

PROFILING OF SURFACE WATER POLLUTION IN ZARIA

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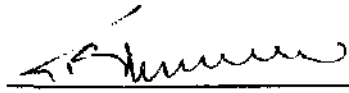
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**Being a thesis submitted to the Postgraduate School, Ahmadu Bello University, Zaria,
in partial fulfillment of the requirement for the award of Master of Science in
Analytical Chemistry.**

OCTOBER, 2000

CERTIFICATION

The thesis entitled "Profiling of Surface Water Pollution in Zaria" by IREKPITA HELEN meets the regulation governing the award of Master of Science of Ahmadu Bello University and is approved for its contribution to knowledge and literary presentation.



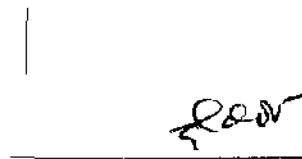
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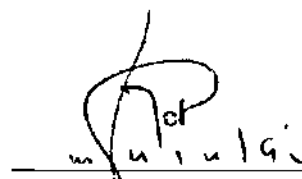
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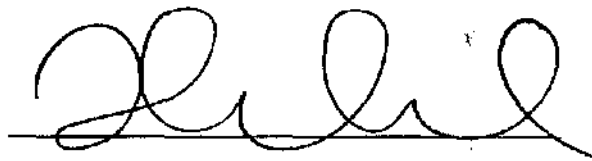


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DECLARATION

I hereby declare that this thesis has been written by me and is a record of my own research work. It has not been presented in any previous application for a higher degree. All quotations and sources of information are acknowledged.

A handwritten signature in black ink, consisting of several loops and curves, positioned above a horizontal line.

Candidate

DEDICATION

This work is dedicated to my entire family.

ACKNOWLEDGMENT

I wish to express my sincere gratitude to my supervisor, Dr. E. J. Ekanem, for his guidance, counseling and assistance all through the programme. I am also grateful to my second supervisor DR. G. F. S. Harrison. I wish to also express my gratitude to the head of department and all the staff for their assistance. I wish to acknowledge with profound gratitude and appreciation the contributions of Dr. C.A. Okuofu, Dr. J. K. Adewunmi and Mr. P. C. Alike. I also acknowledge the contributions of Mr. P. O. Esekhaigbe for his support and help. I am also grateful to my all friends and colleagues.

ABSTRACT

The profile of surface water pollution in Zaria was studied between August 1998 and July 1999, a period which covered both the rainy and dry seasons. Surface water in the Zaria area is supplied and distributed by a combination of three rivers including river Kubanni, river Sheka and river Galma. Monthly samples were collected from twelve sites located on the rivers studied during the period. Standard methods were used throughout for the measurement of physical and chemical parameters of samples. The results reveal seasonal variations with respect to conductivity, solids and nitrate. Results also show considerable variations parameters that relate to phosphate, BOD, COD especially at sites that receive waste discharges. These result show that the rivers of this study are getting polluted as shown by BOD (249 ppm), nitrate (23.6mg/L), phosphate (18.6). A monitoring program on these rivers is recommended.

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CHAPTER ONE

1.0 INTRODUCTION

In the earlier days, the impact of man's activity on the earth's environment was rather little and nature could resist and compensate for it. At the end of the 19th century, environmental problems arose due to growing cities and industrialization. Pollution of air and water channels in the bigger cities became severe. In the 20th century, the increase in intensity of agriculture and cattle rearing, changes and growth in industrial processing and in the nature of compounds used from natural to synthetic compounds made environmental problems even greater. Nature could no longer resist and compensate for them.

A pollutant is a material that is introduced into the environment as a result of man's activities and causes injury to the health of the environment including life forms present in it, appliances installed in it and reduces the aesthetic quality of the environment (Goulden, 1978). Most pollutants enter the environment as emissions to the atmosphere or discharges to water bodies or dumps on land. Most materials emitted to the atmosphere eventually return to the earth either as particulate fallout or with rain or snow. They may be absorbed by soil and eventually vegetation or they may be washed into waterways. They may become incorporated into sediments or may be metabolized by plants and animal life in water and thus enter the food chain.

With growing environmental awareness of the seventies and eighties, environmental quality monitoring intensified. Sampling has intensified, not only on surface water, but also on sediments and aquatic organisms (Chapman, 1992).

With the growing awareness, the range of requirements for the quality of the environment has widened. Requirements for drinking water, personal hygiene, agriculture, industrial production and recreation have emerged in most of the developed world. Laws have been established to protect the environment, especially the waterways since most, if not all, pollutants eventually end up there. Guidelines and standards have been provided especially for effluents to be discharged to the environment. In Nigeria, the Federal Environmental Protection Agency (FEPA) was established by Decree 58 of 30th December 1988 to control pollution in the country. The National Environmental Policy was also launched in Abuja on 27th November 1989.

Drinking water supplies and industrial water requirement exert the greatest demand on water quality. Water has always been used since ancient times to clean, disperse, transport and dispose waste. Each water use leads to specific and generally predictable impacts on the quality of the aquatic environment. Pollution and degradation of water interfere with vital and legitimate uses of water.

1.2 Sources of water pollution

In general pollutants can be released into the environment from point sources and non-point sources. They enter the environment as gases, dissolved substances or particulate forms. These pollutants almost always find their way into the waterways either through rain or snow. The major proportion of water degradation is due to anthropogenic activities like agriculture, industrial processing and domestic activities.

1.2.1 Agricultural Activities

Agricultural activities produce and introduce wastes into waterways through the use of fertilizers, herbicides and pesticides. One of the major requirements for satisfactory crop production is the availability of nutrients when the crop is growing. Fertilizers or manure are added to the soil especially in the areas where the soil nutrient is not sufficient. Generally only about 10-30% of fertilizer phosphorus is taken up by the growing crop, the remaining being leached through the soil into the waterways (Loehr, 1977). This is the major contributor of nutrient to surface water. Efforts have been made to discover a direct relationship between applied fertilizer nitrogen and the concentration of nitrogen in stream and drainage water (Ezeonu *et al.*, 1994; Tonderski *et al.*, 1995). This has not been possible due to the pre-existence of a large reservoir of nitrogen in the soil and the rate of biological transformation of this reservoir. Pesticides applied to plants to control pests are easily washed by rain into the soil and ultimately the waterways. Some pesticide residues have been found to persist in the environment long after application (Peakall and Lincer, 1970; Krimbrough, 1974). Such residues in water are taken up by aquatic organisms and eventually man through the food chain (Coleman - Cooke, 1965).

1.2.2 Industrial Activities

Industry is another major source of pollutants to the environment. Industrial activities include discharge of wastewater with little or no treatment, and improper disposal of solid waste and transportation accidents such as those of vehicles that move petroleum products and other chemicals (Keller and Wilson, 1992). The intensely coloured fluids that fill drainage systems in the immediate vicinity of textile

industries, particularly in Nigeria, silently indict those industries for polluting the terrain and waterways in which the effluents pass (Ekanem and Fodeke, 1996).

Pollution of the environment by heavy metals resulting from industrial activities like metal plating and fuel combustion is increasing with resultant ecological impacts (Fergusson, 1990). Most heavy metals are emitted to the atmosphere as particulate and are removed by wet and dry deposition. When very acidic water of pH 3.5 and below is applied to soil, an increased leaching of calcium, magnesium and aluminium occurs. Sulphate concentration in air pollution has increased probably because of the pollution of the air mass passing over an area where SO_2 and other sulphur containing gases (SO_x) and vapours are generated by the combustion of petroleum products in automobiles, boilers and stacks. These gases form weak acids and are washed down with rain or snow into the soil and waterways. Globally, pollution by acid deposition has increased substantially since the advent of industrial activities. Manmade emission of SO_2 derived largely from fossil fuel combustion is now similar in magnitude to that from natural sources such as volcanic activities. Similar emissions of nitrogen oxides (NO_x) from anthropogenic activities such as fuel combustion, biomass burning and natural sources (microbial and lightning) have increased the level of NO_x in the environment. SO_x and NO_x are transported by prevailing winds for distances up to 1000km from their original sources before returning to the earth's surface as either wet or dry deposition (Tolba, 1983; Rodhe *et al.*, 1988).

1.2.3 Other Sources

Other sources of pollutants to the environment include sewage treatment, urban land runoffs and domestic wastes. Pollution due to untreated domestic wastes occurs in all urban areas. In highly populated areas of most developing and underdeveloped nations, the population is not provided with waste handling facilities due to cost and lack of proper planning. As a result, household sewage and refuse are discharged untreated into the environment. Most waterways passing through urban centres are used as dump sites with open gutters leading from households direct to the waterways. A lot of toxic materials are leached by rain into waterways from such dumpsites. Other uncommon non-point sources of pollutants to the environment include fire-fighting activities, storm overflow of sewage works, accidental release of chemical from industries, excessive use of agricultural chemicals etc.

1.3 Effects of Environmental Pollution

1.3.1 Chemical Effects

Man's first interest in the quality of the environment was provoked by health considerations. Pollution of the environment, especially water, affects the lives of a great number of people throughout the world especially those living in the industrialized areas. Each year, hundreds of new chemicals and products are created and, because many of these substances differ significantly from natural substances, detailed biochemical studies have to be designed to discover any potentially harmful effects. Often when synthetic substances are introduced into the environment, their movement through the ecosystem is difficult to track. Therefore there is the need to have established data to monitor what is in the environment at all times. Many of the synthetic substances are not biodegradable

and are of particular concern especially if they can accumulate in organisms including man. Such accumulation has effects, which are long term and can cause diseases such as cancer, cardiac disorder and birth defects (Murdoch, 1975).

Many chemicals are essential or, at least, beneficial to human health but can be toxic when taken in excess through means such as food or water. An example is nitrate, which causes methemoglobinemia at high levels in water with an acute toxic response in children (Wrobel and Brebbia, 1993).

A number of heavy metals are toxic to humans because of their interaction with sulfur containing biochemicals such as enzymes and protein (Fergusson, 1990). The Minamata case in Japan is an example of heavy metal poisoning (Luckey and Venugopal, 1977) Children were born with physical abnormalities as a result of mercury poisoning. This occurred because the population consumed water and fish highly contaminated with mercury. The discharge of such contaminated water was over a long period of time and was not controlled until the effects were seen. Heavy metals such as cadmium used in metal plating can cause kidney and bone mass diseases at high concentration (Lee and Mudd, 1979; Mennear, 1979).

Air pollution as a result of materials such as smoke and dust can cause respiratory tracts diseases such as lung cancer especially in older population (Baker *et al.*, 1961).

By far the most important effects that pollutants have on the environment is on aquatic life. Excessive nutrients from land used for crop production or waste disposal cause an imbalance in the natural ecosystem and intensify eutrophication

in streams and lakes. Pesticides are accumulated in aquatic organisms and eventually man through the food chain. Such an accumulation in man causes cancer. Synthetic organic materials such as industrial chemicals, detergents and other materials are toxic to man, plants and aquatic life. The effects can be observed in the number of fish kills that occur with the release of such pollutants into the environment. Such materials are resistant to ordinary waste treatment processes and may have long-term effects (Vesilind, 1974).

1.3.2 Acidic Deposition

Adverse effects on the environment result from acid deposition causing acidification of fresh water and terrestrial ecosystems (Rodhe *et al.*, 1988; Suess, 1986). Changes in soil acidity and transfer of the rainwater acidity to streams are a function of the hydrogen ion concentration of water entering the soil (Miller and Miller, 1983).

Effects of acid deposition can be seen from the world's popular monuments and buildings. The acid causes corrosion and dissolves the materials used in the making of such structures and figurines.

1.3.3 Infective Agents

Disease causing agents, mainly infective organisms, are carried into surface and ground waters in sewage from cities, hospitals, farms, food processing and dump sites. Man and animals come into contact with such organisms by ingestion or through washing with and drinking such water. Most outbreaks of diseases such as cholera and typhoid arise from such pollutants (Cairncross and Feachem, 1993). Microorganisms in waste discharges may impair the use of surface waters

for recreational purposes by depleting dissolved oxygen. This can also cause fish kills and septic conditions.

1.3.4 Heat

Machinery and product cooling increases the temperature of receiving waters as a result of heat. This leads to a decrease in dissolved oxygen in the water. The high temperature also tends to stimulate the growth of biological organisms thereby increasing the demand for dissolved oxygen. Attendant algal bloom, oxygen depletion and autoanihilation and reoxygenation are stages in eutrophication.

1.4 Water Quality Variables

Knowledge of the chemical content of natural water is often of value. This is because, no matter the source of pollution, the pollutant invariably ends up in the waterways. Samples collected for water analysis from any water site can be used as an indicator of pollution of the environment. The type of analysis carried out on the sample depends on the end use of the data to be collected. The type of equipment required to sample waters is governed partly by the nature of analysis required; and water samples are subject to changes in chemical composition due to microbial or interchemical reactions.

Some general variables are discussed below.

1.4.1 Physical Variables

Temperature - Temperature is influenced by latitude, altitude, season, time of day, air circulation, cloud cover, flow and depth of the water body (Chapman, 1992). Temperature affects physical, chemical and biological processes in water

and also many other variables. Temperature is measured at site with a thermometer and can range between 0°C and 30°C in most parts of the world.

Colour and Turbidity - These determine the depth to which light is transmitted and controls photosynthesis. Colour can be measured with a nephelometer or by visual observation.

Solid Matter - Solid matter controls turbidity of water bodies. This consists of silt, clay, and fine particles of both organic and inorganic nature. This is measured by weighing the residue remaining after evaporation and drying for total solids, and after filtration and drying for suspended solids; a difference between these two gives the value of dissolved solids.

Conductivity - This is a measure of the ability of the sample to conduct an electric current. This is related to the amount of ionizable solids dissolved and ions present.

pH - pH is a measure of the acid/base balance of a sample and can be affected by effluent discharged into a waterbody. Most water bodies have pH 6.0 - 8.5.

Acidity and Alkalinity - Acidity and alkalinity are the base and acid neutralizing capacities of water and can be determined by titration

1.4.2 Chemical Variables

Dissolved Oxygen - Dissolved Oxygen varies with temperature and is a measure of the amount/solubility of oxygen in water bodies. Dissolved oxygen is used to indicate the degree of pollution by organic matter and also in the determination of

the Biochemical Oxygen Demand (BOD) which is the amount of oxygen required to biochemically oxidize a sample of water at constant temperature.

Nutrients - Nitrate and nitrite, which can be of natural origin, can be sourced or enhanced by municipal and industrial waste in urban areas and by the use of fertilizers in rural and semi-urban/sub-urban farming areas. Nitrate levels give a general indication of nutrient status and level of organic pollution. Its concentration can be determined spectrophotometrically.

Phosphates are generally the limiting nutrient for algal growth and excesses can lead to eutrophication. It occurs as ortho- and polyphosphates. Domestic and industrial wastes and fertilizer runoffs contribute to increased levels in surface water. Its concentration can be measured colorimetrically.

Pesticides - These are chemicals used to exterminate insects and other pests. Some of them are highly persistent in the environment and occur in detectable concentrations, enough to cause pollution of water. They are determined by highly sophisticated analytical techniques such as gas chromatography-mass spectroscopy coupled techniques (Chapman, 1992; Mckeeney, 1981).

Boron -Boron is a natural component in water bodies but levels can be increased due to industrial and municipal wastewater. It is also a component of pesticides. Concentration in water can be measured colorimetrically (Chapman, 1992).

Oils and Grease - These may be present in water as an emulsion from industrial wastes. They are insoluble in water but can be emulsified or saponified by

detergent, alkalis or other chemicals also present in the water. They can be determined by solvent extraction methods.

Metals - Trace metals can vary in concentration in surface water due to climate and geographical condition. Levels can be high and can be of different ranges depending on the type of wastewater discharges. They can be determined spectrophotometrically.

1.4.3 Organic Matter

Organic matter can be measured by measuring related properties principally BOD, COD and TOC.

Chemical Oxygen Demand (COD) - COD is a measure of the oxygen equivalent of the organic and inorganic matter in a water sample that is susceptible to oxidation by a strong chemical oxidant such oxygen or dichromate (APHA, 1985). This is a non-selective process in which all oxidizable matter of organic and inorganic nature are oxidized. Levels can be high for water receiving industrial wastewater. COD is measured by titration or by colorimetry.

Biochemical Oxygen Demand (BOD) - BOD is the amount of oxygen required by bacteria to biochemically oxidize organic matter in a water sample. BOD is determined by measuring the amount of oxygen consumed after incubation of the sample at constant temperature for a specific number of days. Levels are high for water receiving wastewater and sewage discharges.

1.4.4. Microorganisms

Disease causing organisms contaminate water mainly by the presence of waste from both man and animals. The presence of indicator bacteria in water is indicative of faecal contamination of the water. Faecal coliforms, mainly Escherischia coli, are used as indicator organisms. Communities that use untreated water, as most areas in developing countries, are faced with serious epidemic problems (Cairncross and Feachem, 1993).

