THE EFFECT OF NNPC REFINERY EFFLUENT ON THE BIOTA OF ROMI STREAM, KADUNA

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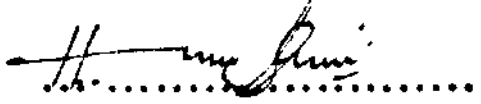
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DEDICATION

This work is affectionately dedicated to my family: Halimatu Ali Hassan (Wife) for her endurance in a special way; Maryam Ali Hassan (daughter) for being able to remember "Papa" despite my habitual absence from the family, even on her first birthday anniversary.

DECLARATION

This research has been my own work, and has not been presented in any form for any other qualification at any other university or institution. Information derived from other works has been duely acknowledged.



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1989

CERTIFICATION

This dessertation entitled "The Effect of NNPC Refinery Effluent on the Biota of Romi Stream, Kaduna" by HASSAN, Ali Sanusi meets the regulations governing the award of the degree of Master of Science of the Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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Praise be to Allah the most beneficient and the most merciful.

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ABSTRACT

The effect of Nigerian National Petroleum Corporation (NNPC) Kaduna refinery effluent on the physico-chemical characteristics and biota of Romi Stream, Kaduna was studied for 12 months, from November, 1987 to October, 1988. The biological parameters measured were the abundance and diversity of the surfacewater and benthic macroinvertebrates, zooplankton and phytoplankton. The physico-chemical characteristics of the stream measured were the water temperature, optical density, surfacewater and sediment pH; metals, concentration of oil in water, H_2S & RSH, Phenol, surfactant, NO_3-N, PO_4-P, Chlorophyll 'a', O_2, CO_2, BOD, COD, alkalinity, water hardness, conductivity, dissolved and suspended solid and Cl ions.

Three groups of surfacewater macroinvertebrates, 2 of benthic macroinvertebrates, 2 of zooplankton and 3 of phytoplankton, with 6, 4, 3 and 13 genera were recorded respectively.

Hydrogen sulphide and mercaptan, oil, phenol, PO_4-P, chlorophyll 'a', BOD, Cl, suspended solid, alkaline-earth metals, Fe; Ca in sediment, Cu, Mn, Ni; surfacewater macroinvertebrates, phytoplankton and zooplankton density exhibited significant variation between stations ($P < 0.05$).

Significant seasonal variation in concentrations of surfactant, CO_2, surfacewater Cr and benthic macroinvertebrates was recorded ($P < 0.05$). The COD, hardness, alkalinity, conductivity, O_2

saturation, sediment pH and Mg also varied from station to station ($P < 0.05$). Significant positive correlation was observed between surfacewater and sediment K, Ca, Pb, Cu, Mn, Cr, and Ni ($P < 0.05$), while the correlation between Mg, Na, Fe and Cd in both surfacewater and sediment was insignificant ($P > 0.05$).

The density of surfacewater macroinvertebrates was inversely proportional to the levels of oil, phenol, surfactant, water and hardness. pH was observed to have corresponding decrease in surfacewater macroinvertebrate density. Increasing amount of H_2S & RSH, oil, phenol and surfactant were observed to cause significant drop in zooplankton density.

Decrease in benthic macroinvertebrates with increasing concentration of H_2S & RSH, oil, phenol and sediment Pb was recorded, while the phytoplankton population was less susceptible to changing physico-chemical characteristics ($P < 0.05$).

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ABBREVIATIONS

CO_2	=	Carbondioxide
O_2	=	Oxygen
Cl	=	Chloride
BOD	=	Biochemical Oxygen Demand
COD	=	Chemical Oxygen Demand
NO_3-N	=	Nitrate-Nitrogen
PO_4-P	=	Phosphate-Phosphorus
H_2S	=	Hydrogen Sulphide
RSH	=	Mercaptan
K	=	Potassium.
Ca	=	Calcium
Mg	=	Magnesium
Na	=	Sodium
Pb	=	Lead
Fe	=	Iron
Cu	=	Copper
Zn	=	Zinc
Mn	=	Manganese
Cr	=	Cromium
Ni	=	Nickel
Cd	=	Cadmium
PPm	=	Parts per million
$\mu g. l^{-1}$	=	Microgram per litre
^{o}C	=	Degree centigrade

ANOVA	=	Analysis of variance
Sp.	=	Species
X	=	Mean
df	=	Degree of freedom
SS	=	Sum squared
Ms	=	Mean squared
F	=	f-ratio
S	=	Significante
NS	=	Not Significant

CHAPTER ONE

1.0.0 INTRODUCTION

Water has from time immemorial been one of the most important criteria for human settlements. The early man looked for a regular supply of freshwater perhaps more than any other factor. Thus human settlements were sited where water was available.

Ancient civilization has therefore revolved around water bodies. Earliest cities are thought to have originated on the alluvial plains of the Tigris and Euphates valleys in Mesopotamia (Iraq). Growth and civilization of Egyptian cities have been closely associated with River Nile. According to Whynne-Hammond (1979), Lincoln, a cathedral city (U.K.) grew most rapidly during the middle ages dating back to 11th century across river Whittom. Today Lincoln is both a tourist and an important engineering centre in the United Kingdom. Along the East coast of England and Scotland numerous trading and fishing settlements developed. Until recently, Grimsly was the world's greatest fishing port. Early account suggests that at one time the Thames estuary was an excellent Salman river too.

Similarly, the growth and development of some Nigerian towns such as Jebba, Lokoja and Makurdi are traced to their proximity to rivers Niger and Benue respectively. The siting of Kaduna town with its major industries near Kaduna river is another example of human preference to settle near water bodies in both his residential, commercial and industrial activities.

Closely associated with the contribution of water to the growth and development of human settlements and industries, is also the problem of waste-disposal into the water bodies. The most common method of disposing industrial and domestic wastes is by dumping into the water bodies, most often untreated. This practice renders

most of our inland waters grossly polluted and disrupts the balance of nature. Prominent among such wastes discharged into the water bodies is oil and effluents from oil refineries.

The most remarkable incidents involving oil pollution occurred in the marine environment due to the fact that over 60 per cent of world oil is transported by sea. A survey of incidents involving oil pollution in England and Wales between April 1968 to March 1969 reveals a total of 483 incidents, 3 of which involved pollution from boats on inland water (Whitton, 1975). The wreckage of an oil vessel (Torrey Canyon) in 1967, involving the loss of 120,000 tonnes of oil to sea; that of 'Amaco Cadize' in 1978 spilling 220,000 tonnes of oil into Brittany Coast and the Buzzards Bay disaster, Massachussets (U.S.A) in 1969 with the loss of 600-700 tonnes have been reported by Laws (1981).

The incidents of oil pollution in Nigeria tend to be confined to the exploration and production phases, and in particular, to spillages and leakages of crude oil, with occasional incidence in connection with effluent disposal. Major examples involve the 1982 system 20, Warri-Kaduna crude oil pipeline leakage at Owa-Abudu, Bendel State, with the loss of 18,818 barrels (2,992 m^3) of oil to farmland with gross pollution of Umeku Stream (Orubima, 1983). On 29th October, 1983, the Daily Times reported that many rivers and lagoons in oil exploration areas of Nigeria were so grossly polluted with oil to the extent that fish and other forms of aquatic life no longer inhabit them.

Other reports on oil spillage in Nigeria indicate that 784 oil spill incidents occurred within the period 1976 to 1980, mostly in Bendel, Cross River, Rivers and Ondo States (Nwanko and Ifeadi, 1983) In Bendel State, the settlements of Uzere and Oyakama were polluted with oil in 1980 as a result of flow and pipeline leakages, with considerable damage to fish ponds, lakes, creeks, rivers and the sea (Adeniyi et al.,1983). In 1985, extensive oil spillage at Kaduna refinery extending to Kaduna river with considerable fish kill has been reported (Sunday New Nigeria, 3rd November, 1985). Similar spill was reported in August 1988, involving wide destruction of farmland in Chukudu Romi and Rido villages including Romi stream (The Reporter, 26, August, 1988).

1.0.1 KADUNA TOWN

Kaduna town is located at an elevation of 634 meters above sea level. It is positioned between Latitude 10° and 30°N; and longitude 7° and 21°E (Fullard, 1980). It has maximum temperature of 35.2°C and average rainfall of 36.7m, falling mostly during the months of April to October.

Dividing Kaduna town (now capital of Kaduna State) is river Kaduna, from which the town and state derived their names. Kaduna has presently attained the status of being administrative, commercial and highly industrial centre, in which are located the 3rd Nigerian National Petroleum Corporation (NNPC) refinery, Kaduna Federal Super-phosphate industry, various textile mills, peugeot Automobile Assembly Plant of Nigeria (PAN), Dagazau Carpet industry, various

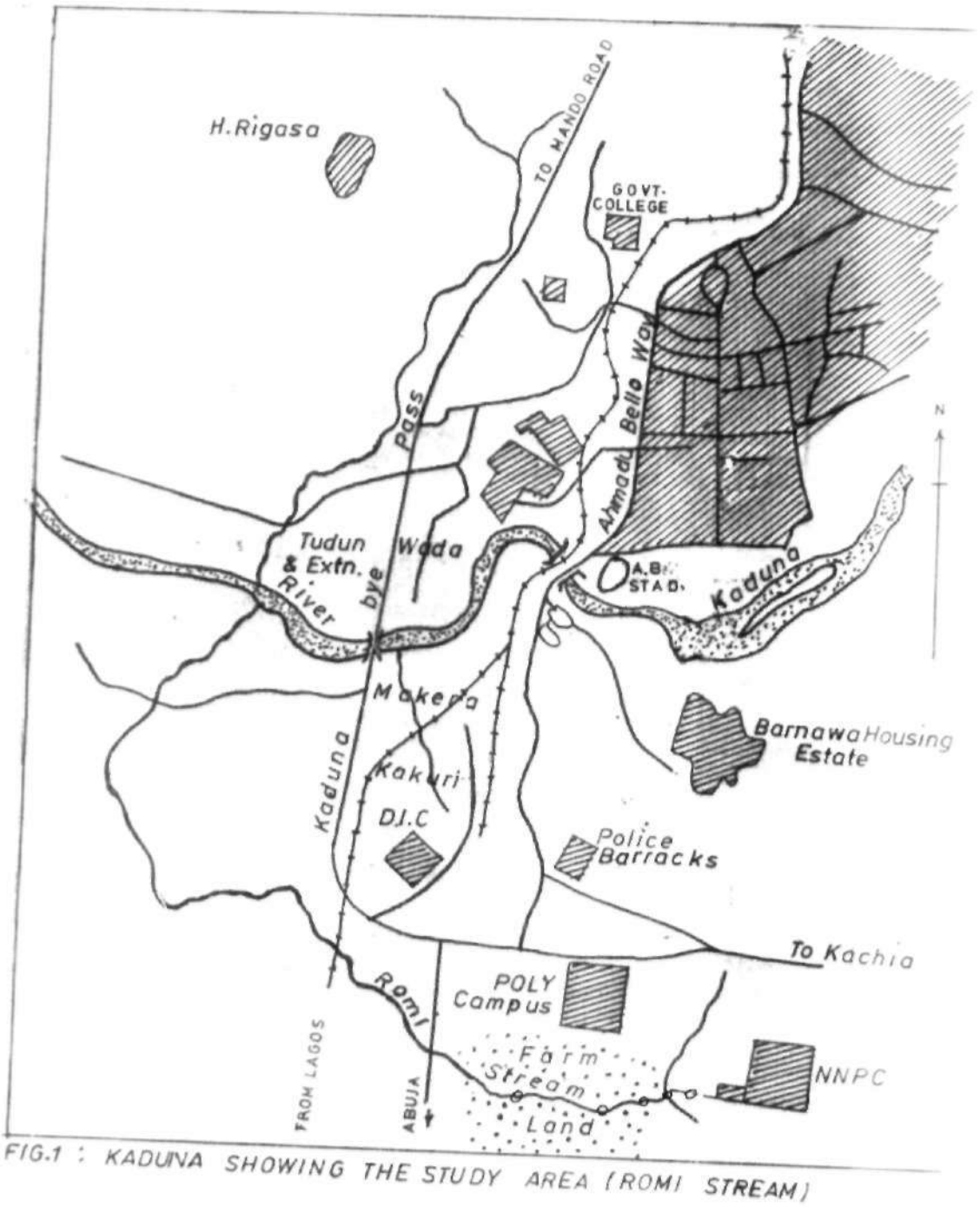


FIG.1 : KADUNA SHOWING THE STUDY AREA (ROMI STREAM)

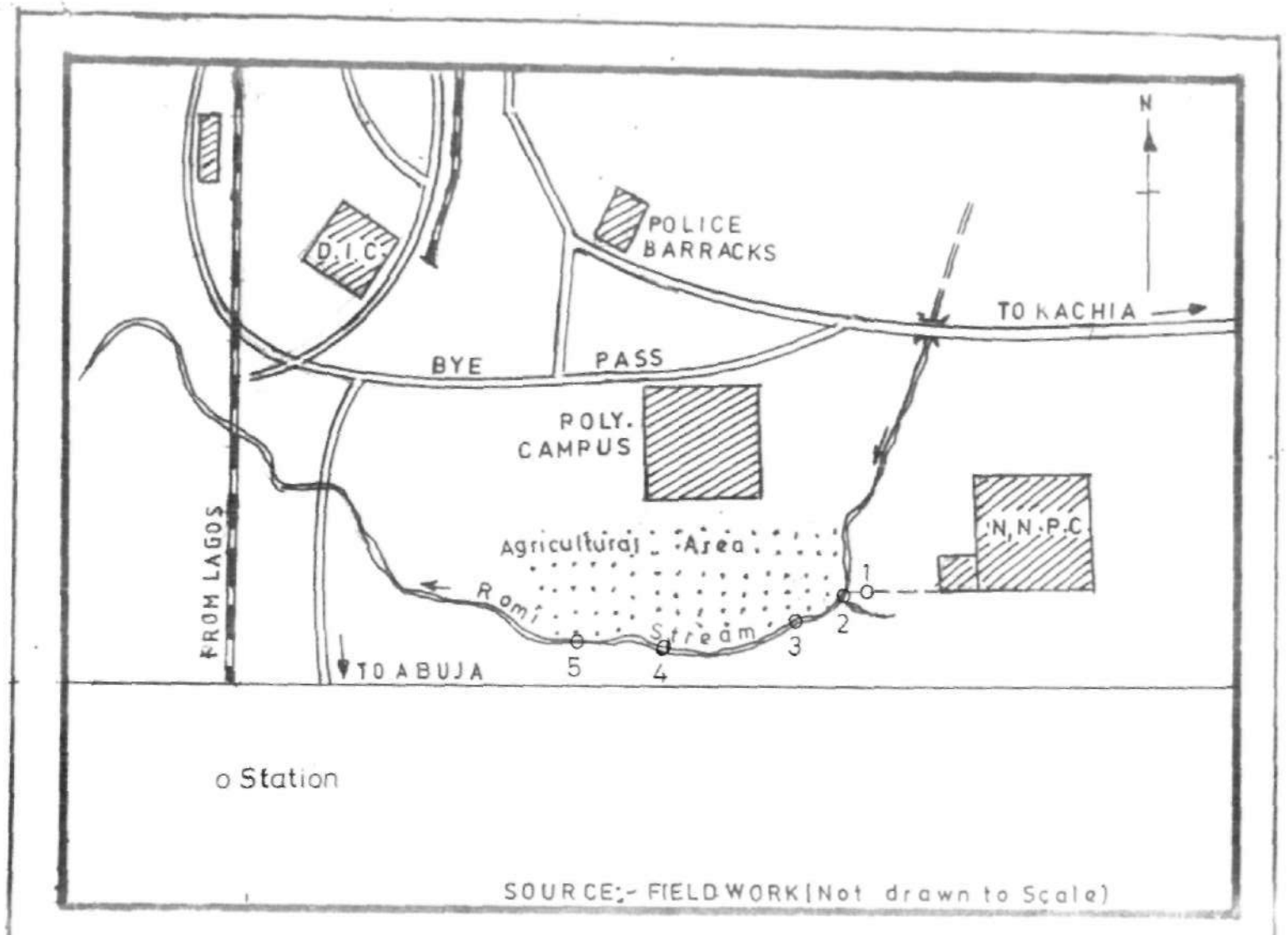


FIG. 2: KADUNA SOUTH (PART OF) SHOWING STUDY AREA – ROMI STREAM

breweries, modern abattoirs, and a population of over 50,000 people. As a result of the numerous industries, increasing population and the traditional waste disposal practice of both industrial and residential sources via effluents, Kaduna river becomes a potential recipient of pollutants of both industrial and residential origin.

1.0.3 KADUNA RIVER

Kaduna river is a tributary of river Niger. It divides Kaduna town into largely residential section on the Northern bank and mostly industrial area on the southern bank. It is the major source of water for irrigation, drinking, and highly used by the industries for processing and cooling, among other uses. Despite the various beneficial use the water is put to, the river is frequently used as a dump for a variety of wastes, the most notable being industrial and domestic wastes. The major contributors to such wastes dumping include the Kaduna abbatoir drain, the effluents from Tudun-Wada, Tudun-Nufawa residential areas and Kaduna Textile Limited. The contribution of tributaries such as Rafin-Bazamfare with its year-round high turbidity and oil from mechanical workshops and servicing stations located at Tudun-Wada, Tudun-Nufawa, and Doka residential areas; as well as the Rigasa tributary which enters into Kaduna river from Rigasa residential area, 44 military hospital, Karmin-mashi and new Panteka market (Hassan, 1983). Romi stream is another tributary of Kaduna river which carries along wastes from NNPC Kaduna refinery and Dagazau carpet industry.

1.0.4 ROMI STREAM

Romi stream is a tributary of Kaduna river, in the Southern part of Kaduna. It is characterized, for most parts of the year by high concentration of salt, low current velocity and low water level, particularly during the later part of the dry season (Lolomari, 1983). It is a major source of drinking water for the inhabitants of Romi, Rido-chuduku and Rido-hausa settlements. In addition, these settlements depend on the stream for small-scale fishing, dry season irrigation and as a source of drinking water for their animals.

Besides the possible danger of enriching the stream with excessive nutrients from agricultural activities that take place along its banks, Romi stream receives the effluent from Nigerian National Petroleum Corporations Refinery Kaduna.

Since the commissioning of the Refinery in 1980 there have been notable changes in the physical and chemical qualities of the stream, which has been suspected to cause a corresponding decline in fisheries and agricultural potentials of the area. In 1986 the inhabitants called the attention of the refinery to the rapid deterioration of the physico-chemical quality of the stream in particular, and to a greater extent the notable destruction of the surrounding habitat by effluent from the refinery.

The waste-water treatment plant of the refinery serves to remove some toxic and obnoxious components of the refinery wastes discharge via effluent before discharging it into Romi stream; thus conserving the environment. Inspite of such treatment, small quantities of contaminants such as oil, phenol, hydrogen sulfide,

surfactant, various metals, dissolved and suspended solids, and many others are still contained in the effluent discharge into the stream and pose a threat to both the aquatic fauna and flora inhabiting the stream. Lolomari (1983) indicated that living organisms, including humans, natural resources, the atmosphere and recreational facilities are all subject to the harmful effects of petrochemical pollution.

1.0.5 JUSTIFICATION

Although there has been no adequate environmental impact assessment of the area, all fingers tend to point at the refinery (NNPC Kaduna refinery) as being responsible for the degradation of the quality of the surroundings through its operations. It is therefore important to pay attention to the assessment of the environmental quality of the stream in particular, considering its role as the recipient of effluent discharge from the refinery.

The area surrounding the refinery has been reported to be threatened by oil spillage from cracked oil pipeline of the refinery for a period of about 10 years (The Reporter, August 26, 1988). The situation becomes increasingly devastating during the last 4 years to the extent that 2 boreholes were sunk in October 1987 to serve the villages as alternative source of drinking water. At Romi, maize and millet farms were reported to have been covered with thick black soot, and a thin layer of brown oil forms slick on the stream water, which has been reported to become aflamed with loud explosions when ignited (Ibid.).

The stream is thus reported to be subjected to rapid degradation in both quality and its potential in fisheries, agriculture and domestic use.

The term pollution has been defined as the introduction of substances to environment which change the natural composition of such environment by accumulation beyond physiological level. Also as the unfavourable alteration of surroundings either wholly or largely as a result of man's action in terms of radiation levels, chemical activities or change in the physical constituent of an area (Gyuse, 1982). In view of this, it therefore becomes necessary to maintain a biologically approved balance between industrialization, urbanization and our natural surroundings, of which one of the most critical to life sustainance is the aquatic environment, otherwise, the balance of existence would on the long run become distorted.

1.0.6 RESEARCH OBJECTIVES:

This research was designed to fulfil the following:

1. To assess the effect of the NNPC Kaduna refinery effluent discharge on the physico-chemical properties of the water and sediment of Romi-stream, Kaduna.
2. To assess the variation and mode of distribution of the pollutant from point-source downstream.
3. To investigate how the prevailing physico-chemical properties affect the relative abundance and distribution of the biota of the stream.

4. To evaluate the effectiveness of the waste-water treatment plant of the refinery.

1.0.7 WORKING HYPOTHESES:

As guide in the formulation of a working design, the following Null hypotheses were proposed:

i. The physico-chemical properties of the stream is not influenced by the effluent discharge from the refinery.

ii. The distribution of pollutants from point-source downstream is homogenous.

iii. The abundance and distribution of the biota are not affected by the physico-chemical properties of the water.

iv. The nature of substratum and its physico-chemical characteristics is independent of the physico-chemical properties of the surface water.

v. The effluent discharge falls within the allowable limit set by the International Standards for Effluent discharge.

CHAPTER TWO

2.0. LITERATURE REVIEW

2. 1 CHEMICAL COMPONENTS OF REFINERY EFFLUENT

Review on the chemical components of Canadian petroleum refinery effluents has been made by Cote (1976). Detectable substances include oil and grease, phenolics, sulfides, ammonia, suspended solids, various nitrogenous compounds, biochemical oxygen demand (BOD), chemical oxygen demand (COD) chlorides and often associated with high temperature. Various metalic constituents such as Cr , Cu , Pb , Zn , Fe , Ni , Mn , and Cd have been reported as usual components of petroleum refinery effluents by several workers, particularly Mckee and Wolf (1963), Huber (1976), Lolomari (1983).

The interactions between these contaminants further result in the occurrence of high concentrations of other substances such as carbondioxide, hydrogen sulfide and a number of abnoxious substances.

2. 2 Oil: The presence of oil in refinery effluents is traceable to the refining processes and occasional spills from either pipeline leakage or during off-loading and on-loading of crude and refined products. Six major spills involving over 400 litres of oil were reported at refinery sites in Canada in 1974 by the Environmental Protection Service (Cote, 1976). Appreciable amount of oil is usually introduced to refinery effluent from the process and cooling water as well as ballast and storm water (Ibid.). Oil concentration of 0.3ppm has been reported among the possible pollutants from Linear Alkyl-benzene (LAB) plant of the Kaduna refinery effluent (Lolomari, 1983).

2 .3 Phenols: Phenolic compounds are produced and made available to refinery effluents through thermal and catalytic cracking of crude oil in the distillation process (Cote, 1976). Field and laboratory studies conducted by Zoulalian et al. (1974) on the level of phenolics in Saint Lawrence river below an oil refinery effluent outfall indicated the presence of these substances beyond 3000 meters from the outfall downstream, despite their being biodegradable. A range of pollutants discharged from petroleum refinery effluents indicates phenolics and parafins to be the major components of the waste based hydrocarbon (Keith, 1974).

2 .4 Sulphides: Sulfides originate from the desalting distillation hydrotreatment (DDTH) and hydrocracking of crude oil of sulphur constituent (Cote, 1976). Effluent specification of 0.20mg.L^{-1} has been reported by Lolomari (1983) from the LAB-plant of the Kaduna refinery. In the study of toxicity of treated effluent from NNPC Kaduna refinery to Tilapia nilotica (L), a range of sulfide from 0.00-20.50ppm has been detected by Onwumere (1986). The conversion of sulphur to abnoxious H_2S in aquatic environment has been reported by Hynes (1960), Korting (1970), Smith and Oseida (1972).

2. 5 Ammonia, chlorides and surfactant: The presence of ammonia in refinery effluent has been reported by Cote (1976) to originate primarily from crude oil distillation, hydrocracking and hydro-treating processes.

Chlorides have been listed among the minor contaminants of refinery effluent. According to Glaze and Henderson (1975), Cote

(1976), chloride in refinery effluents may originate from chlorination of cooling water or from plant where chloride is used for disinfection. In addition to effluent concentration, workers including Gorham (1961), Gibbs (1970, 1972) attributed higher chloride enrichment to water bodies through atmospheric precipitation.

Surfactants, otherwise known as dispersants originate from refinery cooling water. It has been reported by Cote (1976) that the addition of surfactant to cooling water becomes necessary when its oil content elevates to 10-100ppm. This added dispersant (surfactant) finds its way to refinery effluent as a component of the waste water. Lolomari (1983) indicated that 1.0mg.L^{-1} Ammonia is expected to be present in Kaduna LAB-effluent.

2 .6 <u>Suspended solids, dissolved solids and conductivity</u>:

Suspended solids in refinery effluents have been reported to originate from innert materials such as sand, in storm runoff water, from salts in crude oil, from metallic matter from blowdown boilers, corrosion products, bioxidation processes and related sources (PACE, 1974). Soluble substances in refinery effluent mainly of metallic origin, as well as few other non-metallic substances such as chlorides, phosphates, nitrates, and organic salts often dissociate to cause higher ionic enrichment resulting in increased electrical conductivity of refinery wastes and the receiving water body. According to Golterman (1975), conductivity of water body has been found to be proportional to the concentration of its dissolved elements.

