EXTENT OF POLLUTION OF RIVER BENUE IN JIMETA – YOLA, FROM BWARANJI TO GERIO

A THESIS

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YUSUFU LUKA

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School of Engineering and Engineering Technology

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DECLARATION

I declare that this work was carried out in its original form by Yusufu Luka of the Department of Chemical Engineering, Federal University of Technology Yola, Nigeria.

……………………………. ………………………….

Sign Date

APPROVAL PAGE

This thesis entitled EXTENT OF POLLUTION OF RIVER BENUE IN JIMETA – YOLA, FROM BWARANJI TO GERIO, by Yusufu Luka, meets the regulation governing the award of the degree of Master of Engineering (Chemical Engineering) of the Federal University of Technology, Yola, and is approved for its contribution to knowledge and literary presentations.

…………………………….
Prof. Ir. P.B. Onaji
(Project Supervisor)

…………………………….
Mr. T.M. Chiroma
Head of Department

…………………………….
Prof. F. Aberuagba
(External Examiner)

……………………………..
Prof. A Nur
Dean, School of Postgraduate Studies

DEDICATION

This work is dedicated to God Almighty and my younger ones especially Yakubu Drambi Luka and Simon Tumba Luka.

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ABSTRACT

In this research, the physical, inorganic chemical, organic chemical and biological characteristics of River Benue in Jimeta-Yola from Bwaranji to Gerio were monitored. The river is used for aquatic life, irrigation, drinking, recreational purposes and commercial activities and it is imperative to have quality information on its suitability for various uses. The sampling points are namely:-Bwaranji Water Works, Jimeta Water Works, Shinko Ibrahim Kashim Round About, Shinko Drainage and Gerio. Samples were collected two times in a month at an interval of two weeks from each of the five different sampling points for a period of six months from February 2007 to July 2007. The parameters measured with their range values are: temperature (19.0-30 ^{0}C), electrical conductivity (35.3-124.2 μs/cm), velocity (1.0-66.7 cm/s), total dissolved solids (360.0-980.0 mg/l), total solids (1300.0-2800.0 mg/l), pH (7.4-8.2), calcium (2.3-50.0 mg/l), magnesium (1.9-29.4 mg/l), iron (0.00-6.20 mg/l), chromium (0.000-0.035 mg/l), lead (0.0-0.6 mg/l), zinc (0.15-1.30 mg/l), phosphate (1.8-27.5 mg/l), nitrate (0.2-9.0 mg/l), dissolved oxygen (11.1-46.3 mg/l), five days biochemical oxygen demand (1.1-6.2 mg/l), chemical oxygen demand (2.0-13.3 mg/l) and *Escherichia coli* (105-390 cfu/100 ml). The results obtained show that the Gerio sampling point is the highest polluted of all the five sampling points. The mean concentrations of total dissolved solids at the various sampling points were above the set standard for drinking water (500 mg/l) in both during the dry and rainy season. The mean concentrations of iron during rainy season and lead during dry and rainy season at all the five sampling points were above maximum permissible limit for public supply and marine aquatic life of 1.0 mg/l and 0.05 mg/l, respectively. The mean concentration of phosphate at the five sample points were also above the maximum set standard for marine aquatic life (0.0001 mg/l) in both dry and rainy season. The seasonal variation shows that River Benue in Jimeta-Yola from Bwaranji to Gerio is more polluted during dry season than the rainy season. The possible causes of pollution may be agricultural activities, domestic waste and solid waste discharges into the river due to human activities in the study area.

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ABBREVIATIONS

TS	Total Solids
TDS	Total Dissolved Solids
T	Temperature
EC	Electrical Conductivity
V	Velocity
Ca	Calcium
Cr	Chromium
Cu	Copper
Fe	Iron
Mg	Magnesium
Pb	Lead
Zn	Zinc
pH	Hydrogen Ion Concentration
NO_3^-	Nitrate
PO_4^{3-}	Phosphate
DO	Dissolved Oxygen
BOD_5	Five Days Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
E. coli	Echerichia coli
WHO	World Health Organisation
FM ENV	Federal Ministry of Environment
BWW	Bwaranji Water Works
JWW	Jimeta Water Works
SIA	Shinko Ibrahim Kashim Round About

SHD	Shinko Drainage
GER	Gerio
ND	Not Detected

CHAPTER ONE

1.0 INTRODUCTION

Researchers have seen a significant deterioration in the quality of many rivers in Nigeria, which include River Kaduna and the Lagos Lagoon waters to an extent that the fish, which were previously of good quality, are already contaminated with some heavy metals (Shyllon, 1989). Although activities vary from one area to another the pollution of River Benue could equally contaminate fish and other edible aquatic animals and ultimately harm the inhabitants. The pollution can also affect the food obtained from irrigated farmlands as well as the water for drinking, recreational purposes and commercial uses.

The major river that passes along Jimeta-Yola is River Benue which is the second largest river in Nigeria. The river rises from the highlands of Cameroon through Fufore local government area and flows southward to join the River Niger at Lokoja (Adebayo et al., 1999). The river is used mainly for aquatic life, public supply, agricultural activities, recreational purposes and commercial activities.

This research is aimed at determining the extent of pollution of River Benue in Jimeta-Yola from Bwaranji to Gerio. The predominant activities in the catchment area include commercial, crop production, fishing, water works, dumping of refuse, rearing of animals, repairs of cars and motor cycle (road side mechanics), abattoir and sewage disposal through drainage system to the river. These activities in the catchment area cause pollution of the river, which can be classified as municipal, agricultural and solid waste. The pollutants on the surface land can be easily discharged into the river as runoff during irrigation and rainy season. The major areas that have considerable polluting human activities such as dumping of refuse which are close to the rivers include Doubelli, Jambutu and Shinko while the other villages in the catchments area engage in crop production and fishing. Therefore, there is the need to monitor the river to know the extent of pollution caused by the activities occurring along the riverbank, which may affect the use of the river. For this reason sampling point were selected based on human activities along the riverbank.

The parametric indicators of pollution to be considered are the physical characteristics, inorganic chemical characteristics, organic chemical characteristics and biological characteristics. Santuraki (1989) determined the level of phosphate and nitrate in natural water sources including River Benue within Jimeta - Yola metropolis and its environs and the concentrations were below the limits specified for contaminated water.

Kinjir (1990) carried out a research on aqueous environment for inorganic pollutants. A total of six samples which include, water and aqueous sediment were collected from River Benue, Lake Gerio and Kiri dam. In the water samples collected only iron was detected to be high. It was concluded that the values of iron obtained was attributed to high rate of domestic and agricultural activities in the catchment area..

Joseph (2005) carried out pollution studies on River Benue in Yola. Water samples were collected from three different sampling points along the river based on human activities and it was reported that the concentration of iron, copper and lead exceeded the WHO, EC and FEPA limits making the water unsuitable for public supply and aquatic life. In addition, the three sampling points were detected to be predominantly alkaline (pH>7.0).

Torhee (2006) reported that for samples collected from River Benue in Rugange (Yola) the concentration of iron and lead exceeded the WHO, EC and FEPA limit for public supply. Also, the variation of biochemical oxygen demand showed that continual consumption of the water would pose a threat to the health of the inhabitants.

In this present research the extent of pollution of River Benue will be analysed for different locations and in more detail. The study will be conducted for both dry season and rainy season; the location and seasonal variation as well as the diurnal variation in temperature will be studied.

CHAPTER TWO

2.0 SURVEY OF LITERATURE

2.1 Geographical Background

2.1.1 Drainage system of River Benue

River Benue rises from the highlands of Cameroon and flows southward to join River Niger at Lokoja. Most of the other major rivers in Adamawa State, which include River Kilange, River Loko, River Mayo Inne, River Mayo Belwa and River Faro, which rises from Cameroon Republic, are tributaries of the River Benue (Adebayo et al., 1999). A map showing the location and source of River Benue in Adamawa state is presented in Figure 2.1. These rivers, which are the major tributaries are normally flooded during the rainy season and become dry with sandy flat beds during the dry season. Figure 2.1 also shows the main towns and drainage system of Adamawa state.

2.1.2 River Benue in Jimeta-Yola

The study area of investigation is within Jimeta-Yola, which is also known as Yola- North Local Government Area. Jimeta-Yola is situated along the bank of the River Benue which lies between latitude 9° 14” North and longitude 12° 28" East of the Greenwich Meridian (Adebayo et al., 1999). Tahal (1996) stated that the town Jimeta-Yola is the commercial and institutional centre of Yola-North local government area and Adamawa State. It is supplied with water from two sources; boreholes and intake from River Benue.

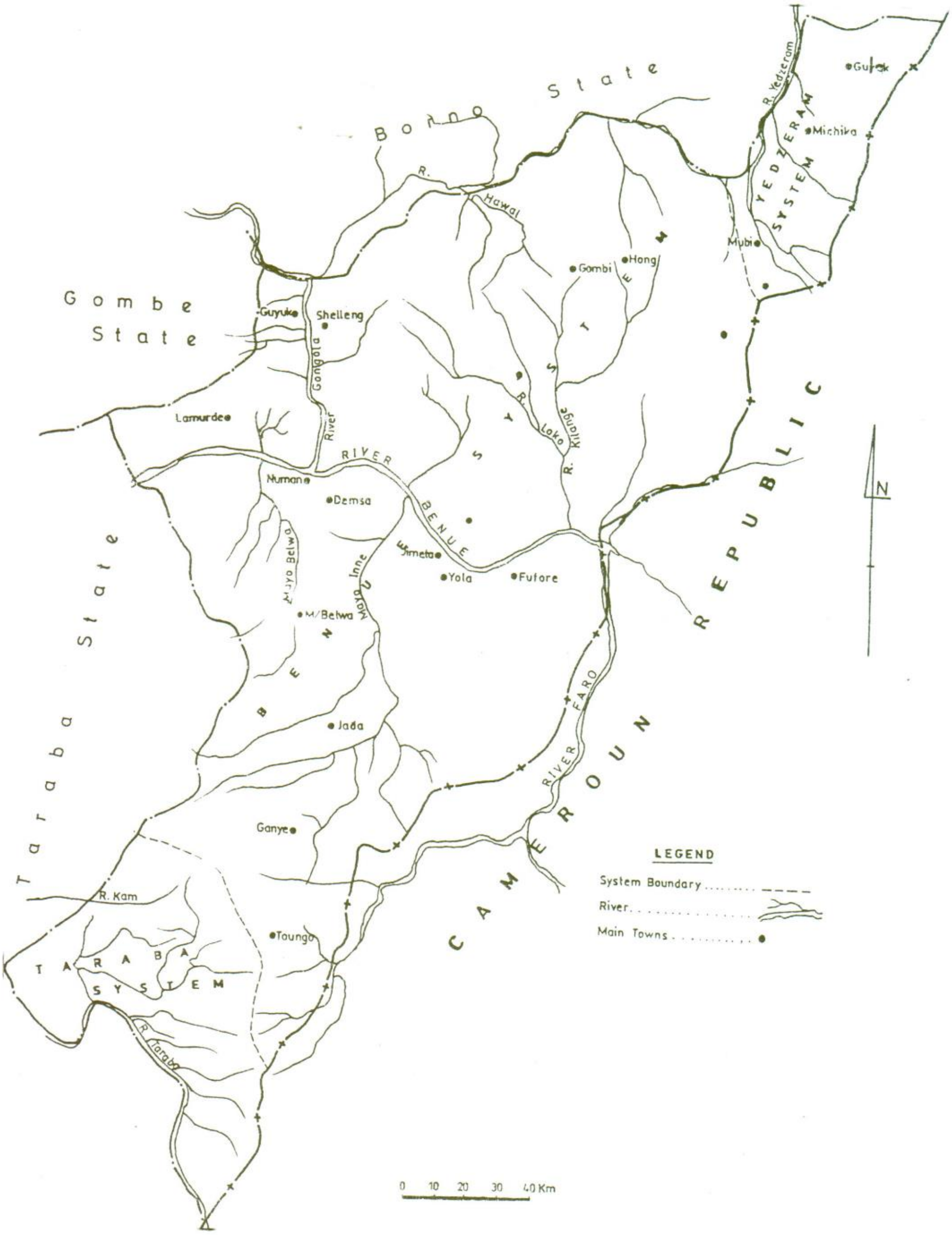

Figure. 2.1: Map Showing Location and Source of River Benue in Adamawa State

River Benue is the major river in Jimeta - Yola and Adamawa State.. A map showing the area of study is shown in Figure 2.2. The Benue River in Jimeta- Yola is normally flooded during the rainy season and the volume of water reduces during the dry season to an extent that the coast is used for farming (Adebayo et al., 1999).

The season determined the mean monthly amount of rainfall, run-off and discharge of the River Benue in Jimeta-Yola. As the amount of mean monthly rainfall increases the value recorded for the discharge and run off also increases. These parameters contribute to the amount of pollutants recorded in the river which varies both during rainy and dry season. The surface water is not available during the dry season except in lake such as Gerio. Also, there is high evapo-transpiration during dry season (Adebayo et al., 1999). Table 2.1 shows that the amount of rainfall, run-off and discharge of River Benue at Jimeta-Yola varies each month with season.

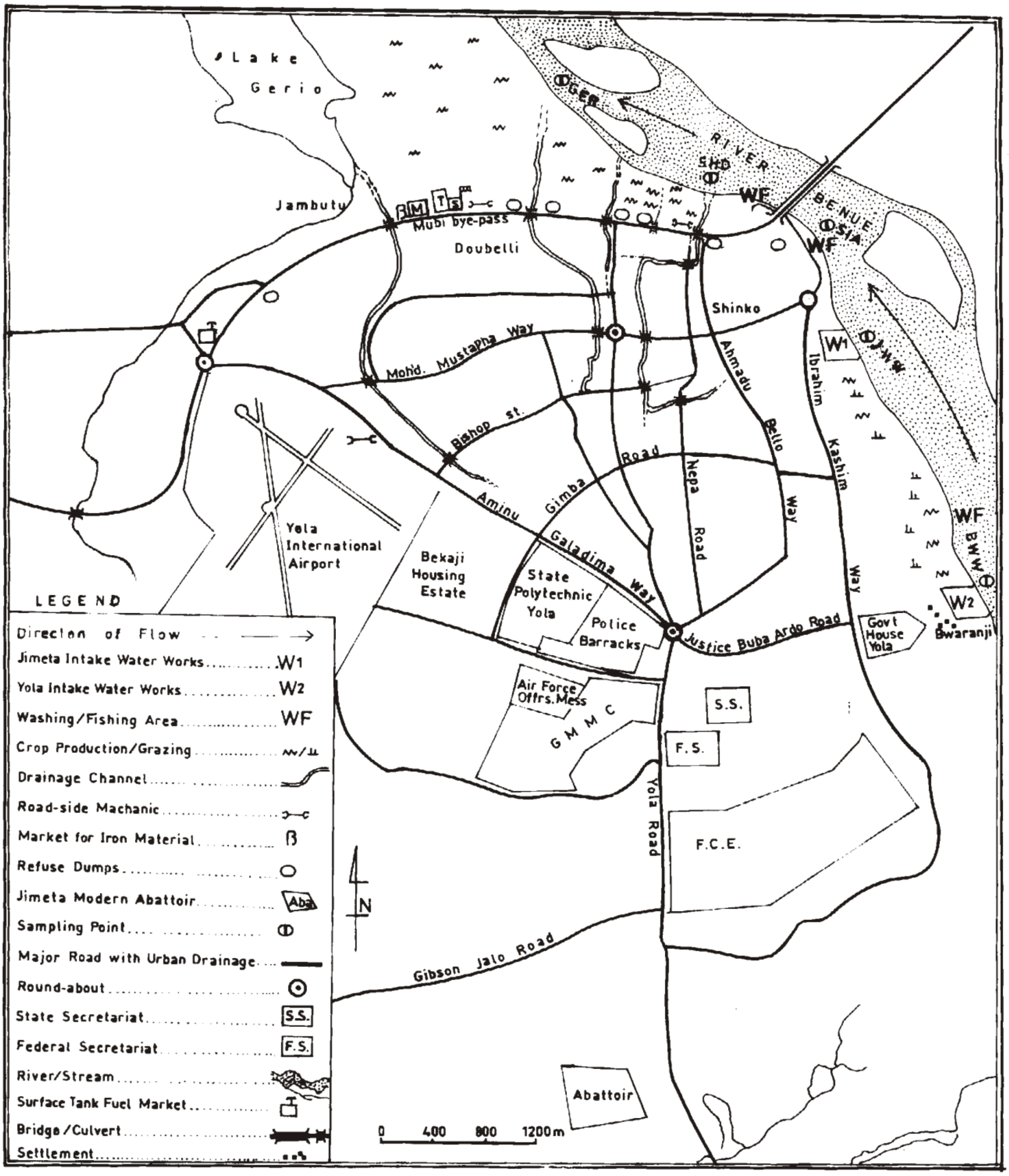

Figure 2.2: Maps Showing the Study Area

Table 2.1: Mean Monthly Rainfall, Run-off and Discharge of the River Benue at Jimeta-Yola

Month	Rainfall (mm)	Discharge (m^3/s)	Run-off volume ($10\ m^3$)
April	19.8	82	0.21
May	116	86	0.23
June	114	149	0.37
July	225	396	1.16
August	173	988	2.5
September	126	1493	3.8
October	51	742	1.9
November	3.9	164	0.41
December	0.0	92	0.25
January	0.0	79	0.23
February	0.0	74	0.19
March	5.2	78	0.22

Source: Adebayo and Tukur (1999) Adamawa State in Maps Page 19.