1.5 Water Quality Monitoring

Monitoring, in a narrow sense, is the process of going to a site at intervals to measure parameters or to collect samples for laboratory analysis (Keller and Wilson, 1992). Fieldwork involves taking on-site measurements with portable equipment as well as preparing the samples for laboratory analysis. This means filling the appropriate containers, adding the requisite preservatives and despatching the samples for laboratory tests (Whitlow, 1985). The description of the quality of the environment can be in a variety of ways. It can be either through quantitative measurements such as physicochemical determinations (in water, particulate matter or biological tissues) and biochemical tests (BOD measurements, toxicity test etc) or through semi-quantitative and qualitative descriptions such as biotic indices, visual aspects, species inventory, odour etc.

An important reason for monitoring the quality of an environment is in order to have a reference point for estimating the extent of pollution thereafter. Also the trends in the quality of the environment and how they are affected by the release of contaminants, other anthropogenic activities and by waste treatment plants are determined. Such monitoring generates data, which is essential for the

interpretation of the changing environment and in environmental management decisions (pollution control) such as setting of baseline and standards (USEPA, 1993; Chapman, 1992; Goulden, 1978; Keller and Wilson; 1992). It also leads to a vast collection of data necessary for the preliminary assessment of the impacts of societal activities.

3 **Research Objectives**

In this study the objectives were to

- (i) Survey the anthropogenic activities in the Zaria area.
- (ii) Identify sources of pollutants and their impacts by collecting and analysing samples of water.
- (iii) Sample for profiling each of the rivers and obtaining baselines for key pollutants.
- (iv) Generate data for the types, concentrations and sources of certain pollutants in the area for future reference (data banking).

The areas of investigation in this study are the river Kubanni and river Galma. River Kubanni drains water from the catchment area of Samaru and flows past Zaria township while river Galma flows in from Jos road and drains the rural areas along Jos road. River Galma receives river Kubanni at the bridge on old Jos road and then flows on to Kaduna. The stretches of rivers are subjected to a number of uses including drinking, irrigation, fishing, industrial activities and waste disposal.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

Initially the problem of environmental pollution was a public health problem, with sickness and debilitation as noticeable effects that had their roots in a contaminated environment (Horton, 1907; Petero and Cingblani, 1908; Parker, 1935). With growing industrialization and human population, pollution problems increased in scope, partly due to increased awareness and partly due to sophistication in research (Sheppard, 1933; Eastwood, 1933; Hubbs, 1934). A change in environmental thinking occurred in the nineties; but before that time the environmental problems were described separately of each other from a chemical, biological, physical and ethical points of view (Arbuckle, 1911; Laybourn, 1929; Oberzill, 1941). Over the years, however, several extreme cases of pollution of inland waterways near urban populations have brought to light the damage done to the environment and it has become clear that more care must be taken in monitoring hazardous chemicals in the environment (Hubbs, 1934; Sheppard, 1933; Jerden, 1933).

As precipitation falls to the earth, it absorbs small amounts of materials from the air it traverses. These materials are brought down as dilute acids, which, on passing through the ground, dissolve many inorganic compounds. Therefore there is the potential for river water to contain a wide range of inorganic substances some usually derived from the natural substratum of the watercourse. These substances undergo complex chemical reactions and interactions with the precipitation, the soil and its biota and the underlying strata through which they

percolate (Tolba, 1983; Forslund, 1986). The water picks up peaty substrates and humus in the soil.

Anthropogenic activities introduce a range of inorganic substances, many of which are at levels that can be detected in the environment. This is due partly to improved sensitivity of analytical techniques and partly to increased releases of substances into the environment (Marvin and Marvin, 1965; Goderis, 1975; Fisch, 1953; Smith 1983; Goulden, 1978; Keller and Wilson, 1992).

Soluble compounds from exhaust fumes of internal combustion engines accumulated in the air and on road surfaces are washed into rivers. Detergents from home laundry and industrial activities have resulted in increasing phosphate content of surface water with subsequent eutrophication. Industrial and other discharges into river systems are all increasing the background concentration of many pollutants in the environment. Such pollutants and activities need to be monitored so that changes can be noted and precaution taken to prevent extreme cases of pollution of the environment with its accompanying devastating effects (GESAMP, 1988; Vengenechten 1983; Suess 1986; Grahn, 1980; Anonymous, 1982).

2.2 **Monitoring of Surface Water Pollutants**

The concept of monitoring is not new and examples include routine species analysis by river authorities and observations of weather patterns by meteorological stations. The main purpose of introducing a monitoring program is to enable the rapid identification of potential hazards so that prompt precaution may be taken. A particularly comprehensive study on pollution monitoring is the

United Nations Global Environmental Monitoring Systems (GEM/WATER) initiated in 1974 to promote and co-ordinate the collection of environmental data. Another global environmental monitoring program is EARTHWATCH (Jensen, 1974).

Rivers are by far the most studied water bodies for which a number of variables have been measured. The rivers of Europe and North America are the best monitored, while those of Africa and South America are poorly monitored. Some rivers are monitored due to experiences gathered from accidental discharges which can bring about changes in levels of some parameters (Friege, 1988), while some rivers are monitored as routine programs over a long period of time (Malz, 1971; Shewchuk, 1982; Jakob, 1994; Bertram 1993).

2.3 Variables in Water Monitoring

There are three main systems of analysis for pollution detection and monitoring. They are physical, chemical and biological. Variables are monitored to evaluate the environmental impacts of anthropogenic activities on surface water.

2.3.1 *Physical Variables*

Certain physical variables of water are used to give an indication of pollution of surface water. These variables include pH, conductivity and temperature (Sexena and Chanchan, 1993), transparency and colour.

2.3.2 *Chemical and Biological Variables*

Chemical and biological parameters are monitored using both sensitive chemical screening methods and biological testing (Skulberg, 1971). A significant deterioration in water quality is observed first at urban centres on the course of the

river. Contamination in such cases is due to urban sewage and industrial discharges. The parameters mostly affected by such discharges are dissolved oxygen due to high levels of BOD of such water bodies (Bucci *et al.*, 1993; Updegraff, 1977; Kumashiro *et al.*, 1987; Benka-coker and Ojior, 1977; Chaudhuri, 1985; Ottmers, 1983; Kulbik, 1994; Yoshida, 1994). Levels when compared to data obtained from previous years show significant increases due to increase in population and production.

Levels of nutrients arising from agricultural activities are monitored to determine changes in agricultural practices such as fertilizer application and seasonal variations of such nutrients (Ezeonu, 1994; Tonderski *et al.*, 1995; Cann, 1994; Yoneda *et al.*, 1993; Takahashi *et al.*, 1994; Yoshida, 1994). These nutrients have been shown to vary with seasons, type and the methods of application of fertilizers. Variables affected by fertilizers are nitrates, phosphates, nitrites and COD. Nutrient levels are also enhanced by urban, domestic and industrial discharges.

The sale and handling of pesticides is so unrestricted that many people misuse such chemicals. Pesticides have been found to persist in the environment several months after application and to be transported by surface water long distances from the point of application. Transport calculation shows that 0.01 - 0.9% of applied pesticides can be transported in surface water leaving the area of application (Kreuge, 1995). Large fluctuations in concentration may result due to season, time of spraying and flow events. Results can also be affected by the frequency and the location of sampling, but high amounts can be detected on both banks of the river (Portal *et al.*, 1994; Mon *et al.*, 1992; Hayak *et al.*, 1995; Samanidou, 1987).

Effects of acid deposition have been shown in the increasing acidification of water bodies (Dillon, 1983; More, 1986; Wright, 1983; Nilsson, 1986; Lang *et al.*, 1986). Surface water is mainly fed by precipitation, which has passed through the soil. Acidification has been shown to cause the leaching of some heavy metals and micronutrients out of the soil into surface water (Tolba, 1983). As water becomes more acidic the amount of aluminium in it increases rapidly and can result in large fish kills (Dannevig, 1959; Jensen and Snekvik, 1972). Increasing acidification in surface water is detected by monitoring the pH of such water bodies.

2.4 Procedures for Physicochemical Analysis

All programmes to monitor the quality of water for human consumption or use depend on reliable analytical measurements. A large variety of analytical methods have been developed to determine important physical, chemical and microbial parameters. Several of the analytical methods used are not concerned with the concentration of specific substances but measure a general property of the water. These methods, of which BOD is an example, are empirical (Suess, 1986; Lawrence, 1976). The number of published methods and variants of methods for any one determinant is often so large that different methods are used in different places. In some places there exists some agreement on analytical methods to be used in order that result may be comparable while in some places samples are sent out for analysis in different laboratories to ascertain their levels of accuracy (Smith, 1983). The method used for a particular determination is selected for its ability to provide information required and recognize interference. Analytical errors have occasionally been found to be much larger than anticipated even with standard methods (Whitlow, 1985; Belmelli & Alciaturi, 1985).

Fieldwork usually involves taking on site measurements with portable equipment for most physical parameters such as pH, temperature and conductivity. Using standard methods, simple tests are much preferred to a series of more complex or sophisticated tests. However, complex tests are applied when it is necessary to carry out more detailed investigation for special parameters. Sophisticated procedures such as ion exchange and continuous solvent extraction are used in fieldwork where warranted (Whitlow, 1985). Samples requiring more exhaustive chemical analysis are sent to laboratories where a full range of analytical tests are performed. Atomic absorption spectrometry is used in most metal determinations. Most nutrient determinations are colorimetric, using complexing agents to develop colours for particular parameters (Robinson and Thompson, 1948; Fisch, 1953; Goderis, 1975; Umenoto *et al.*, 1978; Motomizu *et al.*, 1983; Takita, 1995).

Organic analysis particularly for trace contaminants are performed on gas chromatography/mass spectroscopy coupled systems. These are equipped with libraries of spectra permitting identification and quantification of substances, sometimes at nanogram/litre levels (Whitlow, 1985; Korenman & Fokin, 1995; Lawrence, 1976).

Most water analysis is performed according to standard recommendations such as International Standards for Drinking water (WHO, 1971), Standard Methods for water and wastewater (APHA, 1985), Methods for Microbial Analysis of water, wastewater and sediments (Belmelli and Alciaturi, 1985) among others.

2.5 Use of Environmental Monitoring

Most of the industrialized nations have made particularly dramatic advances in solving the problems of pollution of the environment (Vossen, 1910; Eastwood, 1933). However, in more recent years, due to rapid industrial growth, pollution of the environment is again becoming a matter of intense public concern (Weaver, 1960; Raisaku, 1963; Upde-graff *et al.*, 1977; Kokubu *et al.*, 1982; Angelidis *et al.*, 1995).

Environmental chemistry is a relatively new science, which is concerned with the measurements of levels of man-made pollutants in air, water, soil and related biota against natural baselines. Governments in setting standards for the release of many waste products of modern society require knowledge of these levels. Environmental pollution monitoring is concerned with such measurements.

Legislation against pollution in industrialized countries dates back to the 1670s (Keller and Wilson, 1992; Eastwood, 1933; Vossen, 1910). Nigeria has been slow to follow the example of other nations in monitoring and controlling pollution of the environment. The creation of a ministerial department for matters of environment in 1999 must indicate intensifying public and official concern for the environment.

Very limited work has been documented in the area of environmental monitoring in the area presently under study. A few reports published are on metal contamination and self-purification of the rivers in the area (Eigbefor, 1978; Smith, 1975; Oguejiofor, 1994; Adakole *et al.*, 1999). The rivers in the area are subjected to domestic, irrigation and industrial uses. The seasonal variations in the intensity of rainfall cause both the quality and quantity of flow of the rivers to vary. During the

wet season, the storm runoff conveys solid matters into the rivers but in the dry season, most of the rivers either dry up or have very little flow.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the study area

The rivers Kubanni, Sheka and Galma are the main sources of surface water in the Zaria area (Map 1). Rivers Kubanni and Sheka drain into the Galma after they course through Zaria town. The rivers are used for domestic, industrial and agricultural purposes. Previous surveys conducted (Sham-Suddin, 1969; Smith, 1975) show that the climatic condition of the area is of semi-arid type. The rainy season lasts from May to October with August being the wettest month. The basin is underlain by superficial alluvial deposits and laterite (Eigbefor, 1978).

The river Kubanni catchment originates in the precincts of Ahmadu Bello University (ABU) main campus, south west of its teaching hospital as a trench in an undulating agricultural land. Four or five tributaries feed the river. The University dam is the main feature on the Kubanni and is situated on the main course of the river south of the main campus. The river drains the southern zones of SabonGarin local government area and receives effluent mainly from domestic activities. The ABU teaching hospital is situated just north of the river source and effluent from the hospital is expected to enter into it. The watercourse is a sluggish meandering type (Oguejiofor, 1994) impounded at the University dam, and maintained by overflow from the dam and contribution from its tributaries.

The river Sheka drains the northern zone of SabonGarin local government area and flows into the river Galma at a marshy confluence. The Galma is also a meandering type of river coursing through a lot of marshy wetland after it receives

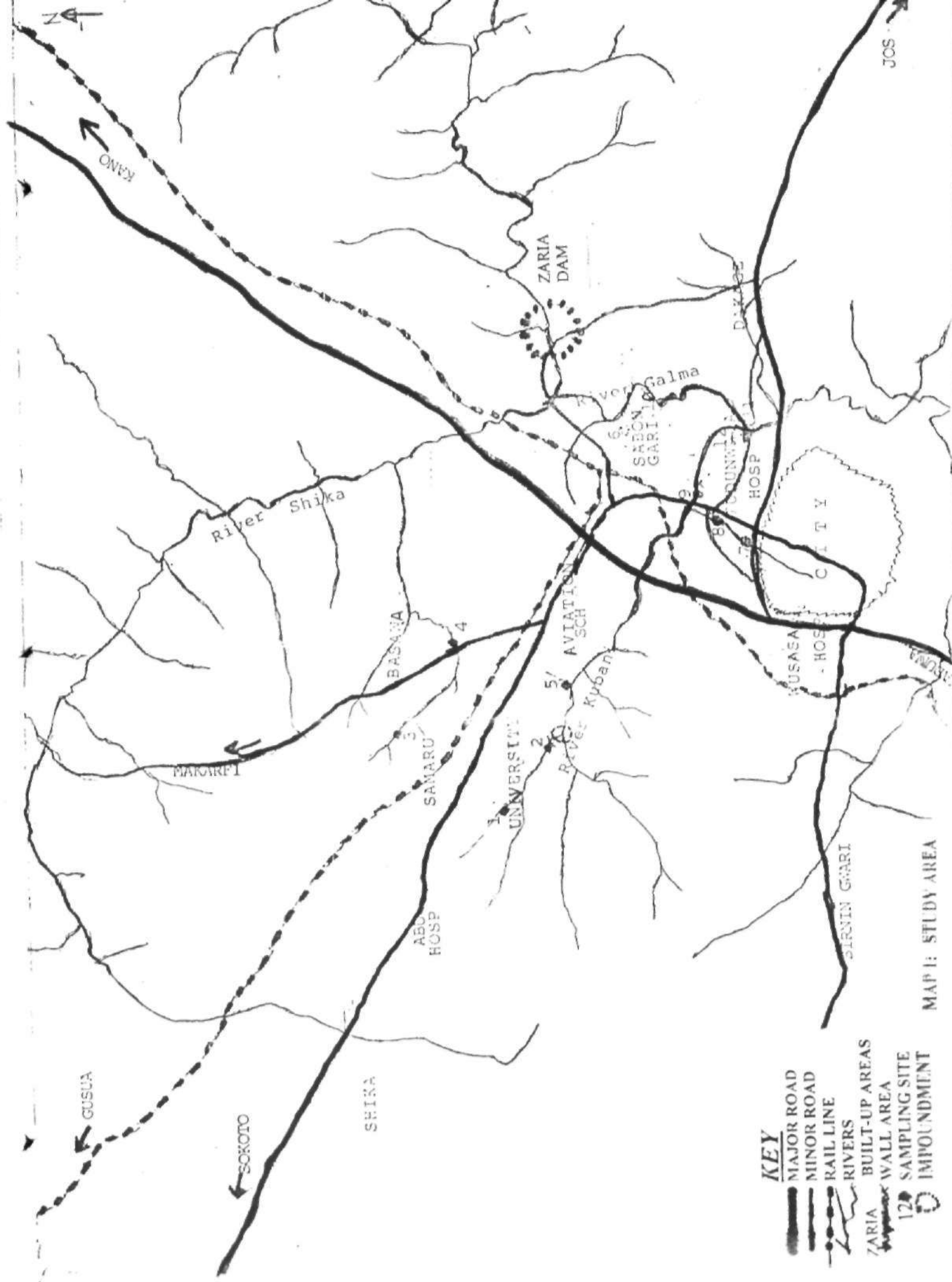
the river Sheka. Most of the industrial activities in the area are situated along the Galma. Bindare stream runs into river Sheka within the marshes that also include the confluence of the latter with river Galma. The Galma receives a lot of industrial effluent before it receives the Kubanni. Zaria town water supply is abstracted after the confluence. Agricultural activities are the major anthropogenic activity in the area and these go on all year round relying on the river and wetlands for irrigation.

There are numerous villages and hamlets scattered about the research area contiguous with and relying on the surface water sources. Samaru is a rapidly growing town with a population of over 100,000 and that accommodates most of the employees of the University.

Other major features of the research area include a large teaching hospital, an abattoir, a civil aviation school, a transport technology institute and a virile railway and locomotive transport technology station. There are many other schools and colleges.

Native occupations are largely agricultural with components in arable and animal farming including institutional ranching and ranging system, fishing etc.