.7 Biochemical oxygen demand and Chemical oxygen demand:

Oxygen depleting stress imposed by effluent on receiving water body is expressed in terms of either chemical, biochemical oxygen demand or both. In refinery wastes water, the pollutants exerting oxygen demand have been found to be organics, ammonium salts, sulfides and ferrous salts (CONCAWE,1979). C.O.D. loading from the discharges from Canadian refineries were found to range from 8 to 5810kg per day (PACE, 1974). Organic residues form a characteristic component of petrochemical effluents, usually in form of complex organic compounds in solution and suspension, which are readily oxidizable and so use up the dissolved oxygen in water (Hynes, 1960). Meynell (1973) in hydrobiological survey of Rio Ojaile river (Spain) reported that pollution by a refinery effluent had reduced the dissolved oxygen level to $1mg.L^{-1}$ by forming surface to sliks prevent water-air interphase reoxygenation and addition of oxygen demand upon the water body.

.8 Carbondioxide, Alkalinity and Hardness: High level of calcium carbonate content of about $500mg.L^{-1}$ has been reported to be associated with a desired effluent quality of Kaduna refinery (Lolomari, 1983). Alkalinity within the range of 0.00-222.01ppm has been detected in pre-discharged effluent of the refinery by Onwumere (1987). Sprague et al. (1978) reported a range of 0.50-96.50ppm in some Canadian refinery effluents. Alkalinity, as defined by Lind (1979) represents the buffering capacity of water. Close relationship between alkalinity of water hardness, pH and carbondioxide contents of freshwater has been established (Ibid). High Co_2 may result from biodegradation of organics, which in turn increases water acidity (decreases pH). While increase in alkalinity

usually shifts the pH to alkaline side of neutrality. In studying the effects of oil and oil dispersant on an Enclosed Marine Ecosystem, Linden et al. (1987) associated high Co_2 production to increased respiration by invertebrates, phytoplankton photosynthesis and anaerobic bacteria with a relative decrease in hydrogen ion concentration as a net effect, with the major buffer being the carbonate content of the medium.

2.9 Nitrate-nitrogen and Phosphate-phosphorus: The presence of nitrates, sulfides and sulPhites have been reported in refinery effluents by Cote (1979) and Lolomari (1983) in Canadian refineries and Kaduna refinery respectively. However, high enrichment of inland waters studied, particularly by Kemdirin (1987) on some reservoirs in Plateau State (Nigeria), and Beardly (1988) on Chesapeake Bay Water (USA) indicated nutrients enrichment especially phosphates and nitrates to be attributable to surface runoff from agricultural land, sewage-plant outflow and autochthonous sources.

2.10 Metals: The presence of heavy metals in refinery effluents has been reported by several workers: Heavy metals which include Pb , Cd , Cr , Fe , Cu , Mn , Ni , Hg , and Zn have been detected in treated effluents from the biotreaters of seven refineries in Canada (Huber, 1976). The effluent of NNPC Kaduna Lab-plant has been reported to contain a normal quality range of eleven heavy metals from $0.001 mg.L^{-1}$ to $5.0 mg.L^{-1}$ (Lolomari, 1983).

While alkaline-earth Metals are usually natural exchangeable ions in natural waters. High concentrations of sodium, calcium, potassium, and magnessium due to surface runoff, nature of

bedrock and increased precipitation has been reported in inland waters by Kemdirim (1987), and in pre-discharged effluent of Kaduna refinery by Onumere (1987).

2.1 1. DELETERIOUS EFFECTS OF REFINERY EFFLUENT ON THE PHYSICAL & CHEMICAL PARAMETERS

The effects of components of refinery effluents have been both physical and physiological. The oil content has in most instances been reported to create oil sliks on the water surface, thereby blocking air-water reoxygenation with a consequent oxygen depletion, increased biological and chemical oxygen demand (PACE, 1974; Concawe, 1979; Cote, 1979). Soot has been reported to cling to plants and substratum during heavy oil contamination from Kaduna refinery (Anon., 1988). In addition to the oxygen demand associated with the biodegradation of such effluents, other reducing agents such as sulfides, sulfites, nitrates, phenols and other hydrocarbons have been reported by Meynell (1973) and Cote (1979) to create additional deoxygenation. It has been reported by Davis (1975) that severe reduction of oxygen below 3ppm could result in asphyxiation of fishes and marked effect on many physiological and biochemical processes also results.

Taste and odour threshold for phenol in water has been reported to be as low as $0.1mg.L^{-1}$(USEPA, 1973) while concentrations of $40mg.L^{-1}$ has been reported to have caused threshold toxic effects on Scenedesmus (Mckee and Wolf, 1963).

Carcinogenic influence of refinery effluents have been reported by several authors: Hueper and Ruchhoft (1954) found that extracts from receiving waters polluted with oil refinery

effluent caused skin cancer in mice. Heueper (1963) emphasized that some petrochemical compounds are among the most potent carcinogens. Blumer (1972) stated that carcinogenic compounds of oil include 1,2-benzanthracene, alkylbenzonthracene and 3,4-benzopyrene. There have been many reports on growth and structural abnormalities in a wide range of organisms exposed to petrochemical pollutants, which include tumorous skin, alcerations, cancerous lesions, caudal fin defects and lip cancer in fish (Finkelstein, 1960; Young, 1964; Deys, 1969).

Report on the Buzzards Bay Oil spill in Massachusetts (USA) in 1969 indicated oil to have penetrated into benthic sediments with a resultant massive killing of marine organisms including worms, crabs, snails, clams, lobsters and other vertebrates (Blumer, et al. 1971) Abnormal development of crab and barnace larvae at oil concentrations of 10–100ppb and toxicity of oil at concentration of 1ppb to juvenile copepods has been reported by Nelson-Smith (1972). According to Baker (1973) the lethal threshold of phenol to Daphnia magna, in a refinery effluent is 28.9ppm. Reports on the persistence of oil fractions in water (Blumer et al., 1971; Krebs and Burns, 1977) indicates that oil pollution damage could persist for a longer duration due to the low degradation rate of the constituent hydrocarbons that are adsorbed into the sediment. Oil and oil fractions toxicity to phytoplankton has been reported by Nelson-Smith (1977). Accordingly, crude oil has generally been found to be toxic to aquatic plants on the concentration order of 50–200ppb, with a general depression of growth rate even at concentration of about 1ppb.

Reduction in phytoplankton productivity up to 5-ford and a decrease in zooplankton density in pools contaminated with oil and dispersants has been reported by Linden et al. (1987). Pollution of Bayou d'Inde estuary in Louisiana (USA) by petrochemical wastes from a large petrochemical complex has been found to cause drastic reduction in the general species density of Nekton assamblages and crustaceaus (Felley, 1988).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Sampling:

Monthly samples were taken from five different stations from effluent outfall down stream. These stations were marked Rs 1, Rs 2, Rs 3, Rs 4 and Rs 5 respectively. Station 1 was the effluent outfall; station 2 about 300 metres from the outfall; station 3, 500 metres from station 2, station 4 about 1000 metres from station 3, station 5, 700 metres from station 4. The period of sampling covered 12 months (November, 1987 to October, 1988). Dry season samples include November to April, while rainy season samples were those of the months of May to October.

3.2 Physico-Chemical Parameters:

3.2.1 **Water pH:** Water pH was determined on the spot, using portable pH meter. The electrode was immersed into the water for a few seconds to obtain stable readings on the pH scale.

3.2.2 **Sediment pH:** Sediment pH was determined using 1.1 sediment to water ratio (Black, 1966), 20g of air-dried sediment was passed into 50ml beaker through 2mm sieve, and 20ml distilled water was added. The content was stirred several times for 30 minutes with a glass rod. This was allowed to stand for about 30 minutes for the suspended clay to settle out from the suspension.

The pH meter was standardized using 4.0, 7.0 and 9.0 buffer solutions. The electrode was inserted into the partly settled suspension without touching the bottom of the beaker, to obtain the sediment pH without agitation.

3.2.3 Temperature: This was measured on the spot using mercury thermometer calibrated to measure from $-10^{o}C$ to $110^{o}C$. The thermometer was immersed into the water for 5 minutes, after which the water temperature was recorded. Air temperature was also obtained with the mercury thermometer.

3.2.4 Optical Density of the Water: This was determined by spectrophotometry, using Model S101 spectrophotometer. The percentage transmittance of each sample was obtained using 1cm

cuvette against distilled water (blank) by setting the wave-lengths at 750mμ

The optical density (OD) was thus calculated as:

$$OD = \text{Log } \frac{1}{\% \text{ Transmittance}} \text{ (Lee, 1978).}$$

3. . Suspended solid: One hundred ml of water sample was added to a clean, dry preweighed evaporating dish. Reweighing and evaporation followed. After evaporation to dryness, the dish and content were further dried to constant weight at 103°C for 2 hours, cooled in a desiccator for 90 minutes. The dish was reweighed and the amount of suspended solid (SS) thus calculated as total suspended solid on drying at 103°C (TSS, 103°C).

$$\text{TSS, } 103^{\circ}C = \frac{W_2 - W_1 \times 1000}{\text{ml. of sample}} \ (mgL^{-1})$$

(Lind, 1979)

where, W_2 = Final weight of dish and content

W_1 = Initial weight of dish and content.

3. . Dissolved Solid: 100ml of water sample was filtered through 0.45 um filter paper and placed into an already weighed evaporating dish. This was evaporated to dryness in an oven for 2 hours at 103°C. The dish was cooled briefly in air and afterwards placed into a desiccator to further cool down for 90 minutes.

Dissolved solid on drying at 103°C (DS, 103°C) was calculated as:

$$\frac{W_2 = W_1 \times 1000}{\text{ml. of sample}} \quad (mg.L^{-1})$$

(Lind, 1979)

where W_2 and W_1 represent the final and initial weight of dish respectively.

3. . Electrical Conductivity: This was determined on the spot using EBA/10 portable conductivity meter. The electrolytic conductivity cell (K = 0.1) of the meter was rinsed with water sample. This was followed by the introduction of water sample into the cell. The temperature of the meter was adjusted to read the corresponding water temperature.

Conductivity (in Micro mhos /cm^3) was recorded from the meter calibrations.

3. . Water Hardness: 25ml of water sample was diluted to 50ml using distilled water. This was followed by the addition of 1ml NH_4OH (buffer); 2 drops of Erichrome-black-T-indicator were added and titrated against 0.01M EDTA till a light blue colouration was observed.

Water Hardness (ppm $CaCO_3$)

$$= \frac{\text{Vol. of EDTA(Titrant)} \times 100}{\text{Vol. of sample (25ml)}}$$

(APHA, 1980)

3. DISSOLVED CARBONDIOXIDE

100ml of water sample was carefully drawn into Nesler's flask without agitation. This was followed by the addition of 10 drops of Phenolphthalein indicator and titrated against N/44 NaOH to end point (faint pink colouration).

Dissolved CO_2 (ppm) = Vol. of titrant x 10

(APHA, 1980).

Chloride Ion Concentration: 100ml of water sample was transferred into an Elemeyer flask. 2 drops of Potassium Chromate solution were added (indicator). Titration against 0.014N Silver Nitrate solution was followed till an end-point was obtained.

Chloride ion (ppm)

3. .1 Dissolved Oxygen (DO): Dissolved Oxygen was determined by the modified Winkler method (Lind, 1979). Water sample was collected from the marked sampling station in 250ml amber sampling bottles, filled up to neck. Twenty ml standard $MnSO_4$ solution and 2ml alkaline iodide-azide solutions were added on the spot and the content was shaken for 10 seconds. Two ml concentrated H_2SO_4 was added to the sample and the stopper replaced immediately, to avoid air being trapped. The bottle was again shaken for a few seconds till precipitate dissolved.

In the laboratory, 100ml of the content was transferred into 250ml cornical flask and titrated against standardized 0.2 0.0124N. Sodium Thiosulphate ($Na_2S_2O_3$). As the colour changed to pale yellow, 2ml starch indicator was added and further titrated to end-point (the appearance of colourless solution).

The dissolved oxygen (mg L^{-1}) was thus obtained using 1:1 0.0125N $Na_2S_2O_3$ to 1mgL^{-1} oxygen (Lind, 1979).

Percentage saturation of Oxygen (%):

$$= \frac{O_2 \text{ concentration}}{\text{solubility of } O_2^*} \times \frac{100}{1}$$

*expected solubility at the temperature and altitude.

(Golterman, 1970)

3. .2 Water Alkalinity: To 100ml of water sample 4 drops of phenolphthalein indicator were added, followed by titration against 0.02N. H_2SO_4 to end-point. Titre value (vol. of acid) multiplied by 10 represents phenolphthalein alkalinity (a).

For methyl orange alkalinity, the above procedure was repeated except that the phenolphthalein indicator was substituted with methyl orange (b).

Total alkalinity was thus calculated as:

$$(a) + (b)$$

(APHA, 1980)

3. 3 Biochemical Oxygen Demand (BOD): The initial DO of samples of the water determined by modified Winkler Method, was incubated in 250ml BOD bottles at $20^{\circ}C$ for 5 days.

BOD ($mg.L^{-1}$) was calculated as:

$$DO_1 - DO_5 \ (mg.L^{-1})$$

where DO_1 = Dissolved oxygen concentration prior to incubation.

DO_5 = Dissolved oxygen concentration after 5 days of incubation.

(APHA, 1980)

3. 4 CHEMICAL OXYGEN DEMAND (COD):

The water sample was filtered through glass fibre and 10ml transferred into 250ml conical flask. To this, 40ml distilled water was added, followed by the addition of 5ml 0.1N Potassium permanganate ($KMnO_4$) and covered with a beaker. The flask was placed in a water bath at $80^{\circ}C$ for 60 minutes, cooled for 10 minutes, and 5ml potassium iodide, (KI) 10ml 4N. H_2SO_4 were afterwards added. Titration against 0.1N $Na_2S_2O_3$ followed till pale yellow coloration appeared. One ml 1% starch indicator was added and the content was further titrated to end point the disappearance of colourless solution.

3 blanks (50ml distilled water, 5ml 0.1N $KmnO_4$, 5ml 1% KI and 5ml 4N. H_2SO_4) were prepared and titrated as the former. The average value was determined

and designated (a).

COD ($mg.L^{-1}$) was thus calculated as:

$$\frac{(a-b) \times N \times 1000}{\text{vol. of sample (10ml)}} \ mg.L^{-1}$$

(Golterman, 1970)

where a = vol. of $Na_2S_2O_3$ for blank

b = vol. of $Na_2S_2O_3$ for sample

N = Normality of titrant used.

3.2.15. Nitrate-Nitrogen Content: One hundred ml water sample was evaporated to dryness and cooled. Two ml Phenol-disulphonic acid was added to the residue, followed by the addition of 10ml distilled water and 5ml strong ammonia solution.

Setting the spectrophotometer at the wavelength 410mu, absorbance of the treated sample (above) was obtained from the scale against distilled water (blank). Nitrate-nitrogen concentration was obtained from a calibration curve in ppm (APHA, 1980).

3.2.16. Phosphate-Phosphorus: To 100ml of water sample, 1ml Ammonium molybdate and 5 drops of stanous chloride were added, and allowed to stand for 10 minutes. Asorbance was taken at 690mU, using spectrophotometer. Thus PO_4-P concentration was obtained from a calibration curve in ppm (APHA, 1980).

3.2.17. Determination of Chlorophyll 'a': Five hundred ml water sample was filtered through glass fibre filter paper with the aid of a vaccum pump. Near the end of filtration 1ml of 1% aqueous suspension of Magnessium carbonate was added, followed by the addition of 25ml 90% acetone. This was kept in darkness for 24 hours, after which grinding and gravity separation using centrifuge

were carried out.

Absorbance of light by the supernatant containing chlorophyll 'a' was determined on spectrophotometer using 1cm cuvette at 665mu and 750mu. Chlorophyll 'a' concentration (in $ug.L^{-1}$) was calculated using the equation of Talling and Driver (1963) and Weber (1973).

Thus: Ug. chl. 'a'. $L^{-1} = 11.9 (OD_{665} - OD_{750}) \times \frac{Y}{L} \times \frac{1000}{5}$

Where:

OD_{665} = absorbance at 665mU

OD_{750} = absorbance at 750mU

▼ = Volume of acetone used in the extraction

L = Lengt of cuvette (in cm)

S = Original volume of sample (in ml)

11.9 = Conversion factor for chlorophyll 'a' in acetone.

3.2.18 Determination of Metals: Two hundred ml. water sample was collec collected using polythene container previously washed with acid. This was followed by the digestion of 50ml in 10ml concentrated Nitric acid and concentrated Hydrochloric acid in ratio 1:3 in a water bath at $0^{o}C$ for 60 minutes. Alkaline Earth metals (Na, K, Ca, and Mg) were determined using a flame photometer while their concentrations (ppm) were obtained using standard curves.

Heavy metals were determined by using Atomic Absorption Spectrophotometer (AAS), Model 180-80. Corresponding concentrations were obtained from standard curves. Metal concentrations in sediment samples were determined by sediment digestion method (APHA, 1980). Sediment sample was

oven dried at 60°C for 24 hours. 1gm aliquot was weighed out. This was followed by the addition of a mixture of 10ml concentrated nitric and Hydrochloric acids (1:3 ratio). This was placed in water bath at 90°C for 60 minutes. Filtration followed using 45Um filter paper, after which the filtrate was diluted to 50ml using distilled water.

3.3.0. Determination of other Parameters: Concentration of oil in water, hydrogen sulphide and mercaptan surfactant and phenol content were determined by the water laboratory of the Nigerian National Petroleum Corporation (NNPC), Kaduna. Values were expressed in ppm, wt. %, ppm and ug.L^{-1} respectively.

3.4.0. COLLECTION, PRESERVATION, IDENTIFICATION AND NUTRITIONAL COUNT OF THE BIOTA:

Phytoplankton samples were collected using plankton net of 70 meshes/cm^2 and radius of 25cm. This was dragged just below the water surface for a distance of 3 meters. The collected volume of water was concentrated in 50ml collection bottle attached to the net. The content of the bottle was preserved in lugol solution.

Zooplankton samples were collected by the same method (above) over the same distance, and preserved in 4% formalin (WHO, 1963 and APHA, 1980).

Macroinvertebrates in surface water were collected using a sweep net with mesh size 50 meshes/cm^2 and a diameter of 20cm over 2 metres distance.

Benthic macroinvertebrates were collected using Ekman's grab of area 15cm by 20cm ($300cm^2$). Three collections were made per sampling station. Collected sample was washed through a "60" mesh size sieve, and the organisms recovered were preserved in 4% formalin.

Identification of recovered organisms was made with the aid of reference texts: (Edmondsen, 1957 (ed); Hutchinson, 1967 (ed); Pennack, 1978 (ed); Whitton, 1975 (ed); Hynes, 1963 (ed); Needham and Needham, 1975 (ed)). Organisms were identified to generic level.

3. Differential Count of Plankton: This involved the counting and recording of identified phytoplankton and zooplankton communities of each kind quantitatively (WHO, 1963). By means of mechanical stage, the entire content of 1ml concentrate sample placed on the counting cell was moved past low power objective of a microscope for enumeration.

The number of organisms per litre was thus calculated as:

$$N = Nx \times \left(\frac{a}{b} \times \frac{c}{d}\right) \times 1000$$

where,

N = Number of organisms per litre

Nx = Number of organisms recorded in the 1000 fields of standard sedgwick-Rafter cell (1mm deep) i.e. from 1ml concentrate sample.

a = Number of fields in the counting cell (1000)

b = Number of fields counted (1000)

c = ml. of concentrate sample (50ml)

d = ml. of original sample vol. ($\pi r^2 d$).

3. Differential Count of Benthic Macroinvertebrates:

For individual genus, the number of organisms found per square meter was calculated as:

$$\frac{Nx}{A} \times 1000 \text{ (organisms/m}^2\text{)}$$

where Nx = Number of organisms recovered in the 3 samples collected per station.

A = The area covered by the 3 sampling per station

$$\frac{(3 \times .300m^2)}{(3 \times 300cm^2)}$$

3. Differential Count of Macroinvertebrates in Surface Water:

For individual genus, the number per litre was thus calculated:

$$\frac{Ny}{V} \times 1000 \text{ (organisms/Litre)}.$$

where:

Ny = Number of organisms recovered in the sample

V = Volume of water covered by sampling ($\Pi r^2 d$).

3. Relative Abundance: The relative abundance of each genus was determined on individual basis by calculating its monthly percentage composition.

$$\frac{\text{Number of a genus in a month}}{\text{Total number of all the genera in a month}} \times \frac{100}{1}$$

(expressed as percentage).

3. STATISTICAL ANALYSIS:

Two-way analysis of variance was carried out to determine significant differences in all parameters with seasons, station by season, between stations and months, at 0.01 (1%) and 0.05 (5%) levels of significance using computer.

Rank correlation analysis was used to determine the relationship between parameters as they affect each other, using 0.05 (5%) confidence limit, two-tailed and $\pm$ .21574 critical value.

CHAPTER FOUR

4.0 R E S U L T S

Analysis of results based on 2-way analysis of variance, Rank correlation coefficient and graphic representation indicate wide fluctuations in physico-chemical and biological characteristics of Romi stream.

4.1 WATER TEMPERATURE:

Water temperature ranged from 19.70°C to 35°C (Fig. 16). Mean seasonal temperature (Table 1a) indicates a relatively lower temperature during the dry season (20.91°C) as compared to the rainy season mean of 26.17°C.

A two-way analysis of variance (Table 1b) shows highly significant difference in water temperature between seasons, station by seasons, and between months, with lower temperature during the dry season ($P < 0.01$). No significant difference was observed between stations ($P > 0.05$).

Correlation coefficient analysis (Table 1c) indicates increase in water temperature to have corresponding increase in the amount of suspended solid, dissolved solid, alkalinity, H_2S, Oil, Phenol, Zn, Mn, concentration of both surfacewater and sediment; Ni and Cd contents of sediment ($P < 0.05$). No significant correlation was observed between water temperature, and Cl^-, PO_4-P content, surfacewater Pb, Fe, Cu, Cr, Cd; sediment Pb, Fe and Mn ($P > 0.05$). The correlation between water temperature and the numerical abundance of zooplankton, phytoplankton and benthic macroinvertebrates was also found not to be significant ($P > 0.05$).

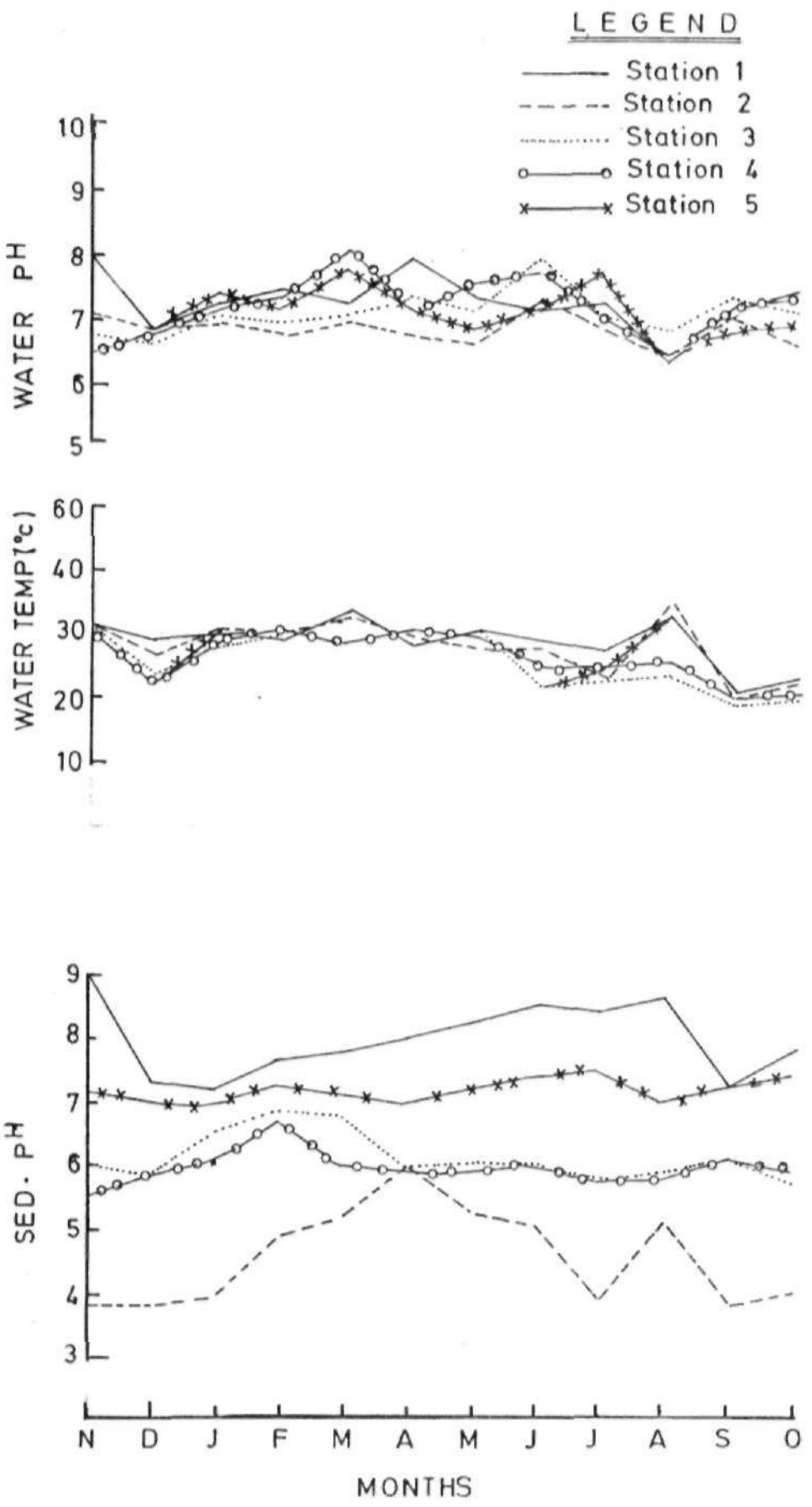


FIG 2 MONTHLY VARIATION IN SEDIMENT pH, WATER pH, AND WATER TEMPERATURE OF ROMI STREAM KADUNA

Table 1a

VARIATION IN WATER TEMPERATURE (^{o}C)

		STATIONS				
		1	2	3	4	5
General Station	$\bar{x}$	26.96	29.34	27.63	27.71	27.[illegible]
Dry Season	$\bar{x}$ 28.91					
Rainy Season	$\bar{x}$ 26.17					

S.E.D. $\bar{x}$ between months 0.751567

S.E.D. $\bar{x}$ between stations 1.24745

S.E.D. $\bar{x}$ between seasons 0.788954

S.E.D. $\bar{x}$ between season by station 1.76416

Station by Seasons $\bar{x}$:	1	2	3	4	5
Dry Season .	30.50	27.75	30.60	26.35	29.[illegible]
Rainy Season.	23.42	28.93	24.65	29.07	24.[illegible]

1b.