2.2 Water Pollution

2.2.1 River pollution

According to Chhatwal et al. (1989) pollution of water means such contamination of water or such alteration of the physical, chemical or biological properties of the water or such discharge of any sewage or of any other liquid, gaseous or solid substance into the water (whether directly or indirectly) as may, or is likely to, create a nuisance or render such water harmful or injurious to public or safety, or to domestic, commercial, industrial, agricultural or other legitimate uses, or to the life and health of animals or plants or of aquatic organisms. The major sources of water contamination have been domestic, industrial, agricultural and solid waste, as well as thermal pollution and oil spills. The contaminants are grouped into four on the basis of the effects on a given system regardless of their source: substances that lead to oxygen depletion, excess plant nutrients, agents of biological dysfunction and sedimentary and erosional processes (Chhatwal, 1996).

Rivers are surface waters in which the entire water body continually moves downhill in natural channels under the force of gravity (Nahanson, 2003). They are shallower and narrower than lakes and have a greater proportion of water exposed to land surfaces. The flowing water carries algae rapidly downstream and tends to discourage the growth of rooted plants on the stream bed. To a limited extent, rivers have the ability to assimilate biodegradable wastes. Therefore, they can recover from the effects of pollution naturally, without significant or permanent environmental damage. The capacity for self-purification depends on the strength and volume of pollutants and on the stream discharge or flow rate.

Modern-day pollution densities are too high for most rivers to assimilate raw sewage discharges without offensive environmental conditions and public health hazards quickly developing (Nathanson, 2003). Typical effects of urbanization are the modification of river channels, increased erosion and sedimentation in the river modified hydrographs and altered bank side or riparian vegetation that changes the river temperature regime. Urbanization of a catchment also changes the releases and delivery of chemicals naturally produced in the catchment, resulting in an increase in macro and micro nutrients for some time after disturbance. After development, the river usually receives a mix of chemical contaminants produced by human activities. This contaminant will affect river organisms and alter the character of the ecosystem (Lijklema et al., 1993).

2.2.2 Parametric indicators of water pollution

Lijklema et al. (1993) and Metcalf and Eddy (2003) observed that the parametric indicators of water pollution or constituents found in wastewater are characterized in terms of its physical, chemical and biological composition. These characteristics are interrelated. For instance, temperature, a physical characteristic, affects both the amounts of gases dissolved in polluted water and the biological activity in the waste water. Metcalf and Eddy (2003) further classified the parametric indicators of water pollution into physical characteristics, inorganic chemical characteristics, organic chemical characteristics and biological characteristics.

2.2.2.1 Physical characteristics

The most important physical characteristics of polluted water is the total solids content (Metcalf and Eddy, 2003). Other important physical characteristics include total suspended solids, total dissolved solids, temperature and conductivity.

Total solids

The test of solids gives a measure of the total amount of solids in waste water (Grolier Incorporated, 2001) and their relative division into suspended and dissolved fractions and into organic and inorganic fractions. Total solids is composed of floating matter, settleable matter, colloidal matter, and matter in solution. (Metcalf and Eddy, 2003; Veslind et al., 1998). Total solids are obtained by evaporating a sample of wastewater to dryness and measuring the mass of residue.

Total dissolved solids

Total dissolved solids are those solids that pass through the filter, and are then evaporated and dried at specified temperature (105 °C). It should be noted that what is measured as total dissolved solids is comprised of colloidal and dissolved solids. Colloids are typically in the size range from 0.001 µm to l µm (Metcalf and Eddy, 2003).

Temperature

Temperature of polluted water is commonly higher than that of the local water supply, because of the addition of warm water from households and industrial activities (Metcalf and Eddy, 2003). Fish and other aquatic organisms require certain conditions of temperature in order to live and reproduce (Nathanson, 2003). The optimum temperature for trout, for example, is 15 °C. Generally, a change of about 5 °C can significantly alter the balance and health of an aquatic environment. Sudden drops in temperature can be harmful, but usually an increase in temperature will cause more damage than a decrease. Depending on the geographical location, the mean annual temperature of polluted water in Africa is as high as 30 to 35 °C and the optimum temperature for bacterial activity are in the range from 25 to 35 °C (Metcalf and Eddy, 2003).

Other than the fact that most people prefer cold drinking water, temperature is of little direct significance in public water supplies. Temperature plays a more important role, however, in wastewater treatment and water pollution control (Nathanson, 2003).

Conductivity

The electrical conductivity (EC) of water is a measure of the ability of a solution to conduct an electrical current (Metcalf and Eddy, 2003). The conductivity increases as the concentration of ions increase because electric current is transported by ions in solution. In general, the measured electric conductivity value is used as a surrogate measure of total dissolved solids concentration. Also, the electrical conductivity of water is one of the important parameters used to determine the suitability of water for irrigation.

2.2.2.2 Inorganic chemical characteristics

The chemical constituents of wastewater or polluted water are typically classified as inorganic and organic (Metcalf and Eddy, 2003). Inorganic chemical constituents of concern include nutrients, nonmetallic constituents, metals and gases. The sources of inorganic nonmetallic and metallic constituents in wastewater derive from the background levels in the water supply and from the additions resulting from domestic use, from the addition of highly mineralized water from private wells and ground water, and from industrial use. Some of the inorganic chemical characteristics include calcium, chromium, copper, iron, magnesium, lead, zinc, nitrates, phosphates, and pH.

Hydrogen- ion concentration (pH)

The pH of a solution is a measure of its hydrogen ion concentration; an abundance of hydrogen ion makes it acidic. The hydrogen-ion concentration is an important quality parameter of both natural waters and wastewater (Metcalf and Eddy, 2003). The concentration range suitable for most biological life is quite narrow and critical which is about pH 6 to 9.5 (Nathanson, 2003). The pH of aqueous systems typically is measured with a pH meter. Various pH papers and indicator solutions that change colour at definite pH values are also used. The pH is determined by comparing the colour of the paper or solution to a series of colour standards (Metcalf and Eddy, 2003).

Calcium and magnesium

Calcium and magnesium ions cause the greatest portion of hardness in natural waters (Nathanson, 2003). These minerals enter the water primarily from contact with soil and rock, especially limestone deposits. In general, ground water is harder than surface water because it is in contact with mineral deposit for long periods. Water with more than 300 mg/1 of hardness is generally considered hard, and water with less than 75 mg/l is considered to be soft. Very soft water is undesirable in public supplies because it tends to increase corrosion problems in metal pipes; also, some health officials believe it to be associated with the incidence of heart disease.

Copper, iron and zinc

Iron does not cause health problems; it does impart a noticeable bitter taste to drinking water, even at a low concentration. Iron usually occurs in groundwater in solution as ferrous ion, Fe^{2+}. When exposed to air, it form the insoluble ferric ion, Fe^{3+} and causes brown or black stains on laundry and on plumbing fixtures (Nathanson, 2003). The level of iron in drinking water should not exceed 0.3 mg/1 (Salvato et al., 2003).

Copper and zinc are nontoxic in small concentrations, and in fact they are both beneficial and essential for human health (Nathanson, 2003). They cause undesirable tastes in drinking water however, and at high concentration zinc imparts a milky appearance to the water. The WHO limit for copper in drinking water is 1.0 mg/l (Salvato et al., 2003). Concentrations of this magnitude are not present in natural waters but may be due to the corrosion of copper or brass piping. A concentration of 0.5 to 1.0 mg/1 in soft water stains laundry and plumbing fixtures blue- green. A concentration in excess of 0.2 to 0.3 mg/1 will cause an “off” flavor in coffee and tea; 5 mg/1 or less results in a bitter metallic taste; l mg/1 may affect film and react with soap to produce a green colour in water; 0.25 to 1.0 mg/l is toxic to fish. Corrosion of galvanized iron and steel fittings is enhanced by copper in public water supplies. The WHO limit for zinc for drinking water is 5 mg/1.

Chromium and lead

The maximum contaminant level and WHO limit for chromium in drinking water is 0.1 mg/1 (Salvato et al., 2003). Chromium is found in cigarettes, some foods, the air, and industrial plating, paint, and leather tanning wastes. Metcalf and Eddy (2003), Chhatwal (1996) and Salvato et al.(2003) have found that the presence of hexavalent chromium compounds can cause cancer of the lung, is corrosive on tissue and causes kidney damage.

Lead as well as zinc and copper are dissolved by carbonated beverages, which are highly charged with carbon dioxide. Limestone, galena, water, and food are natural sources of lead. Other sources are motor vehicle exhaust, certain industrial wastes, lead paints, glazes, car battery salvage operations, soil, dust, tobacco, cosmetics, and agricultural sprays. Fallout from airborne pollutants also contributes significant concentrations of lead to water supply reservoirs and drainage basin, Lead can be toxic by ingestion or inhalation of dust or fumes (Metcalf and Eddy, 2003; Salvato et al., 2003). Long term exposure can cause brain and kidney damage as well as birth defects.

Nitrate

Nitrogen particularly in the nitrate form is a basic nutrient that is essential to the growth of plants (Nathanson, 2003). Excessive nitrate concentrations in surface waters encourage the rapid growth of microscopic plants called algae, excessive growth of algae degrades water quality and the process is referred to as eutrophication. Nitrate represents the final product of the biochemical oxidation of ammonia (Salvato et al., 2003). Its presence is probably due to the presence of nitrogenous organic matter of animal and, to some extent, vegetable origin, for only small quantities are naturally present in water. Manure and fertilizer contain large concentrations of nitrates which is used in agricultural area. In general, however, nitrates disclose the evidence of previous pollution of water that has been modified by self-purification process to a final mineral form. Allowing for these important controlling factors, the following ranges in concentration may be used as a guide: low, less than 0.1 mg/1; moderate, 0.1 to 1.0 mg/1; high, greater than 1.0 mg/1. Concentrations greater than 3.0 mg/1 indicate significant man-made contribution.

Excessive nitrate concentrations in drinking water pose an immediate and serious health threat to infants less than three months of age but may affect children up to age six. The nitrate ions react with blood hemoglobin, reducing the blood's ability to carry oxygen; this produces a disease called blue baby or methemoglobinemia (Nathanson, 2003; Salvato et al., 2003). The presence of more than 10 mg/l of nitrate expressed as nitrogen, the maximum contaminant level in drinking water, appears to be the cause of methemoglobinemia. The recommended maximum for livestock is 100 mg/l. Nitrate is corrosive to tin and should be kept at less than 2 mg/l in water used in food canning. There is a possibility that some forms of cancer might be associated with very high nitrate level (Salvato et al., 2003).

Phosphate

Phosphorus can enter water from sewage or from agricultural runoff containing fertilizers and animal wastes (Nathanson, 2003). The usual forms of phosphorus that are found in aqueous solutions include the orthophosphate, polyphosphate and organic phosphate. The orthophosphates, for example, PO_4^{3-}, HPO_4^{2-}, H_2PO_4, H_3PO_4, are available for biological metabolism without further break down. The polyphosphates include those molecules with two or more phosphorus atoms, oxygen atoms and in some cases, hydrogen atoms combined in a complex molecule. Polyphosphates undergo hydrolysis in aqueous solutions and revert to the orthophosphate forms; the hydrolysis is usually slow (Metcalf and Eddy, 2003). All phosphates in nature will, by biological action, eventually revert to inorganic forms to be again used by plants in making high-energy materials. This is because phosphorus in waste water may be either inorganic or organic (Vesilind et al., 1988).

2.2.2.3 Organic chemical characteristics

Organic chemicals are composed of a combination of carbon, hydrogen and oxygen, together with nitrogen in some cases. The organic matter in wastewater typically consists of proteins (40 to 60 %), carbohydrates (25 to 50 %), and oils and fats (8 to 12 %). Urea, the major constituents of urine, is another important organic compound contributing to fresh waste water. Because urea decomposes rapidly, it is seldom found in other than very fresh waste water. Along with proteins, carbohydrates; fats and oils, and urea, wastewater typically contains small quantities of a very large number of different synthetic organic molecules, with structure ranging from simple to extremely complex. Laboratory methods commonly used today to measure gross amount of organic matter in wastewater include dissolved oxygen, five day Biochemical Oxygen Demand and Chemical Oxygen Demand (Metcalf and Eddy, 2003).

Dissolved oxygen

Dissolved oxygen is generally considered to be one of the most important parameters of water quality in streams, rivers and lakes (Nathanson, 2003). Like human beings, fish and other aquatic organisms need dissolved oxygen in the water to survive. The higher the concentration of dissolved oxygen, the better is the water quality. Oxygen is only slightly soluble in water. For example, the saturation concentration at 20 °C is about 9 mg/l or 9 ppm. Because of this very slight solubility, there is usually quite a bit of competition among aquatic organisms, including bacteria, for the available dissolved oxygen. Bacteria will use up the dissolved oxygen very rapidly if there is much organic material in the water. Changes in water temperature have a significant effect on dissolved concentrations. Dissolved oxygen is inversely proportional to temperature (Vesilind et al., 1988).

Dissolved oxygen has no direct effect on public health, but drinking water with very little or no oxygen tastes flat and may be objectionable to some people. Dissolved oxygen does play a part in the corrosion or rusting of metal pipes. It can be determined by using standard wet chemistry method of analysis or membrane electrode meter in the laboratory or in the field (Nathanson, 2003).

Biochemical oxygen demand

Perhaps even more important than the determination of DO is the measurement of the rate at which the oxygen is used (Vesilind et al., 1988). The rate of oxygen used is commonly referred to as BOD. It is important to understand that BOD is not a measure of some specific pollutant. Rather, it is a measure of the amount of oxygen required by bacteria and other microorganisms while stabilizing decomposable organic matter. The more organic material there is in the water, the higher the BOD exerted by the microbes

(Nathanson, 2003). In addition to being used as a measure of the amount of organic pollution in river, the BOD is used as a measure of the strength of sewage.

The complete decomposition of organic material by microorganism takes time, usually 20 days or more under ordinary circumstances. The amount of oxygen used to completely decompose or stabilize all the biodegradable organics in a given volume of water is called the ultimate BOD or BOD_L. The 20 days or so required for the ultimate BOD to develop is much too long a time to wait for laboratory result. It has been found that more than two thirds of the BOD_L is usually exerted within the first five days of decomposition. Therefore, the parameter of BOD_5 is the most widely used parameter of organic pollution applied to both waste water and surface water.

Chemical oxygen demand

Among the many drawbacks of the biochemical oxygen demand test, the most important is that it takes five days to run (Vesilind et al., 1988). Biochemical oxygen demand test provide a measure of the biodegradable organic material in water and there might be non-biodegradable or slowly biodegradable substances that would not be detected by the conventional BOD test (Nathanson, 2003).

The COD is another parameter of water quality, which measures all organics, including the non biodegradable substances (Nathanson, 2003). It is a chemical test using a strong oxidizing agent (potassium dichromate), sulfuric acid, and heat. The results of the COD test can be available in just two hours, a definite advantage over the five days required for the standard BOD test. Chemical oxygen demand values are always higher than BOD values for the same sample, but there is generally no consistent correlation between the two tests for different waters. To measure COD the sample is boiled with an acid after which the excess potassium dichromate (not used for oxidizing) is measured by adding a reducing agent, usually ferrous ammonium sulphate (Vesilind et al., 1988). The difference between the chromate originally added and the chromate remaining is the chromate used for oxidizing the organics. The more chromate used, the more organics were in the sample, and hence the higher the COD.

2.2.2.4 Biological characteristics

The presence or absence of living organism in water can be one of the most useful indicators of its quality. In river the diversity of fish and insect species provides a measure of the biological balance or health of the aquatic environment. In addition, good quality water is one, which is free of disease causing organisms- pathogenic bacteria, viruses, protozoa, or parasitic worms. Water contaminated with sewage may contain such organisms because they are excreted in the faeces of infected individual. A species of organisms that serves the purpose of indicating water quality is called an indicator organism (Nathanson, 2003).

The most frequently used indicator organism is the normally nonpathogenic coliform bacterium E. coli (Atlas, 1995). Most strains of E. coli are generally harmless, but infected individuals also excrete pathogens along with the coliforms. Coliform bacteria are handy organisms and survive in water longer than most pathogens. They are also relatively easy to detect. In general, it can be stated that, if a sample of water is found not to contain coliforms, then there has not been recent sewage pollution and the presence of pathogens is therefore extremely unlikely. On the other hand, if coliforms are detected there is a possibility of recent sewage pollution. Nevertheless, additional test would be required to prove that the coliforms are from sewage and not from other sources. In a nut shell:

No coliforms ⟶no sewage ⟶ no pathogens (Nathanson, 2003).

It has been observed that coliform have thus become universal indicator organism (Vesilind et al., 1988). They occur naturally in the soil as well as the digestive tract of warm-blooded animals, including humans (Nathanson, 2003). It is necessary to make a distinction between two groups: total coliforms and fecal coliforms. Total coliform refers to all members of the group regardless of origin. Fecal coliform are those from the intestines of warm- blooded animals; E. coli are fecal coliforms from humans.

For drinking water, a total coliform test is particularly applicable and must be free of coliforms of any kind. However, a fecal coliform test is more appropriate for monitoring pollution of natural surface waters. When the ratio of the number of fecal coliform bacteria to fecal strep bacteria is more than two, the contamination is likely to be of human origin. When this ratio is less than one, then animal wastes rather than sewage are more likely to be the source of pollution (Nathanson, 2003).