Industries are located in two industrial areas – the Chikaji industrial area and the Jos road industrial estate. While Bindare stream, a tributary of river Sheka, drains the Chikaji industrial area, the river Galma drains the Jos road industrial estate after it has received river Sheka. A notable feature of the pollution causing human activities is that they operate all year round. Since irrigation resources are



- KEY**
- MAJOR ROAD
 - MINOR ROAD
 - RAIL LINE
 - RIVERS
 - BUILT-UP AREAS
 - WALL AREA
 - 12# SAMPLING SITE
 - IMPOUNDMENT

MAP 1: STUDY AREA

JCS

deployed in the dry season, the industries and farming operations are year-round activities.

Sampling Sites

Sampling sites were selected with consideration for accessibility, occupational pattern and the volume of water.

Site 1 – AREA F

This is situated behind AREA F housing area of ABU. The site is characterized by a rocky substratum over which the river Kubanni flows. The site is just below a major tributary of the river Kubanni. The area is highly cultivated and the site is located on a major cattle path. Samples are collected at a point after the cattle path.

Site 2 – AREA BZ

This site is situated behind AREA BZ housing area of ABU. Samples were collected at a bridge that accesses villages behind the Campus. The site is on the main course of river Kubanni just before the impoundment at the University dam. The area is highly cultivated and the soil is of the laterite covered alluvial type.

Site 3 – HAYIN DOGO

This site is situated north of Samaru town. Samples were collected under the bridge linking Samaru town to Basawa village. The area is highly cultivated with the site serving as a water hole for cattle. The site is on a tributary of river Sheka.

Site 4 – BASAWA .

This site is situated on the bridge linking Palladan to Basawa village. The area is highly cultivated with some small-scale industrial activities such as a bakery,

poultry and a range close by. The army cantonment and several academic institutions are located in this vicinity.

Site 5 - ZANGO

The site is situated behind the Zaria abattoir. The area is highly cultivated and the site is on the tributary of the river Kubanni. A road construction project was executed in the area during the research period.

Site 6 – KINGS ROAD

The site is situated on the bridge on Kings road leading to a Commercial College. The site is on Bindare stream, a tributary of river Sheka which receives effluent from the contiguous domestic area and the Chikaji industrial area. The area is highly populated with some agricultural activities. The site also serves as a refuse dump and is located in a major irrigation area.

Site 7 –FIRE SERVICE

The site is situated on the bridge on Kaduna road .The site is on a tributary of river Kubanni, which drains the very densely populated city within the wall. The area is also intensely cultivated.

Site 8 – GASKIYA BRIDGE

The site is situated on the road linking Agoro to Gaskiya.The site is downstream on the same tributary of the Kubanni as site 7. The surrounding area is densely populated with the site serving as a refuse dump and receiving effluent from domestic and commercial activities (mechanic workshops and a slaughterhouse).

Site 9 – TUDUN WADA

The site is situated at the bridge on Maje road, Tudun wada. The area is highly populated and cultivated all year round. The site is on the main course of river Kubanni and receives a lot of domestic effluent.

Site 10 – ZAZZAU GINNERY

The site is situated on the bridge linking Kings road, Sabongari to Sheka village. The site is on the main course of river Sheka before it receives Bindare stream. The effluent of the Nigerian Tobacco Company (NTC) drains into Bindare stream before emptying at this site. The area is a flood plain, and is highly cultivated both in the dry and in the rainy seasons.

Site 11 – GALMA

This site is situated close to the bridge on old Jos road. The area is highly cultivated all year round and contains the Jos road industrial estate. Samples were collected just before river Kubanni joins the river Galma. This site receives effluent from all the industries in the industrial estate.

Site 12 – KUBANNI

The site is situated at old Jos road just before draining into river Galma. The area is also highly cultivated and populated with a refuse dump close to the bank of the river. City water is abstracted immediately downstream of the confluence of rivers Kubanni and Galma, just downstream of sites 11 and 12.

3.2 Sample collection

Twelve sites were selected for sampling. Samples were collected from the sites monthly for a period of twelve months. The sites were observed during monthly sampling for changes and types of activities. Samples were analyzed for physicochemical parameters, and visually observed and described. Samples were collected from 21/08/98 to 22/07/99 starting from 6:30am and lasting till 2:00pm of such days.

Sample collection was done manually using a two litre plastic beaker tied on a long rope. Samples were scooped from the surface of the river and stored in two

litre plastic containers. Conductivity and temperature were measured on site while other parameters were determined in the laboratory immediately following sampling.

3.3 Procedure

Reagents

Unless otherwise stated, all reagents were of analytical reagent grade. Distilled water was used in the preparation of all solutions. A Corning colorimeter 253 was used for all absorbance measurement. A CRISON pH 2000 meter was used to measure pH while a conductivity measuring bridge (Electronic Switchgear Limited London) was used to measure conductivity and temperature.

Parameters Measured

The parameters measured included pH, temperature, conductivity, total solids, suspended solids, nitrates, sulphates, phosphates, dissolved oxygen (DO), biochemical oxygen demand (BOD) and chemical oxygen demand (COD). The parameters were selected in consideration of the type of anthropogenic activities in the area and the type of pollution expected.

Measurement of Physical Parameters (APHA, 1985)

pH: The pH meter (CRISON pH 2000) was used to measure pH of samples. The results are presented in Appendix 1.

Conductivity and Temperature: The conductivity measuring bridge was used to measure the conductivity and water temperature. The results are presented in Appendices 2 and 3 respectively.

Total solids: Each sample was shaken to mix and 50ml was transferred to a dry and pre-weighed evaporating dish and the sample evaporated to dryness on a steam bath. The residue was allowed to cool in a desiccator and weighed. Total solids was calculated using the formula

$$\text{Total solids (mg/L)} = \frac{(A - B) 1000}{\text{Sample volume (ml)}}$$

A = weight of evaporating dish with residue (mg)

B = weight of empty dish (mg)

The results are shown in Appendix 4

Suspended solids: 50ml of mixed samples was filtered through a predried and weighed filter paper. The filter paper and residue was dried to a constant weight in a desiccator. Suspended solids was calculated as-

$$\text{Suspended solids (mg/L)} = \frac{(A - B) 1000}{\text{Sample volume (ml)}}$$

A = weight of filter paper with residue (mg)

B = initial weight of filter paper (mg)

Results are shown in Appendix 5

Measurement of Chemical Parameters (APHA, 1985)

Dissolved Oxygen (DO) – (Azide modification method) (Allen et al., 1977)

Reagents

Manganese sulphate solution: 500g $\text{MnSO}_4 \cdot 4\text{H}_2\text{O}$ was dissolved in water and diluted to 1000ml with water.

Alkaline-iodide solution: 500g NaOH was dissolved in about 500ml of water, cooled and transferred to a polythene bottle and allowed to stand for a few days to

allow Na_2CO_3 settle out. 150g KI was dissolved in water and the supernatant of the alkali-iodide was decanted and mixed with the iodide and diluted to 1000ml.

Sodium thiosulphate (0.1M): 24.82g $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$ was dissolved in freshly boiled and cooled water and diluted to 1000ml.

Starch indicator: 2g of soluble starch was mixed in a small volume of water and poured into 300ml of boiling water. The mixture was allowed to boil for a few minutes, cooled and decanted.

H_2SO_4 : Concentrated H_2SO_4 (sp. gr. 1.86; %purity 98%).

Procedure: A 300ml glass stoppered bottle was filled with sample and stoppered without trapped air. 1 ml each of MnSO_4 solution and alkaline-iodide solution was added and the bottle stoppered carefully to exclude air bubbles. The bottle was inverted several times to mix the content. The precipitate was allowed to settle and 1.5ml conc. H_2SO_4 was added. The bottle was restoppered and the contents mixed by inverting several times. 25ml aliquot was titrated with $\text{Na}_2\text{S}_2\text{O}_3$ solution to a colourless end point using starch as indicator. DO was calculated as:

$$\text{DO (ppm)} = \frac{T(\text{ml}) \times 100}{25}$$

T = volume of titrant used

The results are presented in Appendix 9

Nitrate – N (Phenoldisulphonic acid (PDA) method

Reagents

Phenoldisulphonic acid reagent – 25g of phenol was added to 225ml of concentrated H_2SO_4 (sp. Gr. 1.86: %purity 98%)

KOH (12mol/dm^3) - 672g KOH was dissolved in water and made up to 1000ml with more water.

Standard nitrate solution- 0.7218g KNO₃ was dissolved with water and made up to 1000ml with water. The solution has a concentration of 100mg/ml nitrate-N.

Procedure: For each sample 50ml was pipetted into an evaporating dish, evaporated to dryness and cooled. The residue was dissolved with 2ml phenoldisulphonic acid reagent with the help of a glass rod. The resulting solution was diluted and transferred to an erlenmeyer flask. 10ml of 12mol/dm³ KOH was added and the mixture made up to 100ml with distilled water. The absorbance of each solution was measured at 410nm and the corresponding concentration read from the calibration curve.

Standard curve – For the preparation of the standard curve 1ml, 2ml, 3ml, 4ml and 5ml portions of the standard nitrate solution were each diluted and made up to 50 ml. These were treated the same as the samples. Distilled water was used as blank.

Nitrate – N was calculated using the expression

$$\text{Nitrate– N (mg/L)} = \frac{N \times 1000}{\text{Sample volume (ml)}}$$

N = Concentration from standard curve.

The results are shown in Appendix 6.

Phosphate: (Vanadomolybdophosphoric acid method)

Reagents

Vanadate –molybdate reagent: 25g ammonium molybdate was dissolved in a 300ml water. 1.25g-ammonium metavanadate was also dissolved in 300ml hot water, cooled and 330ml concentrated HCl (sp. Gr. 1.180; purity 98%) was added and the solution was cooled to room temperature. The molybdate solution was then added to the metavanadate solution and diluted to 1000ml with water.

Standard phosphate solution - 0.219g anhydrous KH_2PO_4 was dissolved and made up to 1000ml with water. The solution had a concentration of 50mg/ml phosphate – P.

Procedure: 35ml of each sample was placed in a 50ml volumetric flask, 10ml vanadate – molybdate reagent was added and the solution made up to the mark with water. The absorbance of each solution was measured at 400nm using water as blank.

Standard curve – For the preparation of the calibration curve 1ml, 2ml, 3ml, 4ml and 5ml portion of the standard phosphate solution were diluted and made up to 50 ml with water. These were treated the same as the samples. A standard curve was prepared using the absorbance measured against concentration of the solutions.

Phosphate was calculated as:

$$\text{Phosphate – P (mg/L)} = \frac{P \times 1000}{\text{Sample volume (ml)}}$$

P = concentration from standard curve.

The results are presented in Appendix 7

Sulphate: (Turbidimetric method)

Reagents

Buffer solution- 30g MgCl_2 , 5g CH_3COONa and 1.0g KNO_3 were dissolved in water. 20ml glacial acetic acid was added and the solution made up to 1000ml in a volumetric flask.

Standard sulphate solution- 0.1479g Na₂SO₄ was dissolved in water and diluted to 1000ml with more water. The solution had a concentration of 100 mg/ml sulphate-S.

Procedure – 100ml of each sample was placed in a conical flask and 20ml buffer solution added and stirred. A spoonful of BaCl₂ crystals was added and mixed. The absorbance of each solution was measured after 60 seconds at 420nm using water as blank.

Standard Curve – Portions of 10ml, 20ml, 30ml, 40ml and 50ml of the standard sulphate solution were diluted and made up to 100 ml. These were treated the same as the samples. A standard curve was prepared using the absorbances measured against concentration of sulphate.

Sulphate was calculated as:

$$\text{Sulphate (mg/L)} = \frac{S \times 1000}{\text{Sample volume (ml)}}$$

S = concentration from standard curve.

The results are shown in Appendix 8.

Determination of Organics

Biochemical Oxygen Demand (BOD) (APHA, 1985)

Reagents

Same as in determination of dissolved oxygen.

Procedure 25ml of the sample was placed in a BOD bottle and diluted with water to the brim. The bottle was stoppered and incubated at 20^oC for five days. DO was then determined before and after five days as described in the previous section.

BOD was calculated as:

$$\text{BOD (mg/l)} = \frac{D1 - D2}{P}$$

D1 = DO of diluted sample before incubation

D2 = DO of diluted sample after incubation.

P = Fraction of diluted water that sample

i.e $\frac{\text{Volume of sample (ml)}}{\text{BOD bottle volume (ml)}}$

The results are presented in Appendix 10.

Chemical Oxygen Demand COD (Closed Reflux Colorimetric method) (APHA, 1985)

Reagents

Digestion solution: 10.216g $\text{K}_2\text{Cr}_2\text{O}_7$ was added to about 500ml water. 167ml concentrated H_2SO_4 (specific gravity 1.86: % purity 98) and 33.3g HgSO_4 were added.

The mixture was cooled and diluted to 1000ml with water.

Sulphuric acid reagent:- 5.5g AgSO_4 was added to 1kg H_2SO_4 and allowed to stand 1 to

2 days to dissolve.

Potassium hydrogen phthalate (KHP) standard solution- 425mg KHP was dissolved in water and diluted to 1000ml with more water. KHP has a theoretical COD of 1. 176mg O_2/mg and this solution had a theoretical COD of 500mg O_2/L .

Procedure –2.5ml of each sample was placed in a culture tube and 1.5ml digestion solution was added. 3.5ml sulfuric acid reagent was carefully added to form an acid layer under the sample – digestion solution layer. The tube was capped and inverted several times to mix completely. The tube was placed in a heating mantle and gently refluxed at 150°C for 2 hours. Each tube was then cooled, inverted several times and the

absorbance measured at 600nm using water as blank. The concentration in each sample was read from the calibration curve and COD computed.

Standard Curve: 20ml, 40ml, 60ml, 80ml and 100ml portions of the standard KHP were diluted with water and made up to 100ml. These were treated as the sample and a standard curve was prepared using the standard solutions.

COD was calculated as:

$$\text{COD (ppm)} = \frac{C \times 1000}{\text{Sample volume (ml)}}$$

C = concentration from standard curve.

The results are presented in Appendix 11.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Monthly Visual Observation

August 21: Most of the sites had very high levels of water. Sites 9, 10, 11 & 12 were flooded due to heavy rainfall. Site 5 was diverted due to the then ongoing road construction. Most crops were already grown and fertilizer application was intensive. Samples were very turbid.

September 24: Water levels had gone down at most of the sites while harvesting of crops had started around most of the sites. Water at site 8 was fast flowing with foul odour and the nearby refuse dump was piling up. Site 10 was flooded while site 5 was stagnant due to obstruction by the construction work. Site 9 was less flooded while site 6 had moderate flow with a lot of refuse and strong detergency. Samples were coloured.

October 22: Water levels had reduced at most of the sites but still maintaining moderate to high flows. Harvesting was almost complete in the areas cultivated. Site 8 had an increased volume of refuse. The flood at sites 10, 11 and 12 had receded.

November 24: Most of the flood had receded back within the river channels. Irrigation farming had started at sites 7, 8, 9, 10, 11, and 12. Flow of water was still moderate at most of the sites with the rainy season then over. Samples were less turbid than before.

December 21: Water level was low especially at site 9. Site 5 was now a muddy impoundment with a thriving local block moulding industry. Sites 11 and 12 had waterweed growing. Samples were very turbid. Intensive irrigation farming was taking place at sites 9, 10, 11 and 12.

January 27: Most of the farming areas (sites 9, 10, 11 and 12) were extensively irrigated. Water volume was generally low and samples were very turbid. Waterweed was blooming at sites 11 and 12.

February 24: Water volume was generally low at all the sites. Site 5 was still stagnant, and thick with waterweed while the block making and the road construction work were still in progress. Sites 1, 2, 3, and 4 were not under irrigation while site 6 had a large volume of refuse with foul odour. Waterweed was still blooming at sites 11 and 12.

March 24: The water at sites 1 and 2 were impounded by the people thereby stopping the flow. Samples were collected a few meters upstream from the regular points of collection. Water was brackish at sites 6, 8, and 12. Sites 11 and 12 were still covered with waterweed. Generally, water volume was very low at all the sites. Harvesting was taking place in all the areas cropped under irrigation.

April 22: There was slight increase in water volume due to the first rain of the season. Site 5 was completely dried therefore no sample was collected. Site 3 was now cultivated with cocoyam. Site 9 was now a stagnant pool with black colour, foul odour and a lot of refuse in the water. The river was still covered with waterweed at sites 11 and 12. Sites 10, 11 and 12 were intensively cultivated under irrigation with a variety of crops.

May 24: There was a slight increase in the volume of water. Site 2 was a stagnant pool with no outflow; hence sample was collected a few meters upstream. Site 8 was black in colour with foul odour and a thin film of oil on the surface. The refuse at this site was not cleared. Site 6 was fast flowing, black in colour and foul smelling. Waterweed at sites 11 and 12 was now dead but a new bloom was already sprouting on the dead bloom. Sampling at these sites was obstructed by the waterweed. Rainfall was very little at this time of year.

June 23: All sites had larger volumes of water, fast flowing but turbid. Site 9 was still smelly while the waterweed at sites 11 and 12 had been washed downstream by the heavy rainfall.

July 24: There were very large volumes of water at all the sites. All the sites were fast flowing and turbid.