ANALYSIS OF VARIANCE FOR WATER TEMPERATURE

Source of variation:	df.	ss.	Ms.	F.	s.
Replication (6).	5	240.829	48.1658	5.159	xx
Stations (5).	4	14.9826	3.9826	0.401	NS
Seasons (2).	1	112.34	112.34	112.032	xx
Station by Seasons.	4	232.832	58.2093	6.234	xx
Months (12).	11	803.852	73.0774	21.562	xx
Residual.	34	150.8636	4.43.71		
Total.	59	1555.7042			

** Highly Significant ($P < 0.01$).
* Significant ($P < 0.05$).
NS. Not Significant ($P > 0.05$).

TABLE Ic

	1 (v1)	2 (v2)	3 (v3)	4 (v4)	5 (v5)	6 (v6)	7 (v7)	8 (v8)	9 (v9)	10 (v10)	11 (v11)	12 (v12)	13 (v13)	14 (v14)	15 (v15
1	1														
2	.433	1													
3	-.032	-.118	1												
4	.154	.048	.278	1											
5	-.09	.058	-.09	-.597	1										
6	.383	.289	.017	-.211	.038	1									
7	.237	.038	-.022	.037	.099	.121	1								
8	.207	.269	-.077	-.173	.054	.626	.182	1							
9	-.119	-.221	.003	-.008	.099	-.087	-.019	-.09	1						
10	.008	-.096	.023	.467	-.173	-.319	.133	-.361	.217	1					
11	.214	.246	.035	-.326	.317	.441	.203	.508	-.079	-.508	1				
12	-.186	-.014	.18	.025	.231	-.332	.075	-.214	.032	.206	-.287	1			
13	-.447	-.162	-.234	-.542	.65	-.091	-.248	-.124	.069	-.062	.016	.217	1		
14	.007	-.197	.008	.332	-.239	-.222	.288	-.266	.1	.619	-.207	-.028	-.241	1	
15	.118	-.091	-.05	-.555	.57	.315	.056	.166	.002	-.379	.474	-.025	.422	-.199	1
16	-.195	-.179	-.082	.074	.053	-.145	-.036	-.032	-.003	.034	.005	.151	.097	.069	.01
17	-.385	-.157	-.018	-.334	.596	-.186	.128	-.091	.217	.19	.049	.386	.533	.07	.21
18	-.023	.145	-.147	-.145	.385	.006	.212	-.261	.262	.275	.119	.072	.283	.192	.21
19	.274	.095	-.331	.048	-.083	-.023	-.083	-.141	-.053	.15	-.248	-.024	.057	.126	-.07
20	.25	.069	-.07	.09	-.112	-.005	-.083	.087	-.122	-.117	-.186	-.004	-.104	-.162	-.15
21	.248	-.015	-.142	.356	-.297	.023	-.071	-.006	-.075	.036	-.224	-.113	-.109	-.007	-.29
22	.2	.006	.259	.349	-.263	.019	-.061	-.051	-.036	.12	-.23	-.059	-.243	-.145	-.1
23	.11	.163	-.009	-.402	.508	.073	.121	-.161	.124	-.056	.223	.154	.364	-.118	.4
24	.091	.244	-.19	-.395	.525	.055	.098	-.017	.136	.068	.263	-.051	.362	.026	.41
25	-.001	-.025	.013	-.234	.563	-.113	.046	-.159	.252	.289	.003	.203	.348	.092	.37
26	.095	.171	-.04	-.302	.293	.076	-.051	.131	.023	.03	.331	-.164	.206	-.01	.2
27	-.448	-.361	.054	-.21	-.003	-.129	-.061	.118	-.116	-.285	-.004	1.41	-.018	-.073	-.0
28	-.287	-.14	-.105	-.543	.648	-.116	.069	-.173	.14	-.01	.171	.236	.62	.014	.16
29	-.245	-.415	-.098	-.315	.139	-.145	-.067	-.05	-.043	-.296	.018	-.02	.116	-.004	.0
30	.455	.396	.343	.03	.174	.3	.193	.332	-.139	-.215	.416	.053	-.231	-.201	.2

	1 (v1)	2 (v2)	3 (v3)	4 (v4)	5 (v5)	6 (v6)	7 (v7)	8 (v8)	9 (v9)	10 (v10)	11 (v11)	12 (v12)	13 (v13)	14 (v14)	15 (v15
31	.484	.294	.144	-.107	.177	.526	.258	.468	-.167	-.354	.644	-.288	-.218	-.165	.35
32	-.28	-.335	.139	-.282	.067	-.013	.023	.084	-.23	-.353	.149	.132	.023	-.015	.24
33	-.029	.093	-.097	-.388	.218	.14	-.115	.282	-.249	-.439	.407	-.143	.031	-.165	.40
34	-.515	-.466	-.065	-.158	.113	-.258	-.087	-.044	-.099	-.212	-.09	.136	.25	.069	.07
35	-.086	.063	.312	-.101	.384	-.11	.196	-.009	-.066	-.182	.089	.338	.146	-.141	.25
36	-.055	.12	.091	-.023	.203	.064	.168	.114	.086	-.212	.297	.084	-.064	.127	.22
37	-.11	-.072	-.065	-.395	.408	-.041	-.119	-.021	-.292	-.245	.203	.037	.447	-.179	.42
38	.014	-.077	.078	-.148	.551	-.03	.068	-.286	.273	.066	-.098	.329	.414	-.134	.39
39	-.213	-.267	.018	-.394	.124	-.12	-.079	-.093	-.139	-.252	-.208	.179	.19	-.298	.17
40	-.323	-.183	-.22	-.298	.034	-.24	-.196	-.414	.084	-.06	-.395	-.014	.326	-.194	.10
41	-.149	-.268	-.003	-.23	-.047	-.109	-.084	.006	-.2	-.352	-.049	-.02	-.068	-.29	.03
42	-.208	-.147	.061	-.177	-.052	-.247	-.132	-.394	-.035	-.068	-.284	.102	-.141	-.111	.08
43	.401	.218	-.11	-.128	-.162	.393	.154	.362	-.162	-.23	.452	-.384	-.361	.027	.1
44	-.057	-.217	-.259	-.287	-.186	-.09	-.138	-.194	-.078	-.198	-.253	-.098	.038	-.185	.04
45	.346	.051	.075	-.177	-.101	.211	.191	.112	-.179	-.245	.051	.078	-.261	-.104	.15
46	.325	.003	.019	-.284	.139	.238	.037	.001	-.024	-.242	.073	-.017	.073	-.208	.33
47	-.145	-.036	-.241	.045	-.17	-.09	-.07	-.138	-.005	.252	.157	-.31	.004	.421	.05
48	-.135	-.106	-.177	.196	-.029	-.251	-.126	-.33	.075	.229	-.146	.052	.092	.212	.04
49	-.011	-.03	-.025	.069	-.169	.091	.099	.036	-.06	.119	.059	-.157	-.115	.404	.13
50	-.014	-.114	.268	.565	-.639	-.196	-.163	-.241	.028	.47	-.434	.09	-.45	.468	-.48

TABLE 1c CONT'D

	16 (v16)	17 (v17)	18 (v18)	19 (v19)	20 (v20)	21 (v21)	22 (v22)	23 (v23)	24 (v24)	25 (v25)	26 (v26)	27 (v27)	28 (v28)	29 (v29)
16	1													
17	.182	1												
18	-.076	.513	1											
19	-.078	-.185	-.163	1										
20	-.142	-.388	-.555	.634	1									
21	-.066	-.396	-.417	.698	.756	1								
22	-.038	-.253	-.285	.223	.304	.329	1							
23	-.037	.463	.68	-.229	-.537	-.509	-.304	1						
24	.022	.392	.634	-.188	-.528	-.532	-.306	.767	1					
25	.04	.584	.586	-.232	-.468	-.528	-.178	.672	.758	1				
26	.006	.223	.353	-.264	-.514	-.461	-.314	.473	.643	.538	1			
27	.19	.127	-.398	-.157	.012	-.109	.059	-.38	-.421	-.257	-.388	1		
28	.132	.674	.439	-.205	-.515	-.485	-.349	.549	.546	.531	.427	.085	1	
29	-.019	.139	-.221	-.096	.035	-.084	.037	-.312	-.284	-.185	-.308	.713	.139	1
30	-.115	-.148	-.043	-.218	-.023	-.088	-.179	.228	.185	.113	.246	-.185	.001	-.[illegible]
31	-.102	-.224	-.007	-.293	-.216	-.22	-.031	.217	.298	.046	.314	-.058	.045	-.15
32	.251	.08	-.338	-.17	-.158	-.197	-.111	-.073	-.145	-.171	-.035	.632	.253	.34
33	.151	.005	-.206	-.03	-.095	-.262	-.077	.005	.118	-.019	.2	.407	.199	.30
34	.425	.194	-.363	-.013	.059	.036	-.07	-.34	-.348	-.248	-.298	.674	.214	.55
35	.122	.266	.095	-.226	-.13	-.165	-.323	.4	.183	.301	.184	-.011	.297	-.19
36	.133	.179	.24	-.415	-.512	-.502	-.453	.33	.397	.278	.24	.02	.28	.08
37	.148	.236	.006	-.124	-.096	-.14	-.154	.267	.245	.175	.392	-.042	.387	-.06
38	.012	.433	.334	-.043	-.064	-.137	-.219	.483	.306	.495	-.039	-.207	.386	-.16
39	-.141	-.108	-.316	.052	.192	-.026	-.024	-.044	-.192	-.094	-.086	.312	.119	.33
40	-.071	.023	.182	.122	-.039	-.101	-.075	.315	.221	.196	.026	-.141	.116	-.03
41	-.057	-.327	-.485	.153	.379	.168	.113	-.38	-.393	-.384	-.304	.492	-.052	.38
42	-.027	-.11	-.051	.037	-.006	-.093	-.076	.23	.13	.074	-.005	-.077	.108	-.05
43	-.102	-.433	-.015	-.176	-.184	-.209	.042	.009	.137	-.218	.194	.006	-.182	-.09
44	-.07	-.263	-.227	.093	.072	-.09	.185	-.075	-.13	-.249	-.168	.189	-.05	.21
45	-.053	-.329	-.342	-.109	.094	-.147	.151	-.025	-.177	-.229	-.166	.246	-.104	.12
46	-.084	-.14	.034	-.13	-.031	-.204	-.166	.357	.146	.085	.055	-.118	0	-.16
47	.145	.028	.308	-.19	-.596	-.383	-.24	.216	.396	.171	.367	-.094	.219	-.09
48	.41	.169	.389	-.27	-.585	-.327	-.204	.35	.384	.381	.242	-.113	.231	-.15
49	.093	.081	.286	-.213	-.462	-.294	-.187	.206	.324	.168	.3	-.098	.151	-.13
50	.004	-.145	-.095	-.005	-.104	.054	.1	-.248	-.27	-.066	-.036	-.07	-.33	-.28

	31 (v31)	32 (v32)	33 (v33)	34 (v34)	35 (o35)	36 (o36)	37 (v37)	38 (v38)	39 (v39)	40 (v40)	41 (v41)	42 (o42)	43 (v43)	44 (v44)
31	1													
32	.207	1												
33	.386	.597	1											
34	-.242	.62	.356	1										
35	.162	.317	.156	.115	1									
36	.38	.278	.323	.049	.406	1								
37	.151	.408	.29	.265	.296	.064	1							
38	-.048	-.122	-.175	-.086	.398	.205	.134	1						
39	-.147	.295	.177	.284	.272	-.199	.186	.128	1					
40	-.438	-.015	-.112	-.075	.131	-.074	.177	.246	.427	1				
41	-.034	.446	.196	.329	.074	-.235	.041	-.193	.606	.222	1			
42	-.195	.198	.015	.011	.372	-.035	.189	.167	.571	.712	.385	1		
43	.615	.132	.355	-.203	-.403	.161	-.036	-.432	-.125	-.268	.024	-.221	1	
44	-.175	.253	.152	.153	-.378	-.184	.129	-.087	.397	.509	.422	.38	.29	1
45	.358	.361	.246	.018	-.026	.081	.06	.046	.348	-.048	.303	.137	.455	.54
46	.279	.091	0	-.14	.035	.098	.182	.38	.186	.236	.006	.19	.291	.43
47	.161	.076	.193	-.056	-.253	.235	.129	-.24	-.301	-.32	-.313	.029	.312	.06
48	-.089	.045	.051	.062	.067	.308	.099	.162	-.214	.171	-.399	.085	-.027	-.02
49	.141	.072	.074	-.12	.032	.286	.024	-.095	-.225	.11	-.273	.161	.146	-.03
50	-.279	-.037	-.209	-.076	-.087	-.054	-.289	-.252	-.233	-.077	-.208	-.007	-.13	0.1

	46 (v46)	47 (v47)	48 (v48)	49 (v49)	50 (v50)
46	1				
47	-.035	1			
48	.025	.567	1		
49	.005	.566	.449	1	
50	-.178	.149	.216	.234	1

* Values above critical (2-tail, =0.05) ± .21574 significant
Values below critical (2-tail, =0.05) ± .21574 not significant

4.2 WATER pH:

Mean seasonal water pH was found to be fairly stable during both dry and rainy seasons. Mean pH values of 7.00 and 7.08 were recorded for dry and rainy seasons respectively.

The highest pH value (8.0) was recorded in station 4 in March, and the lowest pH of 6.3 was recorded in station 1 in August (Fig. 2). Analysis of variance (Table 2b) indicates a highly significant difference in mean surfacewater pH between months ($P < 0.01$). The differences between stations, seasons and stations by seasons were insignificant ($P > 0.05$).

Significant positive correlation was observed between surfacewater pH and sediment pH, surfactant, phytoplankton, Zn, and concentration of K in the sediment. The correlation between surfacewater pH and Cl, H_2S, Fe and Cr content in sediment; macroinvertebrates in surfacewater was significantly negative ($P < 0.05$).

4.3 SEDIMENT pH:

Highest sediment pH (8.90) was recorded in station 1 in November, and the lowest (3.80) recorded in station 2 in September, November and December (Fig. 2). Mean seasonal pH of 6.03 and 6.34 were recorded during the dry and rainy seasons respectively.

Analysis of variance for sediment pH (Table 3b) reveals a highly significant difference between stations and station by seasons ($P < 0.01$). The difference between seasons and months was however found to be insignificant.

Table 2a

VARIATION .IN.WATER.PH.....

		STATIONS				
		1	2	3	4	5
General Station	$\bar{x}$	7.30	7.083	7.01	6.91	6.91
Dry Season	$\bar{x}$ 7.00					
Rainy Season	$\bar{x}$ 7.08					

S.E.D. $\bar{x}$ between months .....0.132959.....

S.E.D. $\bar{x}$ between stations .....0.156397.....

S.E.D. $\bar{x}$ between seasons .....9.89139E - 02.....

S.E.D. $\bar{\bar{x}}$ between season by station 0.221178.....

	1	2	3	4	5
Station by Seasons $\bar{x}$:					
Dry Season .	7.40	7.07	6.83	6.79	6.92
Rainy Season.	7.20	7.10	7.18	7.03	6.90

Table 2b.

ANALYSIS OF VARIANCE FOR WATER PH .....

Source of variation:	df.	ss.	Ms.	F.	s.
Replication (6).	5	1.22083	.244166	1.564	NS
Stations (5).	4	1.26167	.315417	2.149	NS
Seasons (2).	1	.104165	.104165	.71	NS
Station by Seasons.	4	.575	.14375	.979	NS
Months (12).	11	3.81323	.346657	3.269	xx
Residual.	34	0.651565	.0191636		
Total.	59	8.76583			

** Highly Significant ($P < 0.01$).
* Significant ($P < 0.05$).
NS. Not Significant ($P > 0.05$).

Table 3a

VARIATION .IN.SEDIMENT.PH.....

		STATIONS				
		1	2	3	4	5
General Station	$\bar{x}$	6.79	6.98	5.18	5.69	6.74
Dry Season	$\bar{x}$ 6.20					
Rainy Season	$\bar{x}$ 6.34					

S.E.D. $\bar{x}$ between months 0.192851.....

S.E.D. $\bar{x}$ between stations 0.205238.....

S.E.D. $\bar{x}$ between seasons 0.129798.....

S.E.D. $\bar{x}$ between season by station 0.290236.....

	1	2	3	4	5
Station by Seasons $\bar{x}$:					
Dry Season .	7.75	8.02	4.60	4.37	6.39
Rainy Season.	5.83	5.93	5.75	7.00	7.17

Table 3b.

ANALYSIS OF VARIANCE FOR SEDIMENT PH .....

Source of variation:	df.	ss.	Ms.	F.	s.
Replication (6).	5	.488	.0976	.0386	NS
Stations (5).	4	30.2327	7.55817	29.908	xx
Seasons (2).	1	.266665	.266665	1.055	NS
Station by Seasons.	4	50.8867	12.7217	50.341	xx
Months (12).	11	3.21045	.2918	1.307	NS
Residual.	34	.161485	.2400436		
Total.	59	93.246			

** Highly Significant ($P<0.01$).
* Significant ($P<0.05$).
NS. Not Significant ($P>0.05$).

Positive significant correlation between sediment pH and percentage saturation of oxygen, BOD, Phenol, and surfactant as well as phytoplankton abundance was observed. A significant but negative correlation between sediment pH and alkalinity, Cl, COD, PO_4-P, surfacewater K, Ca, Mn, Na, Fe, Cu, Cr, Ni; sediment Mg, Pb, Fe, Cu, Cr, and Cd was recorded.

4.4 HYDROGEN SULPHIDE AND MERCAPTAN:

With the exception of station 5 where the concentration was below detection level, a range of 0.01 to 4.60 wt. % was recorded in stations 4 and in January and August respectively. Mean seasonal values for dry and rainy seasons (Table 4a) were 0.72 and 0.26 wt. % respectively.

The concentrations of H_2S and RSH were observed to show significant difference between stations and between months, but no significant difference was observed with station by seasons ($P>0.05$).

Water temperature, oil, phenol and surfactant were found to exhibit significant positive correlation with H_2S and RSH content ($P<0.05$), while water temperature, alkalinity, surface-water K, Mg, Na, Zn, Mn, sediment K, Ca and zooplankton population showed significant negative correlation.

4.5 OIL IN WATER:

Oil concentration within the range of 0.27ppm to 10.42ppm was recorded. The lowest concentration (0.27ppm) was recorded in station 4 in October and the highest (10.42ppm) in station 1 in August (Fig. 3).

During the dry season a mean of 0.63ppm was obtained, while the rainy season mean was found to be lower (0.01ppm). Highly significant difference in oil concentration between stations and seasons ($P<0.01$), with significant difference between station by seasons ($P<0.05$) was observed, while the monthly variation was insignificant ($P>0.05$).

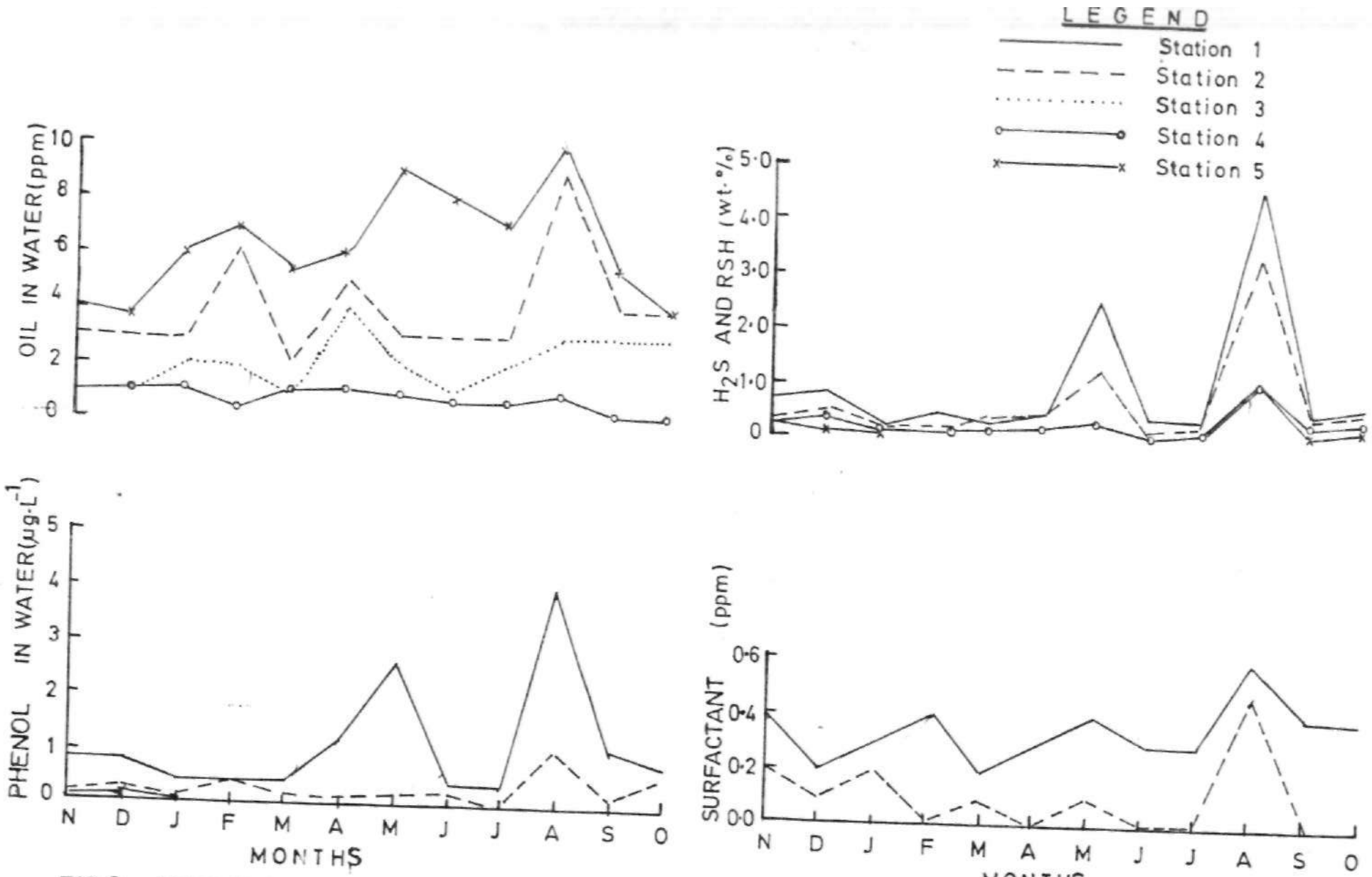


FIG.3. MONTHLY VARIATION IN OIL, PHENOL, H_2S & RSH, AND SURFACTANT IN WATER.

Table 4a

VARIATION IN HYDROGEN SULPHIDE AND RSH. (Wt %)

		STATIONS				
		1	2	3	4	5
General Station	$\bar{x}$	0.47	1.01	0.36	0.52	0.11
Drv Season	$\bar{x}$ 0.72					
Rainy Season	$\bar{x}$ 0.26					

S.E.D. $\bar{x}$ between months .....0.249215.....

S.E.D. $\bar{x}$ between stations .....276319.....

S.E.D. $\bar{x}$ between seasons .....174759.....

S.E.D. $\bar{\bar{x}}$ between season by station .....390774.....

	1	2	3	4	5
Station by Seasons $\bar{x}$:					
Dry Season .	0.50	1.53	0.32	1.05	0.21
Rainy Season.	0.44	0.49	0.39	0.00	0.00

Table 4b

ANALYSIS OF VARIANCE FOR HYDROGEN SULPHIDE AND RSH

Source of variation:	df.	ss.	Ms.	F.	s.
Replication (6).	5	7.39859	1.47972	3.23	x
Stations (5).	4	5.24941	1.31235	2.865	x
Seasons (2).	1	3.1236	3.1236	6.819	x
Station by Seasons.	4	3.51956	.879889	1.921	NS
Months (12).	11	16.5563	1.50511	4.038	xx
Residual.	34	6.68234	0.1965394		
Total.	59	39.9062			

** Highly Significant ($P < 0.01$).
* Significant ($P < 0.05$).
NS. Not Significant ($P > 0.05$).

Table 4c

VARIATION .OIL CONCENTRATION IN WATER (PPM)

		STATIONS				
		1	2	3	4	5
General Station	$\bar{x}$	3.81	4,34	2.35	2.38	1.14
Dry Season	$\bar{x}$ 4.67					
Rainy Season	$\bar{x}$ 0.94					

S.E.D. $\bar{x}$ between months .....0.569752.....