2.2.2.5 Standard quality of raw water source

The standard of quality of raw water sources are presented in Table 2.2.

Table 2.2: The Standard Quality of Raw Water Sources.

	FM ENV QUALITY CRITERIA*			
Parameter	**Irrigation**	**Public supply**	**Marine Aquatic life**	**WHO**
Temperature °C	No limit	Potable		
pH	4.5 – 9.0	5.0 – 9.0	6.5 – 8.5	6.5 – 8.5
BOD$_5$	No Limit	1 – 5	1 – 5	1 – 5
COD				No limit
DO		No limit	6	
TS				
TDS	2000 – 5000	500.00		500.00
Velocity (cm/s)				
EC (µs/cm)	1000.00	1000.00		1000.00
Zn		5.0		5.0
Ca	500.00	75.0	500.00	500
Cr	0.1	0.05	0.1	0.05
Cu	0.2	1.0	0.05	0.05
Fe	5.0	0.3	0.3	01.0
Mg	500.00	30.0	500.00	500
Pb	5.0	0.05		5.0
NO_3^-	No limit	10.0		0.05
Phosphate		No limit	10^{-4}	10.0
Fecal coliform/ml	10			

* Unit mg/l

Sources: Shyllon (1989) The law and the Environment in Nigeria, page 48; Salvato et al. (2003) Environmental Engineering Fifth Edition, John Wiley and Sons, Inc., Canada, page 272- 313.

2.2.3 Typical impurities and their origin in raw water.

It is a frequent occurrence to find some minor and often unsuspected impurities in a water source, which happens to cause trouble in a particular set of circumstances (Grolier Incorporated, 2001; Lorch, 1987). The typical impurities and their origin in raw water are shown in Table 2.3.

Table 2.3: The Typical Impurities and their Origin in Raw Water

Class of impurities	Typical impurities and their origin
Dissolved materials	
Dissolved inorganic salts	Leaching of minerals can lead to hardness, alkalinity and other mineral content. Fertilizer run off, phosphate and nitrate can increase the amount of phosphorus and nitrogen based salt respectively.
Dissolved organic matter	Natural impurities from decay of vegetable and animal matter, leading to colouring material. Domestic waste; general biological debris and decay product, soap, detergent.
Suspended materials	
Colloids: organic and inorganic	Inorganic colloids such as clay and iron oxides, component of sewage solid.
Suspended inorganic	Natural materials, mostly sand.
Suspended organic	Plants and animals particles, domestic product.

Living Matter	
Microorganisms	Algae, viruses, bacteria, protozoa, micro fungi occur in all natural waters. Occurrence is promoted by nutrient and favourable breeding grounds e.g. domestic sewage. Exposure to light promotes algae growth.
Larger life forms	Fish, worm, insect larvae occur naturally and may breed in large numbers where food is plentiful. Aquatic plants, floating and rooted.
Gases	O_2 and CO_2 occur in all natural waters. Algae growth removes CO_2 and may raise O_2 to suspersaturation in day time with some reversal at night.

Source: Lorch (1987) Handbook of water purification, 2nd edition, Ellis Horwood Limited England, pp. 70 and 72.

2.2.4 Classification of water pollutants

Water pollutant means any substances, bacteria or viruses present in such concentrations or numbers as to impair the quality of the water rendering it less suitable or unsuitable for its intended use and presenting a hazard to man or to his environment (Chhatwal et al., 1989). It is useful to classify pollutants into various groups or categories. First, a pollutant can be classified according to the nature of it's origin as either a point source or a dispersed (non-point) source pollutant (Nathanson, 2003).

A point source pollutant is one that reaches the water from a pipe, channel or other confined and localized source. The most common example of a point or direct source of pollutants is a pipe that discharges sewage into a stream or river, while a disperse or non-point or indirect source is a broad, unconfined area from which pollutants enter a body of water. Surface runoff from agricultural areas, for example, carries silt, fertilizers, pesticides and animal wastes into a stream or river, but not at only one particular point. In addition to being classified by their origin, water pollutants can be classified into groups of substances based primarily on their environmental or health effects, namely: pathogenic organisms, oxygen-demanding substances, plants nutrients, toxic organics, inorganic chemicals, sediment, radioactive substances, heat and oil (Nathanson, 2003; Lijklema et al., 1993).

2.2.5 Sources of pollutants

The major source of water contamination include agricultural, domestic (municipal) and solid waste. These sources are discussed in this section (Chhatwal, 1996).

2.2.5.1 Agricultural Waste

Processing of agricultural products is the source of a number of water pollutants such as sediment from the erosion of crop lands, animal wastes, and pesticides used to destroy crop pests, and fertilizers that contain phosphorus and nitrogen (Grolier Incorporated, 2001). During period of rainfall or as runoff and irrigation of farm land, agricultural wastes are carried into waterways which can cause a steadily growing problem to the receiving water (Chhatwal, 1996).

2.2.5.2 Domestic waste

Domestic waste includes waste from homes and commercial establishments. Domestic waste water arises from many small sources spread over a fairly wide area but it is transmitted by sewers. The sewage is mostly released into waterways or rivers (Chhatwal, 1996).

Stream channels are modified as a result of urbanization (Lijklema et al., 1993). The most severe modifications involve complete containment. In many towns, including Jimeta-Yola natural drainage systems have changed into close conduits to pass storm water and sewage.

2.2.5.3 Solid waste

Chhatwal (1996) observed that solid waste varies in composition with the socio-economic status of the generating community. The following materials could be classified as solid waste.

(i) Garbage which includes all decomposable materials from households, as well as from food and meat-processing.

(ii) Rubbish includes all non-decomposable wastes. These materials may be combustible or non-combustible.

(iii) Sewage sludge is generated from the settling processes in primary, secondary, and tertiary treatment method.

(iv) Miscellaneous materials include wastes such as chemicals, paints and explosives.

2.2.6 Effects of water pollutants

A pollutant is regarded to have an undesirable or deleterious modification of the environment. The modification may actually or potentially influence human life, living conditions, cultural assets, or the life cycles of the indigenous plant and/or animal communities that inhabit a given system (Chhatwal, 1996). In summary, water pollution biologically affects all living organisms and also produces economic and aesthetic effects (Grolier Incorporated, 2001). The effects of water pollution are varied, they include poisonous drinking water, poisoned food animals (due to these organisms having bioaccumulated toxins from the environment over their life span), unbalanced river and lake ecosystems that can no longer support full biological diversity, deforestation from acid rain, and many other effects. These effects are of course, specific to the various contaminants. The major effect of the water pollutants are discussed in the following section.

2.2.6.1 Plants and animals

The addition of plant nutrients (nitrates and phosphates) to water stimulates the growth of undesirable aquatic weeds and algae-eutrophication. The presence of chemicals such as chloride in large amount in water can reduce the yields and adversely affect the quality of some crops (Grolier Incorporated, 2001).

Chhatwal (1996) observed that a very interesting source of information about water pollution is that it affects aquatic life. Fish and other aquatic animals such as lobsters, shrimp and mussels, live in a precise physiological adjustment with the various factors in their aquatic environment -temperature, oxygen content of the water, salinity, bottom sediments, suspended material and light. Various pollutants in water may affect any or all of these factors (Grolier Incorporated, 2001).

Mass killing of fish was among the earliest and most dramatic results of indiscriminate pollution of water. During the ten years period from 1980 - 1989, a total of 345 million fish were reported killed in more than 6,200 cases of pollution in India, the contamination coming from diverse sources which vary from year to year (Grolier Incorporated, 2001).

2.2.6.2 Man

Water pollution affects man's health, aesthetic appreciation and recreational use of water (Grolier Incorporated, 2001). Regarding water pollution and health Chhatwal (1996) observed that several water borne infectious diseases are directly related to polluted water. Also, the aquatic food chain acts to concentrate several toxic substances, as it ascends from microorganisms through various predators and prey to fish eaten by birds or by people. Emphasis has shifted from concern over bacterial disease to concern over waterborne viral disease. For instance, viral hepatitis has been found to occur more frequently in cities whose water supplies have comparatively high levels of water turbidity (Grolier Incorporated, 2001).

Concerning aesthetic appreciation, the smells associated with anaerobic process in sewers, stagnant ponds, septic tanks and other places are repulsive. Floating materials, such as sewage solids and other suspended sediment, including dyes found in industrial waste, are also repulsive. Dense algae growth resulting from large amounts of sewage residue and plant nutrients dumped into water also makes the water unattractive and malodorous (Grolier Incorporated, 2001).

For recreational use of water, the water must not only be aesthetically attractive but must also meet certain conditions. For instance, where the load of organic waste reduces the level of dissolved oxygen in the water, or toxic chemicals affect fish, sport fishing may be seriously affected. Sports such as swimming that involve direct contact with water raise the water standards even higher. The range of water quality necessary or desirable for drinking water and commercial fisheries demand water qualities similar to those required for sport fishing and for swimming. Water is a dynamic system and any changes in its normal constituents and processes affect local, regional, and eventually the worldwide environment (Grolier Incoporated, 2001).

2.3 Water Sampling

Sampling programmes are undertaken for a variety of reasons (Metcalf and Eddy, 2003) and to meet the goals of the sampling programme, the data collected must be:

a) **Representative**: The data must represent the environment (water) being sampled.

b) **Reproducible**: The data obtained must be reproducible by others following the same sampling and analytical protocols.

c) **Defensible:** Documentation must be available to validate the sampling procedures. The data must have a known degree of accuracy and precision.

d) **Usefulness:** The data can be used to meet the objectives of the monitoring plan.

The systematic basis of any sampling program includes (Krajca et al., 1989):

(i) Definition of the purpose of sampling.

(ii) Determination of the type, scope and required accuracy of the analyses to be carried out;

(iii) Definition of character of the samples to be collected;

(iv) Selection of the localities and sources to be sampled, and of the sampling points at these localities (the selection itself will be based on a survey of local conditions);

(v) Consideration of the occupational safety and hygiene of those collecting the samples.

(vi) Preparation of an optimal program;

(vii) Selection of sampling and measuring equipment suited to the sources to be sampled, and determination of its state;

(viii) Selection of the most suitable technique in line with the fixed programs and selected equipment for the given source/site, including preparation, subsidiary measurements and observations;

(ix) Selection of appropriate procedures, sample handling equipment and tools, transport from site to laboratory, and storage after delivery;

(x) Consideration of most suitable methods of analysis on site and in the laboratory;

Surface water sampling is fundamental to quality studies relating to use (water supply, irrigation and fisheries) or to degree of pollution. It is the basis of such studies.

2.3.1 Surface-water sampling sites.

When selecting surface-water sampling sites the following are taken into consideration (Wilde et al., 1998).

1) Safety of field personnel comes first;
2) Considering the study objectives, types of data needed, equipment needs, and sampling method;
3) Obtain all available historical information;
4) Consider physical characteristics of the area, such as size and shape, land, use, tributary and runoff characteristics, geology, point and non point sources of contamination, hydraulic condition, climate, water depth, and fluvial-sediment transport characteristics;
5) Consider chemical and biological characteristics of the area (aquatic and terrestrial).

2.3.2 Method of Sampling

Proper sampling procedures are important part of any survey to test water quality and to check compliance with water quality standards. There are two basic sampling methods: Grab sampling and Composite sampling (Nathanson, 2003).

a) Grab samples

As its name implies, a grab sample is a single sample collected over a very short period of time. Most people envision this as a quick "scoop", but technically it can take up to 15 min to fill the sample container and still be considered a grab sample. The test results from a grab sample only represent the conditions of the water at the particular time and location of sample collection. Grab samples are most suitable when testing pH, coliform, and dissolved oxygen. They are usually collected manually (Nathanson, 2003).

b) Composite samples

The composite sample is obtained by taking a series of grab samples and mixing them together (Vesilind et al., 1988). This is particularly true for water collection in which quality as well as quantity changes from hour to hour (Nathanson, 2003). Composite sampling is more appropriate when it is necessary to determine overall or average conditions over a certain period of time. For example, a composite sample may consist of a mixture of smaller samples taken every 20 min over 8 hour period. In pollution studies, the volumes of the smaller grab samples that make up the composite are generally taken in proportion to the flow rate, for more meaningful results. For example, if a 100 ml grab sample is taken when the flow rate is 5 1/s, then a 200 ml sample would be taken when the flow increased to 10 1/s (Nathanson, 2003).

2.3.3 Sample preservation

Sample preservation is the measure or measures taken to prevent reduction or loss of targets analytes. Analyte loss can occur between sample collection and laboratory analysis because of chemical, physical and biological processes that result in chemical precipitation, adsorption, oxidation, reduction, ion exchange, degassing or degradation. Preservation stabilizes analyte concentrations for a limited period of time. The preservation method includes filtration, chilling and chemical treatment (Wilde et al., 1998). Table 2.4 shows how chilling and chemical treatment are used as a method of preservation (Aina et al., 1992).

In chilling method, as soon as the sample are collected and processed, samples that require chilling must be packed in ice or placed in a refrigerator and maintained at 4°C or less, without freezing, until analyzed (Wilde et al., 1998).

For chemical treatment, chemicals used for sample preservation depend on the target analyte. Note that a chemical preservative for one sample may be a source of contamination for another. Some of the chemicals used include nitric acid (HNO_3), hydrochloric acid (HCl), Sulfuric acid (H_2SO_4) and sodium hydroxide.

After sample collection and processing, some sample need to be filtered immediately to remove some of the suspended solids contained in it, which can easily change the properties of the analyte to be determined (Wilde et al., 1998).

Table 2.4 Preservation of Samples, Sample Volumes, Recommended Containers and Holding Times.

Parameter	Volume required (ml)	Container	Preservation	Holding Time
BOD	1000	P,G	Cool 4°C	6 h
COD	5	P,G	H_2SO_4 to pH<2	7 d
Dissolved oxygen probe	200	G	Determine on site	No holding time
Dissolved oxygen Winkler	200	G	Fix on site	4-8 h
Hardness (Mg and Ca)	100	P,G	Cool 4°C HNO_3 to pH < 2	7 d
Total Solids	100	P,G	Cool 4°C	7 d
Total Dissolved Solids	100	P,G	Cool 4°C	7 d
Total suspended solid	100	P,G	Cool 4°C	7 d
pH	25	P,G	Determine on site	No holding time
Acidity	100	P,G	Cool 4°C	24 h
Alkalinity	100	P,G	Cool 4°C	24 h
Nitrate	100	P,G	Cool 4°C H_2SO_4 to pH<2	24 h
Phosphate	50	P,G	Cool 4°C	24 h
Fecal coliform	100	P,G	Cool 4^oC 0.008% $Na_2S_2O_3$	6 h
Temperature	200	P,G	Determine on site	Analyse immediately

P = Plastic

G = Glass

Source: Aina et al. (1992) Towards Industrial Pollution Abatement in Nigeria, FEPA Monograph 2, Ibadan University Press Nigeria, page 250; Hach (1997) DR/2010 Spectrophotometer Handbook U.S.A Page 13 – 14.

2.3.4 Handling and transporting of samples

Samples should be packaged and transported to the laboratory for analysis as soon as possible (Wilde et al., 1998). Generally, the shorter the time between sample collection/processing and sample analysis, the more reliable the analytical results will be. Before transporting samples to the laboratory, it should be ensured that sample bottles are labeled correctly and as pack samples are carefully arranged in the transporting container to prevent bottle breakage, transporting container leakage, and sample degradation. It should also be checked that the bottle caps are securely fastened.

2.4 Analytical Techniques

Several techniques are usually available for water analysis (Standard method, 1998; Stirling, 1985). In this section only two techniques will be described namely; the atomic absorption spectrophotometer (AAS) and UV-visible spectrophotometer. These are considered based on the availability of the instruments and scope.

2.4.1 Atomic absorption spectrophotometer

The technique of AAS involves the aspiration of the sample solution into a flame whose high temperature converts the analyte ion and atoms in the vapour state (Standard Method, 1998). The free atoms absorb radiation from an external source. The absorption of radiation by atoms in the flame involves a transition of these atoms from the highly populated ground state to the first excited atomic state. Part of the energy of the incident radiation is absorbed and the transmitted power can be expressed in a similar manner to Beer-Lambert Law. The absorbance and concentration are related as shown in Equation 2.1

$$\text{Absorbance (A)} = \text{Log}\,({}^{Io}/I) = KC. \qquad (2.1)$$

Where

Io = intensity of the incidence beam

I = the intensity of the beam transmitted by the atoms

C = the concentration of atoms in the atomizer

K = absorption coefficient (constant)

The relationship between the amount of light absorbed (absorbance) and the concentration of known standards can be used to determine unknown concentration. The Pye Unican Sp 9 atomic absorption spectrophotometer is an example of instrument that uses the principle discussed in this section. The schematic diagram of Pye Unican Sp 9 AAS is shown in Figure 2.3.

