industrial , commercial and mining activities. Combustion products from the motor vehicle industry are generally washed from the surfaces into the river during rainy seasons. Down the study area, the changes in the mean levels were rather small. The lower level of 0.09 mg/l at R2 (Tables 4.1.1 to 4.1.7) deviated very much from the other results.

Lead levels of Ngong River are very much higher than the maximum permissible level of lead in drinking water and the international average for fresh water of 0.05mg/l and 0.00004 mg/l respectively.

These results indicate a high level of lead pollution of Ngong River. When compared to rivers around Thika with a mean of 0.0007 mg/l, Ngong River was 10 to 20 times more polluted with lead.

4.1.20.1 Effect of Effluent Discharge.

The drainages had mean levels ranging between 0.12 and 0.755 mg/l (Tables 4.1.1.1 to 4.1.1.7). These levels were by far higher than those recorded for the river indicating high pollution contribution from the drainages emanating from the surrounding industries. The paint manufacturing industries close by could be the culprits.

D3 had the highest mean level and this was reflected in the high mean level for the corresponding river sampling point R3.

4.1.21 Soluble Zinc.

Zinc is used in the metal finishing industry , rubber, chemical industry and in agriculture and is a common pollutant in industrial effluent[4].

Fluctuating mean levels of between 0.27 and 0.82 mg/l zinc were recorded with the entry point level of 0.366 mg/l. The mean levels recorded for Ngong River were still within the maximum permissible levels for drinking water of 5 mg/l but were above the international averages for fresh water of 0.0002 mg/l [43]. We can say that zinc pollution along Ngong River is still quite low.

4.1.21.1 Effect of effluent Discharge on Zinc levels.

The draining points to Ngong River had mean zinc levels ranging between 0.18 and 4.47 mg/l. These levels were much higher than those observed for the river. The high mean levels at D4 was reflected at R4 which had the highest mean level along the river. This indicated direct contribution of zinc from that drainage. The high mean levels recorded for the drainages imply usage of zinc as a raw material in some neighbouring industries, for example those carrying out metal galvanizing.