S.E.D. $\bar{x}$ between stations .....560283.....

S.E.D. $\bar{x}$ between seasons .....354354.....

S.E.D. $\bar{x}$ between season by station .....79236.....

	1	2	3	4	5
Station by Seasons $\bar{x}_s$					
Dry Season .	4.71	7.56	4.02	4.75	2.
Rainy Season.	2.91	1.12	0.67	0.00	0.

Table 4d

ANALYSIS OF VARIANCE FOR .OIL.CONCENTRATION.IN.WATER.....

Source of variation:	df.	ss.	Ms.	F.	s.
Replication (6).	5	8.68308	1.73662	.922	NS
Stations (5).	4	78.1881	19.547	10.378	xx
Seasons (2).	1	208.246	208.246	110.563	x
Station by Seasons.	4	43.059	10.7648	5.715	x
Months (12).	11	35.4579	3.22344	1.654	*
Residual.	34	40.29992	1.4499976		
Total.	59	422.934			

** Highly Significant (P < 0.01).
* Significant (P < 0.05).
NS. Not Significant (P > 0.05).

A significant positive correlation was established between oil and water temperature, H_2S and RSH, Phenol surfactant and surfacewater Cu ($P < 0.05$). The relationship with PO_4-P, Chlorophyll 'a', surfacewater K, Ca, Mg, Na, Fe, Mn, sediment Ca, zooplankton and benthic macroinvertebrates was negative and significant.

4.6 PHENOL:

Concentration of phenol in stations 4 and 5 was below detection level. A range of $0.02 ug.L^{-1}$ to $4.06 ug.L^{-1}$ was recorded in other stations, the lowest and the highest being in station 3 in October and station 1 in August respectively.

Highly significant difference between stations, seasons and station by seasons ($P < 0.01$) was obtained, with dry season mean of $0.63 ug.L^{-1}$ and rainy season mean of $0.01 ug.L^{-1}$ (Table 5a).

Significant positive correlation was established between phenol and oil concentration, water temperature, sediment pH, H_2S and RSH and surfactant ($P < 0.05$). The correlation with conductivity, alkalinity, COD, PO_4-P, Chlorophyll 'a'; surface-water K, Ca, Mg, Na, Fe, Mn, Ni; sediment Ca, macroinvertebrates in surfacewater and zooplankton population was significant, but negative.

4.7 SURFACTANT:

Mean seasonal variation in surfactant concentration (Table 6a) indicates high dry season value as compared to rainy season. The lowest concentration was recorded in stations 2 and 3 (Fig. 3). The highest concentration was recorded in station 1 in August.

Table 5a

VARIATION IN PHENOL CONTENT ($\mu g.\ L^{-1}$)

		STATIONS				
		1	2	3	4	5
General Station	$\bar{x}$	0.34	0.86	0.14	0.21	0.05
Dry Season	$\bar{x}$ 0.63					
Rainy Season	$\bar{x}$ 0.01					

S.E.D. $\bar{x}$ between months 0.196168

S.E.D. $\bar{x}$ between stations ..... .178409

S.E.D. $\bar{x}$ between seasons ..... .112835

S.E.D. $\bar{x}$ between season by station ..... .252308

Station by Seasons $\bar{x}$:	1	2	3	4	5
Dry Season .	0.62	1.73	0.29	0.43	0.10
Rainy Season.	0.07	0.00	0.00	0.00	0.00

Table 5b

ANALYSIS OF VARIANCE FOR PHENO CONTENT .....

Source of variation:	df.	ss.	Ms.	F.	s.
Replication (6).	5	1.69169	.338339	1.772	NS
Stations (5).	4	4.94519	1.2363	6.474	XX
Seasons (2).	1	5.67953	5.67953	29.739	XX
Station by Seasons.	4	4.95723	1.25931	6.459	XX
Months (12).	11	3.88315	.353014	1.523	NS
Residual.	34	4.71081	0.13855		
Total.	59	25.8676			

** Highly Significant ($P < 0.01$).
* Significant ($P < 0.05$).
NS. Not Significant ($P > 0.05$).

Table 6a

VARIATION IN SURFACTANT CONTENT (Wt (PPM)

		STATIONS				
		1	2	3	4	
General Station	$\bar{x}$	0.47	0.20	0.05	0.067	0.
Dry Season	$\bar{x}$ 0.31					
Rainy Season	$\bar{x}$ 0.01					

S.E.D. $\bar{x}$ between months .....0.193263.....

S.E.D. $\bar{x}$ between stations .....0.19786.....

S.E.D. $\bar{x}$ between seasons .....0.125138.....

S.E.D. $\bar{x}$ between season by station .....0.279816.....

	1	2	3	4	
Station by Seasons $\bar{x}$:					
Dry Season .	0.90	0.41	0.11	0.13	0.
Rainy Season.	0.03	0.00	0.00	0.00	0.

Table 6b

ANALYSIS OF VARIANCE FOR SURFALTANT CONTENT

Source of variation:	df.	ss.	Ms.	F.	s.
Replication (6).	5	1.26843	.253687	1.098	N
Stations (5).	4	1.68064	.420161	1.819	*
Seasons (2).	1	1.39233	1.39233	5.998	*
Station by Seasons.	4	1.45619	.364047	1.57	N
Months (12).	11	2.71489	.246808	1.101	
Residual.	34	7.85522	0.231035		
Total.	59	16.3677			

** Highly Significant (P<0.01).
* Significant (P<0.05).
NS. Not Significant (P>0.05).

The difference between seasons was significant ($P < 0.05$), while that between stations, station by seasons, and months was insignificant ($P > 0.05$).

Surfactant content and phenol, water pH, sediment pH, H_2S and RSH and oil were positively correlated ($P < 0.05$), while conductivity, alkalinity, Cl, PO_4-P, chlorophyll 'a' surfacewater K, Ca, Na, Fe, Cd; sediment Ca, Na, and macroinvertebrates on surfacewater showed negative, but significant correlation ($P < 0.05$).

4.8 NITRATE-NITROGEN:

The lowest concentration of NO_3-N recorded was 1.70ppm in station in April, while the highest value of 7.70ppm was recorded in stations 2 and 3 in November (Fig. 4). Means of 3.93ppm and 2.59ppm were obtained for the dry and rainy seasons respectively. Analysis of variance (Table 7b) indicates that there was no significant difference with stations, seasons, station by seasons and months ($P > 0.05$).

Significant positive correlation was observed between NO_3-N concentration and surfacewater Cr, Cd, and zooplankton population ($P<0.05$), without significant correlation with phytoplankton abundance.

4.9 PHOSPHATE-PHOSPHORUS:

PO_4-P ranged between 4.95ppm to 16.32ppm, recorded in station 3 in November and the month of July respectively. Means dry season value of 0.09ppm and rainy seasonal value of 1.19ppm were recorded (Table 8a), with highly significant difference between stations, seasons, station by season and months ($P < 0.01$).

Significant positive correlation between PO_4-P and conductivity, DO, hardness, Cl, COD, chlorophyll 'a', surface-water K, Mg and Na was observed ($P<0.05$). The correlation with water temperature, sediment pH, oil, phenol, surfactant, surfacewater Mn, Cu in sediment, Mn and Ni was noted to be negative ($P < 0.05$).

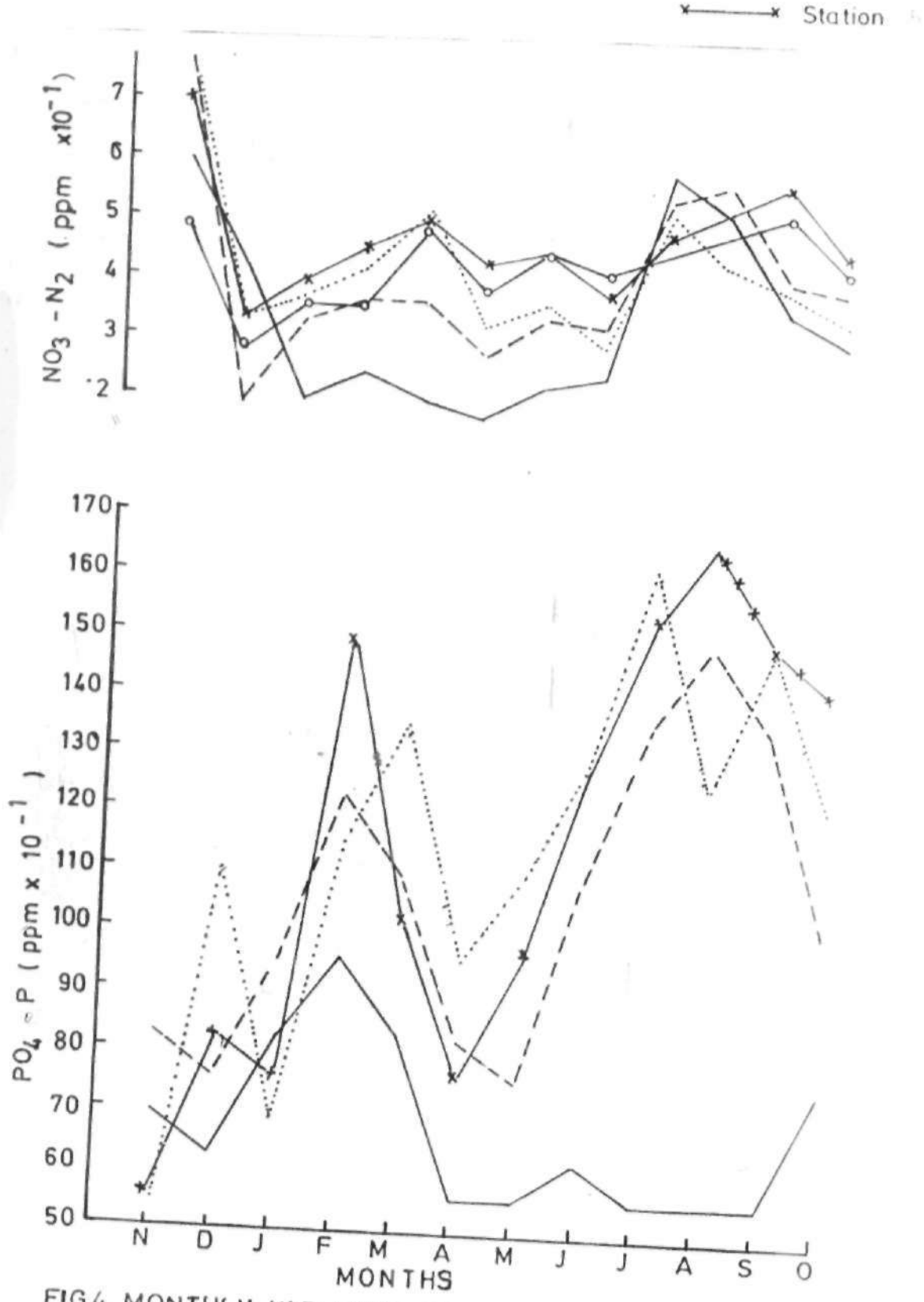


FIG 4. MONTHLY VARIATION IN NO_3-N & PO_4-P.

Table 7a

VARIATION IN NITRATE - NITROGEN (NO_3-N) (PPM)

		STATIONS				
		1	2	3	4	5
General Station	$\bar{x}$	3.53	4.11	4.24	4.56	52.
Dry Season	$\bar{x}$ 3.93					
Rainy Season	$\bar{x}$ 23.59					

S.E.D. $\bar{x}$ between months .30.2061.....

S.E.D. $\bar{x}$ between stations .30.2182.....

S.E.D. $\bar{x}$ between seasons .19.1117.....

S.E.D. $\bar{x}$ between season by station 42.7235.....

Station by Seasons $\bar{x}$:	1	2	3	4	5
Dry Season .	3.09	3.79	3.85	4.36	4.
Rainy Season.	3.97	4.42	4.64	4.75	100.

Table 7b

ANALYSIS OF VARIANCE FOR ..NITRATE - NITROGEN.....

Source of variation:	df.	ss.	Ms.	F.	s.
Replication (6).	5	27500.9	5500.18	1.004	
Stations (5).	4	22576.7	5594.18	1.021	NS
Seasons (2).	1	5796.55	5796.55	1.058	
Station by Seasons.	4	21630.2	5407.56	.98	
Months (12).	11	60500.7	5500.06	1.004	
Residual.	34	185046.9	5471.96		
Total.	59	323852			

** Highly Significant ($P < 0.01$).
* Significant ($P < 0.05$).
NS. Not Significant ($P > 0.05$).

Table 8a

VARIATION IN PHOSOPHATE - PHOSPHORUS (PPM)

		STATIONS				
		1	2	3	4	5
General Station	$\bar{x}$	10.36	7.80	11.75	10.42	11.8
Dry Season	$\bar{x}$ 9.92					
Rainy Season	$\bar{x}$ 11.82					

S.E.D. $\bar{x}$ between months 0.79499

S.E.D. $\bar{x}$ between stations ..... .695523

S.E.D. $\bar{x}$ between seasons ..... .439888

S.E.D. $\bar{x}$ between season by station ..... .983619

Station by Seasons $\bar{x}$:	1	2	3	4	5
Dry Season .	7.52	6.08	9.52	11.87	9.63
Rainy Season.	13.20	9.52	13.98	9.08	13.64

Table 8b

ANALYSIS OF VARIANCE FOR PHOSPHATE - PHOSPHORUS .....

Source of variation:	df.	ss.	Ms.	F.	s.
Replication (6).	5	143.247	28.6495	9.871	xx
Stations (5).	4	121.528	30.3819	10.457	xx
Seasons (2).	1	131.394	131.394	45.269	xx
Station by Seasons.	4	132.193	33.0483	11.386	xx
Months (12).	11	290.078	26.3707	6.954	xx
Residual.	34	159.464	4.69011		
Total.	59	977.904			

** Highly Significant ($P < 0.01$).
* Significant ($P < 0.05$).
NS Not Significant ($P > 0.05$).

4.10 CHLOROPHYLL 'a':

The concentration of chlorophyll 'a' was found to vary with a range of $0.15ug.L^{-1}$ to $14.99ug.L^{-1}$ in station 1 in April and station 4 in August respectively (Fig. 5). The mean chlorophyll 'a' concentration in dry season ($3.05ug.L^{-1}$) was observed to be lower than that of rainy season ($7.28ug.L^{-1}$). Highly significant difference in chlorophyll 'a' content was observed between stations, seasons and months ($P< 0.01$). However, the difference with respect to station by season was found to be insignificant ($P>0.05$).

Positive correlation between chlorophyll 'a' and conductivity, dissolved solid, DO and percentage saturation, Cl, COD, surfacewater, Mg, Fe, K; both sediment and surface-water Ca, Na; and benthic macroinvertebrates ($P< 0.05$). The relationship was however found to be significantly negative with CO_2, oil, phenol, surfactant, surfacewater Pb, Cu, Cr, Cd; sediment Pb, Cu, Cr and Ni ($P< 0.05$).

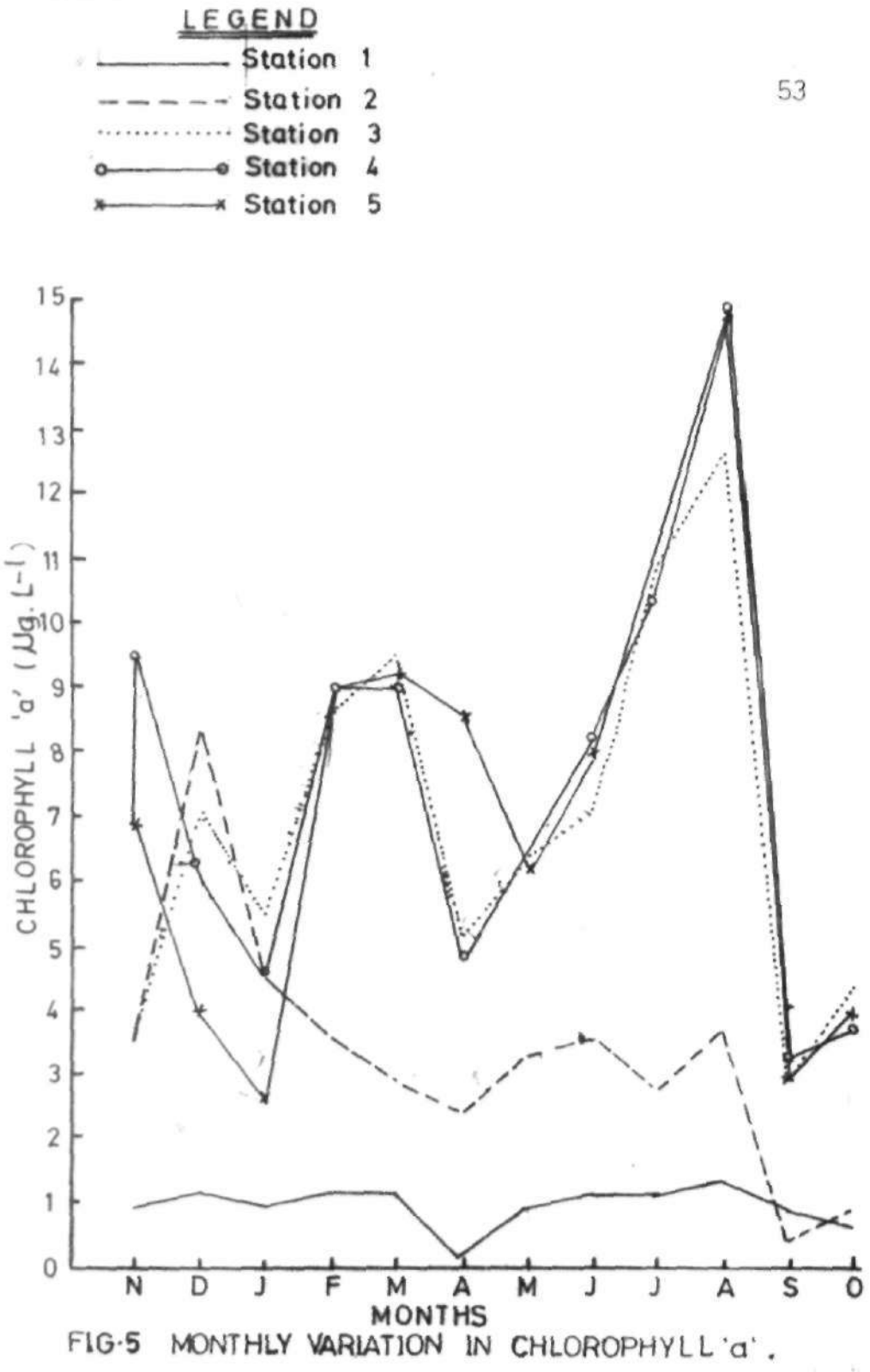


FIG-5 MONTHLY VARIATION IN CHLOROPHYLL 'a'.

Table 9a

VARIATION IN CHLOROPHYLL 'a' ($\mu g.\ L^{-1}$)

		STATIONS				
		1	2	3	4	5
General Station	$\bar{x}$	4.08	3.96	6.15	4.4[illegible]	7.[illegible]
Dry Season	$\bar{x}$ 3.05					
Rainy Season	$\bar{x}$ 7.28					

S.E.D. $\bar{x}$ between months .....0.88093.....

S.E.D. $\bar{x}$ between stations .....1.05936.....

S.E.D. $\bar{x}$ between seasons .....0.66899.....

S.E.D. $\bar{x}$ between season by station .....1.49816.....

Station by Seasons $\bar{x}$:	1	2	3	4	5
Dry Season .	0.94	1.07	4.21	2.50	.
Rainy Season.	7.22	6.85	8.09	6.41	7.[illegible]

Table 9b

ANALYSIS OF VARIANCE FOR CHLOROPHYLL 'a'

Source of variation:	df.	ss.	Ms.	F.	s.
Replication (6).	5	122.539	24.5077	3.64	x[illegible]
Stations (5).	4	98.9729	24.7432	3.67[illegible]	x[illegible]
Seasons (2).	1	268.817	268.817	39.9[illegible]	xx
Station by Seasons.	4	46.0203	11.5051	1.709	NS
Months (12).	11	241.746	21.9769	4.719	xx
Residual.	34	61.2598	1.80176		
Total.	59	839.355			

** Highly Significant ($P < 0.01$).
* Significant ($P < 0.05$).
NS. Not Significant ($P > 0.05$).

4.11 DISSOLVED OXYGEN:

The lowest amount of oxygen (1.3mg.L^{-1}) was recorded in station 2 in March, while the highest (4.6mg.L^{-1}) was recorded in station 4 in November (Fig. 6). Mean DO for dry and rainy seasons were 3.02mg.L^{-1} and 4.62mg.L^{-1} respectively.
The differences in DO with respect to stations, seasons, station by season and months were not significant ($P > 0.05$).

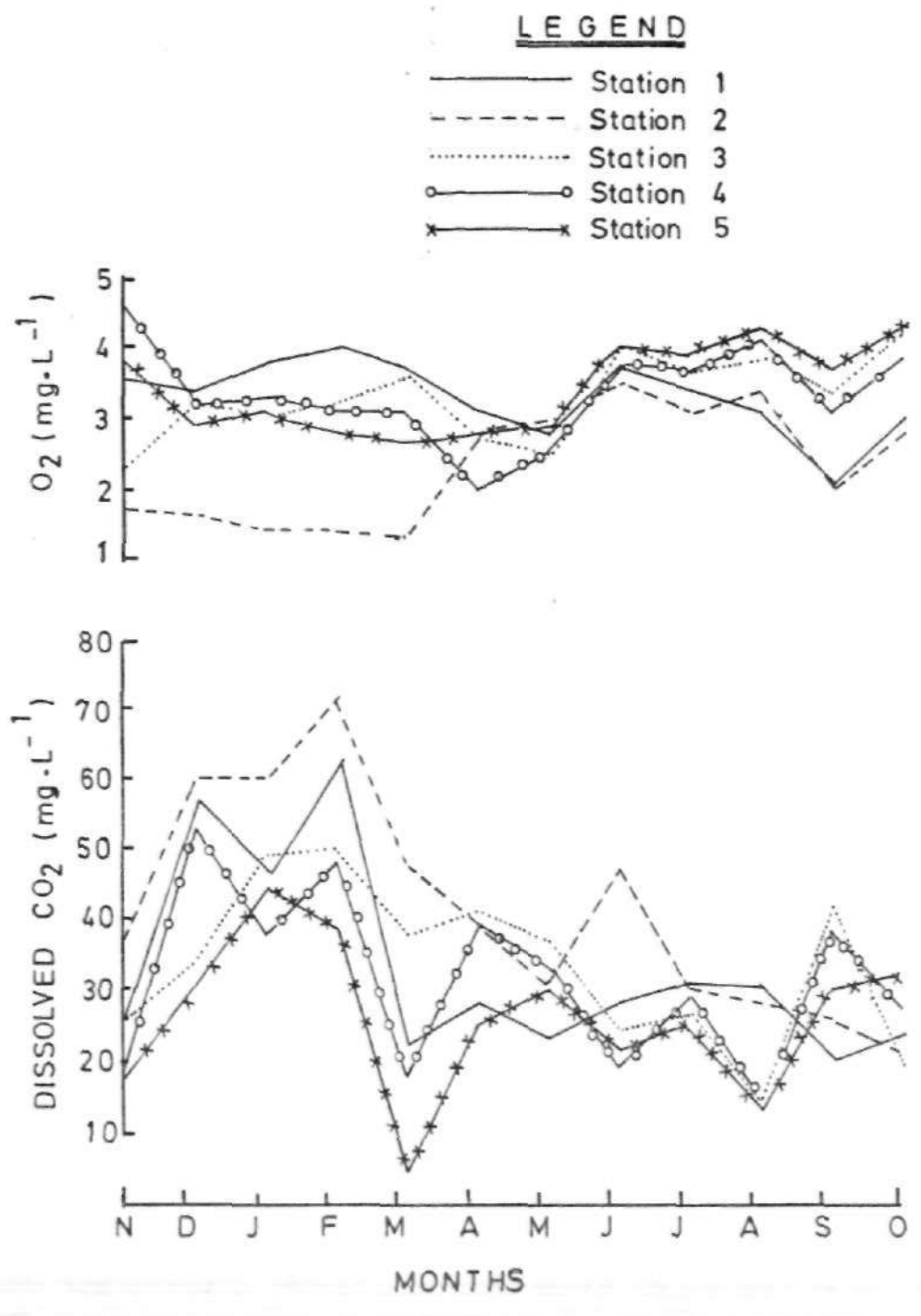
Highly significant variation in percentage saturation was however recorded between stations, and station by season ($P < 0.01$), with significant variation between months ($P < 0.05$).

On seasonal comparison, 42.58% saturation value of O_2 was recorded in rainy season compared to 37.35% observed during the dry season (Table 10c). Station 2 was observed to have the lowest saturation of 18.59% in February, while the highest (61.00%) was obtained in station 4 in November. DO was positively correlated to oxygen saturation value, PO_4-P, surfacewater Mg, Ni; Na in sediment and chlorophyll 'a' ($P < 0.05$). The correlation was however found to be significantly negative with air temperature, surfacewater Cr, Ni; and Na concentration in sediment.

Saturation value of O_2 was also found to correlate positively with zooplankton, phytoplankton, macroinvertebrates in surfacewater ($P < 0.05$).