4.2 Activities in the Study Area

The main anthropogenic activity in the area under study that affects the quality of surface water is agriculture. Farming is practised all year round. In the rainy season crops like maize, millet, guinea corn, yam, potato and pepper are cultivated while in the dry season, vegetables like carrot, cabbage, tomatoes, and okro are cultivated. Fertilizers are intensively applied to provide nutrients for the crops. The fertilizers commonly in use include product names like urea, superphosphate, NPK, morris and "compound". The main components of these fertilizers are nitrogen as nitrate, phosphorus as phosphates, calcium and potassium. Manure is also used to provide nutrients for the crops.

Fishing is common, but on a small scale in the parts of the rivers where there is enough water. Industrial activities in the area are at a low level. The industries include a textile factory, a pharmaceutical company, a vegetable oil mill, a packaging factory along the river Galma while a ginnery, a tobacco factory, an agricultural processing company, an electricity meter company are along the river Sheka.

Refuse disposal is more of a problem in the urban than the rural area. Large quantities of solid wastes (mainly organic) are produced and form enormous heaps

along the parts of the rivers that pass through urban areas. These unplanned dumps cause flooding due to blockage of the poorly built drainage ways.

4.3 Analytical Results

4.3.1 *Physical Parameters*

pH

The measured pH values are shown in Appendix 1. From the results, the pH values fluctuated throughout the study period from month to month with peaks in September, December, February, April and June (Fig. 4.1). The observed pH (between 6.3 and 7.9) fell within the permissible pH range 6-8 for surface water (Chapman, 1992; WHO, 1985). Fig.4.1 also shows that the pH of the waters at all sites varied uniformly throughout the period of study though the sites were not all on the same watercourse.

Conductivity

Conductivity values (Appendix 2) fluctuated irregularly from site to site and from month to month (Fig. 4.2). Generally, however, sites 6, 8 and 9, which receive effluent discharges from industrial and domestic sources, had the highest conductivity as, would be expected.

Also the observed conductivity at many sites was generally higher in the dry months probably because of the effects of increased evaporation of the water and there being no dilution. Conductivity values tended to decrease with rainfall (June to October) inspite of increased agricultural activities. Values observed for conductivity were still within the tolerable limits of 1500 mhos (Keller and Wilson, 1992).

Conductivity displayed a strong correlation with solids indicating that solids content affects conductivity.

Temperature

Temperature values obtained are shown in Appendix 3. The temperature of the waters shows a close correlation with climatic trends in the study area. Temperature at all sites dropped from August to December, when the lowest temperatures were recorded (Fig.4.3) and then rose steadily until June, when the highest values were obtained. In the area of study, the month of December is the peak of the harmattan, with cold and dry northeast winds. Temperature showed a weak correlation ($r=0.193$) with DO; this is in agreement with the fact that the amount of oxygen remaining dissolved depends on the water temperature.

Solids

The solids content of the waters (Appendix 4 & 5) at all the sites were affected by seasons (Fig. 4.4 and Fig. 4.5). The concentrations of both suspended and total solids were highest during the rainy months. This is likely to be, because of storm runoff during rainfall, which normally carries a lot of silt and particles into waterways. Another factor would be the tilling of agricultural land for cultivation during the rainy months and this tends to aggravate the natural erosion rates. Although some irrigated agriculture is practised during the dry season months (October to January), it was observed that suspended solid content at different sites was low since the flow of irrigation water was low and not as strong as storm runoffs during rainfall. Therefore, the concentrations of solids in streams remained generally constant during the dry season months. The observed high values of total solids during the period would be due to concentration of material in the water, a

higher rate of evaporation and little dilution. The highest solids contents were observed at sites 6, 8, and 9 (Fig. 4.4 and 4.5), which receive industrial and domestic effluents.

Chemical Parameters

Dissolved Oxygen (DO)

The concentrations of DO at the sites fluctuated randomly from month to month (Appendix 9). However, the highest DO concentration at any site was in December (Fig. 4.9), corresponding to the month with the lowest temperature (Fig. 4.3). While the lowest values of O ppm were obtained in May and June (the hotter months) DO concentrations at sites 6, 8, and 9 were particularly low in the hot months. The release of untreated effluents with high organic contents coupled with elevated microbial activity may explain the rather low DO content at these sites. Naturally also gas solubility decreases as temperatures increase. It would also be observed that even in December the DO of sites 6 and 8 remained very low (Fig. 4.9), suggesting that the organic loading at these sites is excessive.

The values observed indicate a high degree of pollution at most of the sites and for most of the year since most of these values are lower than the recommended limits (Appendix 14). The month of December stands out and represents a recovery, yielding acceptable values at all sites except 6 and 8 (Appendix 9). This recovery may receive a contribution from a number of pollution sources that suspended operation before the November sampling.

Dissolved oxygen showed a strong correlation with COD ($r=0.798$) in agreement with the fact that the demand is removed from DO to oxidize reducing solutes in samples. DO also correlated strongly with BOD ($r=0.914$) since the demand is also removed from DO values.

Nitrates

Nitrate values observed at all sites showed seasonal trends (Fig. 4.6). Across the rainy season months with active agricultural activities (land preparation and fertilizer application), nitrate concentration was high between March and November. Tilling aerates the soil thereby accelerating bacterial nitrogen fixation. Lightning in the early rains also enhances nitrogen fixation. The fixed nitrogen is subsequently washed down by storm runoff. High values in the months of April may be as a result of concentration in the dry season which was just ending. Water volume was low while urban as well as animal wastes arising from nomadic cattle herds were continuously introduced. The highest values of between 18.0 – 23.6mg/L (Appendix 12) obtained in April, August & September were above desirable limits (Appendix 14). These values were obtained at sites 6,8 and 9, which receive effluent discharges. These values are indicative of pollution at these sites. As previously mentioned (section 4.3.1) and although some irrigated agriculture is practised during the dry season, not much material gets washed into the streams and so, nitrate levels remain low during the dry season months.

Phosphate

Phosphates values (Appendix 7) were generally high especially for sites 6,8 & 9 that receive effluent discharges from urban and industrial activities (Fig. 4.7). In spite of evaporative concentration, values are lower during the months of August to

February for most other sites and higher in the months of March to June. This is probably due to fertilizer residue brought down by runoff from farmlands into the river channels as well as domestic discharges. The low values obtained in the months of July to October may be due to dilution effects where more water, as a result of rainfall, dilutes the amounts of substances in the rivers.

Phosphate values were generally higher than the recommended limits (Appendix 14) and therefore show pollution potential with respect to that parameter. Nitrate and phosphate were present at relatively high levels. The high levels of these parameters together with high temperatures and abundant sunlight may account for the prolific bloom of waterweed at sites 11 and 12 all through the dry season months.

Sulphate

The concentration of sulphate in the rivers was generally low throughout the study period (Appendix 8). Unusually high values may be a result of disturbance of the bottom sediments during sampling leading to re-suspension of material from there. There is no evidence of seasonal influence (Fig. 4.8).

It is not clear what sources contribute to the sulphate contents of the water. Probably the sulphate is indigenous in the channel substratum i.e. sulphate minerals may be native in the riverbed.

4.3.3 Organics

Biochemical Oxygen Demand (BOD)

In general, BOD values were low (Appendix 10) especially in the cooler months (Fig. 4.10) Higher values were obtained in the dry season months especially at sites 6 and 8 due to the effluent discharges and probably proximity to refuse dump from

which leachates are added to the water. Also, cattle dung was more visible at sites in the dry months. This enhances BOD. Values are lowest during the rainy months of the year. BOD values show slight correlation with temperature (Fig. 4.3 and Fig. 4.10) corroborating that biochemical oxygen removal is more severe at warmer times. Values obtained are outside the desirable limits of 20 – 200ppm (Appendix 14) and are therefore indicative of pollution. BOD displayed a strong correlation with phosphate ($r=0.811$) showing that phosphate concentration affects the value of BOD. This may be as a result of phosphate being a nutrient for biological growth. There was also a strong correlation ($r=0.250$) with nitrate that is also a nutrient for growth of organism.

Chemical Oxygen Demand (COD)

High values of COD were observed during the months of March to May (Fig. 4.11) and correspond to high values of conductivity (Fig. 4.3) Values decreased during the rainy season months of June to September. It is possible that the chemical burden of a site may remain the same, but more water, during the rainy season, dilutes the chemicals and so reduces COD (dilution effects). The high values are due to increased evaporation as a result of higher temperatures as well as low flow of water in the river since most of the contributions from the tributaries are dried up. Other factors may be due to the large effluent discharges and runoff from agricultural catchment during irrigation periods. Sites 6, 8 and 9 had the highest values (Appendix 11), which are a result of the large effluent discharges and low flow of water in the dry season months when most of these sites were stagnant. Generally, values obtained were higher than desirable limits (Appendix 14) indicating pollution. COD showed a strong correlation ($r=0.692$) with solids;

reducing components of solids assert COD and reduce remaining DO as they increase.