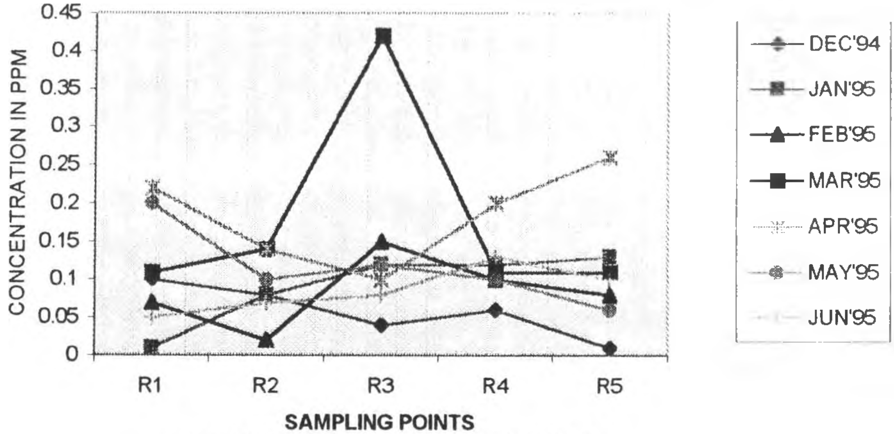


FIG. 4.1.20 LEAD LEVELS IN NGONG RIVER

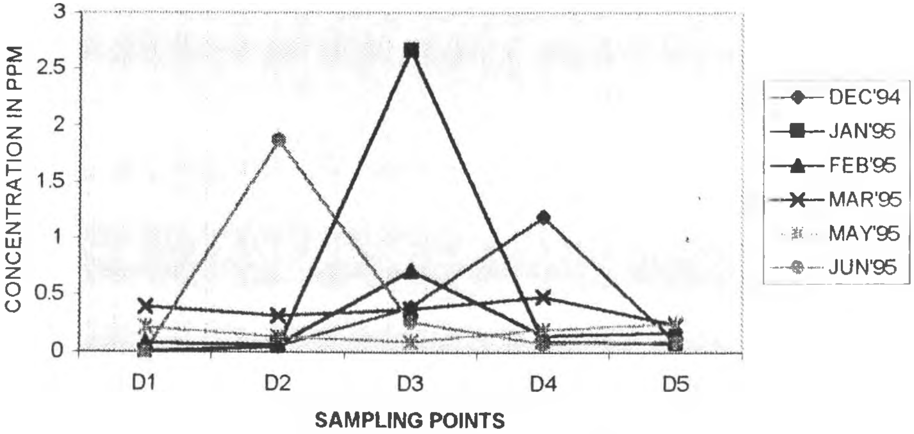


FIG. 4.1.20.1LEAD LEVELS OF DRAINAGE SAMPLES

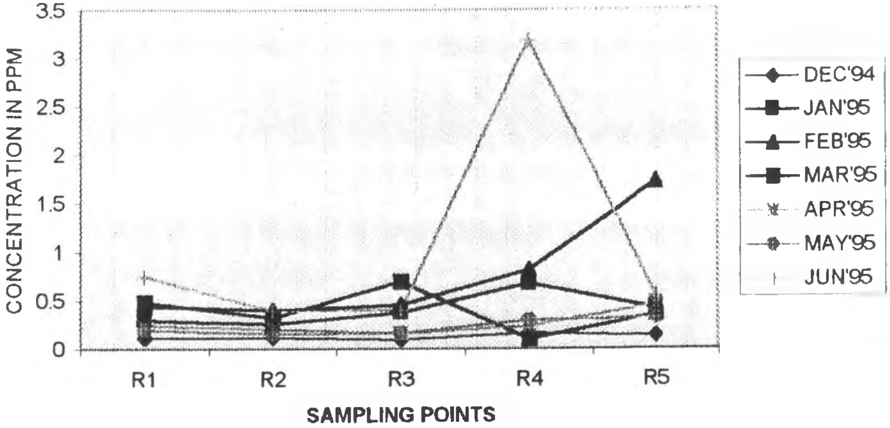


FIG. 4.1.21 ZINC LEVELS IN NGONG RIVER

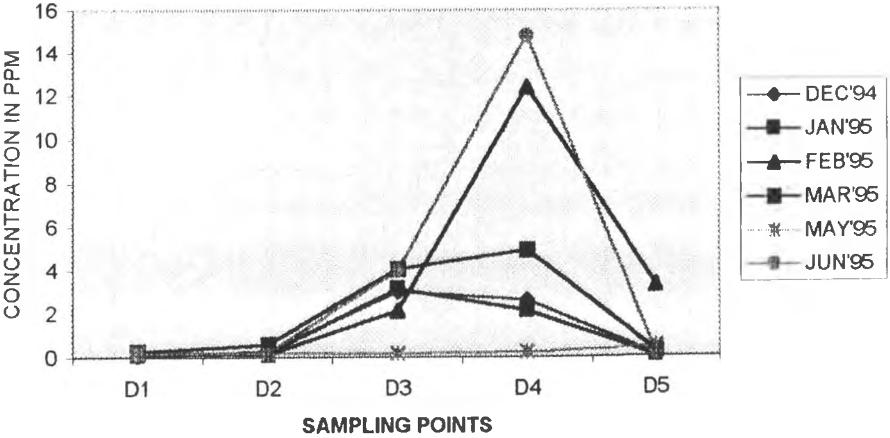


FIG. 4.1.21.1 ZINC LEVELS OF DRAINAGE SAMPLES

CHAPTER FIVE

5.0 CONCLUSION

The sampling strategy employed in the study was aimed at monitoring the direct effects of industrial discharges on a section of Ngong River. After overcoming difficulties in accessing each selected drainage as well as the area of the river around the discharge point, samples were taken monthly and studied over a seven-month period.

One of the objectives of this study was to establish the extent of the organic pollution in order to enable the local authorities to devise a solution to the problem. The trends in dissolved oxygen, suspended matter, turbidity, biological and chemical oxygen demand have been presented. Discharges from the surrounding industries as well as from the slum dwellers upstream of and around the study area were found to contribute significantly to organic pollution. Storm waters also contribute a heavy load of organic pollution in Ngong River. The Nairobi City council can now use the results to earmark locations to establish mechanical aerators. The results can also be used to home in on the culprits.

This study has also established that the activities of the surrounding industries contribute to significant pollution of Ngong River with respect to dissolved solids, particularly metals.

Lead, chromium, iron and zinc concentrations increase downstream the river and especially around sampling points D3 and D4. It is now for the Council to identify the polluting industries and institute measures to minimize these discharges. Rural communities use this river downstream and the levels of these metals in the river should be minimized for their sake.

5.1 RECOMMENDATIONS.

The results obtained in the study were for the period December to June. Further work needs to be carried out over a longer period of time and at least one year so that all the dry and wet seasons in the year can be properly represented during sampling.

It is recommended that sampling be carried out consistently by establishing permanent sampling points. This will give a good comparison over a period of time. The local authority should invest in data acquisition technologies.

All industries should be connected to the sewer line so that only storm water runs into drainages. Pre-treatment methods should be applied by industries before discharging effluent into the sewer or any authorized water body as this will ease pollution load at the treatment works.