4.12 DISSOLVED CARBONDIOXIDE:

There were highly significant variations in dissolved CO_2 with seasons, station by seasons and months ($P < 0.01$). The variation between seasons was insignificant ($P > 0.05$).


LEGEND
Station 1
Station 2
Station 3
Station 4
Station 5
O2 (mg·L-1)
DISSOLVED CO2 (mg·L-1)
N D J F M A M J J A S O
MONTHS

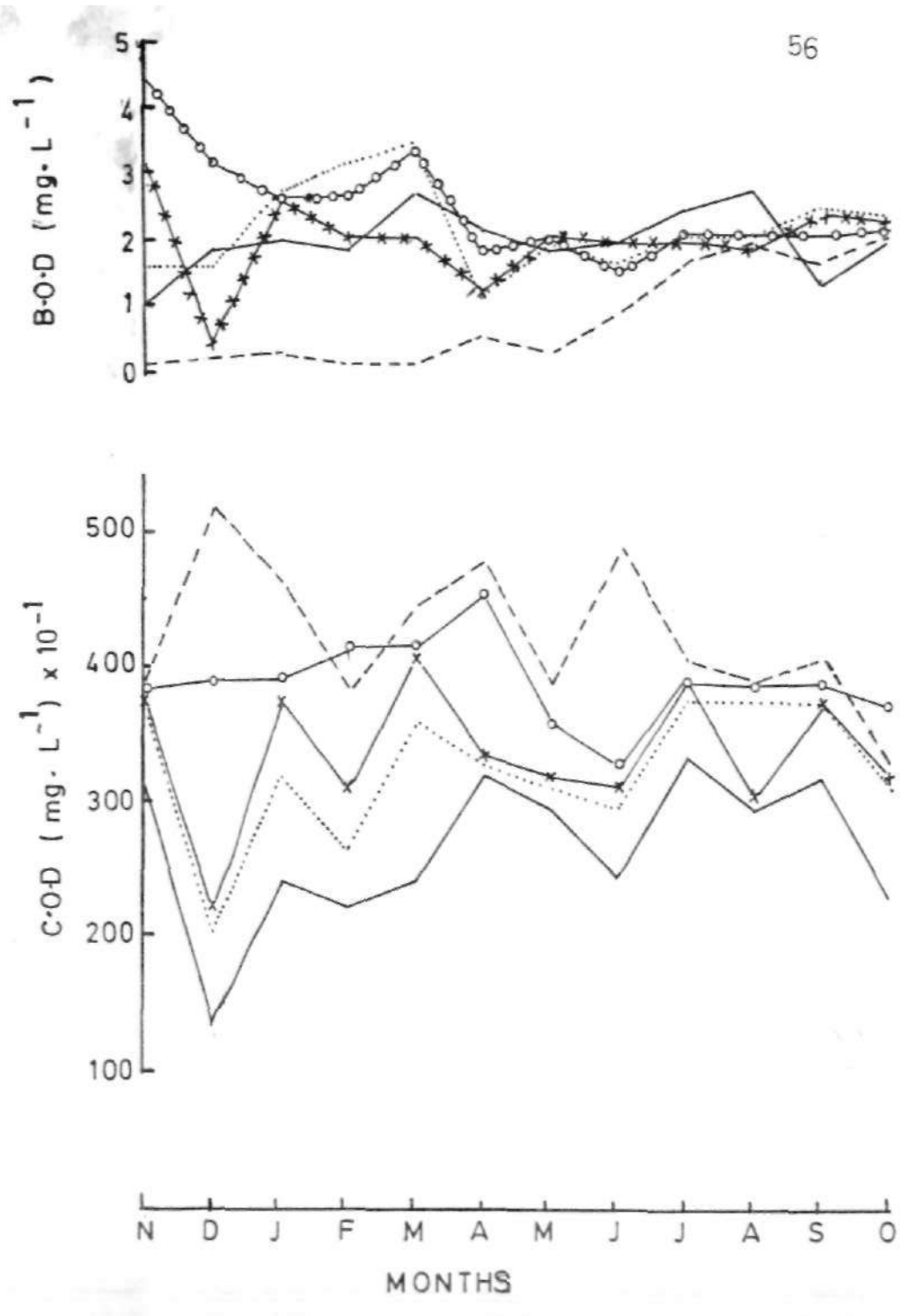

B·O·D (mg·L-1)
C·O·D (mg·L-1) x 10-1
N D J F M A M J J A S O
MONTHS

Table 10a

VARIATION IN DISSOLVED OXYGEN (PPM)

		STATIONS				
		1	2	3	4	5
General Station	$\bar{x}$	3.60	3.12	5.56	2.98	3.[illegible]
Dry Season	$\bar{x}$ 3.02					
Rainy Season	$\bar{x}$ 4.62					

S.E.D. $\bar{x}$ between months .....1.89214.....

S.E.D. $\bar{x}$ between stations .....1.89985.....

S.E.D. $\bar{x}$ between seasons .....1.20157.....

S.E.D. $\bar{x}$ between season by station .....2.68679.....

	1	2	3	4	5
Station by Seasons $\bar{x}$s					
Dry Season .	3.60	3.02	1.70	2.95	3.8[illegible]
Rainy Season.	3.60	3.22	9.42	3.00	[illegible]

Table 10b.

ANALYSIS OF VARIANCE FOR .DISSOLVED OXYGEN.....

Source of variation:	df.	ss.	Ms.	F.	s.
Replication (6).	5	108.623	21.7246	1.003	NS
Stations (5).	4	51.3323	12.8381	.593	NS
Seasons (2).	1	38.2402	38.2402	1.76[illegible]	NS
Station by Seasons.	4	140.528	35.1322	1.62[illegible]	NS
Months (12).	11	261.354	23.7594	1.1[illegible]	[illegible]
Residual.	34	713.1925	20.97625		
Total.	59	1313.29			

** Highly Significant (P < 0.01).
* Significant (P < 0.05).
NS. Not Significant (P > 0.05).

Table 10c

VARIATION IN PERCENTAGE SATURATION OF OXYGEN (%)

		STATIONS				
		1	2	3	4	5
General Station	$\bar{x}$	45.68	40.51	32.96	39.33	43.1
Dry Season	$\bar{x}$ 37.54					
Rainy Season	$\bar{x}$ 42.88					

S.E.D. $\bar{x}$ between months .....3.09174.....

S.E.D. $\bar{x}$ between stations .....3.053.....

S.E.D. $\bar{x}$ between seasons .....1.93088.....

S.E.D. $\bar{x}$ between season by station .....4.31759.....

		1	2	3	4	5
Station by Seasons	$\bar{x}$					
Dry Season .		81.33	60.67	64.00	73.333	90.
Rainy Season.		75.07	55.333	90.67	47.333	91.

Table 10d

ANALYSIS OF VARIANCE FOR PERCENTAGE SATURATION OF OXYGEN

Source of variation:	df.	ss.	Ms.	F.	S.
Replication (6).	5	7942.61	1588.52	4.243	xx
Stations (5).	4	5617.56	1404.39	3.75	xx
Seasons (2).	1	64.8958	64.8958	.173	NS
Station by Seasons.	4	5664.92	1416.23	3.784	xx
Months (12).	11	1408.59	128.054	2.23	x
Residial.	34	15437.02	454.030		
Total.	59	36135.5			

** Highly Significant ($P < 0.01$).
* Significant ($P < 0.05$).
NS. Not Significant ($P > 0.05$).

Table 11a

VARIATION IN DISSOLVED CARBONDIOXIDE (PPM)

		STATIONS				
		1	2	3	4	5
General Station	$\bar{x}$	33.50	30.75	38.25	28.[illegible]	38.[illegible]
Dry Season	$\bar{\bar{x}}$ 37.40					
Rainy Season	$\bar{\bar{x}}$ 27.97					

S.E.D. $\bar{x}$ between months 3.39154

S.E.D. $\bar{x}$ between stations 4.46322

S.E.D. $\bar{\bar{x}}$ between seasons 2.82279

S.E.D. $\bar{\bar{x}}$ between season by station 6.31194

		1	2	3	4	5
Station by Seasons	$\bar{x}$:	40.17	25.83	50.83	30.50	46.67
Dry Season		26.83	35.67	25.67	26.33	41.17
Rainy Season.						

Table 11b.

ANALYSIS OF VARIANCE FOR DISSOLVED CARBONDIOXIDE

Source of variation:	df.	ss.	Ms.	F.	s.
Replication (6).	5	1122.68	224.537	1.[illegible]	[illegible]
Stations (5).	4	635.567	158.892	1.[illegible]	NS
Seasons (2).	1	1334.82	1334.82	11.[illegible]	**
Station by Seasons.	4	2067.43	516.858	4.[illegible]	**
Months (12).	11	6120.58	556.417	8.062	**
Residual.	34	742.077	21.8257		
Total.	59	12023954			

** Highly Significant ($P<0.01$).
* Significant ($P<0.05$).
NS Not Significant ($P>0.05$).

The mean seasonal variation (Table 11a) indicates a considerable difference with $37.40mg.L^{-1}$ for dry season and $27.97mg.L^{-1}$ for rainy season. The lowest amount ($4.00mg.L^{-1}$) was recorded in station 5 in March, while the highest ($71.00mg.L^{-1}$) was in station 2 in February.

The correlation of dissolved CO_2 with the amount of suspended solid, alkalinity, surfacewater Zn, Mn, Ni; sediment Mn was positive ($P < 0.05$). The correlation was however negative with DO, BOD, chlorophyll 'a', sediment Na, Fe, Zn; zooplankton and phytoplankton abundance ($P < 0.05$).

4.13 BIOCHEMICAL OXYGEN DEMAND:

The variation in BOD is represented in Fig. 6 , with a range of 0.10mg. to $4.40mg.L^{-1}$ recorded in stations 2 and 4 in November respectively. The mean seasonal values (Table 12a) indicates a low value of $1.55mg.L^{-1}$ for dry season as compared to $2.16mg.L^{-1}$ recording during the rainy season.

Analysis of variance (Table 12b) shows highly significant difference between stations, and seasons ($P < 0.01$), with significant difference with station by seasons ($P < 0.05$), while monthly difference was found to be insignificant ($P > 0.05$).

BOD was noted to have positive correlation with sediment pH, dissolved solid, oxygen saturation, macroinvertebrates in surfacewater, benthic macroinvertebrates and phytoplankton abundance ($P < 0.05$), with negative correlation between BOD and conductivity, suspended solid, CO_2, Cl; sediment Pb and Zn

Table 12a

VARIATION IN BIOCHEMICAL OXYGEN DEMAND ($mg.\ L^{-1}$)

		STATIONS				
		1	2	3	4	5
General Station	$\bar{x}$	1.97	2.48	1.08	1.53	2.13
Dry Season	$\bar{x}$ 1.55					
Rainy Season	$\bar{x}$ 2.16					

S.E.D. $\bar{x}$ between months .....0.283077.....

S.E.D. $\bar{x}$ between stations .....0.244155.....

S.E.D. $\bar{x}$ between seasons .....0.154419.....

S.E.D. $\bar{x}$ between season by station .....0.345291.....

		1	2	3	4	5
Station by Seasons	$\bar{x}$:					
Dry Season .		1.90	2.00	.22	1.37	2.25
Rainy Season.		2.03	2.97	1.93	1.68	2.00

Table 12b

ANALYSIS OF VARIANCE FOR BIOCHEMICAL OXYGEN DEMAND .....

Source of variation:	df.	ss.	Ms.	F.	s.
Replication (6).	5	2.7295	.5459	1.5[illegible]	NS
Stations (5).	4	13.6977	3.42442	9.574	xx
Seasons (2).	1	5.7041	5.70416	15.94[illegible]	xx
Station by Seasons.	4	6.981671	1.74542	4.88	x
Months (12).	11	5.05251	.459319	.[illegible]	NS
Residual.	34	11.05299	0.32500		
Total.	59	45.20[illegible]			

** Highly Significant ($P < 0.01$).
* Significant ($P < 0.05$).
NS. Not Significant ($P > 0.05$).

4.14 CHEMICAL OXYGEN DEMAND:

A range of 244 to 520mg.L^{-1} COD was observed (Fig. 6). The lowest amount (224mg.L^{-1}) was recorded in station 5 and the lowest (520mg.L^{-1}) in station 2, all in December. Means of 341.93mg.L^{-1} and 358.27mg.L^{-1} were obtained for dry and rainy seasons respectively (Table 13a).

The relationship between COD and conductivity, suspended solid, alkalinity, Cl, PO_4-P, surfacewater K, Mg, Ca, Na, Fe, Zn, Mn, Cr, Ni; sediment K, Ca, Mg, Na and Cd was observed to show positive correlation ($P<0.05$). Significant negative correlation was however recorded with sediment pH, oxygen saturation, phenol and phytoplankton abundance ($P<0.05$).

The COD differences between months, station by seasons, and between stations were highly significant ($P<0.01$), with significant difference between months ($P<0.05$). The difference between seasons was however insignificant ($P>0.05$).

Table 13a

VARIATION IN CHEMICAL OXYGEN DEMAND ($mg.\ L^{-1}$)

		STATIONS				
		1	2	3	4	5
General Station	$\bar{x}$	290.67	348.00	419.67	366.83	426.33
Dry Season	$\bar{\bar{x}}$ 341.93					
Rainy Season	$\bar{\bar{x}}$ 358.27					

S.E.D. $\bar{x}$ between months .....19.3972.....

S.E.D. $\bar{\bar{x}}$ between stations .....19.7848.....

S.E.D. $\bar{\bar{x}}$ between seasons .....12.513.....

S.E.D. $\bar{\bar{\bar{x}}}$ between season by station .....27.98.....

	1	2	3	4	5
Station by Seasons $\bar{x}$:					
Dry Season .	248.00	286.67	458.67	395.00	421.33
Rainy Season.	333.33	409.33	372.67	338.67	357.33

Table 13b.

ANALYSIS OF VARIANCE FOR .CHEMICAL OXYGEN DEMAND.....

Source of variation:	df.	ss.	Ms.	F.	s.
Replication (6).	5	23879.8	4775.96	2.013	NS
Stations (5).	4	102564	25640.9	10.807	**
Seasons (2).	1	4001.67	4001.67	1.704	NS
Station by Seasons.	4	95461.3	23865.3	10.161	**
Months (12).	11	51355	4668.64	2.068	*
Residual.	34	54333.2	1598.0353		
Total.	59	331595			

** Highly Significant ($P < 0.01$).
* Significant ($P < 0.05$).
NS. Not Significant ($P > 0.05$).

4.15 ALKALINITY:

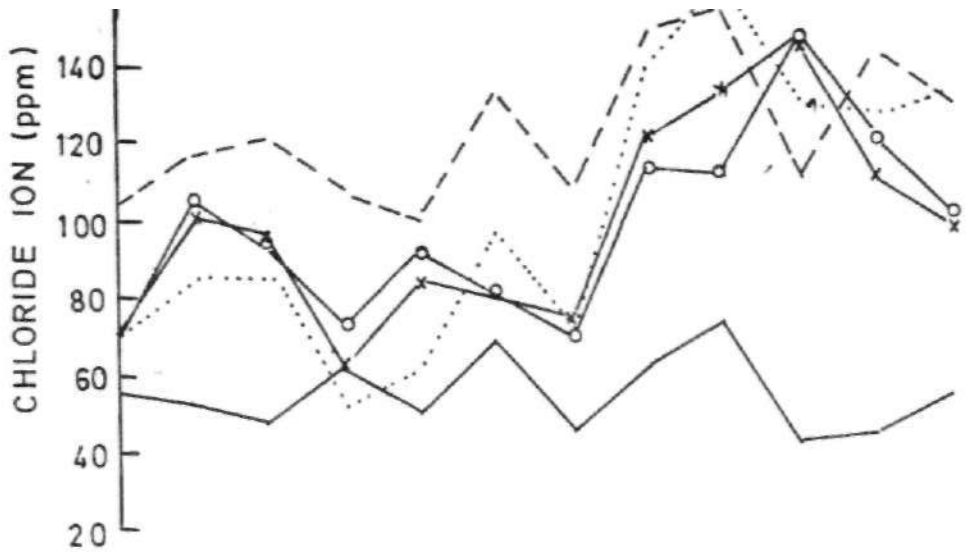
Alkalinity was found to show highly significant difference between stations, station by season and months ($P < 0.01$) with no significant difference between seasons ($P > 0.05$). A range of 21.00 to 187.00ppm was recorded. The lowest value (21.00ppm) was recorded in station 1 in January and the highest (187.00ppm) in station 5 in October (Fig. 7).

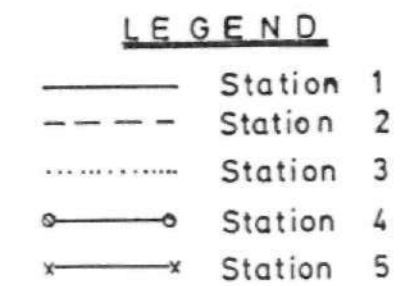
Mean seasonal values of 74.37ppm and 71.20ppm were observed for the dry and rainy seasons respectively (Table 14a). Correlation analysis (Table 1c) reveals positive correlation between alkalinity and air temperature, suspended solid, conductivity, CO_2, COD, surfacewater K, Ca, Na, Zn, Mn, Ni; sediment Ca and Mg ($P < 0.05$). Significant negative correlation was observed with sediment pH, DO, sediment Zn, Fe, Cr, phytoplankton abundance, hardness, H_2S, phenol and surfactant ($P < 0.05$).

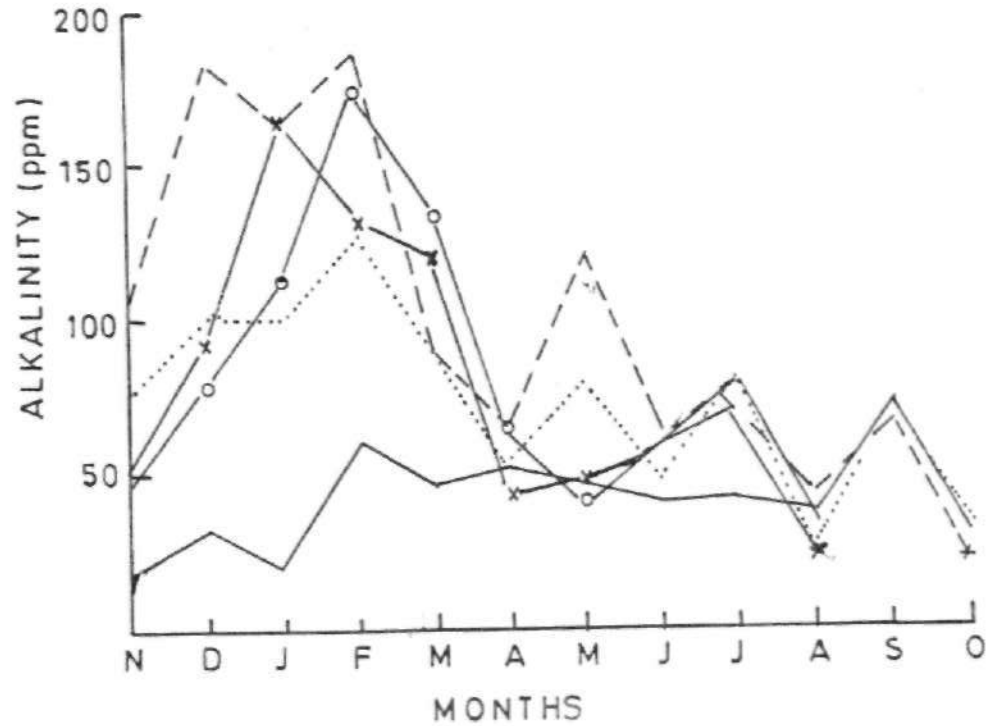
4.16 HARDNESS:

Variation in water hardness was found to be within the range of 12.00 to 116.00ppm. The lowest value (12.00ppm) was recorded in station 4 in November, while the highest (116.00ppm) was recorded in stations 1,3 and 4 in March and August. Mean seasonal values of 69.87ppm and 71.95ppm for dry and rainy seasons were recorded (Table 15a).

Highly significant variation between stations, station by seasons and months was observed ($P < 0.01$). The difference between seasons was insignificant ($P > 0.05$).







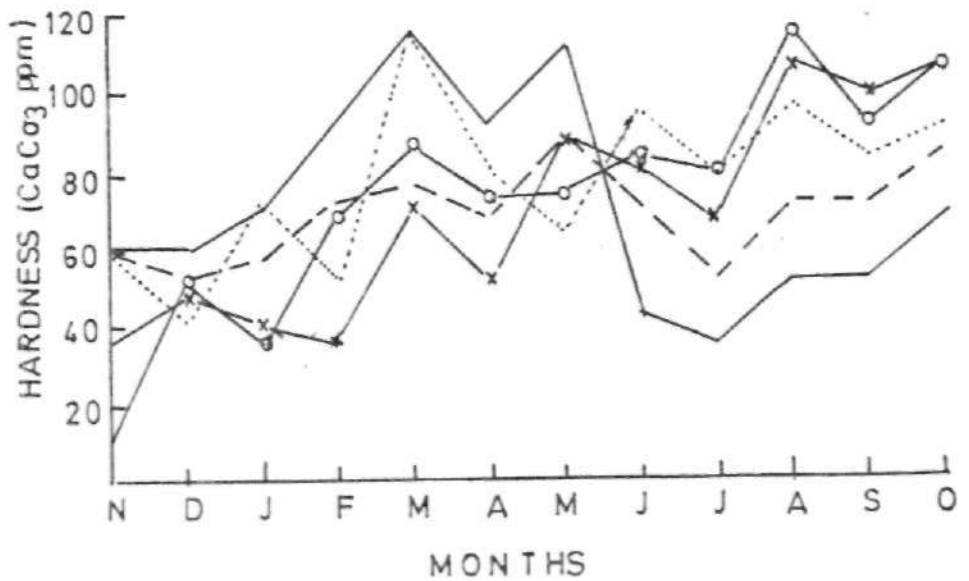


FIG.7 MONTHL VARIATION IN CHLORIDE ION, ALKALINITY AND HARDNESS.

Table 14a

VARIATION ..WATER ALKALINITY.....

		STATIONS				
		1	2	3	4	5
General Station	$\bar{x}$	47.58	72.33	91.00	82.93	70.
Dry Season	$\bar{x}$ 74.37					
Rainy Season	$\bar{x}$ 71.20					

S.E.D. $\bar{x}$ between months .....10.8196.....

S.E.D. $\bar{x}$ between stations .....12.0594.....

S.E.D. $\bar{x}$ between seasons .....7.62704.....

S.E.D. $\bar{x}$ between season by station ....17.0546.....

		1	2	3	4	5
Station by Seasons	$\bar{x}$:					
Dry Season .		38.67	44.67	131.33	65.83	91.
Rainy Season.		56.50	100.00	50.67	99.83	49.0

Table 14b

ANALYSIS OF VARIANCE FOR .WATER ALKALINITY.....

Source of variation:	df.	ss.	Ms.	F.	s.
Replication (6).	5	17505.9	3501.18	4.013	xx
Stations (5).	4	12899.3	3224.82	3.696	xx
Seasons (2).	1	150.417	150.417	0.172	NS
Station by Seasons.	4	38354.7	9588.67	10.989	xx
Months (12).	11	57539	5230.82	7.447	xx
Residual.	34	18273.37	537.4503		
Total.	59	144722.6			

xx Highly Significant ($P < 0.01$).
x Significant ($P < 0.05$).
NS. Not Significant ($P > 0.05$).

Table 15a

VARIATION IN WATER HARDNESS (PPM. $Ca\ Co_3$)

		STATIONS				
		1	2	3	4	5
General Station	$\bar{x}$	78.20	58.00	77.33	60.67	86.33
Dry Season	$\bar{x}$ 69.87					
Rainy Season	$\bar{x}$ 71.95					

S.E.D. $\bar{x}$ between months .....9.06926.....

S.E.D. $\bar{x}$ between stations .....7.89882.....

S.E.D. $\bar{x}$ between seasons .....4.99565.....

S.E.D. $\bar{x}$ between season by station .....11.1706.....

	1	2	3	4	5
Station by Seasons $\bar{x}$:					
Dry Season .	81.333	60.667	64.00	73.33	7.00
Rainy Season.	75.07	55.33	90.67	47.33	91.33

Table 15b

ANALYSIS OF VARIANCE FOR WATER HARDNESS.....

Source of variation:	df.	ss.	Ms.	F.	s.
Replication (6).	5	7942.61	1588.52	4.243	xx
Stations (5).	4	5617.56	1404.39	3.752	xx
Seasons (2).	1	64.8958	64.8958	.173	NS
Station by Seasons.	4	5664.92	1416.23	3.783	xx
Months (12).	11	14246.9	1295.17	2.624	xx
Residual.	34	2598.71	76.4327		
Total.	59	36135.6			

** Highly Significant ($P<0.01$).
* Significant ($P<0.05$).
NS. Not Significant ($P>0.05$).

Water hardness was observed to have positive correlation with conductivity, Cl, PO_4-P, surfacewater Fe, K and Na ($P < 0.05$), with significant negative correlation between hardness and surfacewater macroinvertebrates ($P > 0.05$).

4.17 CHLORIDE:

Variation in chloride ion concentration is shown in Fig. 7 . A range of 41.00 to 161.00ppm was recorded, with the lowest value (41.00ppm) observed in station 1 in August and the highest (161.00ppm) in station 3 in July. Mean seasonal Cl concentrations (Table 16a) indicates variations between seasons. The dry and rainy seasons means were 88.57 and 103.10ppm respectively. The difference between seasons, stations, station by seasons and months were highly significant ($P < 0.01$).