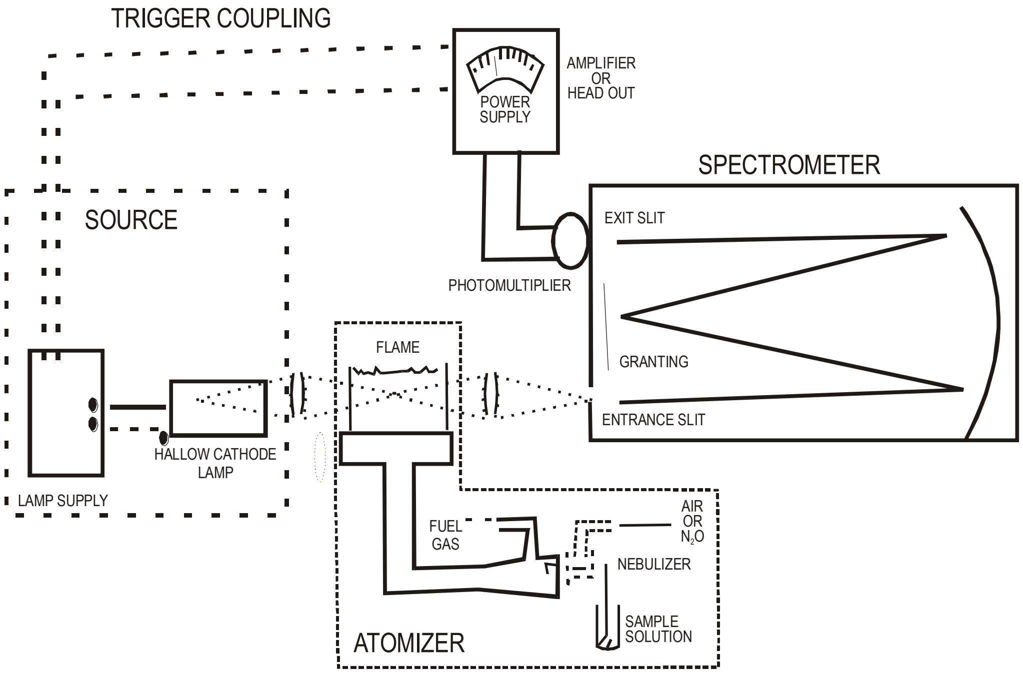

Figure. 2.3: Pye Unican Sp9 Atomic Absorption Spectrophotometer Schematic Diagram

2.4.2 UV- visible spectrophotometer

The UV-visible spectrophotometer techniques uses the theory of colorimetry (Standard Method, 1998; Stirling, 1985). The principle is based on absorption of electromagnetic radiation by molecules and ions in the ultra-violet and visible region of the spectrum. For coloured solutions, the relation of colour intensity to concentration of coloured components may be observed. Beer-Lambert Law also serves as the basis for the quantitative colorimetric determination of such substance. The absorbance of solution is proportional to the concentration of absorbing substance as stated by Beer-Lambert Law:

$$I = Io\ (10^{-abc}) \tag{2.2}$$

Where

Io = incident radiation

I = emergent radiation

a = absorbitivity

b = path length

c = concentration

Series of standard solution are prepared in respect of the desired constituent or parameters. The absorbance of each solution is measured and calibration curve is prepared. From the absorbance of the unknown solution, its concentration is obtained directly from the calibration curve (Standard Method, 1998; Saxena, 1990). The B. Bran 722-2000 spectronic – 20 is an example of model that uses the principle of UV-visible spectrophotometers. Its easy operation, and wide wave length range of 330-1000 nm make the instruments ideal for spectrophotometer experiment in the visible region of electromagnetic spectrum. The schematic diagram of B.Bran 722-2000 spectronic – 20 is shown in Figure 2.4.

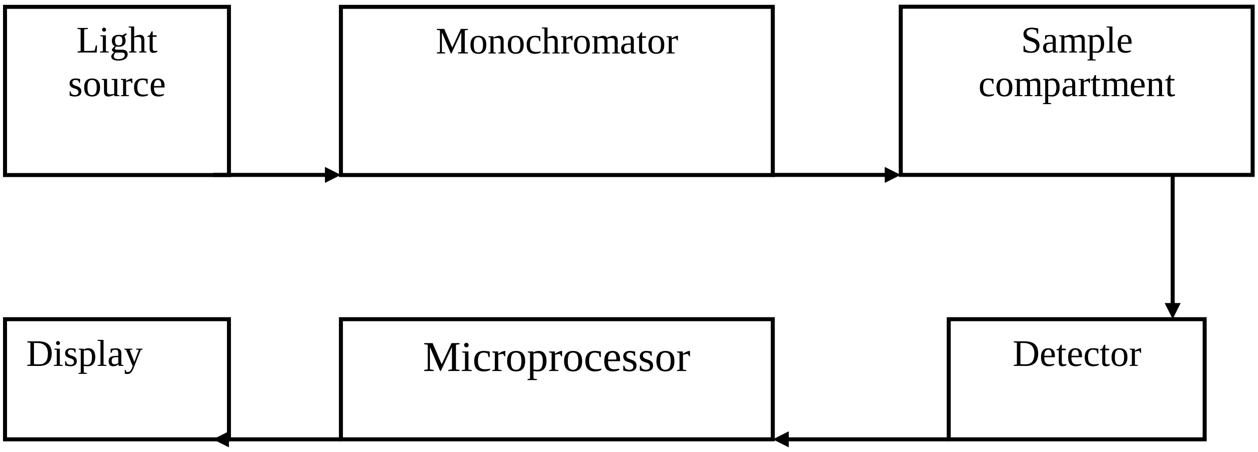

Figure. 2.4: The B. Bran 722-2000 Spectronic-20 Schematic Diagram.

CHAPTER THREE

3.0 EXPERIMENTAL PROCEDURE

3.1 Sampling

The sample points were selected based on human activities along the River Benue in Jimeta – Yola. They are given in Table 3.1 and have been shown in the map of the study area in Figure 2.2.

Table 3.1: Sampling Points and Locations

Sampling points	Locations
BWW	Bwaranji Water Works
JWW	Jimeta Water Works
SIA	Shinko area between the bridge and Ibrahim Kashim Way Round About
SHD	Shinko
GER	Gerio

Grab method of sampling was used for the collection of samples. The sampling was carried out two times in a month for the duration of six months from February 2007 to July 2007 to obtain results for location and seasonal variations. The dry season results were measured from February to April whereas the rainy season values were recorded from May to July. The sample was collected in the morning between 6:00 am to 9:00 am on each sampling day for location and seasonal variations. A day was used to measure the diurnal variation in temperature each for both dry season and rainy season. The diurnal variation in temperature was recorded on 15th March, 2007 for dry season while the results for rainy season were recorded on 6th June, 2007. The results of diurnal variation in temperature were recorded at an interval of two hours each from 8:00 am to 6:00 pm on day of sampling. For taking the samples, the plastic and glass containers were washed with the river water at each sampling point three times before the sample was finally put into the container. The pre-cleaned sample containers were completely immersed to the depth of about 12 cm with the mouth facing the direction of the current. It was allowed to remain in that position for about 5 min and the container was turned upright and the container cap replaced.

3.2 Field Measurements

Some Parameters were measured in the field to obtain the exact values so that the actual conditions of the sampling points were dully represented. These were pH, temperature, dissolved oxygen, biochemical oxygen demand and velocity.

3.2.1 Hydrogen-ion concentration (pH)

Two hundred and fifty millilitres of each of the sample was poured into a beaker and the probe was standardized using buffer solutions before it was dipped into the beaker. The pH meter (EDT Instrument, GP 353) gave the pH after dipping the probe for about 2 min.

3.2.2 Temperature

From each of the sampling points 250 ml of the sample was poured into a beaker. The mercury thermometer was dipped into the beaker and the temperature of each sample was recorded.

3.2.3 Dissolved oxygen and biochemical oxygen demand

Sample for DO was collected in air tight 250 ml bottles whereas those for BOD were collected in a 250 ml glass bottle painted black. Two separate pipette were used to add 2 ml each of manganous sulphate and alkaline potassium iodine solutions respectively.

3.2.4 Velocity

The velocity of the water at each of the sampling points was measured using floating object, measuring tape and stopwatch. The floating object (corn stork) was allowed to flow from one point to another with a known distance. The time taken for the floating object to reach the final mark point was recorded. The velocity was obtained using the relationship.

$$\text{Velocity (cm/s)} = \frac{\text{Distance traveled (displacement)}}{\text{Time taken}} \tag{3.1}$$

3.3 Laboratory Measurements

3.3.1 Conductivity

The sample from each of the sampling points was poured into a 250 ml beaker. The conductivity probe was standardized using de-ionized water before it was dipped into the beaker containing the sample and allowed to stabilize for 3 min before the reading on the conductivity meter was recorded. The conductivity was obtained at room temperature from the expression:

$$\text{Electric conductivity EC } (\mu\text{S/cm}) = \text{OEC x K} \tag{3.2}$$

Where

OEC = Observed conductivity, K = cell constant

3.3.2 Total solids

The sample from each of the sampling points for total solid was well mixed to avoid settling of some solids at the bottom of the container and 150 ml of it was taken in a clean, dry, and weighed evaporating dish. The sample was evaporated to dryness using Greenfield LTE- 48242/3 dryer (0-350 ^{o}C) at a specific temperature of 105 ^{o}C and after cooling the weight of the evaporating dish and the solids obtained was measured. The total solids were calculated from the relationship

$$\text{TS (mg/l)} = \frac{(F-I)}{V} \times 100 \qquad (3.3)$$

Where:

F = Final weight of evaporating dish + solid
I = Initial weight of evaporating dish only
V = volume of sample

3.3.3 Total dissolved solids

Filtration step was used to separate the total suspended solid from the total dissolved solids using Whatman No 5 filter paper with a nominal pore size of about 2.5 µm for each of the samples. The filtrate was collected for each sampling point and was allowed to evaporate in a Greenfield LTE-48242/3 dryer (0-350 ^{o}C) at a specific temperature of 105 ^{0}C and the total dissolved solids was obtained using the same method as in total solid.

3.3.4 Dissolved oxygen

Dissolved oxygen was measured for all the samples taken from the sampling points in the laboratory using Winkler’s method. A precipitate was formed in each of the bottles for DO and BOD as a result of the addition of 2 ml each of manganous sulphate and alkaline potassium iodide solutions. The bottles were thoroughly shaken before 2 ml of tetraoxosulphate (VI) acid was added and shaken again to dissolve the precipitate. The sample was gently transferred into a conical flask and three drops of starch was added and titrated against sodium thiosulphate solution. An end-point was obtained when the colour changed from blue to colourless and the titre value recorded. The dissolved oxygen was obtained from the formular.

$$\text{DO (mg/l)} = \frac{(V_1)(N)(8)}{(V_2 - V_3)} \times 100 \quad (3.4)$$

Where

V_1 = volume of titrant (ml)

V_2 = volume of sample bottle

V_3 = volume of reagents used

N = Normality of titrant (0.025)

3.3.5 Biochemical oxygen demand

The oxygen concentration in water samples from the various sampling points were measured and the samples were incubated for five days in a darkroom after which the remaining oxygen was determined by the Winkler's method of titration. The difference between the starting concentration of dissolved oxygen and the residual dissolved oxygen represents the amount of oxygen consumed by the indigenous microorganism in degrading the organic materials in each of the water sample (BOD_5).

3.3.6 Chemical oxygen demand

One hundred millilitres of water sample for each sampling point was poured into a 250 ml volumetric flask followed by 10 ml potassium permanganate solution. Ten mililitres 25% v/v tetraoxosulphate (VI) acid was poured as a control. The above reagents was added to 100 ml of distilled water. The water samples were placed in a boiling water bath (Kotterman, SFS 20 - 100 ^{O}C) for 30 min, removed and allowed to cool. One mililitre iodide solution was added, mixed and titrated against sodium thiosulphate solution. An end-point was obtained when the colour changed from purple to colourless. Chemical oxygen demand was calculated from the relationship:

$$\text{COD (mg/l)} = \frac{V_1 - V_2}{V_1} \qquad (3.5)$$

Where:

V_1 = volume of thiosulphate titrated for the control

V_2= corresponding titre for the sample

3.4 Inorganic chemical characteristics

Pye Unican Sp 9 atomic absorption spectrophotometer was used to determine the concentration of Ca, Mg, Cr, Cu, Fe, Pb, and Zn, and B. Bran 722-2000 spectronic – 20 was used to determine the concentration of Nitrate and Phosphate.

3.4.1 Standard stock solution

The mass of each of the salts that gave 1 g of each individual metal parameter to be measured was calculated and weighed using Mettler Toledo analytical balance- AB204. The exact amount calculated for each salt was dissolved in 1000 ml volumetric flask to give 1000 mg/l. The quantities of the salts used are given in Tables 3.2 and 3.3.

Table 3.2: Mass of Materials for Stock Solution for Pye Unican Sp 9 AAS Calibration

Parameter	Reagent	Weight (g)
Ca	$Ca(NO_3)_2.4H_2O$	5.90
Mg	$MgCl_2.6H_2O$	8.47
Cr	$Cr(NO_3)_2.9H_2O$	7.70
Cu	$Cu(NO_3)_2.3H_2O$	3.79
Fe	$Fe(NO_3)_2.9H_2O$	7.21
Pb	$Pb(NO_3)_2$	1.59
Zn	$ZnCl_2$	2.10

Table 3.3: Mass of Materials for Stock Solution for B. Bran 722 – 2000 spectronic – 20 calibration

Parameter	**Reagent**	**Weight (g)**
PO_4^{3-}	KH_2PO_4	0.1098
NO_3^-	KNO_3	0.722g

3.4.2 Serial dilutions

From the 1000 mg/l standard stock solution, a dilution expression was used to obtain the various volumes “V_1” taken for each metal parameter concentration prepared in mg/l for both the Pye Unican Sp 9 AAS and the B.Bran 722 – 2000 spectronic – 20:

$$C_1V_1 = C_2V_2 \tag{3.6}$$

Where

V_2= volume of volumetric flask selected (100 ml)

C_2 = the desired final concentration after dilution

C_1= standard stock solution concentration (1000 mg/l)

V_1= volume required to obtain the desired concentration for the dilution

3.4.3 Working conditions

The working condition for the Pye Unican Sp 9 AAS are summarized in Table 3.4

Table 3.4: Working Condition for Pye Unican Sp 9 AAS

Parameter	Wavelength (nm)	Flame	Temperature (^{0}C)
Ca	422.2	A/A	1000
Mg	285.2	A/A	1100
Cr	357.9	A/A	1100
Cu	324.7	A/A	850
Fe	248.3	A/A	1100
Pb	283.3	A/A	750
Zn	213.9	A/A	500

A/A = Air Acetylene

The working conditions for B.Bran 722-2000 spectronic –20 are presented in Table 3.5

Table 3.5: Working Condition for B. Bran 722 – 2000 Spectronic – 20

Parameter	Wavelength (nm)
PO_4^{3-}	650
NO_3^-	410

3.4.4 Absorbance measurement and parameter determination

3.4.4.1 Pye Unican Sp 9 AAS

Pye Unican Sp9 AAS was used for determination of the concentration of the following elements; Ca, Mg, Cr, Cu, Fe, Pb and Zn. The instrument was switched on and allowed to stabilize for few minute. The instrument was equipped with a digital read-out where the absorbance was noted directly. Air/acetylene was used as oxidant fuel. Hollow cathodes lamp for each element was employed. The current and resonance line wavelength were selected as summarized in Table 3.4. The gas control system was adjusted to give rich fuel flame. The instrument was calibrated using water as blank solution. The absorbance reading was measured for each parameter standard solutions and various samples. The calibration curves for each parameter was constructed and used to obtain the concentration of the parameters in each water sample as shown in Appendix A.

3.4.4.2 B. Bran 722-2000 spectronic – 20

The B. Bran 722-2000 spectronic-20, which is a single beam spectrophotometer with wavelength range of 330-1000 nm was used for determination of the concentration of phosphate and nitrate. The instrument was allowed to warm for at least 15 min. The desired wavelength for each of the parameters was selected as shown in Table 3.5. Absorbance mode was selected as the desired operating mode. The blank solution, standard solutions and various samples were all put inside 10 mm path length cuvette. Each sample was placed inside the sample compartment, which was closed before taking any reading. The absorbance reading were measured for both phosphate and nitrate standard solution and various samples. The calibration curves for each parameters was constructed and used to obtain the concentration of phosphate and nitrate in each water sample as shown in Appendix A.

Phosphate

Five milimetres water sample was poured into 10 ml volumetric flask. One milimetre of ammonium molybdate solution was added. The flask was rotated and was allowed to stand for 10 s. One milimetre of hydroquinone solution was added to the mixture. The mixture was rotated again followed by addition of 1 ml of Na_2SO_3. The mixture was diluted with H_2O and shaken thoroughly and allowed to stand for 30 min. The absorbance was measured using B.Bran 722 – 2000 Spectronic – 20 at 650 nm. The concentration of phosphate was obtained from the calibration curve as depicted in Appendix A.

Nitrate.

Twenty five millilitres of each water sample was put into a porcelain basin and evaporated to dryness on a hot water bath (Kotterman, SFS 20 – 100^oC). About 0.5 ml of phenol disulphonic acid was added to the residue and dissolved with the help of a glass spatula. Later, 5 ml of distilled water and 1.5 ml of potassium hydroxide solution were added to the mixture and mixed thoroughly. The absorbance was obtained for the standard solution and water sample against distilled water blank at 410 nm using B.Bran 722-2000 spectronic-20. The concentration of nitrate at the various sampling points was obtained from the calibration curve as shown in Appendix A.