Also, there should be a mechanism to ensure that all industries furnish the Nairobi City Council Water and Sewerage Department with some details of their manufacturing processes and the nature of their waste products. The Nairobi City Council should only license industries which have incorporated pollution control measures in their industries. The City Council should have a database for all the industries within its jurisdiction.

Samples should be taken from the industrial discharges regularly so that the Council can establish a method for charging the offenders based on the levels of pollutants. In this regard, the Council should set the basic discharge standards for various pollution parameters which industrialists would be expected to maintain.

The general public should be made aware of their rights so that they feel confident and obliged to report to the authorities on pollution around their environment or elsewhere. The public should also be aware that most rivers in Nairobi are already contaminated and should not use these waters for drinking and other domestic activities.

The public also has a responsibility of not using any water body in their neighborhood as a dumping ground for garbage and sewage as this also increases the pollution in the respective water bodies.

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APPENDIX I.
LIST OF TABLES.

APPENDIX I: VALUES OF QUALITY PARAMETERS FOR RIVER SAMPLES.

TABLE 4.1.1 SAMPLES OF 01/12/94.

River points

Parameters	R1	R2	R3	R4	R5	AVG	MAX	MIN
T,oC	22	22	22.5	22	22	22.1	22.5	22
pH	7.3	7.3	7.3	7.6	7.5	7.4	7.6	7.3
D.O, mgl-1	2	2.2	1.9	2	1.8	1.98	2.2	1.8
B.O.D, mgl-1	200	48	100	65	55	93.6	200	48
C.O.D,mgl-1	1000	560	780	660	1200	840	1200	560
Suspended Solids,mg	196	140	248	88	54	145	248	54
Dissolved Solids,mgl-	230	240	240	620	240	314	620	230
Chlorides,mgl-1	34	34	34	46	38	37.2	46	34
Nitrates, mgl-1	0.7	0.5	0.4	0.7	0.8	0.62	0.8	0.4
Total Phosphates,mg	1.88	1.22	1.32	0.9	0.5	1.16	1.8	0.5
Corrosivity, %	11	10.8	10	10.3	10.4	10.5	11	10
Turbidity, NTU	70	78	83	87	52	74	87	52
Total hardness, mgl-1	151	142	167	144	155	152	167	142
Calcium hardness,mg	86	84	74	50	96	78	96	74
Magnesium hardness	16	14.1	23	23	14.3	18.1	18.1	14.1
Chromium,mgl-1	0	0.01	0.01	0.02	0	0.01	0.02	0
Copper,mgl-1	0.01	0.02	0.03	0.02	0.02	0.02	0.03	0.01
Iron,mgl-1	1.01	1.08	0.86	1.7	1.85	1.3	1.85	0.86
Manganese,mgl-1	0.07	0.12	2.1	0.15	0.16	0.52	2.1	0.12
Lead,mgl-1	0.1	0.08	0.04	0.06	0.01	0.06	0.08	0.01
Zinc,mgl-1	0.12	0.12	0.1	0.17	0.14	0.13	0.17	0.1

TABLE 4.1.2 SAMPLES OF 12/01/95.

River points

Parameters	R1	R2	R3	R4	R5	AVG	MAX	MIN
ToC	21.5	21	21	21.5	21	21.2	21.5	21
pH	7.1	7.3	7.4	7.4	7.5	7.34	7.5	7.1
D.O, mgl-1	1.1	1.8	1.5	1.1	1.4	1.38	1.8	1.1
B.O.D, mgl-1	480	340	340	260	300	344	480	260
C.O.D,mgl-1	1900	2000	1700	1400	1900	1780	2000	1400
Suspended Solids,mg	456	316	356	444	140	342	456	140
Dissolved Solids,mgl-	350	340	810	440	930	574	930	340
Chlorides,mgl-1	48	53	65	78	80	64.8	80	48
Nitrates, mgl-1	0.9	0.7	0.5	0.4	0.2	0.54	0.9	0.2
Total Phosphtes, mgl	2.85	2.08	2.46	1.42	0.9	1.94	2.85	0.9
Corrosivity,%	11	9.8	11	11.2	12	11	12	9.8
Turbidity, NTU	155	120	120	100	160	131	160	100
Total hardness, mgl-1	56	75	80	82	120	82.6	120	56
Calcium hardness,mg	26	36	38	40	96	47.2	96	26
Magnesium hardness	7.3	9.5	10.2	10.2	5.8	8.6	10.2	5.8
Chromium, mgl-1	0	0	0.01	0.03	0	0.01	0.03	0
Copper, mgl-1	0.01	0.01	0.01	0	0.01	0.01	0.01	0
Iron,mgl-1	2.04	2.02	3.32	3.94	2.59	2.78	3.94	2.01
Manganese, mgl-1	1.13	1.62	1.89	1.89	1.73	1.65	1.89	1.13
Lead,mgl-1	0.01	0.08	0.12	0.12	0.13	0.09	0.13	0.01
Zinc,mgl-1	0.3	0.26	0.38	0.68	0.43	0.41	0.68	0.26

APPENDIX I: VALUES OF QUALITY PARAMETERS FOR RIVER SAMPLES.