The correlation between Cl and conductivity, hardness, COD, PO_4-P, surfacewater Ca, Mg, Fe; sediment Mg, Na and Fe contents was positive ($P < 0.05$). Negative correlation with water temperature, pH, dissolved solid, surfactant, surfacewater Zn, Mn; sediment Mn content Ni and photoplankton density was observed ($P < 0.05$).

Table 16a

VARIATION IN CHLORIDE ION CONCENTRATION (PPM)

		STATIONS				
		1	2	3	4	5
General Station	$\bar{x}$	90.50	77.08	111.50	106.10	94.08
Dry Season	$\bar{x}$ 88.57					
Rainy Season	$\bar{x}$ 103.10					

S.E.D. $\bar{x}$ between months ..... 6.99107 .....

S.E.D. $\bar{x}$ between stations ..... 7.8461 .....

S.E.D. $\bar{x}$ between seasons ..... 4.96231 .....

S.E.D. $\bar{x}$ between season by station ..... 11.0961 .....

	1	2	3	4	5
Station by Seasons $\bar{x}$.					
Dry Season .	55.333	68.83	113.00	130.83	74.83
Rainy Season.	125.67	85.33	110.00	81.17	113.33

Table 16b.

ANALYSIS OF VARIANCE FOR .CHLORIDE ION CONCENTRATION.....

Source of variation:	df.	ss.	Ms.	F.	s.
Replication (6).	5	7475.13	1495.03	4.048	xx
Stations (5).	4	8782.5	2195.63	5.948	xx
Seasons (2).	1	3168.27	3168.27	8.578	xx
Station by Seasons.	4	24352.9	6090.73	16.49	xx
Months (12).	11	25376	2306.91	7.866	xx
Residual.	34	14045.5	413.102		
Total.	59	60410.3			

** Highly Significant ($P < 0.01$).
* Significant ($P < 0.05$).
NS. Not Significant ($P > 0.05$).

4.18 ELECTRICAL CONDUCTIVITY:

Mean seasonal conductivity of 3.88×10^3 µmhos for dry season and 3.98×10^3 for rainy season were recorded. The highest conductivity value (8.10×10^3) was obtained in station 2 in August, while the lowest (0.04×10^3) was recorded in station 5 in December (Fig. 8.). Analysis of variance (Table 17b) reveals highly significant difference in electrical conductivity between stations, station by seasons and between months ($P < 0.01$), but no significant difference between seasons ($P > 0.05$).

Correlation between conductivity, alkalinity, hardness, Cl, COD, PO_4-P, chlorophyll 'a', K, Na, Ca, Mg, Fe, Ni of contents/surfacewater was significant and positive ($P < 0.05$). Similarly, the relationship was found to be positive with sediment Ca, K, Mg,Na concentrations, as well as the phytoplankton abundance. The correlation between conductivity and sediment pH, BOD, phenol and surfactant was negative ($P < 0.05$).

4.19 SUSPENDED SOLID:

The variation in amount of suspended solid ranged from 52.00 to 178.00mg.L^{-1} (Fig 8). Mean seasonal amount of suspended solid of 105.77mg.L^{-1} for dry season and 93.77mg.L^{-1} for rainy season were observed. The highest amount was recorded in station 2 in March and the lowest in station 5 in October.

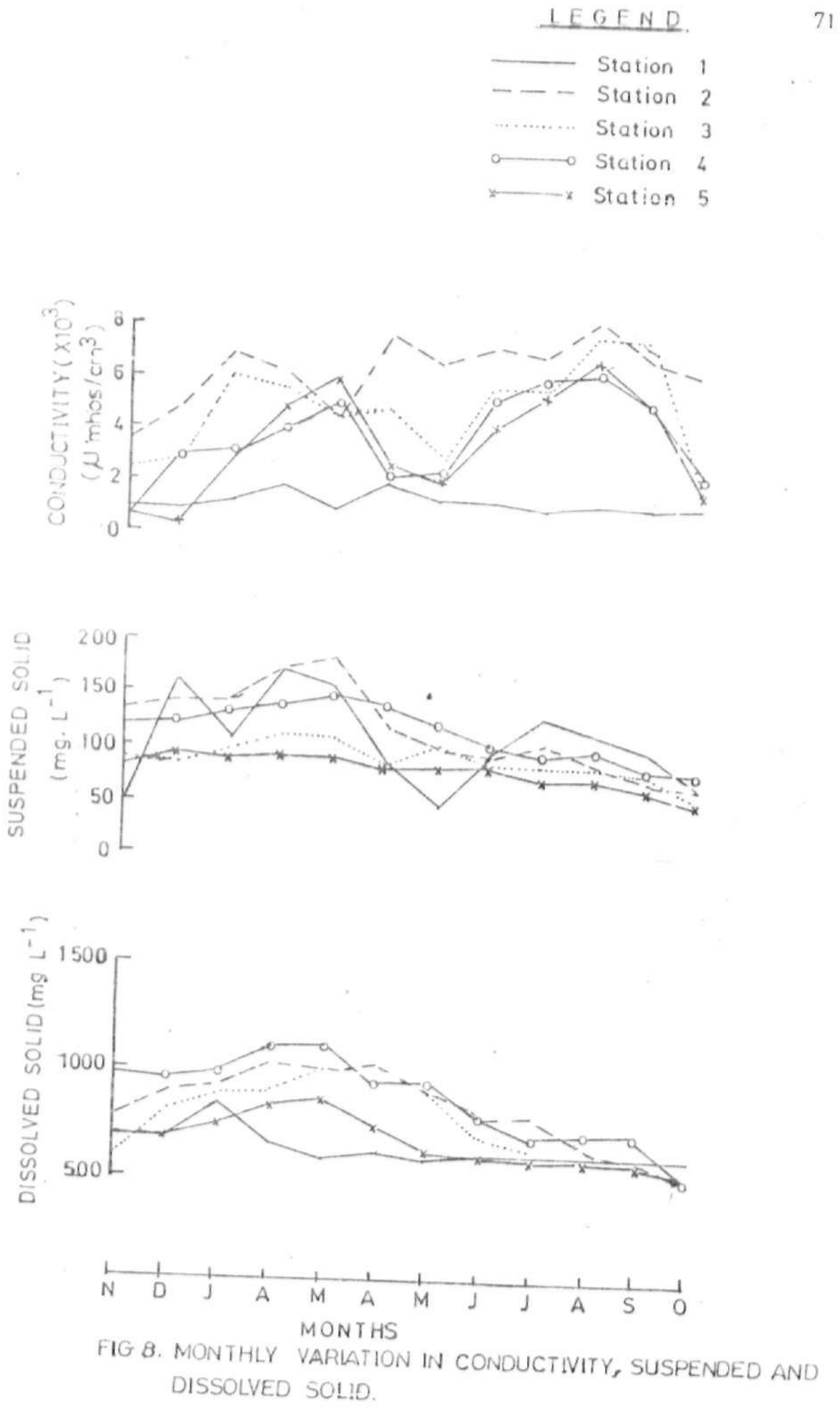


FIG 8. MONTHLY VARIATION IN CONDUCTIVITY, SUSPENDED AND DISSOLVED SOLID.

Table 17a

VARIATION IN ELECTRICAL CONDUCTIVITY ($X10^3$) (Micro mhos/cm^3)

		STATIONS				
		1	2	3	4	5
General Station	$\bar{x}$	3.01	2.18	5.10	5.06	4.28
Dry Season	$\bar{x}$ 3.88					
Rainy Season	$\bar{x}$ 3.98					

S.E.D. $\bar{x}$ between months ..... 0.143461 .....

S.E.D. $\bar{x}$ between stations ..... 0.484825 .....

S.E.D. $\bar{x}$ between seasons ..... 0.30665 .....

S.E.D. $\bar{x}$ between season by station ..... 0.685646 .....

Station by Seasons $\bar{x}$:	1	2	3	4	5
Dry Season .	1.37	1.23	5.52	6.89	4.38
Rainy Season.	4.66	3.12	4.69	3.23	4.18

Table 17b

ANALYSIS OF VARIANCE FOR ELECTRICAL CONDUCTIVITY .....

Source of variation:	df.	ss.	Ms.	F.	s.
Replication (6).	5	51.5021	10.3004	7.304	xx
Stations (5).	4	80.3651	20.0913	14.246	xx
Seasons (2).	1	0.152006	0.1520	0.108	NS
Station by Seasons.	4	85.4661	21.3665	15.15	xx
Months (12).	11	84.124	7.37491	6.507	xx
Residual.	34	17.6593	1.51939		
Total.	59	316.268			

** Highly Significant ($P \leq 0.01$).
* Significant ($P \leq 0.05$).
NS. Not Significant ($P \geq 0.05$).

Table 18a

VARIATION ..... SUSPENDED SOLID ($mg_{\circ} L^{-1}$) .....

		STATIONS				
		1	2	3	4	5
General Station	$\bar{x}$	93.67	111.67	120.67	85.92	86.5
Dry Season	$\bar{x}$ 105.77					
Rainy Season	$\bar{x}$ 93.77					

S.E.D. $\bar{x}$ between months 9.84392

S.E.D. $\bar{x}$ between stations 9.19099

S.E.D. $\bar{x}$ between seasons 5.81289

S.E.D. $\bar{x}$ between season by station 12.998

Station by Seasons $\bar{x}$:	1	2	3	4	5
Dry Season .	107.33	89.50	146.83	84.67	100.
Rainy Season.	80.00	133.83	94.50	87.17	73.5

Table 18b

ANALYSIS OF VARIANCE FOR ..... SUSPENDED SOLID .....

Source of variation:	df.	ss.	Ms.	F.	s.
Replication (6).	5	4950.93	990.187	1.954	NS
Stations (5).	4	11670.9	2917.73	5.757	xx
Seasons (2).	1	2160	2160	4.262	x
Station by Seasons.	4	16426.8	4106.71	8.103	xx
Months (12).	11	21200.8	1927.34	3.314	xx
Residual.	34	1607.27	47.2726		
Total.	59	58016.7			

** Highly Significant ($P \leq 0.01$).
* Significant ($P \leq 0.05$).
NS. Not Significant ($P \geq 0.05$).

The difference between stations, station by seasons and months was highly significant ($P < 0.01$), with significant difference between seasons ($P < 0.05$). Suspended solid showed a positive correlation with water temperature, air temperature, CO_2, COD, alkalinity, surfacewater Zn, Mn; sediment Cd and Mn ($P < 0.05$). The correlation was however found to be negative with O_2 saturation, hardness, BOD, surfacewater Cd; sediment Fe, Zn and zooplankton abundance ($P < 0.05$).

4.20 DISSOLVED SOLID:

The quantity of dissolved solid varied greatly and was between 511.00 and 9940.00mg.L^{-1}, with the lowest value in station 5 in October and the highest in station 3 in March. A high value of 1281.00mg.L^{-1} was recorded as the seasonal mean and 749.10mg.L^{-1} for the rainy season (Table 19a).

Difference between station by seasons was significant ($P < 0.05$) while the difference in dissolved solid between stations, seasons and months was insignificant ($P > 0.05$). Correlation between dissolved solid and water temperature, BOD; and surfacewater Mn was positive ($P < 0.05$).

Variation in optical density (OD) of the surface water (Fig. 86) indicates a peak in OD during the onset of rainy season.

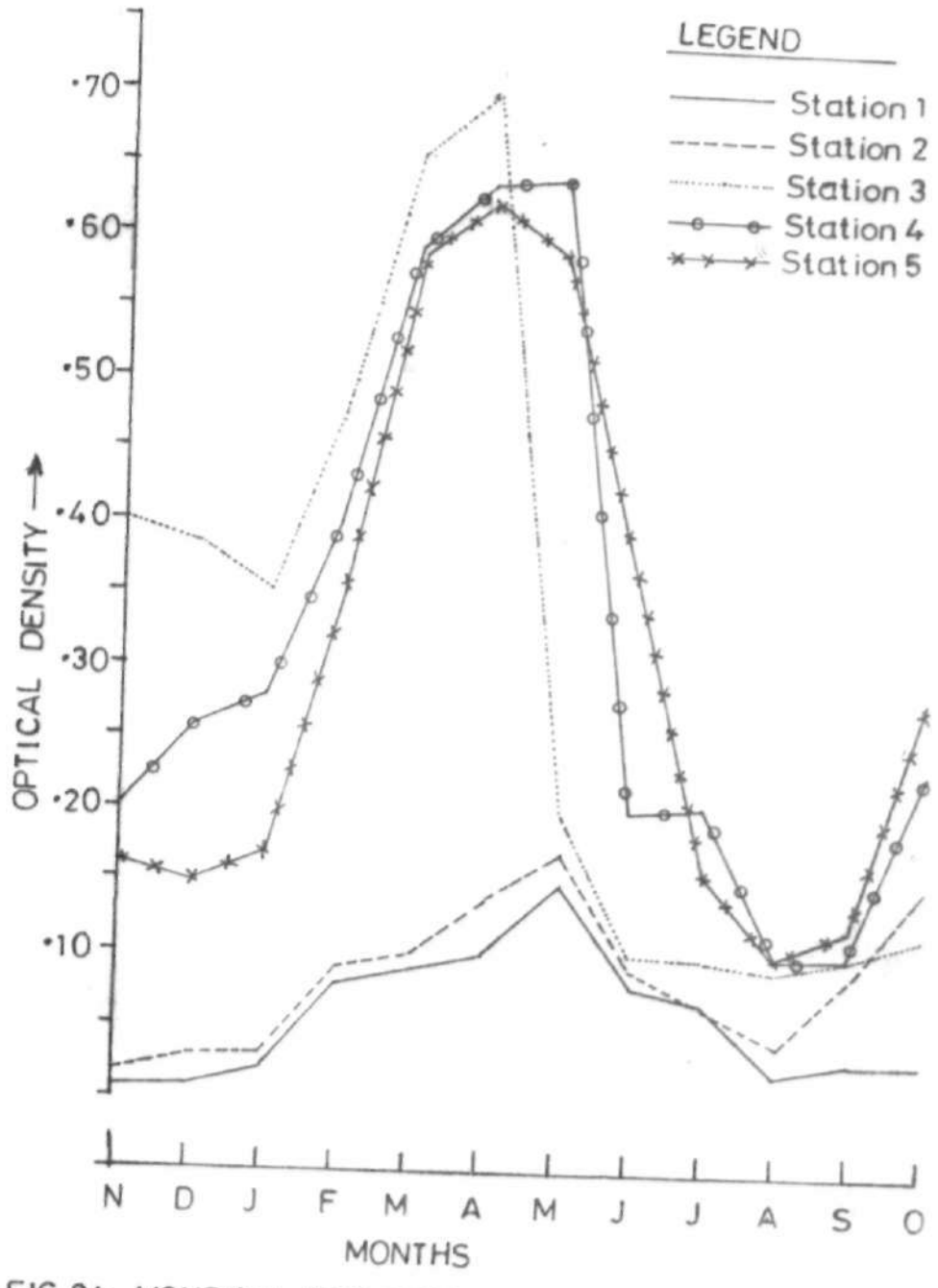


FIG 8b. MONTHLY VARIATION IN OPTICAL DENSITY OF THE SURFACEWATER OF ROMI STREAM

Table 19a

VARIATION IN DISSOLVED SOLID ($mg_{\circ} L^{-1}$) .....

		STATIONS				
		1	2	3	4	5
General Station	$\bar{x}$	671.58	820.92	746.01	743.17	2095.
Dry Season	$\bar{x}$ 1281.57					
Rainy Season	$\bar{x}$ 749.30					

S.E.D. $\bar{x}$ between months 616.914

S.E.D. $\bar{x}$ between stations 590.379

S.E.D. $\bar{x}$ between seasons 373.389

S.E.D. $\bar{x}$ between season by station 834.922

	1	2	3	4	5
Station by Seasons $\bar{x}$:					
Dry Season .	677.50	619.17	779.367	717.50	3614.
Rainy Season.	665.67	1022.67	712.67	768.83	576.67

Table 19b.

ANALYSIS OF VARIANCE FOR DISSOLVED SOLID .....

Source of variation:	df.	ss.	Ms.	F.	s.
Replication (6).	5	1.12169E+07	2.24337E+06	1.073	NS
Stations (5).	4	1.76319E+07	4.40797 E+06	2.108	NS
Seasons (2).	1	4.24967 E+06	4.24967 E+06	2.032	NS
Station by Seasons.	4	2.39426 E+07	5.99564 E +06	2.868	*
Months (12).	11	3.3955E+07	2.8505E +06	1.248	NS
Residual.	34	62+52.43 E+03			
Total.	59	1.51149E +08			

** Highly Significant ($P < 0.01$).
* Significant ($P < 0.05$).
NS. Not Significant ($P > 0.05$).

4.20.0 METALS

Metal concentrations in both surfacewater and sediment samples were studied. The values for, the analysis and the relationships of four alkaline-earth metals (K, Ca, Na, Mg) and eight trace elements (Pb, Fe, Cu, Zn, Mn, Cr, Ni and Cd) in surface water and sediment are presented on Tables 20-23. The means for the dry and rainy seasons are presented in Table 23q.

4.20.1 ALKALINE-EARTH METALS IN SURFACEWATER:

Alkaline-earth metals in surfacewater were found to show small variations throughout the year (Fig. 9).

4.20.1.2 POTASSIUM:

The monthly variations in the concentrations of K is presented in Fig. 9 . , while Table 20a reveals dry seasonal mean of 3.13ppm and rainy season mean of 4.15ppm. Highly significant difference was recorded between stations, seasons, months ($P < 0.01$) with significant difference with respect to station by season ($P < 0.05$).

Positive correlation between surfacewater K and conductivity, alkalinity, PO_4-P, chlorophyll 'a', surfacewater Ca, Mg, Na, Fe, Zn, Mn; sediment K, Ca, Mg, Na, Fe, Zn, Cd, macroinvertebrates in surfacewater, and zooplankton density was observed ($P < 0.05$). The relationship was however negative with sediment pH, Cl, H_2S, Oil, phenol, surfactant, surfacewater Pb, Cu, Cd; sediment Cu and phytoplankton abundance.

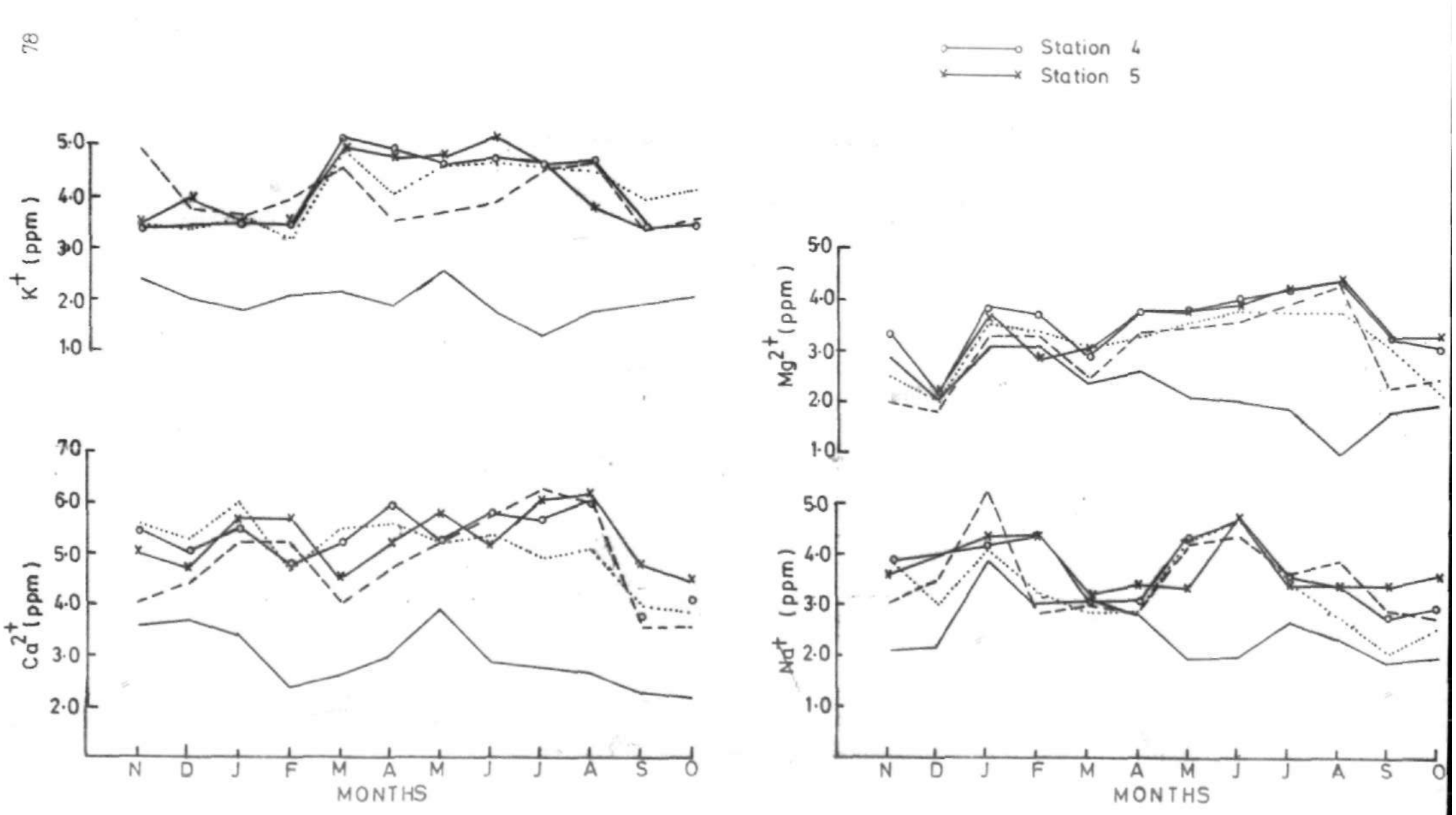


FIG. 9 MONHLY VARIATION IN ALKALINE EARTH METAL CONCENTRATIONS IN SURFACE-WATER OF ROMI STREAM, KADUNA.

Table 20a

VARIATION IN CONCENTRATIONS OF SURFACE WATER POTASSIUM (PPM)

		STATIONS				
		1	2	3	4	5
General Station	$\bar{x}$	3.11	2.96	4.20	3.84	4.09
Dry Season	$\bar{x}$ 3.13					
Rainy Season	$\bar{x}$ 4.15					

S.E.D. $\bar{x}$ between months ..... .204951 .....

S.E.D. $\bar{x}$ between stations ..... .311852 .....

S.E.D. $\bar{x}$ between seasons ..... .197232 .....

S.E.D. $\bar{x}$ between season by station ..... .441025 .....

	1	2	3	4	5
Station by Seasons $\bar{x}$:					
Dry Season .	2.23	1.92	4.06	3.63	3.00
Rainy Season.	3.99	4.00	4.33	4.04	4.38

Table 20b.

ANALYSIS OF VARIANCE FOR SURFACE WATER POTASSIUM .....

Source of variation:	df.	ss.	Ms.	F.	s.
Replication (6).	5	1.98993	.397986	.682	NS
Stations (5).	4	15.4714	3.86786	6.629	xx
Seasons (2).	1	15.657	15.657	26.833	xx
Station by Seasons.	4	8.47292	2.11823	3.63	x
Months (12).	11	18.7713	1.70648	6.77	xx
Residual.	34	7.48665	0.22019		
Total.	59	67.8492			

** Highly Significant ($P < 0.01$).
* Significant ($P < 0.05$).
NS. Not Significant ($P > 0.05$).

4.20.1.3 CALCIUM:

The concentration of Ca was higher during the rainy season than in dry season (Table 20c). Highly significant difference between stations, seasons, station by season and months was recorded ($P < 0.01$). The relationship with conductivity, alkalinity, Cl, COD, PO_4-P, chlorophyll 'a', surfacewater K, Mg, Na, Fe, Mn; sediment Ca, Mg, Na, Fe; macroinvertebrates in surfacewater, zooplankton and benthic macroinvertebrates was positive ($P < 0.05$). Negative correlation was observed between Ca concentration in surfacewater and sediment pH, oil, phenol, surfactant, surfacewater Pb, Cu, Cd; sediment Cu, and phytoplankton density.

4 .20.1.4 MAGNESIUM:

Variation in surfacewater Mg (Fig. 9) indicates a concentration range of 1.08 to 4.42ppm. The mean dry season concentration (2.69ppm) was found to be relatively lower than rainy season (3.46ppm). Highly significant difference was observed between stations, seasons, station by seasons and months ($P < 0.01$).

Negative correlation between surfacewater Mg and sediment pH, H_2S, oil, phenol, surfacewater Pb, Cd; sediment Cu, Cr and Ni was observed ($P < 0.05$), with significant positive correlation with conductivity, DO, Cl, COD, PO_4-P, chlorophyll 'a', surfacewater K, Ca, Na, Fe; sediment K, Ca, Na, and zooplankton density ($P < 0.05$).