3.5 Coliform Organism (*E. coli*)

Membrane filter technique was used for the estimation of coliform bacterial (E. coli). For each of the sample collected from the various sampling points 100 ml were drawn through a special membrane filter called bacterial filter. The bacterial filter has uniform microscopic pores small enough to retain the bacterial on its surface while allowing the water to pass through. The filter was placed in a sterile petri dish. The petri dish also contained a special culture medium (Maccon key Agar) that the bacteria use as food source. The nutrient medium was available in small glass containers called ampules, from which it was readily transferred into the petri dish. Its compositions were such that it promoted the growth of coliforms while inhibiting the growth of other bacteria caught on the filter. The Petri dish holding the filter and nutrient medium were placed in the Gallen Kamp incubator size-1 which kept the temperature at 37 ± 1^{0}C for 24 h. After incubation, the colonies were formed by the reproductive process of binary fission. The concentration was obtained by counting the member of colonies on the bacteria filter using Leica Quebec Darkfield colony counter- 3326.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

The results of this investigation are presented in this chapter, location and seasonal variation of the physical, inorganic chemical, organic chemical and biological characteristics of the river are discussed. The diurnal variation in temperature is also presented. The values of the water quality parameters obtained for both dry season and rainy season are presented in Table B.1 to B.20 in Appendix B.

4.1 Location Variation of Water Quality

The location variation analyses were considered only for the dry season because they are more significant during this season as compared to the rainy season. The mean values of the various water quality parameters along the river course for the different sampling points (locations) during dry season (February – April) are presented in Figures 4.1 – 4.3. Temperature, EC, TS, TDS, and velocity are presented in Figure 4.1, heavy metals (Ca, Mg, Fe, Pb, Cr and Zn), PO_4^{3}- and NO_3^- are presented in Figure 4.2. While pH, DO, COD, BOD_5, and E. Coli are presented in Figure 4.3.

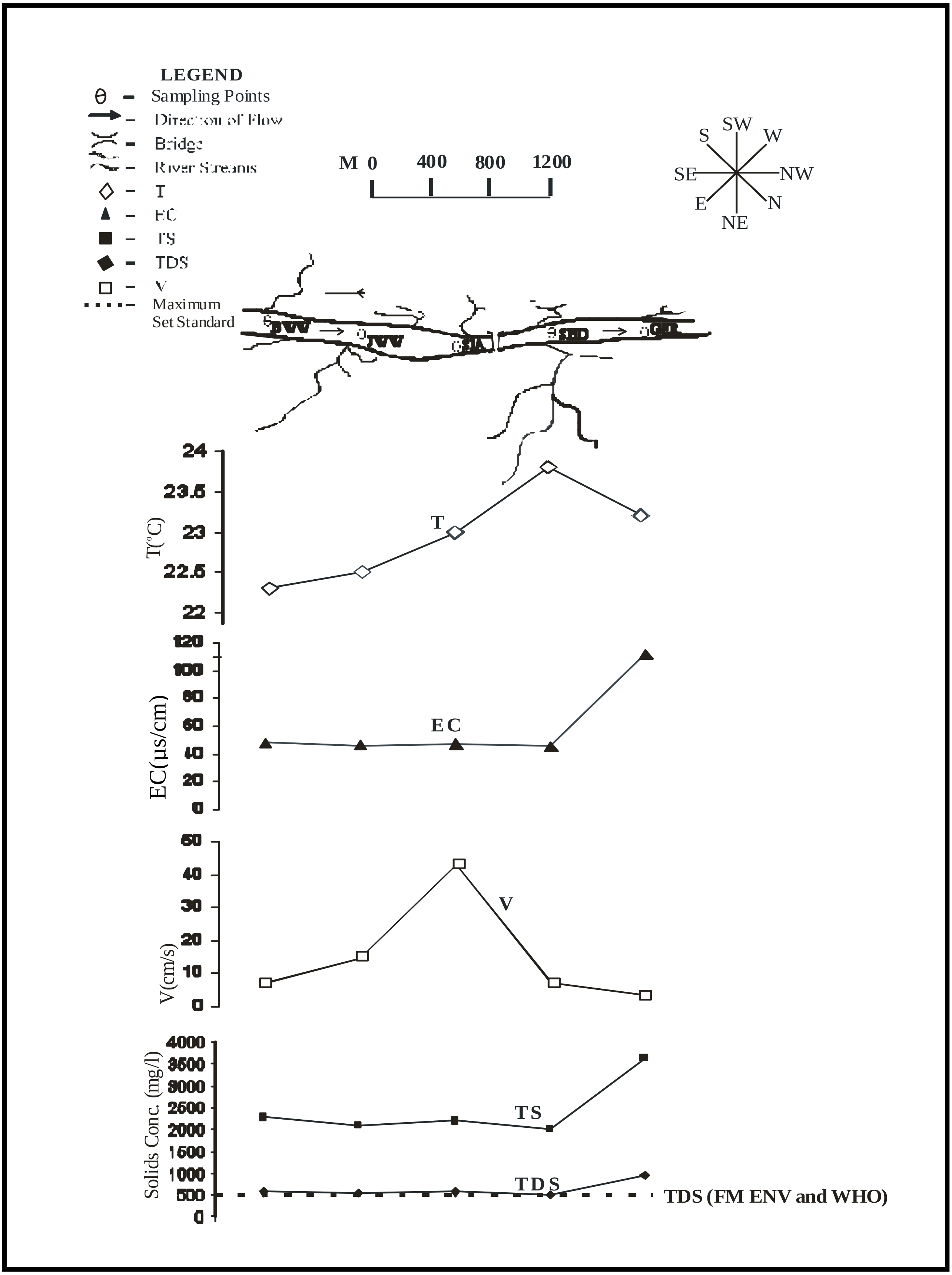

Figure. 4.1 Water Quality Behaviour along River Course for T, EC, TS, TDS and V

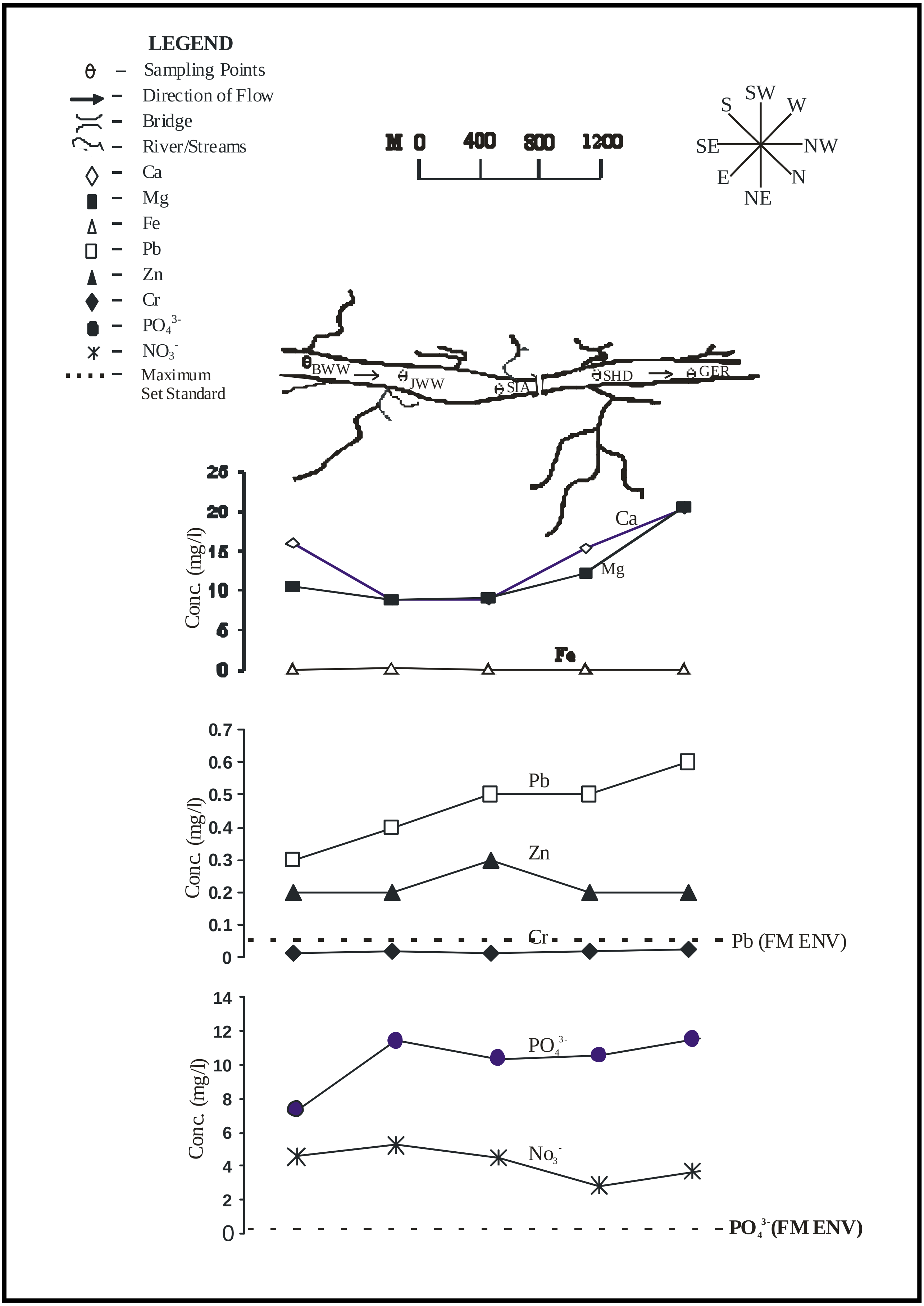

Figure. 4.2: Water Quality Behaviour along River Course for Ca, Mg, Fe, Pb, Zn, Cr, PO_4^{3-} and NO_3^-

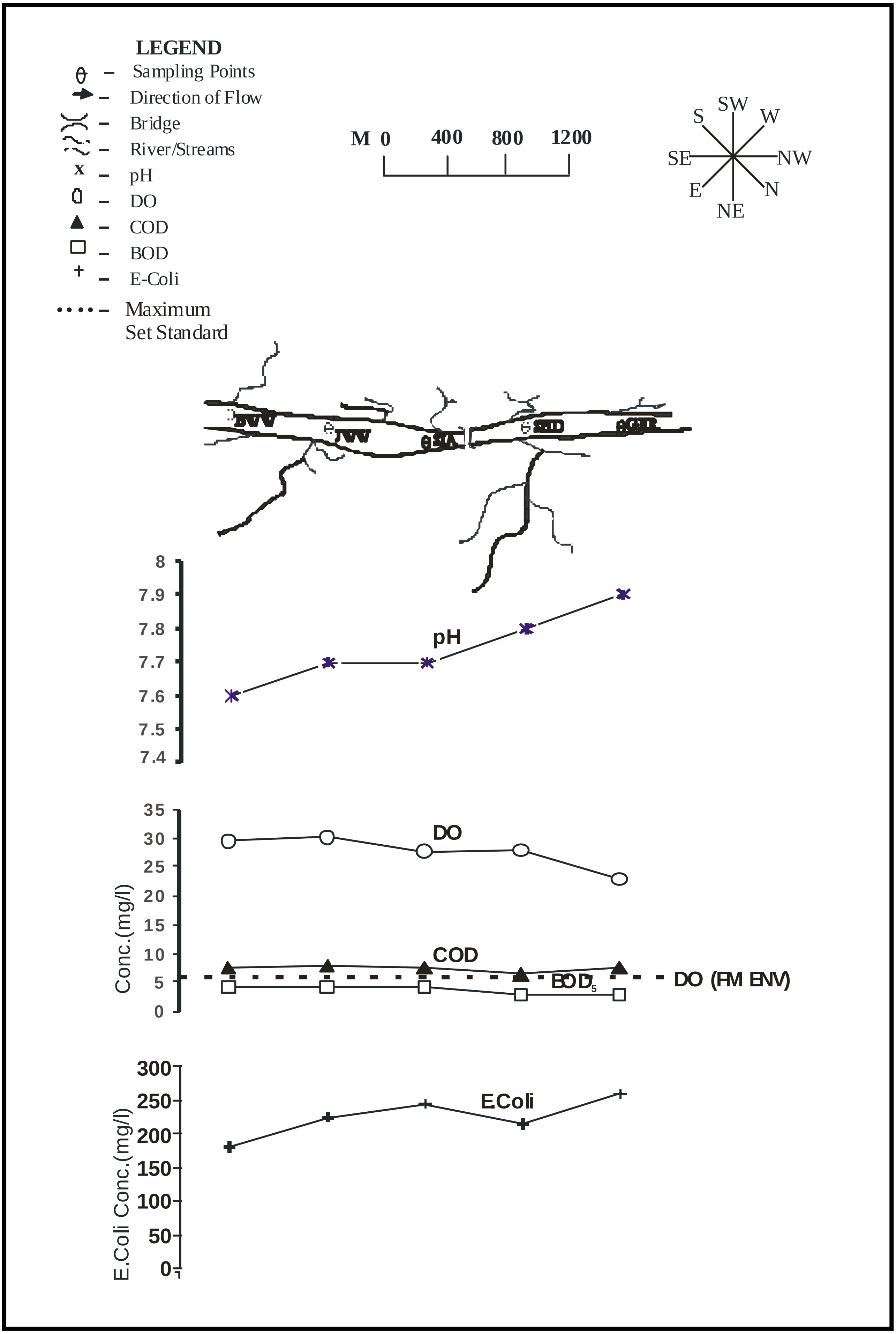

Figure. 4.3 Water Quality Behaviour along River Course for pH, DO, COD, BOD$_5$ and E.Coli

Temperature, Fe, Zn, Cr, BOD_5 and COD do not vary much along the river. The ranges are: 22.3 – 23.8 ^oC, 0.2 – 0.3 mg/l, 0.2-0.3 mg/l, 0.014- 0.026 mg/l, 2.8-4.2 mg/l, and 6.3-8.0 mg/l respectively.

Most parameters: EC, TS, TDS, Ca, Mg, Pb, pH, PO_4^{3-} and E.Coli generally increase and DO generally decreases along the river indicating an increasing level of pollution downstream of the river between BWW and GER. These can be explained by the gradual cumulative effect of the pollution sources from the city increasing gradually downstream.

Lower mean values of TDS, TS and NO_3^- were measured at SHD. The results obtained are: 510.0 mg/l; 1500.0 mg/l and 2.9 mg/l respectively. These results are attributed to neutralization reaction which might occur at the SHD location due to various kind of domestic waste such as bathing water, garbage and solid waste discharge into the river and dumping of refuse closer to the location.

Velocity was generally highest in SIA than other locations. This might be due to geological characteristics of the location. The various water quality parameters are more moderate at JWW and BWW than other locations. This might be due to less rearing of animals, crop production, intensive washing, dumping of refuse, recreational activities and commercial activities observed in the two locations. Therefore the location of waterworks in those areas is in order compared to other locations.

Figures 4.1- 4.3 show that Pb, PO_4^{3-} and DO range from 0.3- 0.6 mg/l; 7.3-11.5 mg/l and 23.0-30.1 mg/l respectively. For Fe the mean values which range from 2.0 -2.9 mg/l at all the five locations are above the FM ENV and WHO set standard of 0.3 mg/l for public supply and marine aquatic life during rainy season.This might be due to the discharge of iron based pollutants into the river as run off during irrigation and rainfall. The mean values of Lead at all the five locations are above the FM ENV set standard for drinking water (0.05 mg/l) during the dry season. This might probably be due to exhaust from motor vehicles, lead paints, car battery salvage operation, soil dust, tobacco, cosmetics and agricultural sprays from the study area channel into the river which is intensive during dry season compared to rainy season (Metcalf and Eddy, 2003; Salvato et al., 2003).

For PO_4^{3-} all the values are above the FM ENV set standard of 0.0001 mg/l for marine aquatic life at all the locations. The results might be due to the increase number of inhabitants using the river for washing and irrigation (Nathanson, 2003; Triveldy et al., 2005) during the dry season because some of the soaps, detergent and fertilizer contained phosphate based substances and it was observed that the values recorded decreased gradually during rainy season.

At all the five locations the values of DO recorded shows that less physico chemical and biological process are going on in the river within the catchment area of study (Stirling, 1985). The DO values are suitable for irrigation, public supply but above the FM ENV maximum permissible limit for marine aquatic life of 6.0 mg/l (Table 2.2). The mean DO, COD and BOD_5 range from 23.0 – 30.1 mg/l, 6.3 -8.0 mg/l and 2.8 – 4.2 mg/l respectively during dry season. From Figure 4.3 low mean values of DO was recorded at Gerio than other locations. This might be due to high pollution load recorded at GER location.

The mean location variation of NO_3^- at BWW, JWW, SIA and GER are above 3.0 mg/l (WHO) with the following values; 4.6 mg/l, 5.2 mg/l, 4.5 mg/l and 3.7 mg/l respectively which indicate significant man-made contribution (Salvato et al., 2003). This implies that the value of NO_3^- recorded is due to activities such as application of nitrate based fertilizer during crop production and from human and animal faeces and urine which are contributed by the inhabitant within the area of study.

4.2 Seasonal Variation of Water Quality

Of the five different locations, the GER location is the highest polluted and for this reason the seasonal variation of water quality parameters at Gerio was studied. The results are presented in Figures 4.4 -4.6. Temperature, EC, TS, TDS and velocity are presented in Figure 4.4, heavy metals, PO_4^{3-}, and

NO_3^- are presented in Figure 4.5. While pH, DO, COD, BOD_5 and E.Coli are presented in Figure 4.6.