TABLE 4.1.3 SAMPLES OF 09/02/95.

River points

Parameters	R1	R2	R3	R4	R5	AVG	MAX	MIN
T,oC	21	21	21	20.5	21	20.9	21	20.5
pH	7.3	7.3	7.3	7.4	7.4	7.34	7.4	7.3
D.O, mgl-1	0.7	1.2	1	1	0.8	0.94	1.2	0.7
B.O.D, mgl-1	200	320	60	140	280	200	320	60
C.O.D,mgl-1	5260	1500	1900	1800	5600	3212	5600	1500
Suspended Solids,mg	380	360	460	266	504	394	504	266
Dissolved Solids,mgl-	900	560	640	664	612	675	900	560
Chlorides,mgl-1	62	50	43	57	58	54	62	43
Nitrates, mgl-1	1.5	1	0.8	0.6	0.4	0.86	1.5	0.4
Total Phosphates,mg	4.64	3.56	3.28	1.83	1	2.86	4.64	1
Corrosivity, %	10.1	10	9.8	9.3	10.2	9.88	10.2	9.3
Turbidity, NTU	275	175	140	130	105	165	275	105
Total hardness, mgl-1	198	100	104	88	74	113	198	74
Calcium hardness,mg	130	48	50	28	38	58.8	130	28
Magnesium hardness	16.5	12.6	13.1	14.6	8.7	13.1	16.5	8.7
Chromium,mgl-1	0	0	0.01	0	0.05	0.01	0.05	0
Copper, mgl-1	0.05	0.04	0.04	0.04	0.04	0.04	0.05	0.04
Iron, mgl-1	2.65	3.61	3.89	6.63	12.8	5.91	12.8	2.65
Manganese,mgl-1	1	1.45	1.5	1.55	1.86	1.5	1.86	1
Lead, mgl-1	0.07	0.02	0.15	0.1	0.08	0.08	0.15	0.02
Zinc,mgl-1	0.45	0.41	0.46	0.82	1.72	0.77	1.72	0.41

TABLE 4.1.4 SAMPLES OF 09/03/95.

River points

Parameters	R1	R2	R3	R4	R5	AVG	MAX	MIN
ToC	22	22	22	21	21	21.6	22	21
pH	8.9	7.3	7.5	7.4	7.3	7.68	8.9	7.3
D.O, mgl-1	2.4	2.6	2.2	2	1.8	2.2	2.6	1.8
B.O.D, mgl-1	200	200	200	260	220	216	260	200
C.O.D,mgl-1	340	250	360	400	480	366	480	250
Suspended Solids,mg	368	440	528	540	208	416.8	540	208
Dissolved Solids,mgl-	720	380	120	240	220	336	720	120
Chlorides,mgl-1	74	55	60	48	51	57.6	74	48
Nitrates, mgl-1	0.9	2.5	1.5	2	1.5	1.68	2.5	0.9
Total Phosphtes, mgl	4.66	1.1	0.8	0.9	0.7	1.632	4.66	0.7
Corrosivity,%	10.3	10.4	10.1	10	10.1	10.18	10.4	10
Turbidity, NTU	145	115	86	76	51	94.6	145	51
Total hardness, mgl-1	124	147	138	133	174	143.2	174	124
Calcium hardness,mg	20	110	56	60	66	62.4	110	20
Magnesium hardness	25	9	20	17.7	26	19.54	26	9
Chromium,mgl-1	0	0	0	0.02	0	0	0.02	0
Copper,mgl-1	0.04	0.03	0.06	0.03	0.02	0.04	0.06	0.02
Iron,mgl-1	2.16	3.07	5.11	4.83	4.15	3.86	5.11	2.16
Manganese, mgl-1	1.63	3.1	2.8	2.89	3.02	2.69	3.1	1.63
Lead, mgl-1	0.11	0.14	0.42	0.11	0.11	0.18	0.42	0.11
Zinc, mgl-1	0.49	0.33	0.7	0.11	0.36	0.52	0.52	0.11

APPENDIX I: VALUES OF QUALITY PARAMETERS FOR RIVER SAMPLES.

TABLE 4.1.5 SAMPLES OF 20/04/95.