Table 20c

VARIATION IN CONCENTRATIONS OF SURFACE WATER CALCIUM (PPM)

		STATIONS				
		1	2	3	4	5
General Station	$\bar{x}$	3.94	4,08	4.86	5.14	5.4
Dry Season	$\bar{x}$ 4.22					
Rainy Season	$\bar{x}$ 5.17					

S.E.D. $\bar{x}$ between months .205694

S.E.D. $\bar{x}$ between stations .235538

S.E.D. $\bar{x}$ between seasons .148967

S.E.D. $\bar{x}$ between season by station .333101

		1	2	3	4	5
Station by Seasons	$\bar{x}_i$					
Dry Season .		3.13	2.815	4.59	5.10	5.45
Rainy Season.		4.76	5.34	5.13	5.18	5.43

Table 20d

ANALYSIS OF VARIANCE FOR SURFACE WATER CALCIUM

Source of variation:	df.	ss.	Ms.	F.	s.
Replication (6).	5	9.38977	1.87795	5.642	xx
Stations (5).	4	20.6888	5.17221	15.538	xx
Seasons (2).	1	13.566	13.566	40.755	xx
Station by Seasons.	4	14.4721	3.61803	10.869	xx
Months (12).	11	16.0371	1.45792	5.743	xx
Residual.	34	1.05797	.031116		
Total.	59	75.21174			

** Highly Significant ($P < 0.01$).
* Significant ($P < 0.05$).
NS. Not Significant ($P > 0.05$).

Table 20e

VARIATION IN CONCENTRATIONS OF SURFACE WATER MAGNESIUM (PPM)

		STATIONS				
		1	2	3	4	5
General Station	$\bar{x}$	2.97	2.50	3.29	3.22	3.4
Dry Season	$\bar{x}$ 2.69					
Rainy Season	$\bar{x}$ 3.46					

S.E.D. $\bar{x}$ between months ..... .202588 .....

S.E.D. $\bar{x}$ between stations ..... .21169 .....

S.E.D. $\bar{x}$ between seasons ..... .133884 .....

S.E.D. $\bar{x}$ between season by station ..... .299375 .....

Station by Seasons $\bar{x}$:	1	2	3	4	5
Dry Season .	2.52	1.83	2,74	3.37	3.00
Rainy Season.	3.41	3.17	3.84	3.073	3.84

Table 20f

ANALYSIS OF VARIANCE FOR SURFACE WATER MAGNESIUM

Source of variation:	df.	ss.	Ms.	F.	s.
Replication (6).	5	4.4543	.89086	3,313	x
Stations (5).	4	6.36034	1.59008	5.914	xx
Seasons (2).	1	8.90891	8.90891	33.134	xx
Station by Seasons.	4	4.75179	1.18795	4.418	xx
Months (12).	11	11.952	1.08655	4.412	xx
Residual.	34	4.89915	0.14409		
Total.	59	36.5747			

** Highly Significant ($P < 0.01$).
* Significant ($P < 0.05$).
NS. Not Significant ($P > 0.05$).

4.20.1.5 SODIUM:

The relationship between surfacewater Na and conductivity, alkalinity, surfacewater Mg, Zn, Mn; COD, PO_4-P, chlorophyll 'a' surfacewater K, Ca, Fe; sediment K, Ca and Mg was observed to be positive, with significant negative correlation between sediment pH, H_2S, Oil, phenol, surfactant, surfacewater Cu, Cd and sediment Cu ($P< 0.05$).

The relationship was also found to be positive between surfacewater Na concentration and zooplankton, macroinvertebrates in surfacewater and benthic macroinvertebrates ($P< 0.05$). Highly significant difference between stations, seasons and months was recorded ($P< 0.01$), with significant difference with station by seasons ($P< 0.05$).

Table 20g

VARIATION IN CONCENTRATIONS OF SURFACE WATER SODIUM (PPM)

		STATIONS				
		1	2	3	4	5
General Station	$\bar{x}$	3.11	2.96	3.54	3.73	3.63
Dry Season	$\bar{x}$ 3.11					
Rainy Season	$\bar{x}$ 3.68					

S.E.D. $\bar{x}$ between months ..... .198003

S.E.D. $\bar{x}$ between stations ..... .23356

S.E.D. $\bar{x}$ between seasons ..... .147717

S.E.D. $\bar{\bar{x}}$ between season by station ..... .330304

	1	2	3	4	5
Station by Seasons $\bar{x}_1$					
Dry Season .	2.87	2.16	3.43	3.66	3.43
Rainy Season.	3.35	3.76	3.64	3.80	3.84

Table 20h

ANALYSIS OF VARIANCE FOR SURFACE WATER SODIUM

Source of variation:	df.	ss.	Ms.	F.	s.
Replication (6).	5	9.406	1.8812	5.748	xx
Stations (5).	4	5.52702	1.38175	4.222	xx
Seasons (2).	1	4.811	4.811	14.699	xx
Station by Seasons.	4	4.18489	1.04622	3.196	x
Months (12).	11	15.51	1.41	5.089	xx
Residual.	34	0.78141	0.02298		
Total.	59	40.22032			

** Highly Significant ($P<0.01$).
* Significant ($P<0.05$).
NS. Not Significant ($P>0.05$).

4.20.2.0 ALKALINE-EARTH METALS IN SEDIMENT:

Gradual increase in concentrations of K and Na with increasing period of drought was recorded, with maxima attained at the early part of rainy season. The concentrations of Ca and Mg were however noted to show little variation throughout the year (Fig. 10).

4.20.2.1 POTASSIUM:

Highly significant variation in the level of sediment K was observed between months ($P < 0.01$). The differences between stations, seasons and station by seasons were insignificant ($P > 0.05$). A range of 9.100 to 595.00ppm was recorded, with dry season mean of 339.47ppm and rainy season mean of 385.10ppm (Table 21a).

Positive correlation was recorded between K concentration in sediment and water pH, conductivity, hardness, COD, PO_4-P, surfacewater K, Mg, Fe, Zn, Cr; sediment Ca, Mg, Na, Zn, and Pb ($P < 0.05$). The relationship with H_2S, surfactant; sediment Mn, Cr, and macroinvertebrates in surfacewater was negative ($P < 0.05$).

4.20.2.2 CALCIUM:

Concentration of Ca concentration in sediment was between 206.00ppm and 601.00ppm. Mean seasonal concentrations of 383.47ppm for dry season and 448.00ppm for rainy season were recorded (Table 21c). Correlation between Ca in sediment and conductivity, alkalinity, COD, PO_4-P; surfacewater Ca, K,

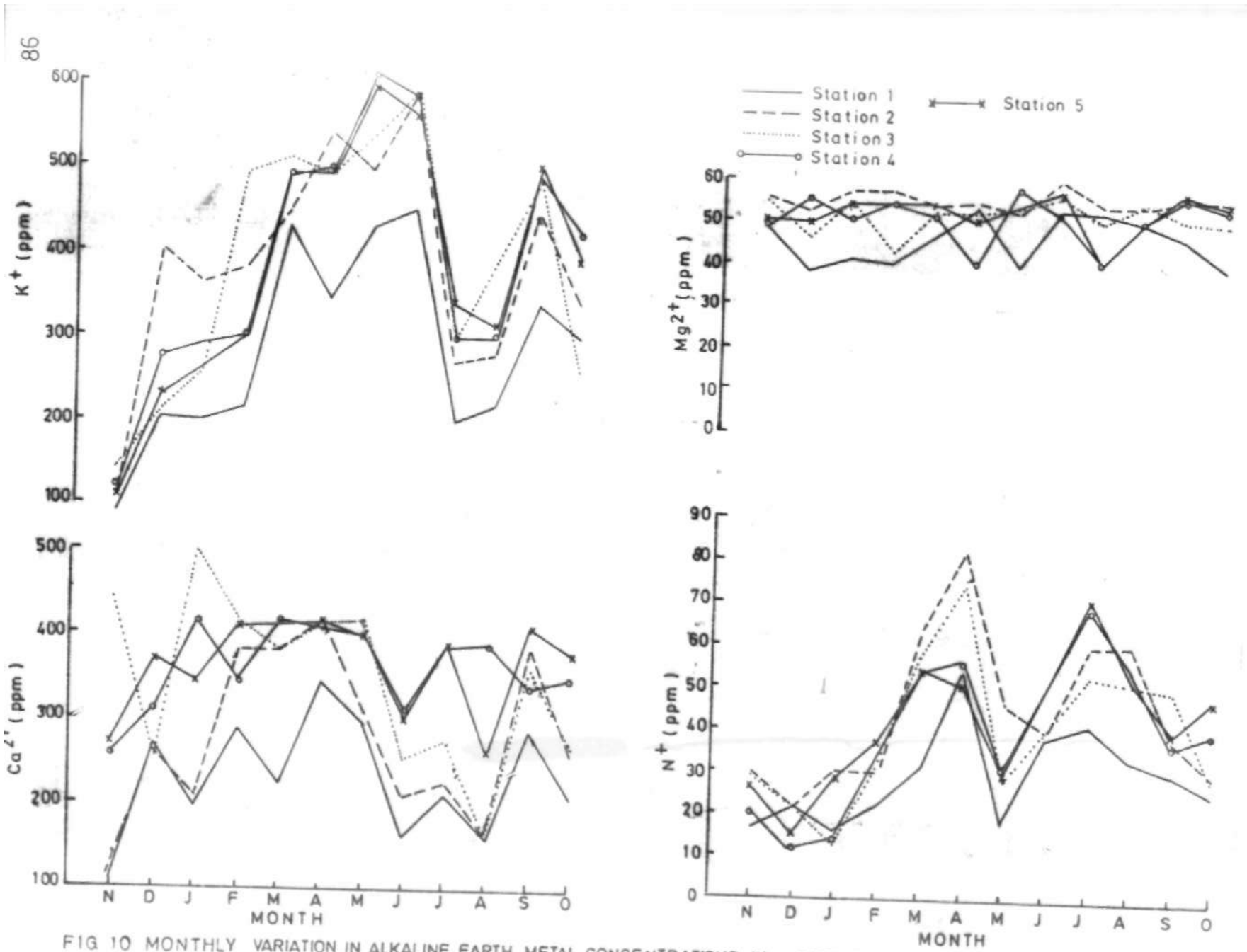


FIG 10 MONTHLY VARIATION IN ALKALINE EARTH METAL CONCENTRATIONS IN SEDIMENT OF ROMI STREAM, KADUNA

Table 21a

VARIATION ..IN CONCENTRATIONS OF POTASSIUM IN SEDIMENT (PPM)

		STATIONS				
		1	2	3	4	
General Station	$\bar{x}$	327.75	326.17	403.33	358.[illegible]	[illegible]
Dry Season	$\bar{x}$ 339.47					
Rainy Season	$\bar{x}$ 385.10					

S.E.D. $\bar{x}$ between months .....19.0198.....

S.E.D. $\bar{x}$ between stations .....51.0704.....

S.E.D. $\bar{x}$ between seasons .....32.2998.....

S.E.D. $\bar{x}$ between season by station .....72.2244.....

Station by Seasons $\bar{x}$:	1	2	3	4	5
Dry Season .	247.50	323.50	372.50	403.33	350.
Rainy Season.	408.00	328.83	434.17	314.00	440.

Table 21b

ANALYSIS OF VARIANCE FOR .POTASSIUM.IN.SEDIMENT.....

Source of variation:	df.	ss.	Ms.	F.	s.
Replication (6).	5	249778	49959.7	3.192	x
Stations (5).	4	63581.8	15895.5	1.016	[illegible]
Seasons (2).	1	31236	31236	1.996	NS
Station by Seasons.	4	105780	26444.9	1.69	NS
Months (12).	11	969877	88170.6	40.622	xx
Residual.	34	265662.0	7813.61		
Total.	59	1685914			

** Highly Significant ($P < 0.01$).
* Significant ($P < 0.05$).
NS. Not Significant ($P > 0.05$).

Table 21c

VARIATION CONCENTRATIONS OF CALCIUM IN SEDIMENT (PPM)

		STATIONS				
		1	2	3	4	5
General Station	$\bar{x}$					
Dry Season	$\bar{x}$ 383.44	364.42	391.00	429.08	414.83	479.33
Rainy Season	$\bar{x}$ 448.00					

S.E.D. $\bar{x}$ between months 23.8646

S.E.D. $\bar{x}$ between stations 29.3785

S.E.D. $\bar{x}$ between seasons 18.5812

S.E.D. $\bar{x}$ between season by station 41.5489

	1	2	3	4	5
Station by Seasons $\bar{x}$:					
Dry Season .	338.50	322.00	395.33	359.17	502.33
Rainy Season.	390.33	460.00	462.83	470.50	456.33

Table 21d

ANALYSIS OF VARIANCE FOR CALCIUM IN SEDIMENT

Source of variation:	df.	ss.	Ms.	F.	s.
Replication (6).	5	54893.9	10978.8	2.12	NS
Stations (5).	4	89629.6	22407.4	4.327	xx
Seasons (2).	1	62468.3	62468.3	12.062	xx
Station by Seasons.	4	59925.9	14981.5	2.893	x
Months (12).	11	180592	16417.5	4.804	xx
Residual.	34	52460.3	1542.95		
Total.	59	499970			

** Highly Significant ($P < 0.01$).
* Significant ($P < 0.05$).
NS. Not Significant ($P > 0.05$).

Mg, Na, Fe, Zn, Mn, Cr, Ni, macroinvertebrates in surfacewater, zooplankton and benthic macroinvertebrate population was found to be positive ($P < 0.05$), with negative correlation between H_2S, oil, phenol, surfactant and sediment Cu concentrations. A highly significant difference between seasons, stations and months was observed ($P < 0.01$). Station by seasonal difference was significant ($P < 0.05$).

4.20.2.3 MAGNESIUM:

Means of 50.78ppm and 51.92ppm were recorded for the dry and rainy seasons respectively. Analysis of variance (Table 21e) shows highly significant difference between stations, seasons and months ($P < 0.01$). The difference was also found to be significant with respect to station by seasons ($P < 0.05$).

The correlation with conductivity, Cl, COD, PO_4-P; surfacewater K, Ca, Na, Cr, Ni, Cd; sediment K was positive ($P < 0.05$). Negative correlation between sediment Mg, sediment pH, DO, and phytoplankton density was recorded ($P < 0.05$).

4.20.2.4 SODIUM:

The mean concentrations of Na in sediment were 36.69 and 40.58ppm for the dry and rainy seasons respectively. The mean concentrations vary significantly between months ($P < 0.01$), but there was no significant difference between stations, seasons and station by seasons ($P < 0.05$).

Table 21e

VARIATION IN CONCENTRATIONS OF MAGNESIUM IN SEDIMENT (PPM)

		STATIONS				
		1	2	3	4	
General Station	$\bar{x}$	48.99	48.68	53.57	54.05	51.
Dry Season	$\bar{x}$ 50.78					
Rainy Season	$\bar{x}$ 51.92					

S.E.D. $\bar{x}$ between months ..... 1.87235 .....

S.E.D. $\bar{x}$ between stations .....2.0026.....

S.E.D. $\bar{x}$ between seasons .....1.26655.....

S.E.D. $\bar{x}$ between season by station .....2.8321.....

	1	2	3	4	
Station by Seasons $\bar{x}_s$					
Dry Season .	44,84	47.44	55.22	55.92	50.4
Rainy Season.	53.15	49.92	51.92	52.18	52.4

Table 21f

ANALYSIS OF VARIANCE FOR MAGNESIUM IN SEDIMENT .....

Source of variation:	df.	ss.	Ms.	F.	s.
Replication (6).	5	60.5462	12.1092	.503	NS
Stations (5).	4	299.168	74.7919	3.108	x
Seasons (2).	1	19.7112	19.7112	.819	NS
Station by Seasons.	4	292.294	73.0735	3.037	x
Months (12).	11	273.141	1094,04	1,18	NS
Residual.	34	809.6696	23.8138		
Total.	59	1754.53			

** Highly Significant ($P < 0.01$).
* Significant ($P < 0.05$).
NS. Not Significant ($P > 0.05$).

Table 21g

VARIATION IN CONCENTRATIONS OF SODIUM IN SEDIMENT (PPM)

		STATIONS				
		1	2	3	4	5
General Station	$\bar{x}$	33.47	31.57	45.09	40.55	42.
Dry Season	$\bar{x}$ 36.69					
Rainy Season	$\bar{x}$ 40.53					
S.E.D. $\bar{x}$ between months		2.92449				
S.E.D. $\bar{x}$ between stations		6.01839				
S.E.D. $\bar{x}$ between seasons		3.80637				
S.E.D. $\bar{x}$ between season by station		8.51129				

	1	2	3	4	5
Station by Seasons $\bar{x}_1$					
Dry Season .	26.73	31.33	43.08	46.05	36.27
Rainy Season.	40.20	31.80	47.10	35.05	48.77

Table 21h

ANALYSIS OF VARIANCE FOR SODIUM IN SEDIMENT

Source of variation:	df.	ss.	Ms.	F.	s.
Replication (6).	5	3112.39	622.478	2.864	*
Stations (5).	4	1543.6	410.901	1.891	NS
Seasons (2).	1	226.204	226.204	1.041	NS
Station by Seasons.	4	1196.16	299.039	1.376	NS
Months (12).	11	12034.4	1094.04	21.319	xx
Residual.	34	2254.754	66.3112		
Total.	59	20467.75			

** Highly Significant ($P < 0.01$).
* Significant ($P < 0.05$).
NS. Not Significant ($P > 0.05$).

Significant positive correlation was established between sediment Na concentration and sediment pH, DO, hardness, Cl, COD, PO_4-P, chlorophyll 'a', surfactant, surfacewater K, Ca, Mg, Fe; sediment Fe and Cd concentrations. The relationship was negative with CO_2, Mn in sediment, macroinvertebrates in surfacewater and phytoplankton density ($P< 0.05$).

4.20.3.0 HEAVY METALS IN SURFACEWATER:

The surfacewater Fe maintained gradual increase towards the period of rainy season with a peak in the later part of rainy season (Fig. 11). Concentrations of Zn and Mn were however on the increase with dry season and attained maxima at later part of dry season, followed by a gradual decline at late rainy season. Pb, Cu, and Ni showed gradual decline as dry season progressed with minima in the later period of rainy season. The concentration of Cd remained fairly stable throughout the period of dry season, with a peak in late rainy season (Fig. 11).

4.20.3.1 LEAD:

The lowest consentration of surfacewater Pb recorded was 0.09ppm in station 3 in November, and the highest (1.83ppm) in station 4 in September. Mean dry season concentration of 0.98ppm and 0.92ppm for rainy season were recorded (Table 22a).

Analysis of variance (Table 22b) shows highly significant variation in mean level of surfacewater Pb between months ($P < 0.01$), while the differences between stations, seasons and station by seasons were not significant ($P > 0.05$).

Correlation between Pb and Cu, Cr, Ni, Cd in surfacewater sediment Pb, Cu, and Ni was significant and positive ($P < 0.05$), with negative correlation between water temperature, O_2 saturation, chlorophyll 'a', surfacewater K, Ca, Mg, Na and surfacewater Pb.

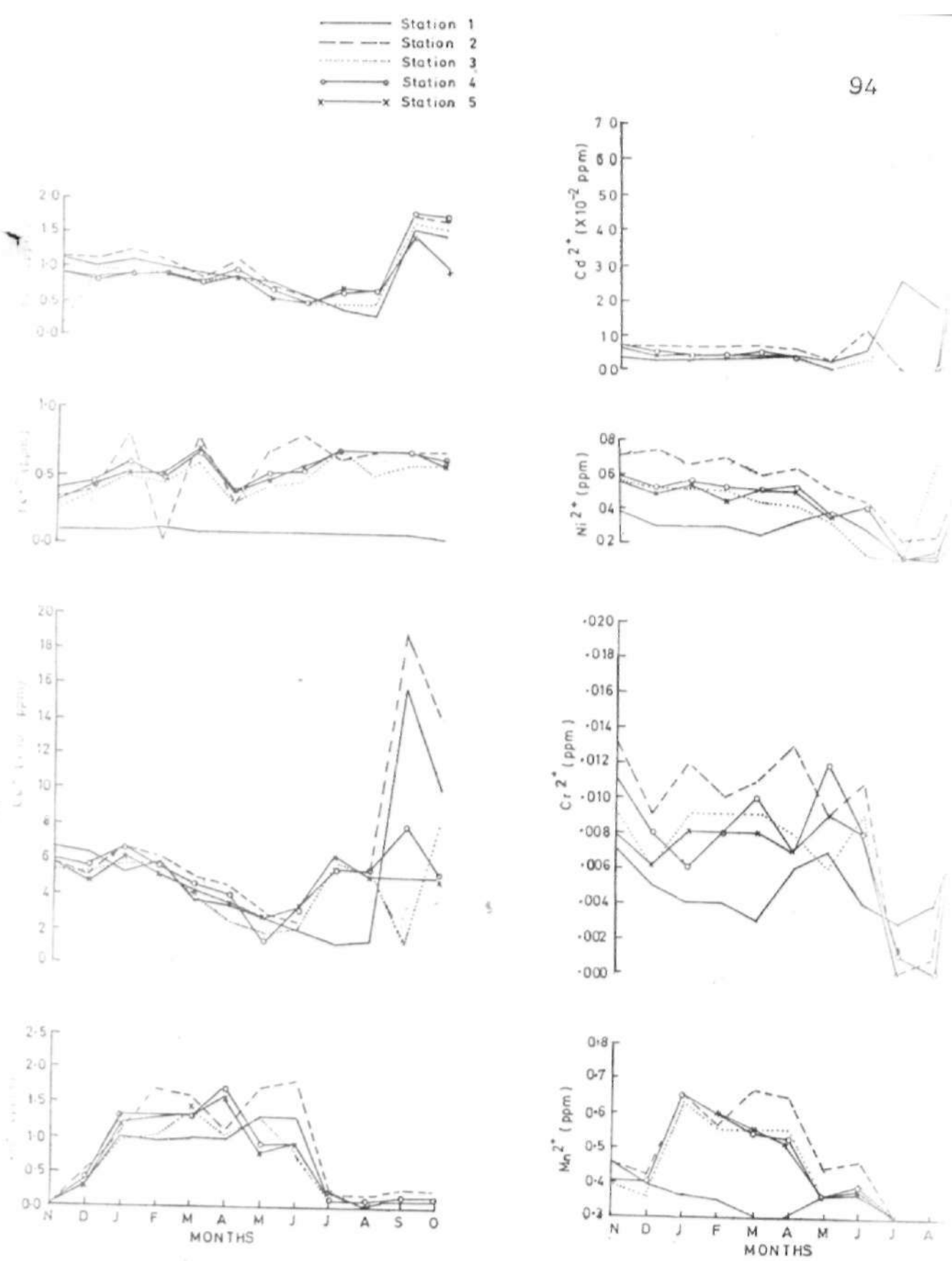


FIG. 11. MONTHLY VARIATION IN METAL CONCENTRATIONS IN SURFACE-WATE
OF ROMI STREAM, KADUNA

Table 22a

VARIATION IN CONCENTRATIONS OF SURFACE WATER LEAD (PPM)

		STATIONS				
		1	2	3	4	5
General Station	$\bar{x}$	0.98	0.90	1.07	0.96	0.81
Dry Season	$\bar{x}$ 0.98					
Rainy Season	$\bar{x}$ 0.92					

S.E.D. $\bar{x}$ between months .....6.76633E-02.....

S.E.D. $\bar{x}$ between stations .....134439.....

S.E.D. $\bar{x}$ between seasons .....8.50268E-02.....

S.E.D. $\bar{x}$ between season by station .....190126.....

		1	2	3	4	5
Station by Seasons	$\bar{x}_i$	1.04	0.91	1.11	1.05	0.78
Dry Season .		0.94	0.90	0.03	0.87	0.84
Rainy Season.						

Table 22b

ANALYSIS OF VARIANCE FOR .....

Source of variation:	df.	ss.	Ms.	F.	s.
Replication (6).	5	3.06131	.612263	5.646	xx
Stations (5).	4	.456824	.114206	1.053	NS
Seasons (2).	1	.056427	.056427	0.52	NS
Station by Seasons.	4	.10056	.025139	0.232	NS
Months (12).	11	6.92799	.62892	22.937	xx
Residual.	34	2.04804	.06024		
Total.	59	12.6511			

** Highly Significant ($P < 0.01$).
* Significant ($P < 0.05$).
NS. Not Significant ($P > 0.05$).

4.20.3.2 IRON:

Surfacewater Fe showed highly significant difference between stations, seasons, station by season and months ($P < 0.01$). The highest concentration of 0.84ppm was recorded in January in station 2, and the lowest value of 0.06ppm in station 1 in October. The mean dry season concentration (0.36ppm) was slightly lower than for the rainy season (0.57ppm).

Surfacewater Fe showed a significant positive correlation with conductivity hardness, Cl, COD, PO_4-P, chlorophyll 'a', sediment and surfacewater K, Ca, Mg, Na; surfacewater Cr; zooplankton density ($P < 0.05$). A negative correlation was obtained with water temperature, sediment pH, H_2S, phenol, surfactant, and phytoplankton density ($P < 0.05$).

4.20.3.3 COPPER:

No significant difference in mean Cu concentration in surfacewater was observed between stations, seasons, and station by season ($P > 0.05$). The difference was however highly significant between months ($P < 0.01$). Mean seasonal variation (Table 22e) reveals fairly uniform concentrations for both dry and rainy seasons, with highest concentration (0.81ppm) at station 3 in October.

Significant positive correlation with surfacewater Pb, Mn, Ni; sediment Pb, Cu and Fe was recorded ($P < 0.05$). The relationship with water temperature, sediment pH, O_2 saturation, chlorophyll 'a', surfacewater K, Ca, Na, Zn and phytoplankton density was found to be negative ($P < 0.05$).

Table 22c

VARIATION IN CONCENTRATIONS OF SURFACE WATER IRON.(PPM)

		STATIONS				
		1	2	3	4	5
General Station	$\bar{x}$	0.35	0.30	0.56	0.60	0.53
Dry Season	$\bar{x}$ 0.36					
Rainy Season	$\bar{x}$ 0.57					

S.E.D. $\bar{x}$ between months ..... 4.80487E - 02 .....

S.E.D. $\bar{x}$ between stations ..... 4.7748E - 02 .....