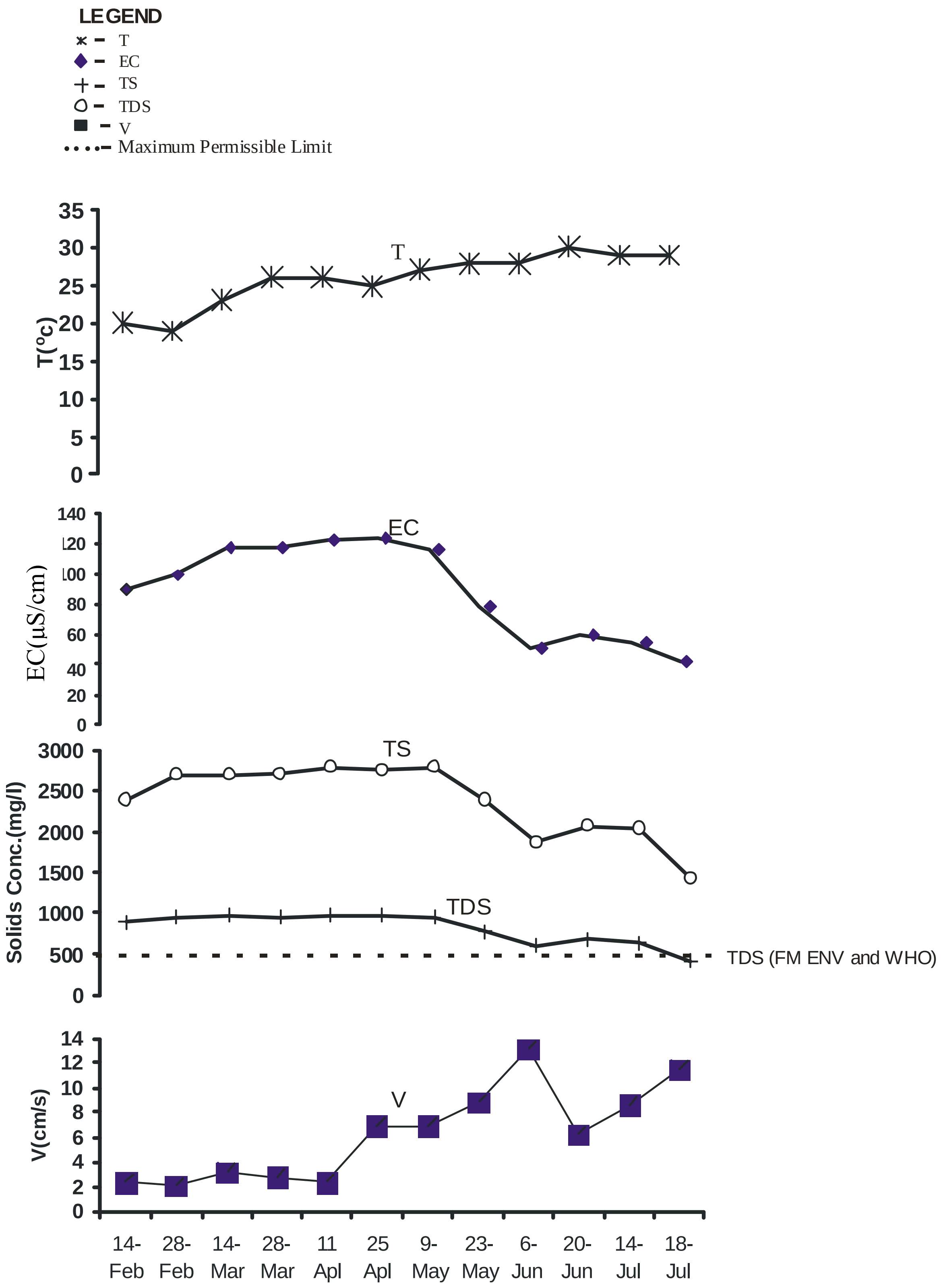

Figure.4.4: Seasonal Variation of Water Quality Behaviour at Gerio for T, EC, TS, TDS and V.

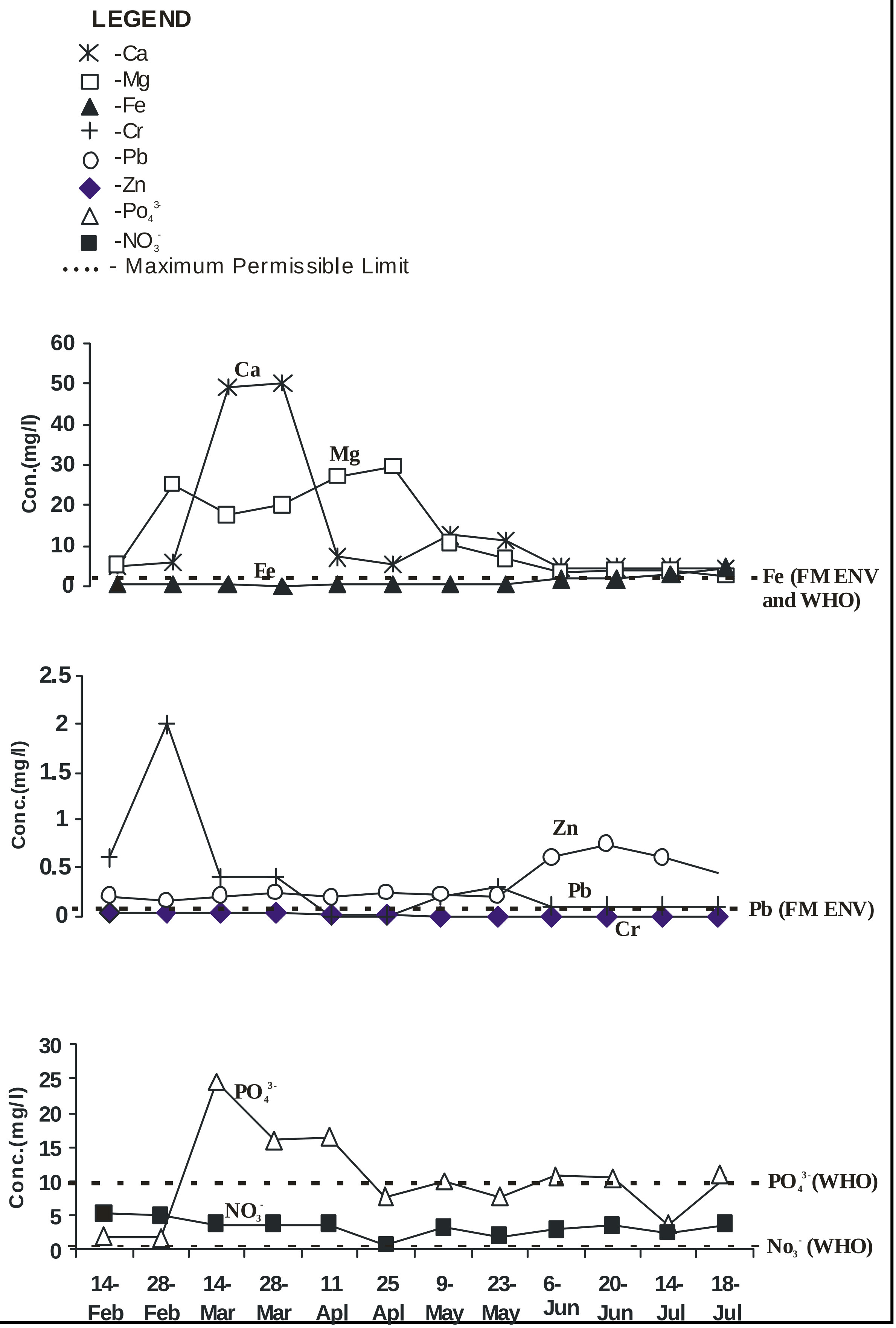

Figure. 4.5: Seasonal Variation of Water Quality Behaviour at Gerio for Ca, Mg, Fe, Zn, Pb, Cr, PO_4^{3-} and NO^-_3

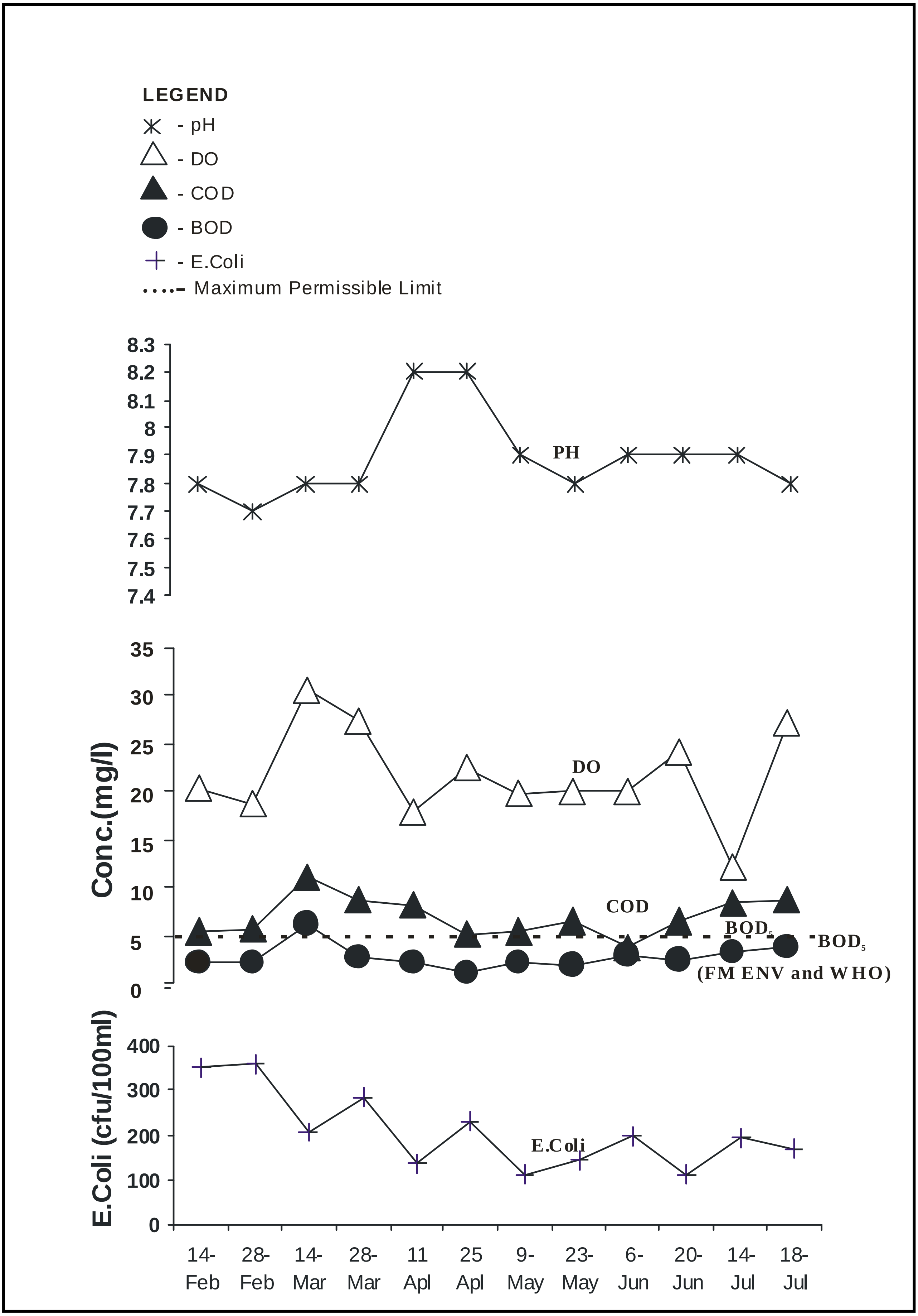

Fig. 4..6: Seasonal Variation of Water Quality Behaviour at Gerio for pH, DO, COD, BOD_5 and E.Coli

Most water quality parameters: EC, TDS, TS, pH, Ca, Mg, Cr, Pb, PO_4^{3-}, NO_3^-, DO, BOD_5, COD and E.Coli of the river are generally higher in the dry season (February – April) than in the rainy season (May – July) at Gerio. The values recorded indicate higher concentration of ions (Nathanson; 2003; Metcalf and Eddy, 2003; Salvato et al., 2003; Trivedy et al., 2005) due to human activities such as washing, farming, dumping of refuse, fishing which is very intensive during dry season compared to rainy season. In addition, dilution effect might also contribute to lower values during rainy season.

The values of temperature, velocity, iron and zinc of the river at GER are observed to be higher in the rainy season than in dry season. The velocity of the river increases with increase in rainfall. Considering temperature, iron and Zinc these might be due to surface run off and leaching of minerals that contained iron and zinc based concentrations which are higher in rainy season than in dry season (Nathanson, 2003; Vesilind et al., 1988; Salvato et al.,2003; Lorch, 1987).

The TDS of the river at GER are generally above the maximum permissible limit (500 mg/l) for drinking water both in the dry season and rainy season (FM ENV and WHO). The values ranged from 420.0 – 980.0 mg/l. The TDS of the river generally decreased with month in the rainy season.

The measured values of iron at GER ranged from 0.00 – 4.60 mg/l. The iron values increased gradually during rainy season with the highest towards ending of July. The results obtained are above the FM ENV and WHO set standard for public supply and Marine aquatic life during rainy season.

Lead concentrations ranged from 0.0-2.0 mg/l at GER which is above the FM ENV maximum permissible limit of 0.05 mg/l for public supply. The mean concentration of PO_4^{3-} at GER (11.5 mg/l) is above the maximum permissible limit (10 mg/l) in the dry season as set by WHO. The concentration of nitrate obtained ranged from 0.7 -5.3 mg/l which is above the maximum set standard of 0.05 mg/l by WHO.

The concentration of DO ranged from 12.1 -30.6 mg/l at GER which is above the FM ENV maximum set standard of 6.0 mg/l for marine aquatic life. The BOD_5 ranged from 1.1 -6.2 mg/l during the season of analysis. In the beginning of March the BOD_5 measured 6.2 mg/l during dry season which is above the maximum permissible limit for public supply and marine aquatic life set by FM ENV and WHO. The values of E.Coli at GER ranged from 110-360 cfu/100 ml. The river is not suitable for drinking since it contains E.Coli (Nathanson, 2003; Salvato et al., 2003; Standard Method, 1998) .

4.3 Diurnal Variation of Temperature

The diurnal Variation in temperature for SIA and SHD locations were observed. The Variation in temperature were measured on 15th March for dry season and are presented in Figure 4.7 while that of rainy season were noticed on 6th June and are presented in Figure 4.8.