River points

Parameters	R1	R2	R3	R4	R5	AVG	MAX	MIN
T,oC	22	22	22	22	22	22	22	22
pH	9	8.2	7.1	6.9	7.4	7.72	9	6.9
D.O, mgl-1	2.8	6	3.4	3.5	3.1	3.76	6	2.8
B.O.D, mgl-1	156	32	120	112	135	111	156	32
C.O.D,mgl-1	540	220	280	300	300	328	540	220
Suspended Solids,mg	240	208	160	160	440	241.6	440	160
Dissolved Solids,mgl	1440	220	188	360	280	497.6	1440	188
Chlorides,mgl-1	88	58	78	115	37	75.2	115	37
Nitrates, mgl-1	5	7.5	2.5	1.3	1.5	3.56	7.5	1.3
Total Phosphates,mg	1.23	1.4	0.1	0	0.3	0.606	1.4	0
Corrosivity, %	10.2	10.4	10	10.5	10.3	10.28	10.5	10
Turbidity, NTU	98	95	88	120	80	96.2	120	80
Total hardness, mgl-1	280	238	218	208	136	216	280	136
Calcium hardness,mg	99	100	96	136	78	101.8	136	78
Magnesium hardness	2.8	34	30	18	14	19.76	34	2.8
Chromium, mgl-1	0	0	0.04	0.04	0	0.02	0.04	0
Copper,mgl-1	0.05	0.02	0.02	0.03	0.01	0.03	0.05	0.01
Iron,mgl-1	2.95	2.39	32.3	53	9.7	20.1	53	2.39
Manganese,mgl-1	2.17	2.03	2.44	3.23	2.5	2.47	3.23	2.03
Lead, mgl-1	0.22	0.14	0.1	0.2	0.26	0.18	0.26	0.1
Zinc,mgl-1	0.25	0.21	0.17	0.24	0.47	0.27	0.47	0.17

TABLE 4.1.6 SAMPLES OF 18/05/95.

River points

Parameters	R1	R2	R3	R4	R5	AVG	MAX	MIN
ToC	21.9	22.4	22.3	22.5	21.7	22.2	22.5	21.7
pH	7.3	7.3	7.2	7.4	7.4	7.32	7.4	7.2
D.O, mgl-1	2	4	2.5	3	2.3	2.76	4	2
B.O.D, mgl-1	160	140	150	230	180	172	230	140
C.O.D,mgl-1	214	250	340	490	900	439	900	214
Suspended Solids,mg	240	140	120	160	220	176	240	120
Dissolved Solids,mgl	280	440	442	460	480	420	480	280
Chlorides,mgl-1	40	41	42	45	46	42.8	46	40
Nitrates, mgl-1	2	2.5	2	1.8	2.3	2.12	2.5	1.8
Total Phosphtes, mgl	1.1	1.5	1.4	1.4	1.3	1.34	1.5	1.1
Corrosivity,%	9.7	2.3	5	7.8	6	6.16	9.7	2.3
Turbidity, NTU	59	41	60	65	82	61.4	82	41
Total hardness, mgl-1	275	310	320	270	324	300	324	270
Calcium hardness,mg	66	72	68	64	74	68.8	74	64
Magnesium hardness	50.7	58	61	51	61	56.3	61	50.7
Chromium,mgl-1	0.04	0.02	0.03	0	0.04	0.03	0.04	0
Copper,mgl-1	0	0.02	0	0.02	0.01	0.01	0.02	0
Iron,mgl-1	1.6	2.2	1.94	1.7	3.52	2.19	3.52	1.6
Manganese,mgl-1	2.11	2.28	2.31	2.11	2.54	2.27	2.54	2.11
Lead,mgl-1	0.2	0.1	0.12	0.1	0.06	0.12	0.2	0.06
Zinc,mgl-1	0.2	0.16	0.17	0.3	0.33	0.23	0.33	0.16

APPENDIX I: VALUES OF QUALITY PARAMETERS FOR RIVER SAMPLES.

TABLE 4.1.7 SAMPLES OF 22/06/95.