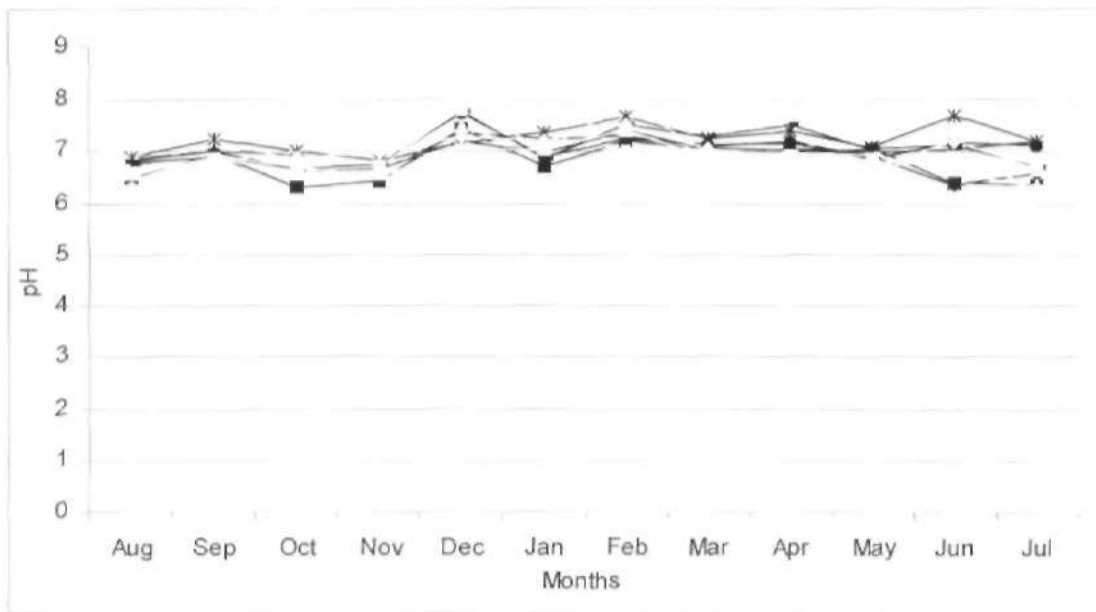


FIG. 4.1 pH

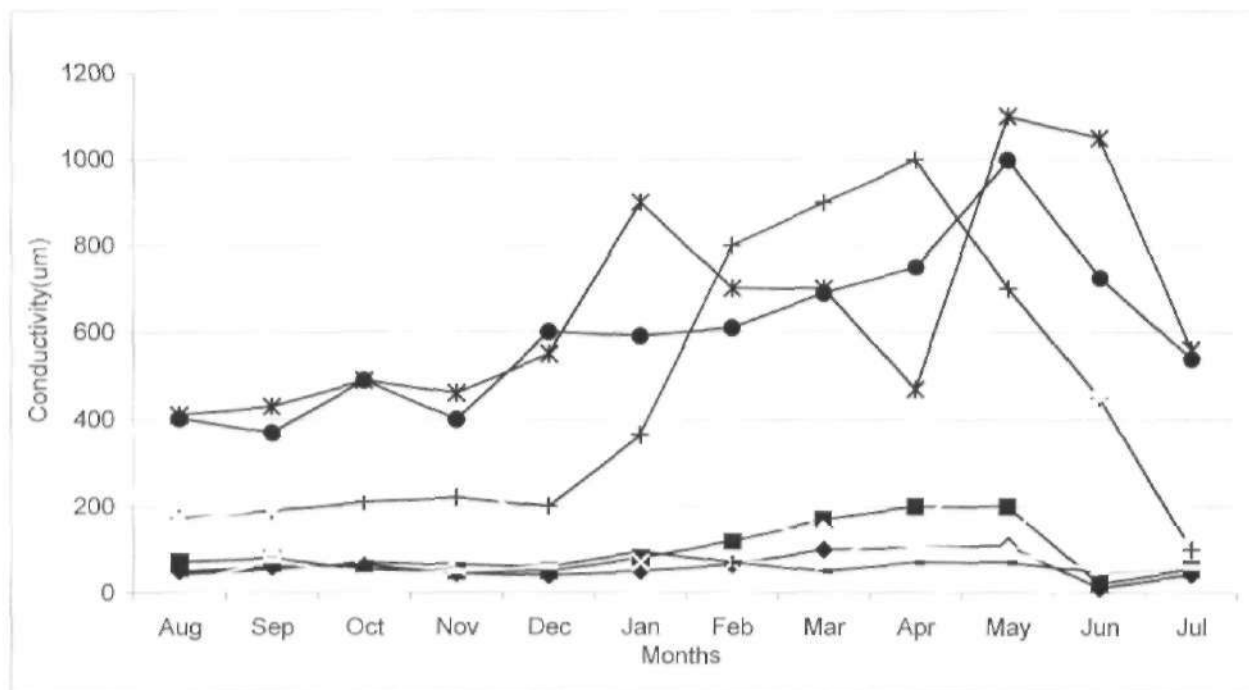


FIG. 4.2 Conductivity

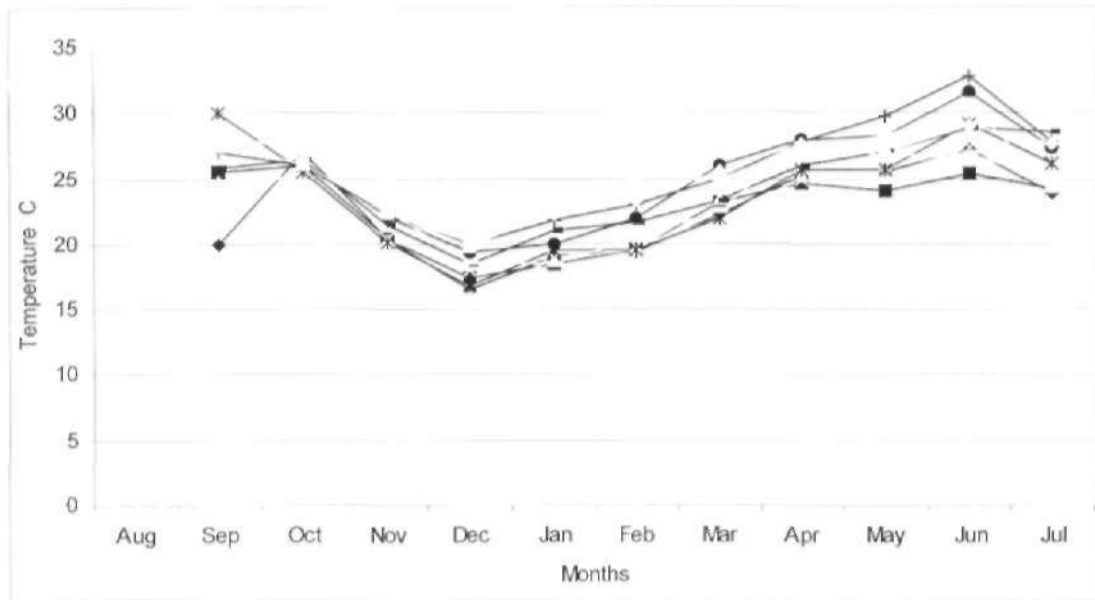


FIG. 4.3 Temperature

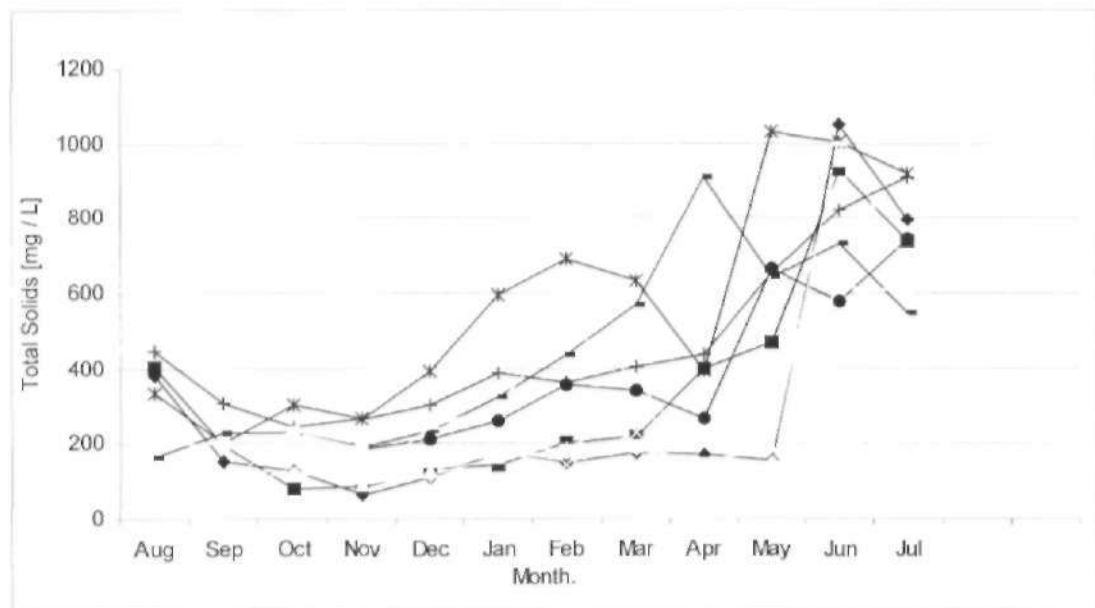


FIG. 4.4 Total solids

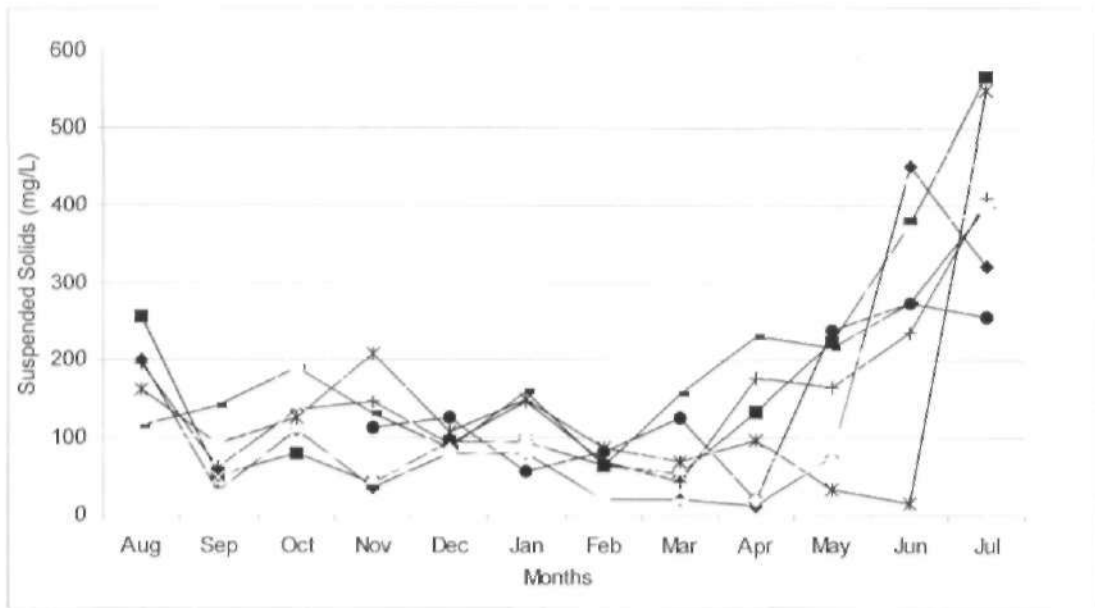


FIG. 4.5 Suspended solids

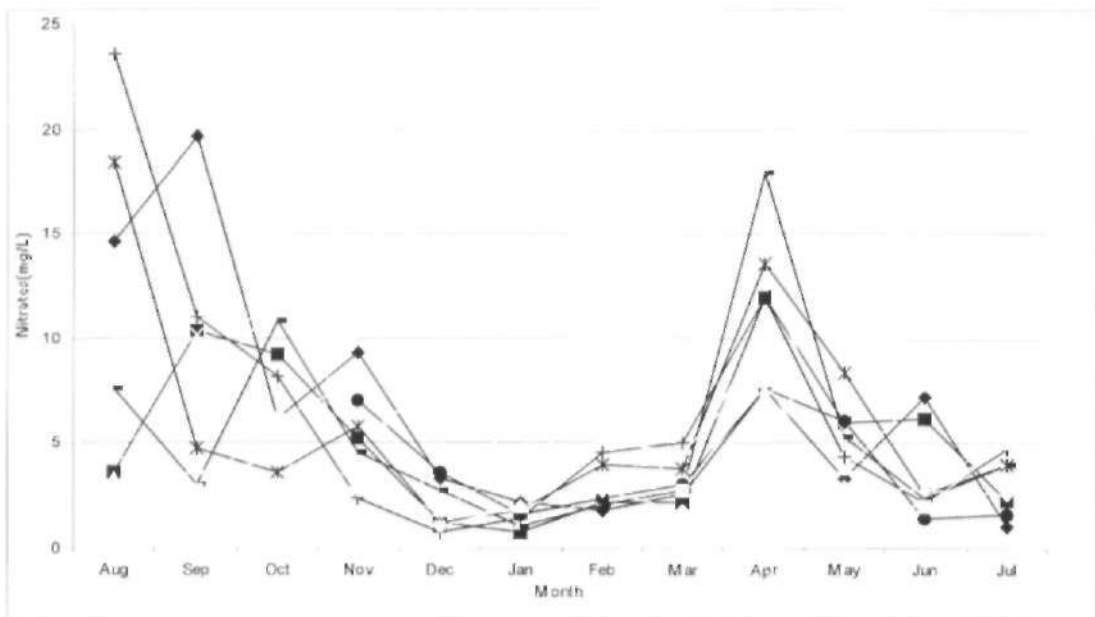


FIG. 4.6 Nitrate

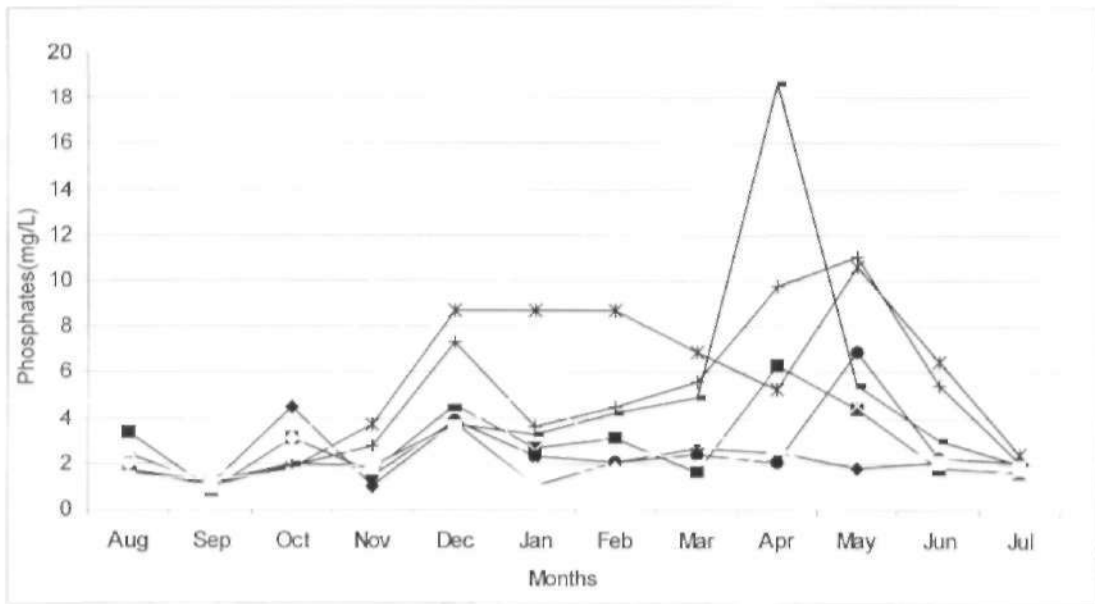


FIG. 4.7 Phosphate

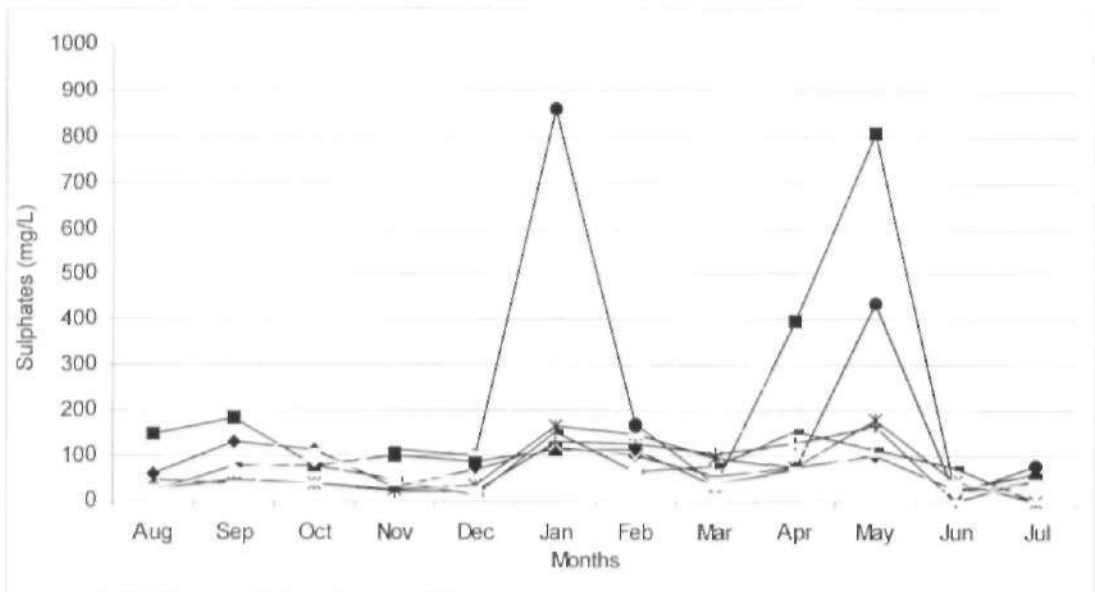


FIG. 4.8 Sulphate

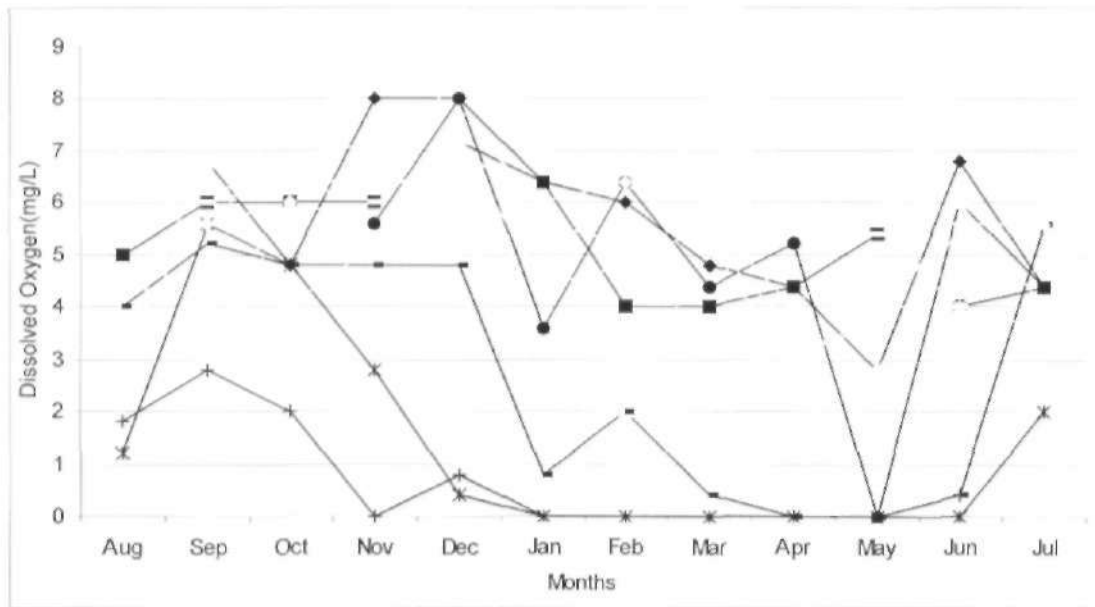


FIG. 4.9 Dissolved Oxygen

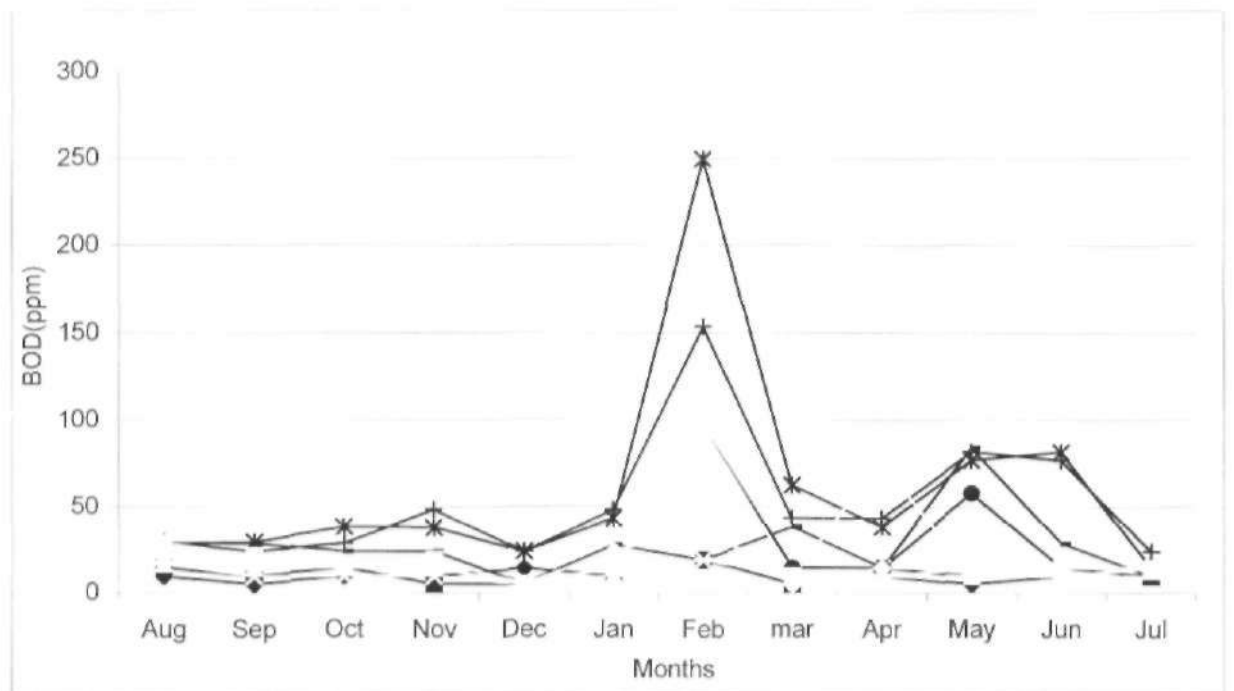


FIG. 4.10 Biochemical Oxygen Demand

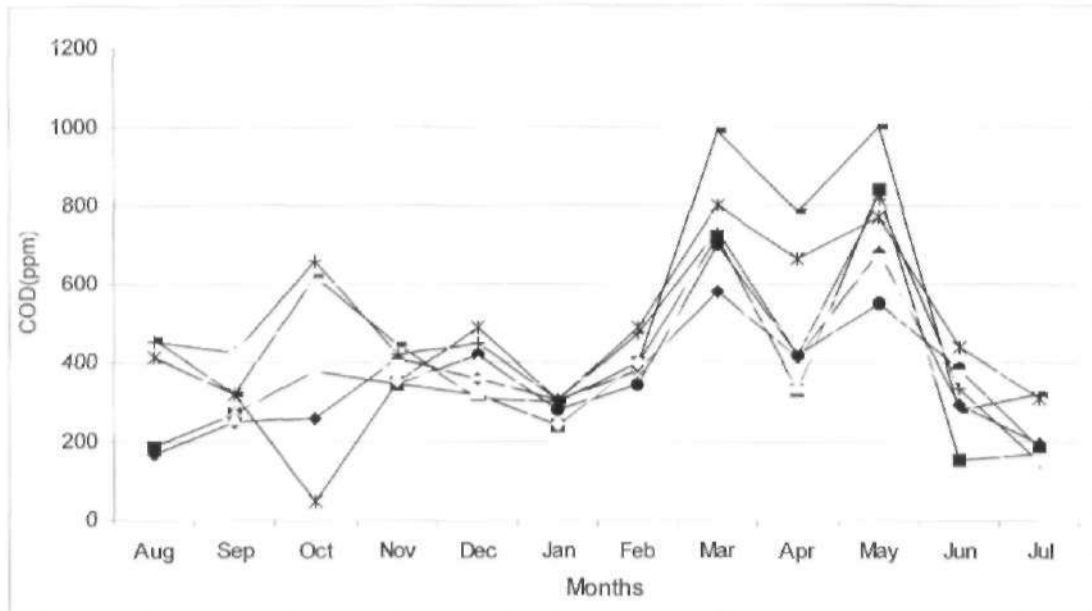


FIG. 4.11 Chemical Oxygen Demand

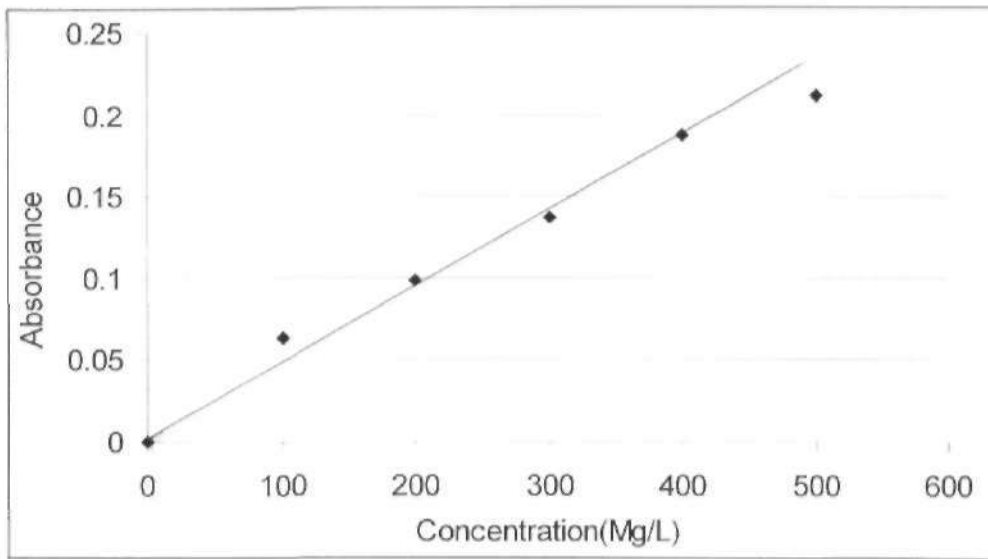


FIG. 4.12 Standard curve for COD

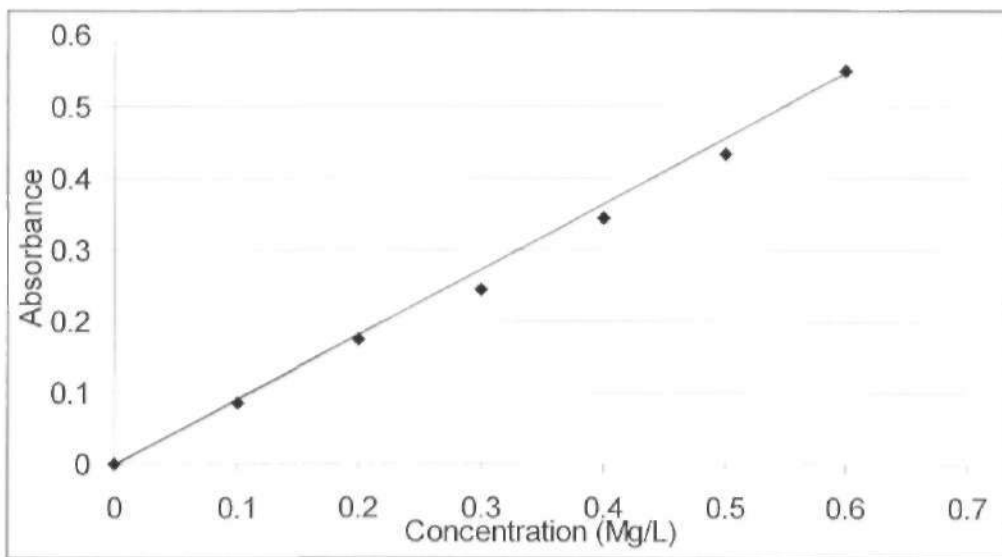


FIG.4.13 Standard curve nitrate

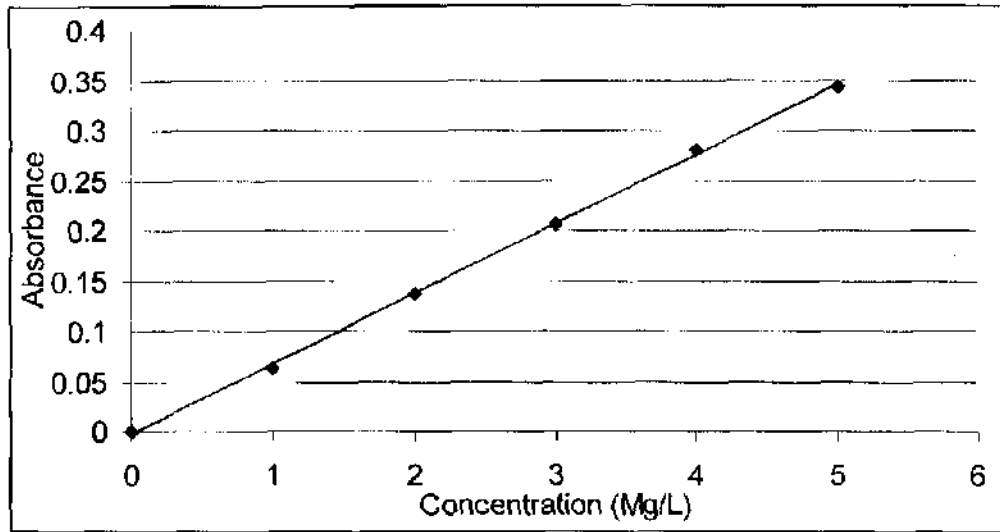


FIG. 4.14 Standard curve for phosphate

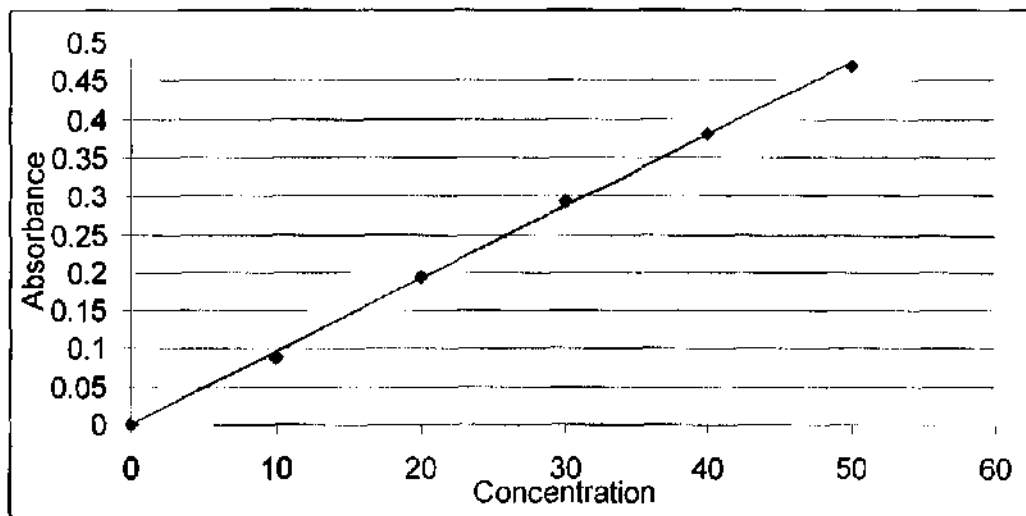


FIG. 4.15 Standard curve for sulphate

Mean correlation coefficient

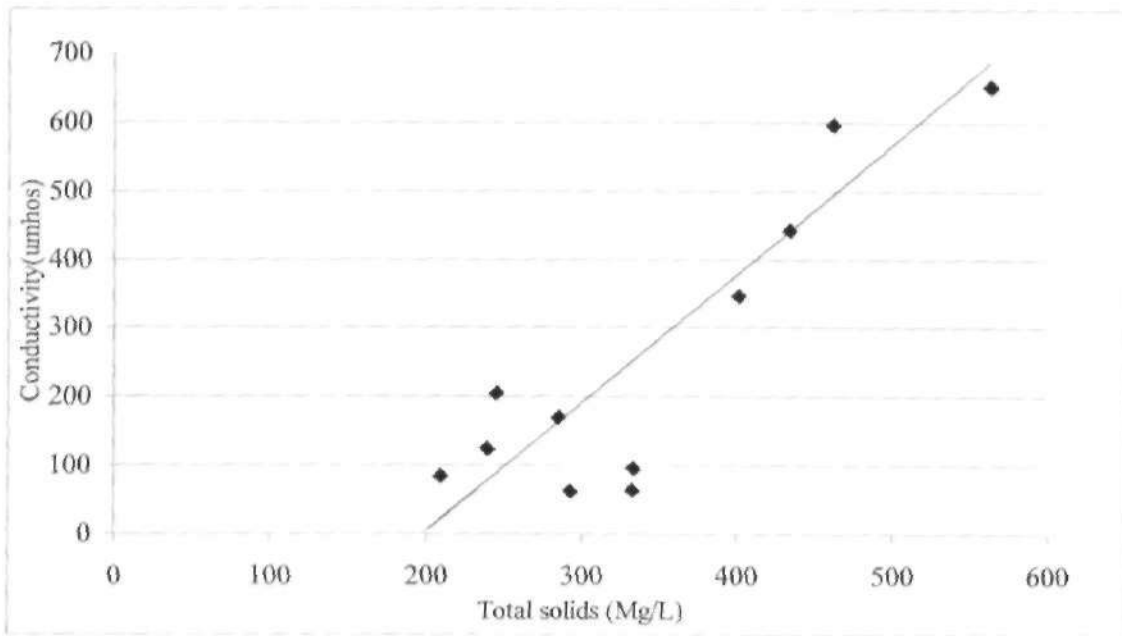


Fig. 4.16 Conductivity against Total solids

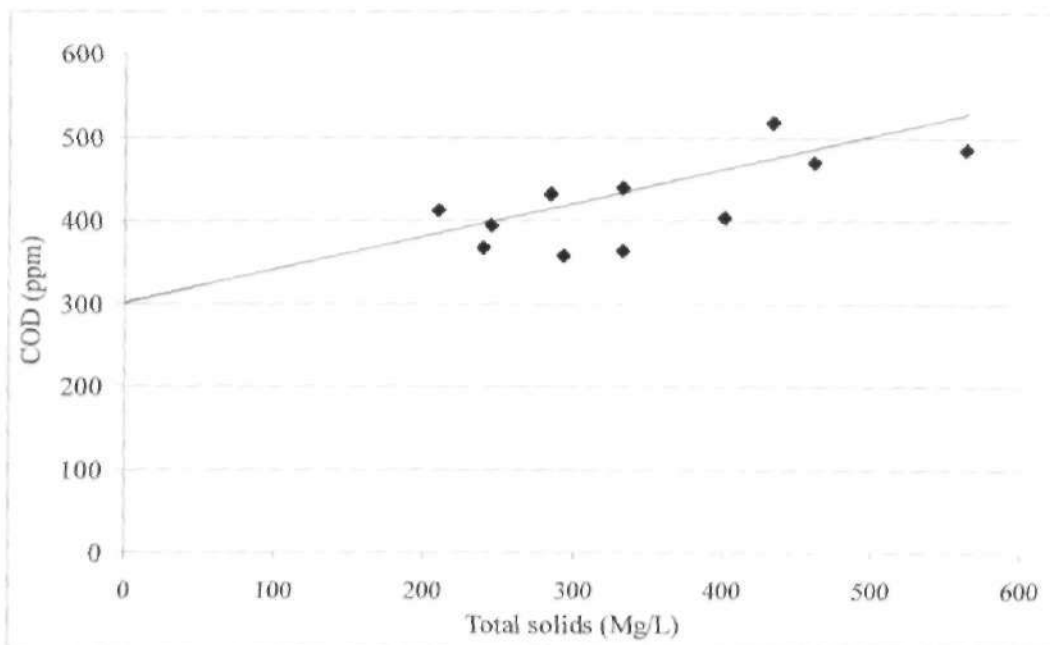


Fig. 4.17 COD against Total solids

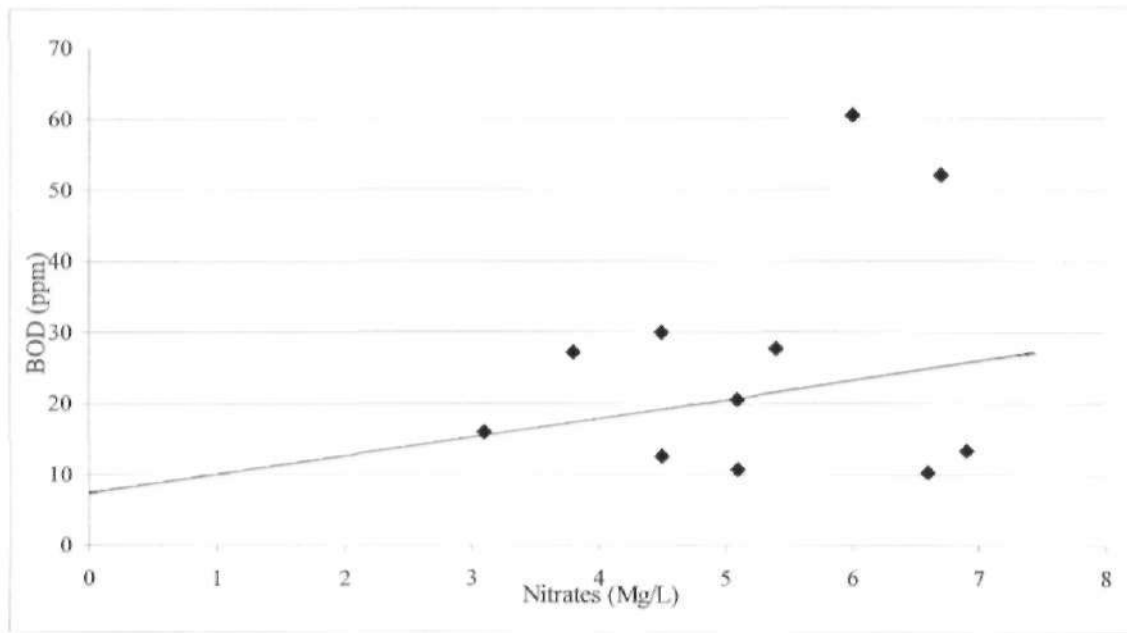


Fig. 4.18 BOD against Nitrate-N

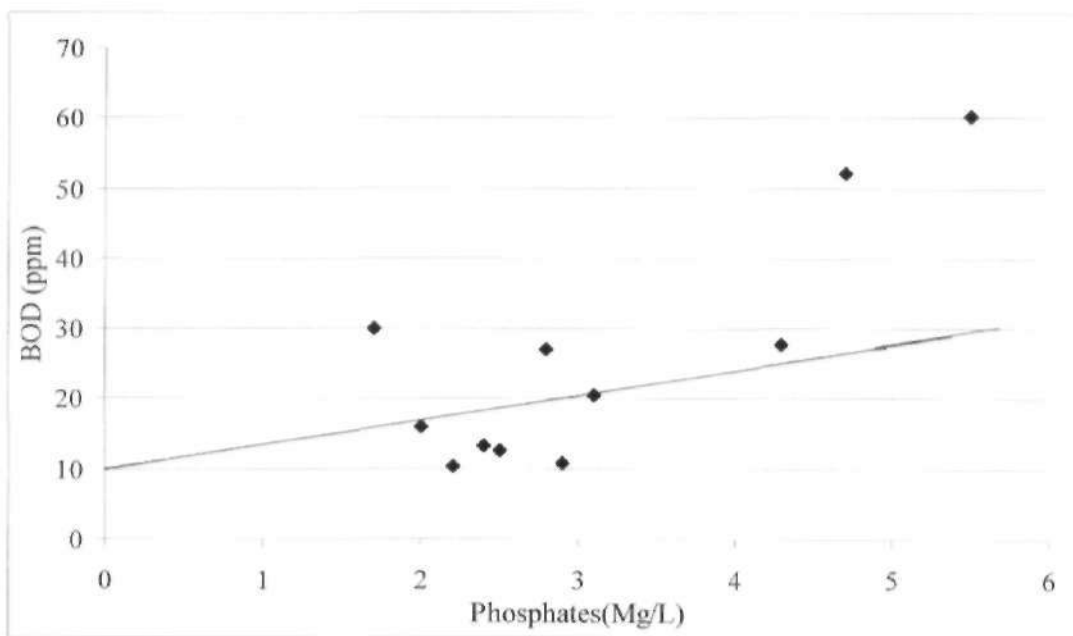


Fig. 4.19 BOD against Phosphates

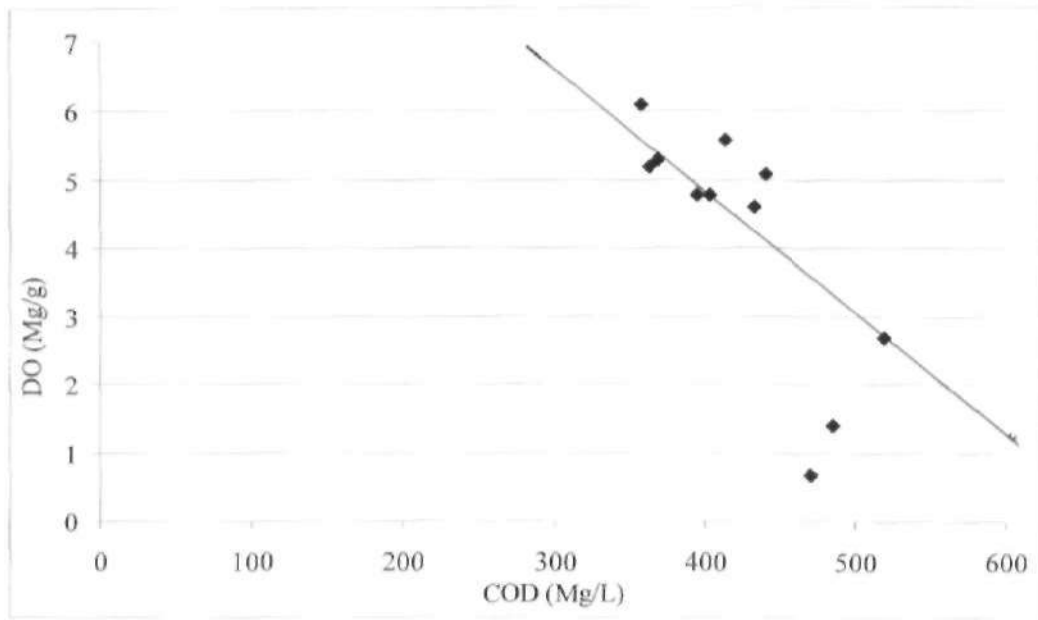


Fig. 4.20 DO against COD

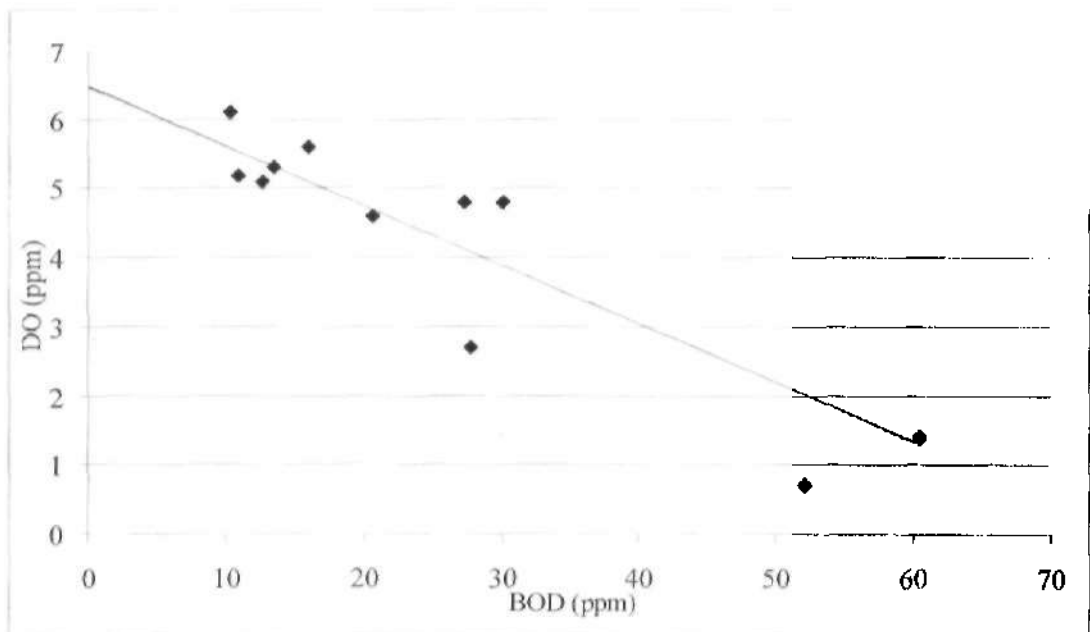


Fig. 4.21 DO against BOD

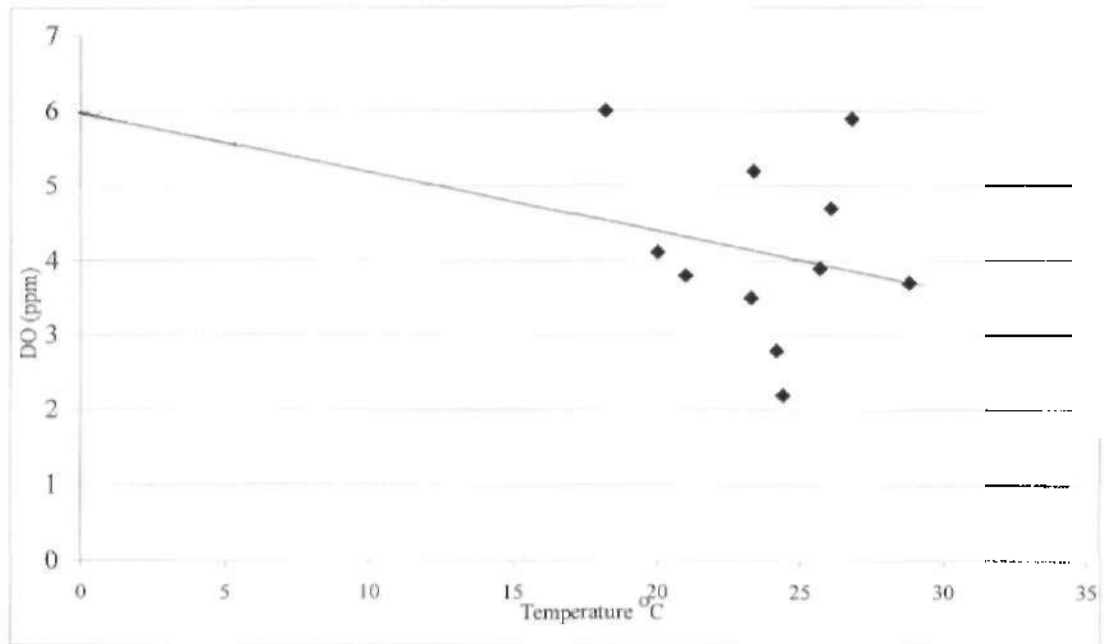


Fig. 4.22 DO against Temperature

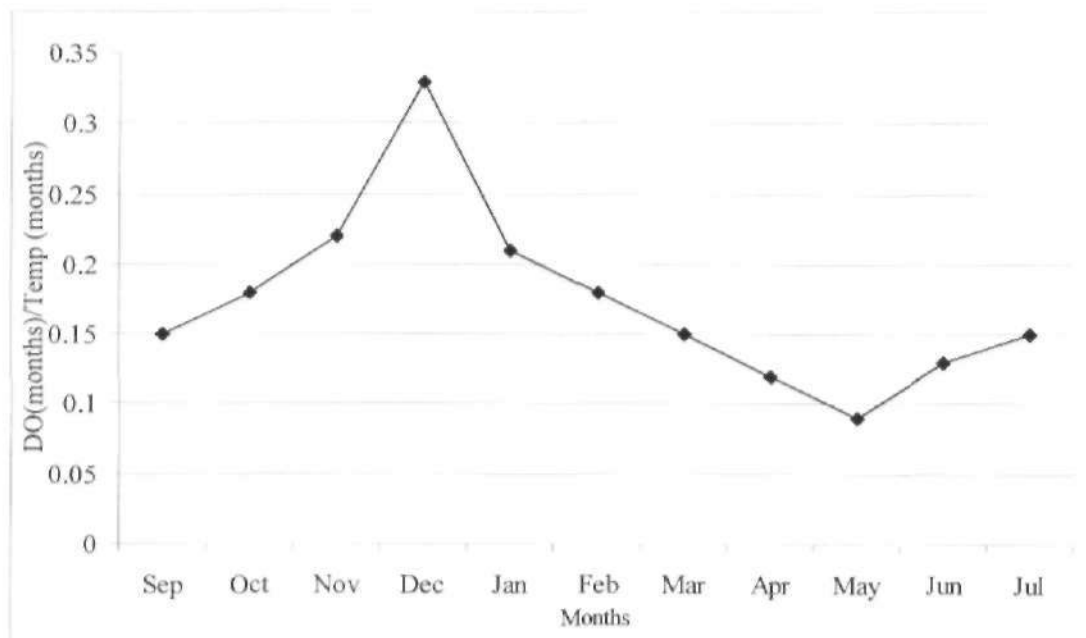


Fig. 4.23 Temperature coefficient of DO

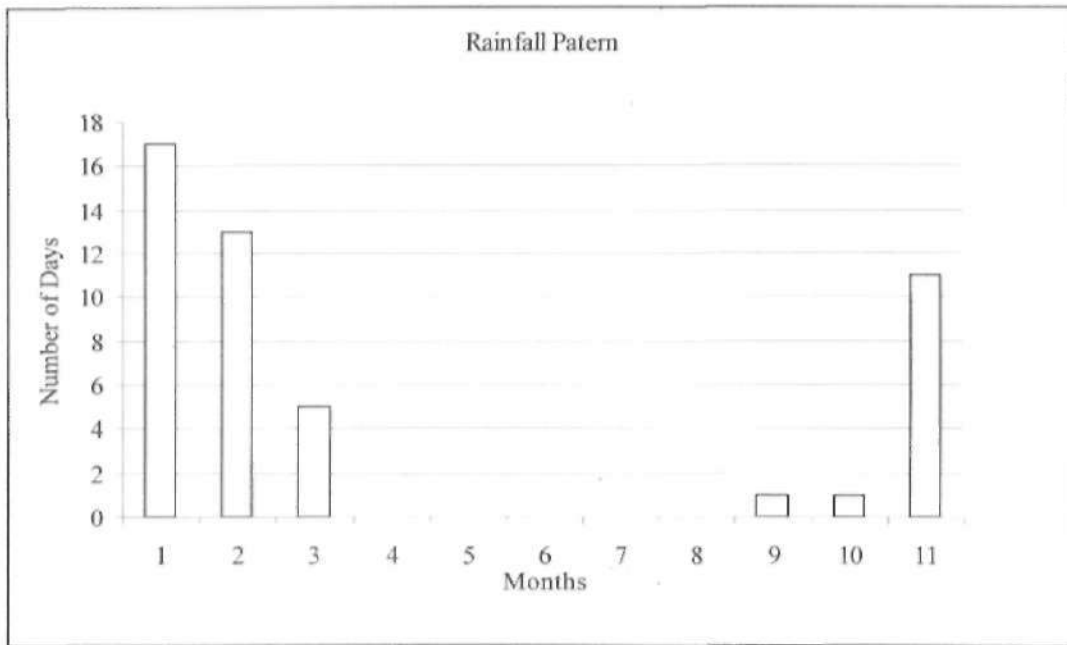


FIG. 4.24

- 1 = Aug
- 2 = Sep
- 3 = Oct
- 4 = Nov
- 5 = Dec
- 6 = Jan
- 7 = Feb
- 8 = Mar
- 9 = Apr
- 10 = May
- 11 = Jun
- 12 = Jul

CHAPTER FIVE

5.0 SUMMARY, CONCLUSIONS AND RECOMMENDATION

5.1 Summary

Evidence has been provided in this work that surface water is definitely polluted at all the sites covered in this work. Indicators include the parameters nitrate, phosphate, BOD and COD. The pollution so indicated spans all seasons: conductivity, nitrate, phosphate, and COD are offensive in the rainy season while nitrate, BOD and phosphate are offensive in the dry season. Respective pollution indicators point out certain sources of pollution. Agriculture (nitrate and COD), industries (phosphate, COD) and domestic and other urban wastes (nitrate, phosphate, and COD) have been shown to cause and intensify pollution.