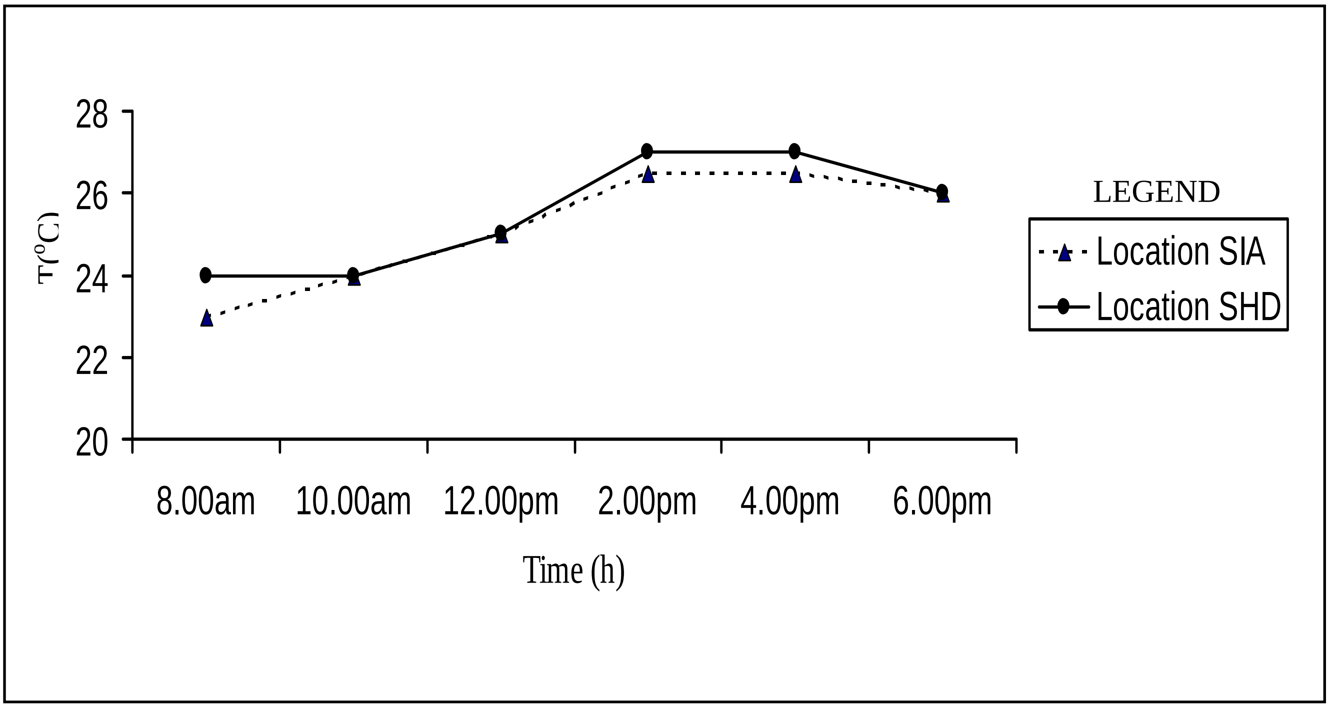

Figure 4.7: Diurnal Variation in Temperature on 15th March, 2007

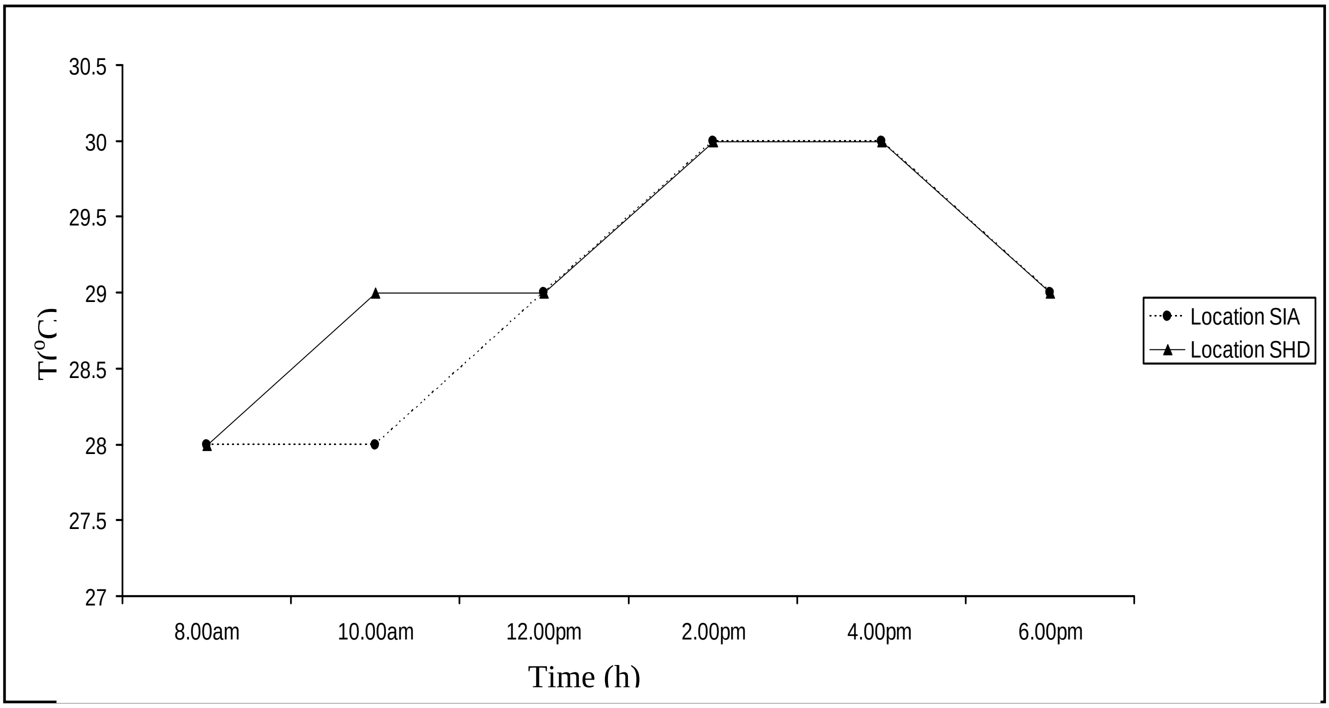

Figure 4.8: Diurnal Variation in Temperature on 6th June, 2007

The results of the diurnal variations in temperature show that on 15th March the temperature varied from 23.0 – 26.0 ^{o}C at SIA location whereas at SHD location the temperature ranged from 24.0 – 26.0 ^{o}C. The temperatures of the two locations were lowest in the morning but increased gradually as the sun rose. The peaks were reached at 2.00 pm and then temperature fell during the day up to 6:00 pm.

For the rainy season on 6th June the temperature ranged from 28.0 – 29.0 ^{o}C for both SIA and SHD locations. The same trends similar to that of dry season were observed. The diurnal variations in temperature for both dry and rainy season show a distinct variation in temperature along the river locations as well as during the season. This implies that variation in other water quality parameters are expected because temperature a physical characteristics, affects both the amount of gases dissolved in polluted water and the biological activity (Metcalf and Eddy, 2003). Higher values of temperature were observed in rainy season than in dry season.

4.4 Comparison with Previous Research

The changes of some pollution parameters with years are presented in Figure 4.9. The parameters compared are; Pb, Fe, TDS and pH.

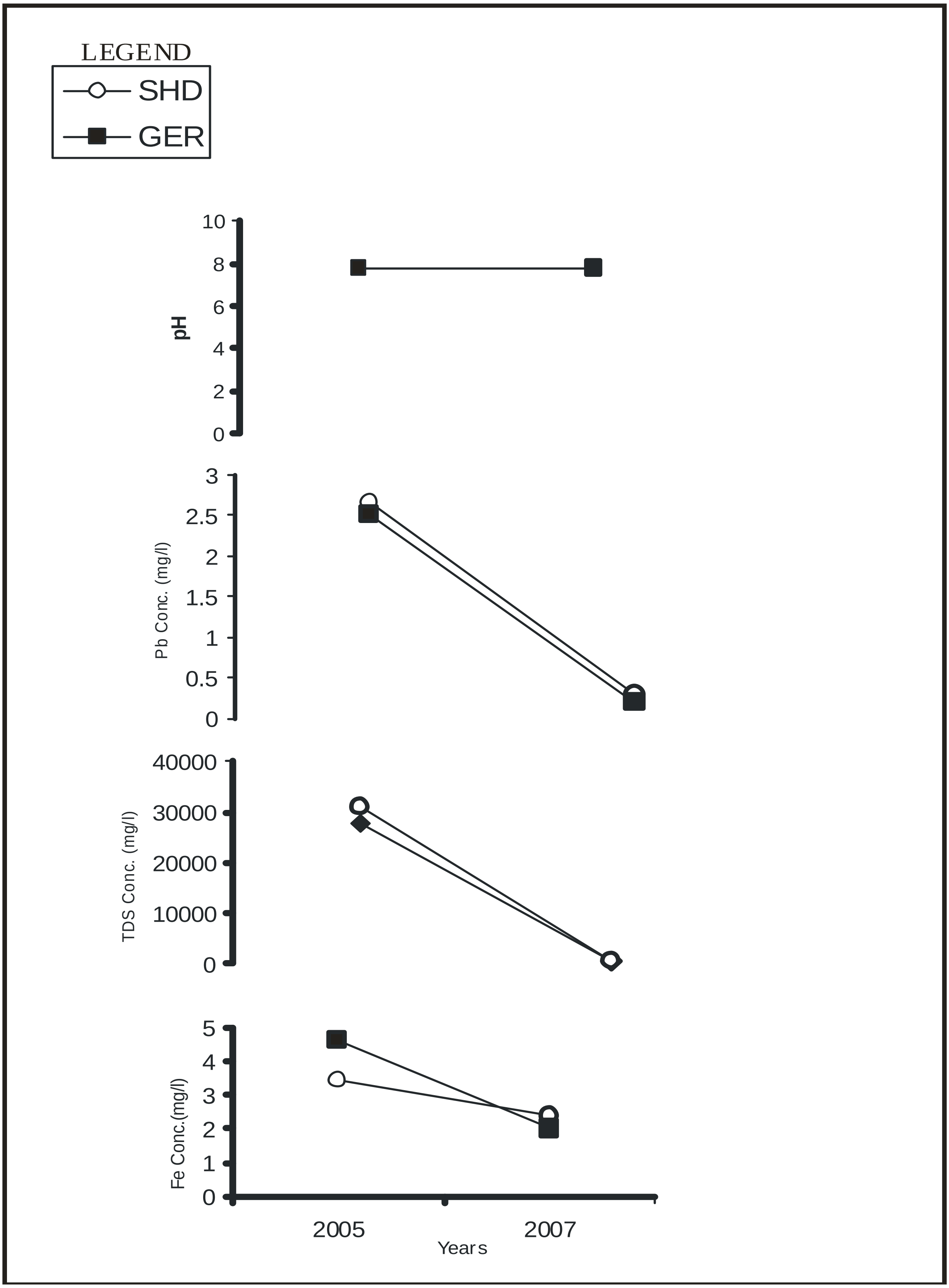

Figure 4.9: Changes of Pollution Parameter with Years.

The results obtained by Joseph in the year 2005 between June to August and the present research carried out in the year 2007 during the rainy season were examined at two same locations namely; GER and SHD within the same study area. The values recorded show that the mean concentration of Pb, TDS and Fe decrease in year 2007 during rainy season whereas no changes in the mean values of pH were observed. The pH mean value recorded were 7.8 at SHD and GER.

CHAPTER FIVE

5.0 CONCLUSION

Based on the results recorded in this work, the following conclusions can be made.

1. Temperature, iron, zinc, Chromium, five days biochemical oxgen demand and chemical oxygen demand do not vary much along the river during dry season. The ranges are: 22.- 23.8^{o}C, 0.2 – 0.3 mg/l, 0.2- 0.3 mg/l, 0.014 – 0.026 mg/l, 2.8 – 4.2 mg/l and 6.3- 8.0 mg/l respectively.
2. Most parameters: electrical conductivity, total solids, total dissolved solids, calcium, magnesium, pH, lead, phosphate and escherichia coli generally increase and dissolved oxygen decreases along the river indicating an increasing level of pollution downstream of the river between Bwaranji and Gerio.
3. Higher discharge of pollutants into the River Benue in Gerio location was observed compared to the other locations. While the various water quality parameters are more moderate at Jimeta Water Works and Bwaranji Water Works than other locations.
4. The mean Fe values which range from 2.0 -2.9 mg/l at all the five locations are above the Federal Ministry of Environment and World Health Organization set standard of 0.3 mg/l for public supply and marine aquatic life during rainy season. The mean values of lead which range from 0.3-0.6 mg/l at all the five locations are above the set standard of 0.05 mg/l for public supply during the dry season.
5. For phosphate the mean values range from 7.3 – 11.5 mg/l which are above the World Health Organization set standard of 10.0 mg/l at all the

locations with the exception of Bwaranji Water Works location (7.30 mg/l) during dry season and also making the river unsuitable for marine aquatic life with a World Health Organization maximum permissible limit of 0.0001 mg/l. The mean values of nitrate range from 2.9 – 5.2 mg/l both during dry and rainy season. The mean values of nitrate at all the locations with the exception of Shinko Drainage location during dry season as well as that of rainy season with the exception of Jimeta Water Works location are above 3.0 mg/l (World Health Organization) which indicate significant man-made contribution.

6. The mean dissolved oxygen values range from 23.0 – 30.1 mg/l during dry season while that of rainy season range from 20.6 – 28.2 mg/l. The dissolved oxygen values are suitable for irrigation, public supply but above the Federal Ministry of Environment maximum permissible limit for marine aquatic life of 6.0 mg/l. The mean total dissolved solids of the river range from 510.0 -960.0 mg/l during dry season while that of rainy season range from 486.7 -680.0 mg/l. The mean total dissolved solids of the river are generally above the Federal Ministry of Environment and World Health Organization maximum permissible limit of 500.0 mg/l for drinking in all the location during dry season. The total dissolved solids of the river stretch decreases with month in the rainy season.
7. The seasonal variation shows that River Benue in Jimeta-Yola from Bwaranji to Gerio is more polluted during dry season than the rainy season.

CHAPTER SIX

7.0 RECOMMENDATIONS

Based on the results of this investigation, the following recommendations can be made for future research.

1. The work needs to be carried out for a period of five years in order to study the extent of pollution of River Benue within the catchments area. This is because the annual rainfall varies each year which may affect the amount of pollutants discharges into the river.
2. Mobile laboratory needs to be used if available for analysis of inorganic chemical characteristics, organic chemical characteristics and Biological characteristics. To avoid contamination or change in the properties of samples during transportation to the laboratory.
3. Efficient treatment and disinfection of water known to be contaminated should be carried out before it is finally discharged into the river.
4. Modern equipment for water analysis should be acquired by the department to ensure that the student gets direct access to them.

APPENDICES

APPENDIX A

A typical example of the preparation of the calibration curve for Mg is given in this section. The calibration curve is shown in Figure A.1 from which actual concentration of Mg can be obtained from the absorbance measured.

Table A.1: Standard for Magnesium

Concentration (mg/l)	Absorbance
5.0	0.146
25.0	0.733
50.0	1.146

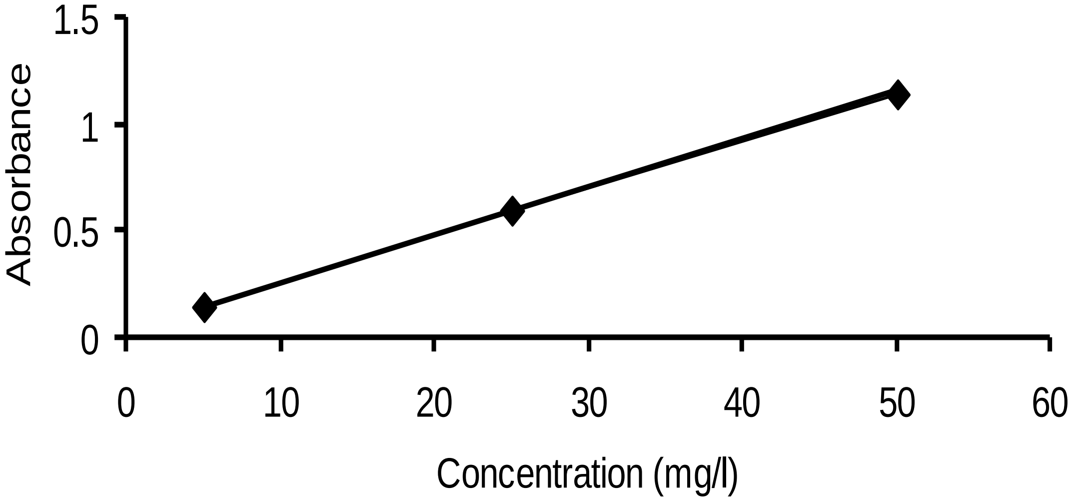

Figure. A.1: Calibration Curve for Mg

APPENDIX B

B.1 Physical Characteristics

Table B.1: Temperature (^0C) at Various Sampling Points

	Sampling points				
Sampling Days	**BWW**	**JWW**	**SIA**	**SHD**	**GER**
14 Feb	19.0	19.1	20.0	22.0	20.0
28 Feb	19.0	20.0	21.0	21.0	19.0
14 Mar	22.0	22.0	22.0	23.0	23.0
28 Mar	25.0	25.0	25.0	26.0	26.0
11 Apl	25.0	25.0	25.0	26.0	26.0
25 Apl	24.0	24.0	25.0	25.0	25.0
Mean (Dry Season)	22.3	22.5	23.0	23.8	23.2
9 May	27.0	26.0	26.0	27.0	27.0
23 May	26.0	26.0	26.0	28.0	28.0
6 Jun	27.0	27.0	28.0	27.0	28.0
20 Jun	30.0	29.0	29.0	30.0	30.0
4 Jul	29.0	28.0	29.0	29.0	29.0
18 Jul	29.0	29.0	28.0	28.0	29.0
Mean (Rainy Season)	28.0	27.5	27.7	28.2	28.5

Table B.2: Diurnal Variation in Temperature on 15th March, 2007.

Time	Temperature ^0C	
	SIA	SHD
8.00am	23.0	24.0
10.00am	24.0	24.0
12.00pm	25.0	25.0
2.00pm	26.5	27.0
4.00pm	26.5	27.0
6.00pm	26.0	26.0

Table B.3: Diurnal Variation in Temperature on 6th June, 2007.