River points

Parameters	R1	R2	R3	R4	R5	AVG	MAX	MIN
T,oC	20.5	19.9	20.2	20.8	20.6	20.4	20.8	19.9
pH	8.3	7.4	7.2	7.6	7.6	7.62	8.3	7.2
D.O, mgl-1	3	2	2.4	2.1	6	3.1	6	2
B.O.D, mgl-1	164	80	144	90	10	97.6	164	10
C.O.D,mgl-1	385	275	260	339	374	326.6	385	260
Suspended Solids,mg	40	40	412	332	20	168.8	412	20
Dissolved Solids,mgl-	640	464	640	600	628	594.4	640	464
Chlorides,mgl-1	56	60	53	113	63	69	113	53
Nitrates, mgl-1	1.8	1.5	2	0.8	0.2	1.26	2	0.2
Total Phosphates,mg	4	3	3.2	1.5	0.6	2.46	4	2.46
Corrosivity, %	10.1	12.4	10.1	11.3	11.1	11	12.4	10.1
Turbidity, NTU	102	65	56	66	55	68.8	102	55
Total hardness, mgl-1	177	174	170	162	192	175	192	162
Calcium hardness,mg	64	61	60	64	72	64.2	72	60
Magnesium hardness	27.4	27.4	26.7	23.8	29.1	26.88	29.1	23.8
Chromium,mgl-1	0	0	0.02	0.16	0	0.04	0.16	0
Copper,mgl-1	0.03	0.01	0.01	0.03	0.01	0.02	0.03	0.01
Iron,mgl-1	1.6	2.03	2	6.33	3	3	6.33	1.6
Manganese,mgl-1	1.38	1.8	1.7	2	1.9	1.76	2	1.38
Lead,mgl-1	0.05	0.07	0.08	0.13	0.1	0.09	0.13	0.05
Zinc.mgl-1	0.75	0.4	0.41	3.18	0.55	1.06	3.18	0.4

APPENDIX I: VALUES FOR DRAINAGE WATER SAMPLES.

TABLE 4.1.1.1 SAMPLES OF 15/12/94.

Drainage points

Parameters	D1	D2	D3	D4	D5	AVG	MAX	MIN
T,oC	21	22	23	23	23	22.4	23	21
pH	7.7	9	8.4	6.2	7.5	7.76	9	6.2
B.O.D, mgl-1	170	100	165	150	175	152	175	100
C.O.D,mgl-1	1200	200	273	880	270	565	1200	200
Suspended Solids,mg	108	200	560	230	10	222	560	10
Dissolved Solids,mgl-	70	660	1100	390	30	450	1100	30
Chlorides,mgl-1	18	65	266	278	90	143	278	18
Turbidity, NTU	57	110	110	160	10	89.4	160	10
Total hardness, mgl-1	69	76	90	82	90	81.4	90	69
Calcium hardness,mg	46	48	40	52	36	44.4	52	36
Magnesium hardness	6	7	12	7.3	13	9.06	13	6
Chromium,mgl-1	0	0.01	0.04	1	0.01	0.21	0.04	0
Copper,mgl-1	0.07	0.04	0.03	0.01	0.01	0.03	0.07	0.01
Iron,mgl-1	1.2	0.8	6.6	7.8	1.2	3.52	7.8	0.8
Manganese,mgl-1	0.06	0.08	0.1	0.6	0.5	0.27	0.6	0.06
Lead,mgl-1	0.01	0.06	0.4	1.2	0.09	0.35	1.2	0.01
Zinc,mgl-1	0.1	0.3	3	2.6	0.08	1.22	3	0.08

TABLE 4.1.2.1 SAMPLES OF 26/01/95.

Drainage points

Parameters	D1	D2	D3	D4	D5	AVG	MAX	MIN
ToC	22.5	22	23	23.5	23	22.8	23.5	22
pH	7.6	10	6.8	7.3	8	7.94	10	6.8
B.O.D, mgl-1	120	242	520	250	86	244	520	86
C.O.D,mgl-1	790	1540	3300	1700	630	1592	3300	630
Suspended Solids,mg	340	420	118	120	96	219	420	96
Dissolved Solids,mgl	970	1728	2800	1530	495	1505	2800	495
Chlorides,mgl-1	82	68	205	350	90	159	350	68
Turbidity, NTU	220	410	110	275	95	222	410	95
Total hardness, mgl-1	143	48	440	48	86	153	440	48
Calcium hardness,mg	98	20	120	18	26	56.4	120	18
Magnesium hardness	10.9	6.8	78	7.3	14.6	23.5	78	6.8
Chromium,mgl-1	0	0	0.02	1.08	0.01	0.22	1.08	0
Copper,mgl-1	0.05	0.03	0.2	0.02	0.01	0.06	0.2	0.01
Iron,mgl-1	1.76	1.08	0.43	3.07	9.2	3.11	9.2	0.43
Manganese,mgl-1	0.4	0.1	0.8	0.51	0.5	0.46	0.8	0.1
Lead,mgl-1	0	0.05	2.66	0.1	0.08	0.58	2.66	0
Zinc,mgl-1	0.08	0.2	3.11	2.13	0.06	1.12	3.11	0.2

APPENDIX I: VALUES OF QUALITY PARAMETERS FOR DRAINAGE WATER SAMPLES.

TABLE 4.1.3.1 SAMPLES OF 23/02/95.