5.2 Conclusion

From the results of this study, it may be concluded that the surface water bodies were relatively polluted as far as the measured parameters are concerned.

There was no appreciable shift in the pH of the water at the different sites investigated. Hence it may be also concluded that the level of industrial activities in the river catchment is relatively low.

Temperature variations were affected by climatic conditions and there was no evidence of thermal pollution.

The levels of nitrate, phosphate and BOD were influenced by seasonal conditions.

The BOD values at some of the sites were quite high because those sites received untreated effluent primarily from domestic sources or received materials leached from waste dumps close by. COD values were high as a result of reducing chemicals dissolved in the water.

Dissolved Oxygen was completely depleted at some of the sampling points.

The study has been able to establish a body of data that can be used subsequently as reference information on the pollution status of the study area since similar studies have not been conducted previously on the area.

5.3 **Recommendations**

Based on the findings of this study, the following recommendations are made:

Although the industrial activities in the study area are still at low ebb, as evidenced by the observed pH values, it is recommended that the pH of the water at all the sites be monitored regularly because industrial activities are on the increase.

The Ahmadu Bello University Teaching Hospital at Shika has just been commissioned. When fully operational, some classified/hazardous wastes may be inevitably discharged into the river catchment. Therefore, regular monitoring of the river catchment is important in order to detect and forestall any hazardous trends.

The observed organic pollution in the water, especially at some specific sites, indicates the need for the treatment of effluent especially by industries prior to discharging them into the waterways in the study area. Furthermore, a proper and effective solid waste management programme is desirable.

Waterweed blooms and proliferation of waterweeds were observed as a direct consequence of the nutrient enrichment of the river from the use of fertilizers and manure. Therefore, appropriate farming practices should be put in place to protect the water from eutrophication.

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TABLES OF RESULTS

APPENDIX 1 PH