Time	Temperature ^0C	
	SIA	SHD
8.00am	28.0	28.0
10.00am	28.0	29.0
12.00pm	29.0	29.0
2.00pm	30.0	30.0
4.00pm	30.0	30.0
6.00pm	29.0	29.0

Table B.4: Electrical Conductivity (µs/cm) at Various Sampling Points

	Sampling Points				
Sampling Days	**BWW**	**JWW**	**SIA**	**SHD**	**GER**
14 Feb	42.5	44.5	45.0	41.8	90.0
28 Feb	47.5	46.4	52.2	46.4	99.4
14 Mar	49.3	47.5	44.3	42.8	117.7
28 Mar	47.2	43.6	44.6	45.4	117.7
11 Apl	51.1	47.9	47.9	47.5	122.8
25 Apl	50.0	49.3	48.2	49.0	124.2
Mean (Dry Season)	47.9	46.5	47.0	45.5	112.0
9 May	54.7	47.9	47.5	48.2	115.9
23 May	65.9	55.4	54.4	55.1	78.1
6 Jun	49.3	42.1	41.8	42.1	50.0
20 Jun	45.7	43.6	43.6	51.1	60.1
4 Jul	38.5	38.2	40.0	39.6	54.0
18 Jul	40.7	36.4	35.3	37.4	41.8
Mean (Rainy Season)	49.1	43.9	43.8	45.6	66.7

Table B.5: Velocity (cm/s) of River at Various Sampling Points

	Sampling Points				
Sampling Days	**BWW**	**JWW**	**SIA**	**SHD**	**GER**
14 Feb	5.3	1.5	39.0	5.5	2.3
28 Feb	5.1	35.2	36.0	5.1	2.1
14 Mar	8.2	1.0	38.1	6.3	3.2
28 Mar	8.8	1.2	40.0	6.5	2.8
11 Apl	9.1	11.8	40.0	6.7	2.4
25 Apl	5.3	40.0	66.7	11.8	6.9
Mean (Dry Season)	7.0	15.1	43.3	7.0	3.3
9 May	12.1	36.4	40.0	7.1	7.0
23 May	13.4	42.0	41.9	11.4	8.9
6 Jun	15.4	49.9	34.2	19.6	13.2
20 Jun	15.2	42.4	33.5	11.4	6.3
4 Jul	18.9	52.4	40.4	12.0	8.6
18 Jul	16.7	51.9	35.5	25.7	11.5
Mean (Rainy Season)	15.3	45.8	37.6	14.5	9.3

Table B.6: Total Dissolved Solids (mg/l) at Various Sampling Points

	Sampling Points				
Sampling Days	**BWW**	**JWW**	**SIA**	**SHD**	**GER**
14 Feb	500.0	520.0	500.0	420.0	900.0
28 Feb	560.0	520.0	600.0	520.0	960.0
14 Mar	580.0	560.0	520.0	500.0	980.0
28 Mar	560.0	500.0	520.0	500.0	960.0
11 Apl	620.0	560.0	560.0	540.0	980.0
25 Apl	600.0	580.0	650.0	580.0	980.0
Mean (Dry Season)	570.0	540.0	558.3	510.0	960.0
9 May	640.0	560.0	560.0	560.0	960.0
23 May	720.0	640.0	640.0	640.0	780.0
6 Jun	580.0	520.0	420.0	500.0	600.0
20 Jun	520.0	520.0	520.0	620.0	680.0
4 Jul	380.0	380.0	420.0	400.0	640.0
18 Jul	420.0	380.0	360.0	380.0	420.0
Mean (Rainy Season)	543.3	500.0	486.7	516.7	680.0

Table B.7: Total Solids (mg/l) at Various Sampling Points

	Sampling Points				
Sampling Days	**BWW**	**JWW**	**SIA**	**SHD**	**GER**
14 Feb	1550.0	1600.0	1680.0	1400.0	2400.0
28 Feb	1580.0	1500.0	1800.0	1580.0	2700.0
14 Mar	1820.0	1540.0	1700.0	1500.0	2700.0
28 Mar	1620.0	1520.0	1540.0	1400.0	2720.0
11 Apl	1900.0	1560.0	1580.0	1600.0	2800.0
25 Apl	1800.0	1600.0	1540.0	1520.0	2760.0
Mean (Dry Season)	1711.7	1553.3	1640.0	1500.0	2680.0
9 May	1940.0	1660.0	1680.0	1670.0	2800.0
23 May	2200.0	1900.0	1930.0	1960.0	2400.0
6 Jun	1800.0	1620.0	1500.0	1640.0	1860.0
20 Jun	1600.0	1630.0	1700.0	1900.0	2080.0
4 Jul	1320.0	1300.0	1520.0	1500.0	2040.0
18 Jul	1520.0	1320.0	1300.0	1340.0	1444.0
Mean (Rainy Season)	1730.0	1571.7	1605.0	1668.3	2104.0

B. 2 Inorganic Chemical Characteristics

Table B.8: pH at Various Sampling Points

	Sampling Points				
Sampling Days	**BWW**	**JWW**	**SIA**	**SHD**	**GER**
14 Feb	7.4	7.5	7.4	7.4	7.8
28 Feb	7.5	7.6	7.5	7.5	7.7
14 Mar	7.8	7.7	7.8	7.7	7.8
28 Mar	7.8	7.7	7.8	7.9	7.8
11 Apl	7.4	7.7	7.7	7.9	8.2
25 Apl	7.9	7.9	8.0	8.1	8.2
Mean (Dry Season)	7.6	7.7	7.7	7.8	7.9
9 May	7.7	7.8	7.8	7.8	7.9
23 May	7.6	7.8	7.9	7.9	7.7
6 Jun	7.7	7.7	7.9	7.8	7.8
20 Jun	7.8	7.7	7.8	7.8	7.9
4 Jul	7.7	7.8	7.8	7.8	7.9
18 Jul	7.7	7.7	7.8	7.8	7.8
Mean (Rainy Season)	7.7	7.8	7.8	7.8	7.8

Table B.9: Concentration of Calcium (mg/l) at Various Sampling Points

	Sampling Points				
Sampling Days	**BWW**	**JWW**	**SIA**	**SHD**	**GER**
14 Feb	4.6	4.4	4.0	9.6	4.9
28 Feb	4.5	3.8	4.6	4.0	6.0
14 Mar	40.0	34.0	35.0	35.5	49.0
28 Mar	40.0	5.0	5.0	35.0	50.0
11 Apl	3.5	3.3	3.1	5.3	7.0
25 Apl	3.5	3.3	2.3	3.2	5.4
Mean (Dry Season)	16.0	9.0	9.0	15.4	20.4
9 May	10.3	9.5	19.6	9.5	12.5
23 May	12.3	10.0	9.5	10.4	11.2
6 Jun	3.5	2.8	2.5	4.3	4.7
20 Jun	2.4	3.4	2.7	3.8	4.5
4 Jul	2.7	2.4	2.5	2.7	4.4
18 Jul	2.7	2.4	2.5	2.5	4.0
Mean (Rainy Season)	5.7	5.1	6.6	5.5	6.9

Table B.10: Concentration of Magnesium (mg/l) at Various Sampling Points

	Sampling Points				
Sampling Days	**BWW**	**JWW**	**SIA**	**SHD**	**GER**
14 Feb	5.8	5.4	5.2	13.4	5.0
28 Feb	15.0	12.5	16.4	16.2	25
14 Mar	9.0	9.9	10	10.5	17.4
28 Mar	12.0	6.0	6.0	11.8	19.8
11 Apl	9.9	9.2	6.4	10.5	27.2
25 Apl	11.4	10.8	10.5	10.5	29.4
Mean (Dry Season)	10.5	9.0	9.1	12.2	20.6
9 May	4.0	3.6	3.6	3.8	10.3
23 May	4.5	3.8	3.6	3.8	6.5
6 Jun	3.0	2.9	2.8	2.6	3.5
20 Jun	2.0	2.6	2.5	2.8	3.6
4 Jul	2.3	2.2	2.0	1.9	3.6
18 Jul	2.4	2.0	2.0	2.4	2.4
Mean (Rainy Season)	3.0	2.9	2.8	2.9	5.0

Table B.11: Concentration of Iron (mg/l) at Various Sampling Points

	Sampling Points				
Sampling Days	**BWW**	**JWW**	**SIA**	**SHD**	**GER**
14 Feb	0.16	0.24	0.20	0.16	0.27
28 Feb	0.30	0.30	0.26	0.30	0.22
14 Mar	0.14	0.20	0.20	0.16	0.22
28 Mar	ND	ND	ND	ND	ND
11 Apl	0.26	0.29	0.26	0.20	0.26
25 Apl	0.26	0.24	0.20	0.24	0.24
Mean (Dry Season)	0.20	0.30	0.20	0.20	0.20
9 May	0.48	0.53	0.29	0.29	0.39
23 May	0.42	0.53	0.32	0.26	0.32
6 Jun	2.80	2.50	2.00	1.60	1.80
20 Jun	6.20	4.60	2.20	2.80	1.80
4 Jul	3.60	2.80	4.00	3.60	2.80
18 Jul	4.00	4.20	5.20	5.70	4.60
Mean (Rainy Season)	2.90	2.50	2.30	2.40	2.00

* ND (Not Detected)

Table B.12: Concentration of Chromium (mg/l) x 10^{-2} at Various Sampling Points

	Sampling Points				
Sampling Days	**BWW**	**JWW**	**SIA**	**SHD**	**GER**
14 Feb	1.7	3.0	1.9	3.2	3.5
28 Feb	1.5	1.8	2.0	3.0	3.3
14 Mar	1.3	1.6	1.6	2.0	3.0
28 Mar	1.5	1.6	1.5	2.0	2.8
11 Apl	1.0	1.6	1.4	1.5	1.6
25 Apl	1.2	1.2	1.2	1.0	1.5
Mean (Dry Season)	1.4	1.8	1.6	2.1	2.6
9 May	ND	ND	ND	ND	ND
23 May	ND	ND	ND	ND	ND
6 Jun	0.3	0.3	0.4	0.3	0.3
20 Jun	0.4	0.4	0.4	0.3	0.4
4 Jul	0.4	0.3	0.4	0.3	0.3
18 Jul	0.3	0.3	0.3	0.3	0.3
Mean (Rainy Season)	0.2	0.2	0.3	0.2	0.2

*ND (Not Detected)

Table B.13: Concentration of Lead (mg/l) at Various Sampling Points

	Sampling Points				
Sampling Days	**BWW**	**JWW**	**SIA**	**SHD**	**GER**
14 Feb	ND	ND	1.0	0.6	0.6
28 Feb	1.6	2.0	1.2	1.6	2.0
14 Mar	ND	ND	0.4	0.3	0.4
28 Mar	0.3	0.5	0.5	0.7	0.4
11 Apl	ND	ND	ND	ND	ND
25 Apl	ND	ND	ND	ND	ND
Mean (Dry Season)	0.3	0.4	0.5	0.5	0.6
9 May	0.2	0.2	0.2	0.3	0.2
23 May	0.4	0.3	0.2	0.5	0.3
6 Jun	0.2	0.3	0.2	0.2	0.1
20 Jun	0.2	0.3	0.2	0.2	0.1
4 Jul	0.1	0.2	0.2	0.2	0.1
18 Jul	0.1	0.2	0.1	0.1	0.1
Mean (Rainy Season)	0.2	0.3	0.2	0.3	0.2

*ND (Not Detected)

Table B.14: Concentration of Zinc (mg/l) at Various Sampling Points

	Sampling Points				
Sampling Days	**BWW**	**JWW**	**SIA**	**SHD**	**GER**
14 Feb	0.20	0.22	0.40	0.22	0.22
28 Feb	0.21	0.16	0.22	0.20	0.15
14 Mar	0.28	0.3	0.28	0.25	0.20
28 Mar	0.16	0.19	0.25	0.19	0.24
11 Apl	0.20	0.19	0.35	0.22	0.19
25 Apl	0.19	0.22	0.20	0.22	0.24
Mean (Dry Season)	0.20	0.20	0.30	0.20	0.20
9 May	0.42	0.30	0.22	0.20	0.23
23 May	0.40	0.20	0.15	0.30	0.20
6 Jun	1.20	1.30	0.75	0.75	0.60
20 Jun	0.60	0.60	0.50	0.45	0.75
4 Jul	0.60	0.50	0.45	0.75	0.60
18 Jul	0.60	0.45	0.45	0.35	0.45
Mean (Rainy Season)	0.60	0.60	0.40	0.50	0.50

Table B.15: Concentration of phosphate (mg/l) at Various Sampling Points

	Sampling Points				
Sampling Days	**BWW**	**JWW**	**SIA**	**SHD**	**GER**
14 Feb	4.40	5.80	3.80	5.50	2.00
28 Feb	4.45	5.78	3.40	5.10	1.85
14 Mar	15.00	27.50	22.00	18.30	24.50
28 Mar	8.40	10.80	14.00	16.40	16.10
11 Apl	1.80	7.50	7.00	8.80	16.60
25 Apl	9.50	11.50	12.20	9.50	7.70
Mean (Dry Season)	7.30	11.40	10.40	10.60	11.50
9 May	9.70	10.80	13.80	9.80	10.00
23 May	7.60	8.40	11.20	7.80	7.75
6 Jun	7.68	8.30	5.50	1.80	10.80
20 Jun	10.20	9.20	8.10	10.90	10.60
4 Jul	7.50	4.00	8.30	7.80	3.80
18 Jul	9.70	8.40	8.20	11.10	10.60
Mean (Rainy Season)	8.70	8.20	9.20	8.20	9.00

Table B.16: Concentration of Nitrate (mg/l) at Various Sampling Points

	Sampling Points				
Sampling Days	**BWW**	**JWW**	**SIA**	**SHD**	**GER**
14 Feb	5.90	6.30	3.50	4.20	5.30
28 Feb	5.88	6.30	3.45	4.10	4.98
14 Mar	4.30	5.20	3.70	2.50	3.80
28 Mar	4.30	5.20	3.65	2.50	3.85
11 Apl	3.90	5.25	3.70	2.20	3.65
25 Apl	3.20	2.90	9.00	1.90	0.70
Mean (Dry Season)	4.60	5.20	4.50	2.90	3.70
9 May	2.50	2.80	1.60	2.75	3.20
23 May	1.55	2.50	2.50	2.20	2.10
6 Jun	3.10	4.50	2.90	6.30	3.00
20 Jun	3.70	4.80	3.70	4.60	3.60
4 Jul	4.20	2.50	4.50	4.10	2.40
18 Jul	4.80	0.20	4.30	5.00	3.70
Mean (Rainy Season)	3.30	2.90	3.30	4.20	3.00

B.3 Organic Chemical Characteristics

Table B.17: Dissolved Oxygen (mg/l) at Various Sampling Points

	Sampling Points				
Sampling Days	**BWW**	**JWW**	**SIA**	**SHD**	**GER**
14 Feb	29.1	46.1	31.3	29.6	20.4
28 Feb	28.9	46.3	30.6	29.8	18.6
14 Mar	35.9	22.6	22.6	35.5	30.6
28 Mar	32.5	31.0	32.3	28.1	27.5
11 Apl	24.6	23.6	24.0	20.3	17.9
25 Apl	26.6	11.1	25.2	24.2	22.6
Mean (Dry Season)	29.6	30.1	27.7	28.0	23.0
9 May	28.3	22.3	22.6	23.0	19.9
23 May	25.6	24.3	30.0	22.6	20.1
6 Jun	25.6	23.4	29.1	22.5	20.1
20 Jun	20.6	34.7	33.9	30.0	24.2
4 Jul	20.2	20.9	18.6	26.3	12.1
18 Jul	21.8	36.9	34.7	33.0	27.1
Mean (Rainy Season)	23.7	27.1	28.2	26.2	20.6

Table B.18: BOD_5 (mg/l) at Various Sampling Points

	Sampling Points				
Sampling Days	**BWW**	**JWW**	**SIA**	**SHD**	**GER**
14 Feb	3.3	5.1	1.9	1.8	2.2
28 Feb	3.4	5.2	2.1	1.7	2.3
14 Mar	6.3	3.4	5.6	5.8	6.2
28 Mar	5.2	3.5	4.3	2.3	2.6
11 Apl	5.3	6.1	5.1	2.8	2.1
25 Apl	1.8	1.2	5.5	2.7	1.1
Mean (Dry Season)	4.2	4.1	4.1	2.9	2.8
9 May	3.4	1.4	1.8	3.0	2.2
23 May	2.9	3.0	4.1	3.6	1.9
6 Jun	2.0	1.9	1.6	1.2	2.9
20 Jun	3.1	3.6	4.0	3.9	2.5
4 Jul	4.8	1.6	5.6	5.9	3.2
18 Jul	4.3	4.6	5.2	4.2	3.7
Mean (Rainy Season)	3.4	2.7	3.7	3.6	2.7

Table B.19: COD (mg/l) at Various Sampling Points

	Sampling Points				
Sampling Days	**BWW**	**JWW**	**SIA**	**SHD**	**GER**
14 Feb	5.5	8.3	4.9	5.7	5.5
28 Feb	5.9	7.5	4.9	5.5	5.6
14 Mar	10.7	8.9	9.0	9.4	11.2
28 Mar	8.7	7.7	6.7	6.3	8.6
11 Apl	11.4	13.3	12.1	7.3	8.1
25 Apl	2.5	2.0	7.4	3.3	5.1
Mean (Dry Season)	7.5	8.0	7.5	6.3	7.4
9 May	4.6	3.3	3.5	4.0	5.5
23 May	3.7	4.0	4.6	4.1	6.6
6 Jun	2.7	2.6	1.8	1.5	3.9
20 Jun	4.0	4.5	5.1	4.1	6.6
4 Jul	5.4	3.0	6.9	8.0	8.4
18 Jul	5.2	6.3	7.3	5.6	8.8
Mean (Rainy Season)	4.3	4.0	4.9	4.6	6.6

B. 4 Biological Characteristics

Table B.20: Coliform organism (E-coli) (cfu/100ml) at Various Sampling Points

	Sampling Points				
Sampling Days	**BWW**	**JWW**	**SIA**	**SHD**	**GER**
14 Feb	159.0	390.0	380.0	360.0	350.0
28 Feb	117.0	182.0	350.0	105.0	360.0
14 Mar	187.0	154.0	147.0	277.0	205.0
28 Mar	278.0	301.0	201.0	198.0	286.0
11 Apl	173.0	156.0	160.0	145.0	135.0
25 Apl	168.0	166.0	235.0	202.0	230.0
Mean (Dry Season)	180.3	224.8	245.5	214.5	261.0
9 May	170.0	190.0	180.0	201.0	110.0
23 May	175.0	165.0	140.0	151.0	145.0
6 Jun	148.0	185.0	200.0	150.0	200.0
20 Jun	156.0	132.0	206.0	140.0	110.0
4 Jul	110.0	120.0	168.0	112.0	195.0
18 Jul	165.0	201.0	210.0	180.0	170.0
Mean (Rainy Season)	154.0	165.5	184.0	155.7	155.0

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