Drainage points

Parameters	D1	D2	D3	D4	D5	AVG	MAX	MIN
T,oC	26	24	24	28	30	26.4	30	24
pH	7.6	9.3	6.6	5.7	7.5	7.34	9.3	5.7
B.O.D, mgl-1	60	90	1000	400	220	354	1000	60
C.O.D,mgl-1	340	230	2600	1500	1900	1314	2600	230
Suspended Solids,mgl	170	220	276	370	560	319	560	170
Dissolved Solids,mgl-1	1376	2220	2790	2680	992	2012	2790	992
Chlorides,mgl-1	360	61	170	48	184	165	360	48
Turbidity, NTU	58	75	100	240	8	96.2	240	8
Total hardness, mgl-1	480	37	75	400	52	209	480	37
Calcium hardness,mgl	454	20	68	100	38	136	454	20
Magnesium hardness,	6.3	4.1	1.7	73	3.4	17.7	73	1.7
Chromium,mgl-1	0	0	0.02	1.08	0	0.22	1.08	0
Copper,mgl-1	0.02	0.01	0.22	0.04	0.05	0.07	0.22	0.01
Iron,mgl-1	0.41	0.56	2.41	20.6	3	5.4	20.6	0.41
Manganese,mgl-1	0.58	0.16	0.9	9	0.41	2.21	2.21	0.16
Lead,mgl-1	0.08	0.07	0.72	0.15	0.18	0.24	0.72	0.07
Zinc,mgl-1	0.2	0.14	2.12	12.4	3.3	3.63	12.4	0.14

TABLE 4.1.4.1 SAMPLES OF 23/03/95.

Drainage points

Parameters	D1	D2	D3	D4	D5	AVG	MAX	MIN
ToC	22	23	28	23	22	23.6	28	22
pH	8.7	10.1	10.6	9	9	9.48	10.6	8.7
B.O.D, mgl-1	120	35	230	95	65	109	230	35
C.O.D,mgl-1	700	760	3500	2700	900	1712	3500	700
Suspended Solids,mgl	40	40	20	400	16	103	400	16
Dissolved Solids,mgl-1	480	1560	1660	2100	280	1216	2100	280
Chlorides,mgl-1	52	163	330	425	40	202	425	40
Turbidity, NTU	82	75	250	230	24	132	250	24
Total hardness, mgl-1	207	36	76	48	87	90.8	207	36
Calcium hardness,mgl	78	26	70	28	46	49.6	78	26
Magnesium hardness,	31	2.4	1.5	4.9	10	9.96	31	1.5
Chromium,mgl-1	0.09	0.06	0.07	2.24	0.045	0.5	2.24	0.05
Copper,mgl-1	0.04	0.04	0.02	0.08	0.03	0.04	0.08	0.02
Iron,mgl-1	1.02	0.44	0.62	42.4	1	9.1	42.4	0.44
Manganese,mgl-1	0.54	0.12	0.41	0.8	0.7	0.51	0.8	0.12
Lead,mgl-1	0.4	0.32	0.38	0.49	0.25	0.37	0.49	0.25
Zinc,mgl-1	0.26	0.6	4.04	4.93	0.26	2.02	4.93	0.26

APPENDIX I: VALUES OF QUALITY PARAMETERS FOR DRAINAGE WATER SAMPLES.

TABLE 4.1.5.1 SAMPLES OF 04/05/95.

Drainage points

Parameters	D1	D2	D3	D4	D5	AVG	MAX	MIN
T,oC	22	24	25	24	24	23.8	25	22
pH	8.2	10.6	8.8	7.5	8	8.62	10.6	7.5
B.O.D, mgl-1	60	248	120	180	20	126	248	20
C.O.D,mgl-1	216	640	500	930	70	471	930	70
Suspended Solids,mgl	120	144	80	480	40	173	480	40
Dissolved Solids,mgl-1	360	2480	1280	1800	480	1280	2480	360
Chlorides,mgl-1	30	180	54	114	95	94.6	180	30
Turbidity, NTU	29	35	55	450	25	119	450	25
Total hardness, mgl-1	166	84	200	182	100	146	200	84
Calcium hardness,mgl	44	28	190	58	56	75.2	190	28
Magnesium hardness,	29.6	13.6	2.4	30	10.7	17.3	29.6	2.4
Chromium,mgl-1	0	0	0.04	0.04	0	0.02	0.04	0
Copper,mgl-1	0.05	0.02	0.02	0.03	0.01	0.03	0.05	0.01
Iron,mgl-1	2.95	2.4	32.3	53	9.8	20.1	53	2.4
Manganese, mgl-1	2.2	2.04	2.44	3.23	2.47	2.48	3.23	2.04
Lead,mgl-1	0.22	0.14	0.1	0.2	0.26	0.18	0.26	0.1
Zinc,mgl-1	0.25	0.21	0.17	0.24	0.47	0.27	0.47	0.17

TABLE 4.1.6.1 SAMPLES OF 08/06/95.