Month Sites	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
1	6.85	7.02	6.93	6.63	7.35	7.25	7.30	7.10	7.19	6.92	6.36	6.58
2	6.54	6.93	6.33	6.43	7.42	6.72	7.19	7.06	6.98	7.06	6.42	6.38
3	7.03	7.25	6.82	6.60	7.48	6.99	7.13	7.01	7.05	7.31	6.84	6.36
4	6.66	7.22	6.93	6.65	7.29	6.94	7.55	6.95	6.82	6.66	6.92	6.80
5	6.99	7.25	7.12	6.72	7.32	7.20	6.97	-	-	-	7.14	6.85
6	6.92	7.24	7.00	6.83	7.16	7.37	7.65	7.25	7.39	7.11	7.69	7.12
7	-	-	-	6.74	7.75	6.89	7.23	7.12	7.17	6.85	7.16	7.14
8	6.83	7.02	6.62	6.67	7.21	6.96	7.40	7.05	7.06	6.97	7.04	7.22
9	6.80	6.89	6.68	6.74	7.79	6.86	7.50	7.27	7.53	7.04	7.13	6.71
10	6.57	6.89	6.70	6.51	7.09	7.03	7.93	6.97	6.97	6.94	6.59	6.33
11	6.32	6.86	6.90	6.96	7.27	7.20	7.52	7.06	6.87	6.73	7.19	6.67
12	6.58	6.87	6.63	6.71	7.81	7.04	7.38	6.90	6.88	6.74	6.89	6.69

APPENDIX 2 CONDUCTIVITY (µmhos)

Month Sites	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
1	50.0	60.0	65.0	45.00	40.0	50.0	65.0	100.0	105.0	110.0	10.0	42.0
2	72.0	80.0	55.0	50.0	50.0	80.0	120.0	170.0	200.0	200.0	20.0	55.0
3	177.0	105.0	170.0	80.0	150.0	130.0	160.0	220.0	255.0	300.0	170.0	135.0
4	142.0	100.0	90.0	60.0	165.0	70.0	70.0	70.0	160.0	320.0	135.0	100.0
5	220.0	200.0	105.0	120.0	140.0	145.0	155.0	-	-	-	255.0	175.0
6	410.0	430.0	490.0	460.0	550.0	900.0	700.0	700.0	470.0	1100.0	1050.0	560.0
7	-	-	-	50.0	290.0	300.0	370.0	400.0	390.0	480.0	435.0	410.0
8	402.0	370.0	490.0	400.0	600.0	590.0	610.0	690.0	750.0	1000.0	725.0	540.0
9	173.0	190.0	210.0	220.0	200.0	365.0	800.0	900.0	1000.0	700.0	450.0	100.0
10	43.0	55.0	70.0	65.0	60.0	95.0	70.0	50.0	70.0	70.0	47.0	60.0
11	20.0	75.0	40.0	50.0	60.0	145.0	175.0	130.0	105.0	95.0	50.0	60.0
12	165.0	200.0	245.0	290.0	130.0	180.0	300.0	145.0	105.0	100.0	460.0	150.0

APPENDIX 3 TEMPERATURE °C

Month Sites	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
1	-	20.0	27.0	20.4	16.5	19.1	19.4	22.3	25.3	25.6	27.2	23.9
2	-	25.5	26.0	20.4	17.4	18.5	16.4	23.2	24.6	24.0	25.4	24.2
3	-	24.8	25.2	20.3	16.0	18.8	19.6	23.4	25.3	25.5	29.3	24.6
4	-	24.5	25.3	20.4	18.1	18.9	19.8	21.9	25.0	25.2	27.4	24.7
5	-	27.2	25.5	20.2	16.8	18.7	19.3	-	-	-	27.4	24.7
6	-	30.0	25.5	20.1	16.8	19.6	19.5	22.0	25.7	25.7	29.2	-
7	-	-	-	22.1	19.4	20.0	22.0	26.0	28.0	28.3	31.6	27.4
8	-	27.0	26.0	22.3	20.0	21.8	23.0	25.0	27.8	29.8	32.7	27.8
9	-	25.9	26.5	21.5	18.5	21.0	21.6	23.3	26.0	27.1	28.8	28.5
10	-	28.5	27.0	22.5	18.7	18.5	20.4	22.6	27.7	26.8	26.9	24.8
11	-	28.5	27.0	25.0	20.0	22.2	23.3	25.6	27.7	27.0	29.0	27.6
12	-	27.5	26.2	22.4	19.8	22.5	24.6	25.0	27.4	28.3	30.6	24.4

APPENDIX 4 TOTAL SOLIDS (mg/L)