Drainage points

Parameters	D1	D2	D3	D4	D5	AVG	MAX	MIN
ToC	34	22	28	24	24	26.4	34	22
pH	7	9.6	9.5	8.7	8.5	8.66	9.6	7
B.O.D, mgl-1	290	115	70	120	65	132	290	65
C.O.D,mgl-1	467	157	487	483	183	355	487	157
Suspended Solids,mgl	40	40	412	332	20	169	412	20
Dissolved Solids,mgl-1	1182	800	900	800	536	844	1182	536
Chlorides,mgl-1	212	41	39	224	100	123	224	39
Turbidity, NTU	38	99	54	115	54	72	115	38
Total hardness, mgl-1	433	152	102	231	114	206	433	102
Calcium hardness,mgl	111	56	48	54	60	65.8	111	48
Magnesium hardness,	78	23	13	43	13	34	78	13
Chromium,mgl-1	0.01	0.02	0.01	0.11	0.02	0.03	0.11	0.01
Copper,mgl-1	0.01	0.01	0.36	0.01	0.02	0.08	0.36	0.01
Iron,mgl-1	0.5	0.73	1.09	21.2	0.64	4.83	4.83	0.5
Manganese,mgl-1	0.25	0.52	0.58	2.5	0.91	0.95	2.5	0.25
Lead,mgl-1	0	1.87	0.27	0.08	0.1	0.46	1.87	0
Zinc.mgl-1	0.19	0.21	4	14.8	0.16	3.87		0.16

TABLE 4.2.8 MEAN RIVER VALUES.

Parameter	R1	R2	R3	R4	R5
ToC	21.56	21.47	21.57	21.47	21.33
pH	7.88	7.44	7.28	7.38	7.44
D.O., mgl-1	2	2.83	2.13	2.1	2.46
B.O.D, mgl-1	222.86	165.71	159.14	165.28	168.57
C.O.D, mgl-1	1377	722.14	802.86	769.86	1536.29
Suspended solids, mgl-1	274.28	234.86	326.28	284.28	226.57
Dissolved solids, mgl-1	651.43	377.71	440	483.43	484.28
Chlorides, mgl-1	57.43	50.14	53.57	71.71	53.29
Nitrates, mgl-1	1.83	2.31	1.39	1.08	0.98
Total phosphates, mgl-1	2.91	1.98	1.79	1.14	0.84
Corrosivity,%	10.34	9.44	9.43	10.06	10.01
Turbidity, NTU	129.14	98.43	90.43	92	83.57
Total hardness, mgl-1	180.14	169.43	171	155.28	167.86
Calcium hardness, mgl-1	70.14	73	63.14	63.14	74.28
Magnesium hardness, mgl-	20.81	23.51	26.28	22.61	22.7
Chromium, mgl-1	0.006	0.004	0.017	0.039	0.013
Copper, mgl-1	0.027	0.021	0.024	0.024	0.017
Iron, mgl-1	2	2.34	7.06	11.16	5.37
Manganese, mgl-1	1.36	1.77	2.11	1.97	1.96
Lead, mgl-1	0.11	0.09	0.15	0.12	0.107
Zinc, mgl-1	0.37	0.27	0.33	0.82	0.57

TABLE 4.2.9 MEAN DRAINAGE VALUES.

	D1	D2	D3	D4	D5
Parameter					
ToC	24.58	22.83	25.12	24.25	22.33
pH	7.8	9.77	8.45	6.34	8.08
B.O.D, mgl-1	136.7	138.33	350.83	199.16	105.17
C.O.D, mgl-1	618.83	587.83	1776.7	1365.5	658.83
Suspended solids, mgl-1	136.33	177.33	244.33	322	123.67
Dissolved solids, mgl-1	739.67	1574.67	1755	1550	468.83
Chlorides, mgl-1	125.67	96.33	177.33	239.83	99.85
Turbidity, mgl-1	80.67	134	113.16	245	36
Total hardness, mgl-1	249.67	72.17	163.83	165.17	88.17
Calcium hardness, mgl-1	138.5	33	89.33	51.67	43.67
Magnesium hardness, mgl-1	26.97	9.48	18.1	27.58	10.78
Chromium, mgl-1	0.016	0.015	0.033	0.925	0.015
Copper, mgl-1	0.04	0.025	0.142	0.032	0.022
Iron, mgl-1	1.31	1	7.24	14.12	4.14
Manganese, mgl-1	0.67	0.5	0.87	2.77	0.915
Lead, mgl-1	0.12	0.42	0.755	0.37	0.16
Zinc, mgl-1	0.18	0.28	2.17	4.47	0.72