Month Sites	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
1	380.0	156.0	128.0	66.0	114.0	176.0	148.0	176.0	168.0	153.0	1050.0	796.0
2	402.0	198.0	82.0	86.0	132.0	145.0	200.0	218.0	398.0	469.0	928.0	740.0
3	226.0	198.0	177.0	90.0	126.0	179.0	186.0	274.0	230.0	295.0	958.0	480.0
4	240.0	126.0	126.0	90.0	134.0	176.0	145.0	228.0	214.0	391.0	606.0	394.0
5	142.0	320.0	126.0	114.0	170.0	245.0	564.0	-	-	-	488.0	378.0
6	336.0	204.0	304.0	266.0	392.0	593.0	690.0	630.0	392.0	1030.0	1004.0	918.0
7	-	-	-	188.0	212.0	262.0	354.0	340.0	266.0	666.0	578.0	742.0
8	444.0	308.0	244.0	266.0	304.0	388.0	363.0	404.0	438.0	655.0	822.0	906.0
9	164.0	226.0	226.0	190.0	234.0	322.0	438.0	570.0	910.0	644.0	732.0	548.0
10	138.0	92.0	232.0	108.0	242.0	303.0	521.0	366.0	152.0	178.0	996.0	668.0
11	102.0	102.0	124.0	94.0	118.0	166.0	174.0	188.0	134.0	148.0	640.0	526.0
12	194.0	204.0	228.0	186.0	154.0	163.0	178.0	190.0	142.0	84.0	614.0	604.0

APPENDIX 5 SUSPENDED SOLIDS (mg/L)

Month Sites	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
1	200.0	30.0	110.0	36.0	78.0	78.0	21.0	20.0	14.0	74.0	452.0	322.0
2	256.0	52.0	80.0	42.0	95.0	94.0	64.0	54.0	134.0	222.0	378.0	568.0
3	131.0	74.0	114.0	49.0	82.0	82.0	40.0	62.0	50.0	88.0	296.0	402.0
4	101.0	48.0	98.0	50.0	60.0	84.0	34.0	54.0	30.0	144.0	324.0	210.0
5	81.0	61.0	156.0	58.0	72.0	95.0	190.0	-	-	-	228.0	238.0
6	162.0	92.0	126.0	206.0	106.0	148.0	86.0	70.0	96.0	34.0	16.0	550.0
7	-	-	-	112.0	124.0	56.0	81.0	126.0	20.0	238.0	274.0	256.0
8	194.0	61.0	136.0	146.0	92.0	114.0	70.0	44.0	176.0	164.0	234.0	410.0
9	116.0	140.0	188.0	130.0	88.0	159.0	64.0	156.0	230.0	214.0	274.0	402.0
10	100.0	30.0	228.0	56.0	174.0	171.0	132.0	18.0	64.0	107.0	526.0	404.0
11	57.0	26.0	144.0	68.0	84.0	100.0	44.0	86.0	20.0	71.0	432.0	460.0
12	126.0	92.0	190.0	164.0	74.0	86.0	20.0	90.0	68.0	56.0	368.0	396.0

APPENDIX 6 NITRATE (mg/L)

Month Sites	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
1	14.6	19.7	6.2	9.3	3.3	2.3	1.8	2.6	7.6	3.3	7.2	1.0
2	3.6	10.4	9.2	5.2	1.2	0.8	2.2	2.2	12.0	6.0	6.2	2.3
3	3.3	7.6	11.6	3.6	1.4	1.2	2.4	3.6	12.8	4.5	3.4	4.2
4	2.5	10.2	11.3	6.2	6.8	4.2	13.4	3.4	10.8	5.6	3.0	5.2
5	2.9	6.6	2.8	2.1	0.8	1.0	4.4	-	-	-	16.6	3.0
6	18.4	4.8	3.6	5.8	1.2	1.8	4.0	3.8	13.6	8.4	2.6	4.0
7	-	-	-	7.0	3.6	1.6	2.4	3.0	7.6	6.1	1.4	1.6
8	23.6	11.0	8.2	2.4	0.8	1.4	4.6	5.0	12.0	4.4	2.2	4.8
9	7.6	3.0	10.8	4.6	2.8	1.0	2.1	2.8	18.0	5.3	2.4	4.0
10	6.2	2.6	3.0	3.6	1.6	1.8	5.1	4.6	8.8	3.6	7.6	5.0
11	3.0	3.6	4.2	2.8	1.0	2.0	2.8	1.8	7.4	2.9	2.8	2.6
12	4.5	2.8	6.2	7.9	1.8	4.0	6.8	2.8	8.0	2.2	2.0	5.0

APPENDIX 7 PHOSPHATE (mg/L)

Month Sites	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
1	2.4	1.1	4.5	1.0	3.8	1.0	2.1	2.7	2.5	1.8	2.1	1.8
2	3.4	0.9	3.1	1.6	4.6	2.7	3.1	1.6	6.3	4.4	1.8	1.6
3	2.6	1.0	1.8	9.8	5.0	1.6	1.6	3.2	3.0	3.3	2.1	1.8
4	1.6	1.0	1.6	1.6	3.8	2.6	1.9	2.6	3.1	4.6	2.2	1.7
5	1.1	1.0	1.5	1.8	3.7	2.3	2.2	-	-	-	1.8	1.7
6	1.6	1.2	1.8	3.7	8.7	8.7	8.7	6.9	5.3	10.6	6.5	2.4
7	-	-	-	1.5	3.9	2.3	2.1	2.4	2.1	6.9	2.2	2.1
8	1.7	1.0	1.9	2.8	7.3	3.6	4.5	5.6	9.7	11.0	5.4	2.1
9	1.7	1.2	2.0	1.9	3.7	3.3	4.2	4.9	18.6	5.4	3.0	2.0
10	1.5	1.3	1.6	2.0	4.7	4.8	2.8	2.1	2.5	3.0	2.2	1.8
11	2.0	1.4	3.1	2.2	6.3	1.8	1.8	1.1	0.9	0.7	1.2	1.8
12	1.4	1.0	1.5	1.8	3.6	1.0	1.5	1.1	2.7	1.0	2.1	1.9

APPENDIX 8 SULPHATE (mg/L)

Month Sites	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
1	62.0	130.0	112.0	31.0	72.0	117.0	100.0	56.0	75.0	101.0	28.0	60.0
2	150.0	185.0	79.0	100.0	87.0	114.0	112.0	36.0	398.0	810.0	20.0	45.0
3	14.0	80.0	160.0	47.0	24.0	50.0	75.0	75.0	58.0	112.0	53.0	0
4	35.0	40.0	100.0	51.0	55.0	125.0	95.0	180.0	110.0	148.0	0	0
5	20.0	40.0	60.0	52.0	17.0	350.0	110.0	-	-	-	26.0	0
6	50.0	40.0	40.0	25.0	35.0	165.0	150.0	95.0	75.0	180.0	44.0	0
7	-	-	-	112.0	99.0	860.0	170.0	40.0	72.0	436.0	18.0	80.0
8	25.0	50.0	40.0	20.0	20.0	120.0	125.0	105.0	125.0	168.0	0	50.0
9	20.0	80.0	80.0	50.0	15.0	152.0	64.0	77.0	152.0	114.0	74.0	0
10	24.0	40.0	40.0	128.0	106.0	326.0	144.0	445.0	124.0	72.0	0	0
11	22.0	70.0	90.0	70.0	18.0	44.0	554.0	33.0	24.0	2.0	22.0	20.0
12	20.0	20.0	100.0	19.0	17.0	49.0	62.0	38.0	59.0	4.0	35.0	3.6

APPENDIX 9 DISSOLVED OXYGEN (mg/L)

Month Sites	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
1	-	6.8	4.8	8.0	8.0	6.4	6.0	4.8	4.4	2.8	6.8	4.4
2	5.0	6.0	6.0	6.0	7.2	6.4	4.0	4.0	4.4	5.4	4.0	4.4
3	7.0	6.4	6.0	5.6	7.2	3.6	2.0	3.2	2.8	4.0	4.0	3.2
4	5.4	6.8	6.8	7.2	7.6	6.0	6.4	5.2	2.8	0	4.0	4.8
5	4.0	6.4	0.2	4.4	5.6	6.0	2.4	-	-	-	3.2	3.6
6	1.2	5.6	4.8	2.8	4.4	0	0	0	0	0	0	2.0
7	-	-	-	5.6	8.0	3.6	6.4	4.4	5.2	0	6.0	4.4
8	1.8	2.8	2.0	0	0.8	0	0	0	0	0	0	0.8
9	4.0	5.2	4.8	4.8	4.8	0.8	2.0	0.4	0	0	0.4	5.6
10	3.2	6.0	6.4	6.0	7.2	4.4	4.8	5.6	4.0	5.4	4.0	3.6
11	4.6	5.6	6.0	6.8	8.4	6.8	6.4	5.2	3.6	2.8	5.6	5.6
12	3.4	6.8	4.0	5.2	7.2	5.6	5.2	3.2	3.2	3.6	6.0	4.0

LIBRARY

APPENDIX 10 BIOCHEMICAL OXYGEN DEMAND (ppm)

Month Sites	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
1	9.6	4.8	9.6	9.6	14.0	9.6	19.2	9.6	9.6	4.8	9.6	14.4
2	14.4	9.6	14.4	4.8	4.8	9.6	19.2	4.8	14.4	9.6	14.4	9.6
3	16.8	14.4	14.4	14.4	4.8	9.6	96.0	14.4	9.2	14.4	19.2	19.2
4	17.4	9.6	9.6	9.6	4.8	9.6	19.2	9.6	14.4	33.6	9.6	14.4
5	14.4	9.6	14.4	24.0	4.8	14.4	38.4	--	-	-	9.6	9.6
6	28.8	29.6	38.4	38.0	34.0	43.2	249.6	62.4	38.4	76.8	81.6	14.4
7	-	-	-	19.2	4.8	14.4	96.0	14.4	14.4	57.6	14.4	9.6
8	29.6	24.0	28.8	48.0	24.0	48.0	153.6	43.2	43.2	81.6	76.8	24.0
9	28.8	28.8	24.0	24.0	4.8	28.0	19.2	38.4	14.4	84.0	28.8	9.6
10	17.2	14.4	19.2	14.4	4.8	14.4	19.2	9.6	9.6	9.6	9.6	9.6
11	17.2	21.6	14.4	14.4	4.8	24.0	38.4	4.8	14.4	14.4	9.6	14.4
12	28.8	21.6	14.4	19.2	4.8	14.2	96.0	9.6	76.8	9.6	14.4	14.4

APPENDIX 11 CHEMICAL OXYGEN DEMAND (ppm)

Month Sites	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
1	172.0	248.0	260.0	408.0	360.0	304.0	380.0	580.0	416.0	680.0	296.0	196.0
2	192.0	272.0	380.0	344.0	320.0	240.0	400.0	720.0	328.0	840.0	156.0	168.0
3	256.0	260.0	408.0	448.0	748.0	296.0	392.0	776.0	340.0	300.0	368.0	184.0
4	240.0	280.0	440.0	428.0	428.0	180.0	368.0	604.0	416.0	704.0	244.0	88.0
5	296.0	260.0	480.0	560.0	340.0	292.0	536.0	-	-	-	276.0	424.0
6	416.0	320.0	48.0	348.0	488.0	304.0	488.0	800.0	664.0	768.0	440.0	308.0
7	-	-	-	344.0	420.0	280.0	344.0	700.0	420.0	552.0	384.0	184.0
8	456.0	424.0	660.0	420.0	448.0	304.0	476.0	736.0	420.0	816.0	336.0	152.0
9	460.0	320.0	620.0	444.0	308.0	300.0	400.0	992.0	784.0	1000.0	280.0	320.0
10	208.0	428.0	612.0	572.0	360.0	340.0	400.0	624.0	336.0	656.0	376.0	376.0
11	252.0	416.0	528.0	356.0	400.0	244.0	400.0	624.0	452.0	620.0	260.0	424.0
12	268.0	408.0	380.0	392.0	324.0	196.0	296.0	760.0	480.0	660.0	42.0	156.0

APPENDIX 12 MEAN VALUES FOR MONTHS .

Months	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
PH	6.74	7.04	6.79	6.68	7.41	7.04	74.0	7.04	7.08	6.94	6.95	6.75
Conductivity (µmhos)	170.4	169.6	184.6	157.5	202.9	254.2	299.6	325.0	328.2	406.8	314.8	273.9
Temperature °C	-	26.8	26.1	23.4	18.2	20.0	21.0	23.3	24.2	24.4	28.8	25.7
Total Solids (mg/L)	251.6	194.0	181.6	145.3	194.3	259.8	330.1	325.8	313.1	428.5	784.7	586.0
Suspended Solids (mg/L)	138.6	64.2	142.7	93.1	94.1	105.6	70.5		75.2	128.4	316.8	384.8
Nitrate-N (mg/L)	8.2	7.5	7.0	5.1	2.2	1.9	4.3	3.7	10.8	4.8	4.8	
Phosphate-P (mg/L)	1.9	1.1	2.2	2.6	4.9	2.9	3.0	3.2	5.2	4.8	2.7	1.9
Sulphate (mg/L)	40.2	70.5	81.9	61.3	47.1	206.8	105.1	158.2	115.6	198.5	26.7	24.3
Dissolved Oxygen (ppm)	4.0	5.9	4.7	5.2	6.0	4.1	3.8	3.5	2.8	2.2	3.7	3.9
BOD (ppm)	20.3	17.1	18.3	20.0	8.8	20.0	64.8	20.1	23.5	36.0	24.8	13.6
COD (ppm)	292.0	331.0	477.0	422.0	412.0	273.0	400.0	719.6	459.6	736.0	319.7	248.3

APPENDIX 13 MEAN VALUES FOR SITES

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11	Site 12
PH	6.96	6.79	6.99	6.95	-	7.24	7.12	7.00	7.08	6.88	6.96	6.93
Conductivity (µmhos)	61.8	96.0	171.0	123.5	-	651.7	347.2	597.3	442.3	62.9	83.8	205.8
Temperature (°C)	22.9	22.6	23.0	22.8	-	23.4	24.8	25.8	24.3	24.0	25.7	25.3
Total Solids (mg/L)	292.6	333.2	284.9	239.2	-	563.3	400.9	461.8	433.7	333.0	209.7	245.1
Suspended Solids (mg/L)	119.6	169.9	122.5	103.1	-	141.0	143.0	153.4	180.0	167.5	132.6	144.2
Nitrates (mg/L)	6.6	5.1	5.1	6.9	-	6.0	3.8	6.7	5.4	4.5	3.1	4.5
Phosphates (mg/L)	2.2	2.9	3.1	2.4	-	5.5	2.8	4.7	4.3	2.5	2.0	1.7
Sulphates (mg/L)	78.7	178.0	62.3	78.3	-	74.9	209.7	71.5	73.2	120.8	39.1	40.8
Dissolved Oxygen (ppm)	6.1	5.2	4.6	5.3	-	1.4	4.8	0.7	2.7	5.1	5.6	4.8
BOD (ppm)	10.3	10.8	20.6	13.4	-	60.4	27.2	52.1	27.7	12.6	16.0	30.0
COD (ppm)	358.3	363.3	433.0	368.3	-	485.3	403.1	470.7	519.0	440.7	413.7	395.0

APPENDIX 14

MEAN OBTAINED AGAINST DESIRABLE LEVELS

	MEAN OBTAINED	MAXIMUM OBTAINED	MINIMUM OBTAINED	MAXIMUM DESIRABLE
PH	6.99	7.41	6.32	Ambient
Conductivity (μ mhos)	285.5	1100.0	10.0	6.5-8.5*
Temperature ($^{\circ}$ C)	24.1	32.7	16.0	1500*
Total Solids (mg/L)	345.2	1050.0	84.0	-
Suspended Solids (mg/L)	143.1	586.0	20.0	25.0#
Nitrates (mg/L)	3.1	23.6	0.8	26.0 * ; 10.0#
Phosphates (mg/L)	5.2	18.6	0.7	5.0#
Sulphates (mg/L)	93.4	860.0	0	250-400*
Dissolved Oxygen (ppm)	4.2	8.4	0	4.0#
BOD (ppm)	25.6	249.0	4.8	3.0-6.0*
COD (ppm)	422.8	1000.0	88.0	20.0-200.0*

+ FEPA (1991)

* CHAPMAN (1992)

WHO (1984)

APPENDIX 15 VALUES FOR STANDARD CURVES

Chemical Oxygen Demand

Concentration mg/L	Absorbance
100	0.046
200	0.101
300	0.142
400	0.187
500	0.231

Nitrate

Concentration mg/L	Absorbance
1	0.125
2	0.246
3	0.331
4	0.461
5	0.564

Phosphate

Concentration mg/L	Absorbance
1	0.079
2	0.155
3	0.223
4	0.289
5	0.378

Sulphate

Concentration mg/L	Absorbance
10	0.089
20	0.204
30	0.292
40	0.383
50	0.445

Appendix 16

Figure	Correlation	Slope	Intercept
Fig. 4.16	0.886	1.77	-352.84
Fig. 4.17	0.692	0.335	307.02
Fig. 4.18	0.250	3.424	7.60
Fig. 4.19	0.811	11.239	19.74
Fig. 4.20	0.798	-0.27	15.62
Fig. 4.21	-0.914	-0.097	6.69
Fig. 4.22	-0.193	-0.074	5.92