S.E.D. $\bar{x}$ between seasons ..... 3.01964E - 02 .....

S.E.D. $\bar{x}$ between season by station ..... 6.75213E - 02 .....

	1	2	3	4	5
Station by Seasons $\bar{x}$:					
Dry Season .	0.12	0.097	.46	0.7	0.43
Rainy Season.	0.58	0.51	0.68	0.49	0.64

Table 22d

ANALYSIS OF VARIANCE FOR SURFACE WATER IRON.....

Source of variation:	df.	ss.	Ms.	F.	s.
Replication (6).	5	.316335	.063267	4.626	xx
Stations (5).	4	.837407	.209352	15.306	xx
Seasons (2).	1	.655215	.655215	47.905	xx
Station by Seasons.	4	.876727	.219182	16.025	xx
Months (12).	11	.720365	.06549	4.727	xx
Residual.	34	.104879	.003085		
Total.	59	3.51092			

** Highly Significant ($P < 0.01$).
* Significant ($P < 0.05$).
NS. Not Significant ($P > 0.05$).

Table 22e

VARIATION IN CONCENTRATIONS OF SURFACE WATER COPPER (PPM)

		STATIONS				
		1	2	3	4	5
General Station	$\bar{x}$	0.06	0.05	0.05	0.07	0.05
Dry Season	$\bar{x}$ 0.06					
Rainy Season	$\bar{x}$ 0.05					

S.E.D. $\bar{x}$ between months .....8.78975E.-.03.....

S.E.D. $\bar{x}$ between stations .....1.28482E.-.02.....

S.E.D. $\bar{x}$ between seasons .....8.1259E.-.03.....

S.E.D. $\bar{x}$ between season by station .....1.81701E.-.02.....

		1	2	3	4	5
Station by Seasons	$\bar{x}_i$					
Dry Season .		0.05	0.06	0.06	0.08	0.05
Rainy Season.		0.06	0.05	0.05	0.05	0.05

Table 22f

ANALYSIS OF VARIANCE FOR SURFACE WATER COPPER.....

Source of variation:	df.	ss.	Ms.	F.	s.
Replication (6).	5	.01563	.002133	2.335	NS
Stations (5).	4	.002584	.000646	.652	NS
Seasons (2).	1	.000799	.000799	.807	NS
Station by Seasons.	4	.003412	.000835	.843	NS
Months (12).	11	.038868	.00353	7.622	xx
Residual.	34	.001628	.000048		
Total.	59	.06285			

** Highly Significant ($P < 0.01$).
* Significant ($P < 0.05$).
NS. Not Significant ($P > 0.05$).

4.20.3.4 ZINC:

Seasonal means of 0.76ppm for dry season and 0.66ppm for rainy season were recorded. Highly significant difference between months was observed ($P < 0.01$), without significant difference between stations, seasons and station by season ($P > 0.05$). Positive correlation was established between surfacewater Zn and water temperature, water pH suspended solid, CO_2, COD, alkalinity; surfacewater K, Na, Mn; sediment K and Ca ($P < 0.05$). Negative correlationship with O_2 saturation, Cl, H_2S, surfacewater Cu, Cd; sediment Fe and Cr was recorded ($P < 0.05$).

4.20.3.5 MANGANESE:

The lowest level of 0.04ppm was recorded in station in August, while the highest (0.92ppm) was recorded in station 2 in March (Fig.11). Mean seasonal concentrations were 0.43ppm for dry season and 0.38ppm for the rainy season (Table 22i). Analysis of variance (Table 22j) indicates highly significant difference in mean concentrations of Mn between months, station by season ($P < 0.01$), with significant difference between stations ($P < 0.05$). The difference between seasons was insignificant ($P > 0.05$).

Significant positive correlation was established between water temperature, suspended solid, dissolved solid, CO_2, COD, alkalinity; surfacewater K, Ca, Na, Zn, Cr, Ni; sediment Ca, Mn, Ni, Cd and Mn concentration in surfacewater ($P < 0.05$), with negative correlation between O_2 saturation, hardness, Cl, PO_4-P, H_2S, oil, phenol; surfacewater Cd; sediment Fe, and phytoplankton density ($P < 0.05$).

Table 22g

VARIATION IN CONCENTRATIONS OF SURFACE WATER ZINC (PPM)

		STATIONS				
		1	2	3	4	5
General Station	$\bar{x}$	0.58	0.76	0.72	0.87	0.64
Dry Season	$\bar{x}$ 0.76					
Rainy Season	$\bar{x}$ 0.66					

S.E.D. $\bar{x}$ between months ..... 9.11205E - 02

S.E.D. $\bar{x}$ between stations ..... .247845

S.E.D. $\bar{x}$ between seasons ..... .156751

S.E.D. $\bar{x}$ between season by station ..... .350505

Station by Seasons $\bar{x}$:	1	2	3	4	5
Dry Season .	0.72	0.51	1.01	0.69	0.99
Rainy Season.	0.43	1.02	.43	1.04	0.40

Table 22h

ANALYSIS OF VARIANCE FOR SURGACE WATER ZINC .....

Source of variation:	df.	ss.	Ms.	F.	s.
Replication (6).	5	.419771	.08395	.228	NS
Stations (5).	4	.59389	.148472	.403	NS
Seasons (2).	1	.147907	.147907	.401	NS
Station by Seasons.	4	2.98676	.746689	2,028	NS
Months (12).	11	18.1579	1.65072	33.1	**
Residual.	34	1.5726	0.04625		
Total.	59	23.87885			

** Highly Significant ($P < 0.01$).
* Significant ($P < 0.05$).
NS. Not Significant ($P > 0.05$).

Table 22 I

VARIATION CONCENTRATIONS OF SURFACE WATER MANGANESE (PPM)

		STATIONS				
		1	2	3	4	5
General Station	$\bar{x}$	0.25	0.43	0.47	0.46	0.41
Dry Season	$\bar{x}$ .43					
Rainy Season	$\bar{x}$ .38					

S.E.D. $\bar{x}$ between months ..... 5.365538E 02 .....

S.E.D. $\bar{x}$ between stations ..... .070293 .....

S.E.D. $\bar{x}$ between seasons ..... 4.44572E -02 .....

S.E.D. $\bar{\bar{x}}$ between season by station ..... 9.94094E - 02 .....

		1	2	3	4	5
Station by Seasons	$\bar{x}_1$					
Dry Season .		0.30	0.21	0.73	0.28	0.62
Rainy Season.		0.20	0.64	0.22	0.64	0.29

Table 22 J

ANALYSIS OF VARIANCE FOR SURFACE WATER MANGANESE

Source of variation:	df.	ss.	Ms.	F.	s.
Replication (6).	5	.06823	.81365	.46	NS
Stations (5).	4	.389307	109733	3.283	x
Seasons (2).	1	.03456	.03456	1.166	NS
Station by Seasons.	4	2.30497	.576243	19.437	xx
Months (12).	11	2.97274	.270249	15.646	xx
Residual.	34	1.638403	.0481953		
Total.	59	7.40845			

** Highly Significant ($P < 0.01$).
* Significant ($P < 0.05$).
NS. Not Significant ($P > 0.05$).

4.20'.3.6 CHROMIUM:

The highest concentration of 0.02ppm was obtained. The means for both dry and rainy season were 0.01ppm. Highly significant difference was established between months ($P < 0.01$), while the difference between stations, seasons and station by season was insignificant ($P > 0.05$). Positive correlation was observed between surfacewater Cr concentration and COD, NO_3-N, surfacewater Pb, Fe, Cu, Mg, Ni, Cd; sediment K, Ca, Mg, Pb, Cu, Mn and Ni ($P < 0.05$). The relationship with water temperature, sediment pH, O_2 and chlorophyll 'a' was negative ($P < 0.05$).

4.20.3.7 NICKEL:

The lowest concentration of 0.01ppm was recorded in stations 1 and 5 in August and July respectively. The highest (0.10ppm) was recorded in station 2 in September (Fig.11). Dry and rainy seasons means of 0.04ppm were recorded. Highly significant difference between months, and station by season was observed ($P < 0.01$), while the difference between stations and seasons was insignificant ($P > 0.05$).

Correlation was positive with conductivity, CO_2, alkalinity, COD, NO_3-N, surfacewater Pb, Cu, Mn, Cr, Cd; sediment K, Cd, Mg, Mn and Ni ($P < 0.05$). The correlation was however negative with sediment pH, DO and phenol ($P < 0.05$).

4.20.3.8 CADMIUM:

Positive correlation was observed between surfacewater Cd and water pH, suspended solid, Cl, NO_3-N; surfacewater Pb, Cu, Cr; sediment Mg, Pb and Cu concentrations ($P < 0.05$), with significant negative correlation with air temperature,

Table 22 k

VARIATION IN CONCENTRATIONS OF SURFACE WATER CHROMIUM (PPM)

		STATIONS				
		1	2	3	4	5
General Station	$\bar{x}$	.006	.008	.011	.05	.0
Dry Season	$\bar{x}$ .008					
Rainy Season	$\bar{x}$ .009					

S.E.D. $\bar{x}$ between months ..... 9.7974E-04 .....

S.E.D. $\bar{x}$ between stations ..... 1.5561E-03 .....

S.E.D. $\bar{x}$ between seasons ..... 9.8417E-04 .....

S.E.D. $\bar{x}$ between season by station ..... 2.2006E-03 .....

Station by Seasons $\bar{x}_i$	1	2	3	4	5
Dry Season .	.005	.006	.011	.01	.008
Rainy Season.	.008	.01	.01	.008	.009

Table 22L

ANALYSIS OF VARIANCE FOR SURFACE WATER CHROMIUOS .....

Source of variation:	df.	ss.	Ms.	F.	s.
Replication (6).	5	6.375E04	1.275E04	8.776	xx
Stations (5).	4	1.099E	2.748E	1.892	NS
Seasons (2).	1	5E-06	5.4E-06	.372	NS
Station by Seasons.	4	8526E-05	2.131E	1.467	NS
Months (12).	11	1.046E	9.515E	15.924	xx
Residual.	34	3.928E -04	1.155E -05		
Total.	59	1-002E -03			

** Highly Significant ($P < 0.01$).
* Significant ($P < 0.05$).
NS. Not Significant ($P > 0.05$).

Table 22 M

VARIATION IN CONCENTRATIONS OF SURFACE WATER NICKEL (PPM)

		STATIONS				
		1	2	3	4	5
General Station	$\bar{x}$	.032	.037	.046	.051	.058
Dry Season	$\bar{x}$ .041					
Rainy Season	$\bar{x}$ .042					

S.E.D. $\bar{x}$ between months .....5.68433E-03.....

S.E.D. $\bar{x}$ between stations .....7.52128E-03.....

S.E.D. $\bar{x}$ between seasons .....4.75687E-03.....

S.E.D. $\bar{x}$ between season by station .....1.06867E-02.....

Station by Seasons $\bar{x}$:	1	2	3	4	5
Dry Season .	0.031	0.021	0.06	0.052	0.043
Rainy Season.	0.033	0.054	0.037	0.051	0.034

Table 22N

ANALYSIS OF VARIANCE FOR SURFACE WATER NICKEL

Source of variation:	df.	ss.	Ms.	F.	s.
Replication (6).	5	2.601E-03	5.20E-04	1.533	NS
Stations (5).	4	3.177E-03	7.94E-06	2.341	NS
Seasons (2).	1	3.27E-06	3.26E-03	.01	NS
Station by Seasons.	4	5.118E 03	1.299E 03	3.77	*
Months (12).	11	1.946E 02	1.08E 03	5.6[illegible]	**
Residual.	34	4.19E-03	1.23E-04		
Total.	59	3.45E-02			

** Highly Significant ($P < 0.01$).
* Significant ($P < 0.05$).
NS. Not Significant ($P > 0.05$).

Table 22. 0

VARIATION IN CONCENTRATIONS OF SURFACE WATER CADNIUM(PPM)

	STATIONS				
	1	2	3	4	5
General Station $\bar{x}$	.001	.001	.001	.001	.00
Dry Season $\bar{x}$ .001					
Rainy Season $\bar{x}$ .001					

S.E.D. $\bar{x}$ between months .....3.77307E.-04.....

S.E.D. $\bar{x}$ between stations .....5.54052E-.04.....

S.E.D. $\bar{x}$ between seasons .....3.50413E- 04.....

S.E.D. $\bar{x}$ between season by station .....7.83548E - 04.....

Station by Seasons $\bar{x}$:	1	2	3	4	5
Dry Season .	0	.001	.001	.002	0
Rainy Season.	.001	.001	.002	.001	.001

Table 22 P.

ANALYSIS OF VARIANCE FOR SURFACE WATER CADNIUM

Source of variation:	df.	ss.	Ms.	F.	s.
Replication (6).	5	4.623E-05	9.25E-06	5.021	xx
Stations (5).	4	2.76E-06	6.911E-07	.375	NS
Seasons (2).	1	1.215E-09	1.215E-09	.001	NS
Station by Seasons.	4	1.56E-05	3.91E-06	2.123	NS
Months (12).	11	1.07E-04	9.73E-06	11.398	xx
Residual.	34	0.24E-04	7.09E-03		
Total.	59	1.95E-05			

** Highly Significant ($P < 0.01$).
* Significant ($P < 0.05$).
NS. Not Significant ($P > 0.05$).

chlorophyll 'a', surfacewater K, Ca, Mg, Na, Mn, and Ni ($P < 0.05$).

Highly significant difference between months was recorded ($P < 0.01$). The difference between stations, seasons and station by seasons was insignificant ($P > 0.05$). Cd level was generally observed to be very low in surfacewater (Fig.11).

4.20.4.0 HEAVY METALS IN SEDIMENT:

Concentration of heavy metals in sediment showed wide variations. The concentration of Mn was noted to show a gradual decrease to late rainy season. Gradual increase in Mn level was however recorded afterwards. Cr level remains fairly stable throughout the year following the observed initial decline with increasing period of drought. Cd, Ni, Fe, Zn, and Cu attained maxima with the onset of rainy season, while Pb concentration was observed to attain a peak rise at the later part of the rainy season (Figs. 12).

4.20.4.1 LEAD:

The lowest concentration of 80.70ppm was recorded in station 4 in February, and the highest (242.00ppm) in station 2 in September. Mean seasonal concentration indicates 158.06ppm for dry season and 136.37ppm for rainy season (Table 23a). Highly significant differences were observed between seasons, station by season and between months ($P < 0.01$).

Correlation analysis indicates positive correlation between sediment Pb concentration and PO_4-P, H_2S, oil; surfacewater Pb, Cu, Cr, Cd; sediment K, Fe, Cu, Zn, Cr and Ni ($P < 0.05$). Negative correlation was observed with sediment pH, O_2 saturation, BOD, chlorophyll 'a', macroinvertebrates in surfacewater, benthic macroinvertebrates and phytoplankton population ($P < 0.05$).

4.20.4.2 IRON:

Seasonal variation in concentration of Fe in sediment is represented in Fig. 10a. Mean seasonal concentration of 68.69ppm was recorded for dry season and 74.81ppm for rainy

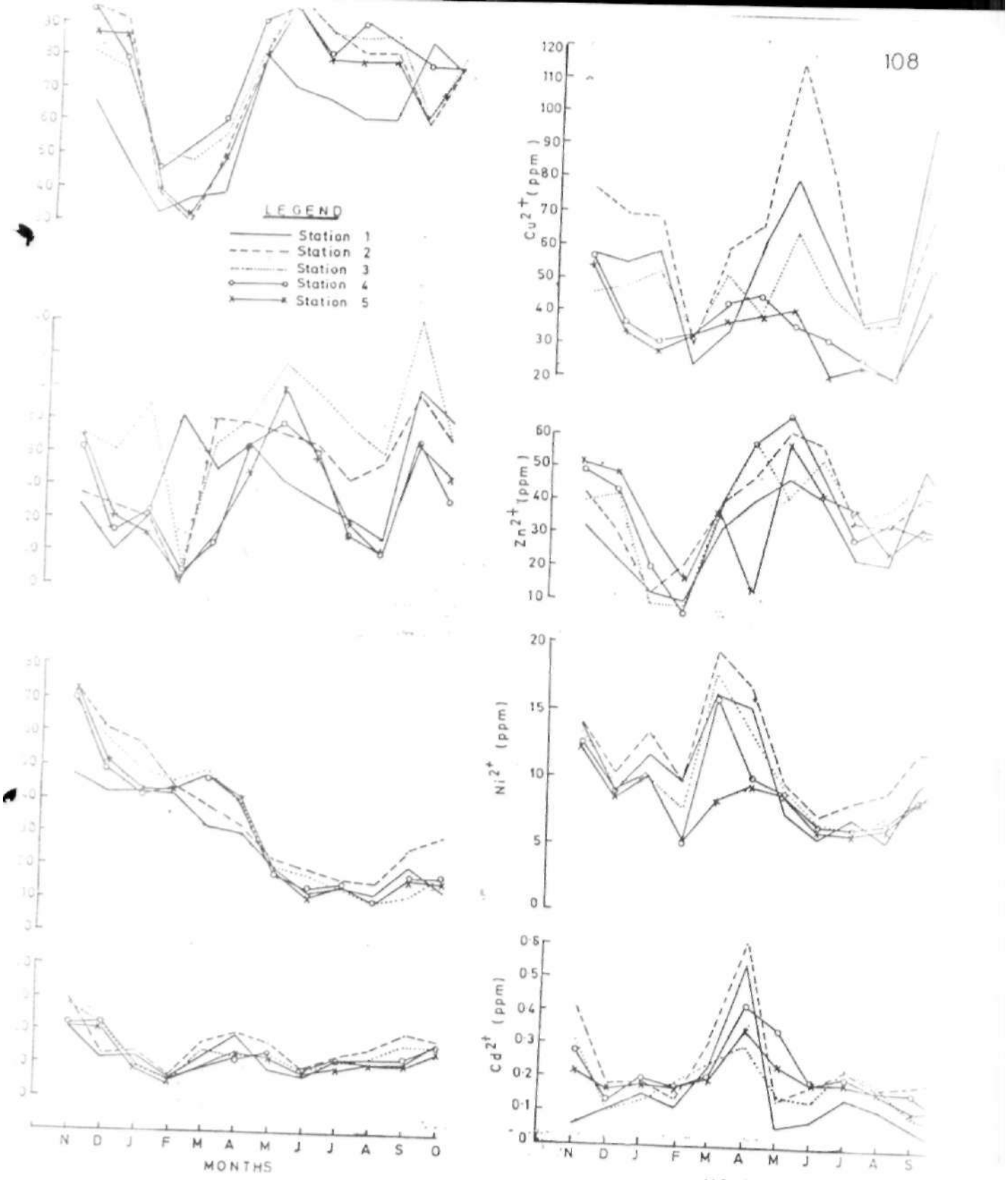


FIG. 12 MONTHLY VARIATION IN METAL CONCENTRATIONS IN SEDIMENT OF ROMI STREAM, KADUNA

Table 23 a

VARIATION IN CONCENTRATIONS OF LEAD IN SEDIMENT (PPM)

		STATIONS				
		1	2	3	4	
General Station	$\bar{x}$	149.83	132.03	153.91	160.1[illegible]	1[illegible]
Dry Season	$\bar{x}$ 158.06					
Rainy Season	$\bar{x}$ 136.37					

S.E.D. $\bar{x}$ between months 10.9449

S.E.D. $\bar{x}$ between stations 11.3376

S.E.D. $\bar{x}$ between seasons 7.17055

S.E.D. $\bar{x}$ between season by station 16.0338

		1	2	3	4	5
Station by Seasons	$\bar{x}$:	141.67	149.25	164.20	197.92	137.6[illegible]
Dry Season .		141.67	149.25	164.20	197.92	137.6[illegible]
Rainy Season.		157.98	124.82	143.62	122.78	132.6[illegible]

Table 23b

ANALYSIS OF VARIANCE FOR LEAD IN SEDIMENT .....

Source of variation:	df.	ss.	Ms.	F.	s.
Replication (6).	5	19689.7	3937.94	5.106	xx
Stations (5).	4	5615.48	1405.87	1.82	NS
Seasons (2).	1	7061.18	7061.18	9.155	xx
Station by Seasons.	4	13631.2	3407.81	4.419	xx
Months (12).	11	28861.1	2623.74	3.65	xx
Residual.	34	5845.24	171.91802		
Total.	52	80703.9			

** Highly Significant ($P < 0.01$).
* Significant ($P < 0.05$).
NS. Not Significant ($P > 0.05$).

Table 23c

VARIATION IN CONCENTRATIONS OF IRON IN SEDIMENT (PPM)

		STATIONS				
		1	2	3	4	5
General Station	$\bar{x}$	67.97	68.08	76.48	73.44	72.79
Dry Season	$\bar{x}$ 68.69					
Rainy Season	$\bar{x}$ 74.81					

S.E.D. $\bar{x}$ between months 3.4551

S.E.D. $\bar{x}$ between stations 5.20413

S.E.D. $\bar{x}$ between seasons 3.29138

S.E.D. $\bar{x}$ between season by station 7.35976

	1	2	3	4	5
Station by Seasons $\bar{x}$:					
Dry Season .	51.00	71.45	70.60	84.30	66.08
Rainy Season.	84.93	64.70	82.37	62.58	79.49

Table 23d

ANALYSIS OF VARIANCE FOR IRON IN SEDMENT

Source of variation:	df.	ss.	Ms.	F.	s.
Replication (6).	5	7911.64	1582.33	9.738	xx
Stations (5).	4	649.632	162.408	.999	NS
Seasons (2).	1	562.428	562.428	3.461	NS
Station by Seasons.	4	5396.22	1349.05	8.303	xx
Months (12).	11	16747.6	1522.51	21.258	xx
Residual.	34	9435.22	277.506		
Total.	59	40702.74			

** Highly Significant ($P < 0.01$).
* Significant ($P < 0.05$).
NS. Not Significant ($P > 0.05$).

season (Table 23c). Analysis of variance (Table 23d) indicates highly significant difference between months and station by seasons ($P < 0.01$). Insignificant difference was observed between stations and seasons ($P > 0.05$).

A positive correlation existed between sediment Fe and Cl, surfacewater K, Ca, Na, Pb, Zn, Cr and Cd. Fe was however found to correlate negatively with water temperature, water pH, sediment pH, suspended solid, CO_2, alkalinity, surfacewater Zn, Mn; and sediment Mn content ($P < 0.05$).

4.20.4.3 COPPER:

Sediment Cu level did not differ significantly with seasons, station, station by seasons and months ($P > 0.05$). Dry season mean concentration of 50.33ppm and rainy season concentration of 41.18ppm were recorded. Significant positive correlation with sediment Ni, Zn, Fe, Pb as well as surfacewater Pb, Cu,Cr, Cd and oil concentrations was established ($P < 0.05$). The relationship with sediment pH, DO, BOD, PO_4-P, chlorophyll 'a', surfacewater K, Ca, Mg, Na; sediment Ca, macroinvertebrates in surfacewater, zooplankton, phytoplankton and benthic macro-invertebrates abundance was observed ($P < 0.05$).

4.20.4.4 ZINC:

The concentration of Zn in sediment was observed to correlate positively with surfacewater K; sediment Pb, Fe, Cu, Cr, K ($P < 0.05$), with negative correlation between sediment Zn and the amount of suspended solid, CO_2, alkalinity and sediment Mn ($P < 0.05$). Mean concentrations of 34.13 and 37.66ppm were

Table 23e

VARIATION IN CONCENTRATIONS OF COPPER IN SEDIMENT (PPM)

		STATIONS				
		1	2	3	4	
General Station	$\bar{\bar{x}}$	53.56	53.20	49.98	54.67	37
Dry Season	$\bar{x}$ 58.53					
Rainy Season	$\bar{x}$ 41.18					

S.E.D. $\bar{\bar{x}}$ between months 4.88501

S.E.D. $\bar{x}$ between stations 5.31084

S.E.D. $\bar{x}$ between seasons 3.35887

S.E.D. $\bar{x}$ between season by station 7.51066

	1	2	3	4	
Station by Seasons $\bar{x}$					
Dry Season .	48.33	65.68	62.12	71.87	44
Rainy Season.	58.78	40.71	37.83	37.47	31

Table 23f.

ANALYSIS OF VARIANCE FOR COPPER IN SEDIMENT .....

Source of variation:	df.	ss.	Ms.	F.	s
Replication (6).	5	7923.48	1584.7	9.364	x
Stations (5).	4	2301.48	575.371	3.4	x
Seasons (2).	1	4517.07	4517.07	26.692	x
Station by Seasons.	4	3551.82	887.956	5.247	x
Months (12).	11	11173.5	1015.78	7.094	x
Residual.	34	3558.15	104.6514		
Total.	59	33025.5			

** Highly Significant (P < 0.01).
* Significant (P< 0.05).
NS. Not Significant (P> 0.05).

Table 23g

VARIATION IN CONCENTRATIONS OF ZINC IN SEDIMENT (PPM)

		STATIONS				
		1	2	3	4	
General Station	$\bar{x}$	34.12	36.51	35.62	38.54	34
Dry Season	$\bar{x}$ 34.13					
Rainy Season	$\bar{x}$ 37.66					

S.E.D. $\bar{x}$ between months .....3.5725.....

S.E.D. $\bar{x}$ between stations .....3.96882.....

S.E.D. $\bar{x}$ between seasons .....2.5101.....

S.E.D. $\bar{x}$ between season by station .....5.61275.....

	1	2	3	4	
Station by Seasons $\bar{x}$s					
Dry Season .	24.73	37.20	30.75	45.13	32
Rainy Season.	43.50	35.82	40.48	31.95	36

Table 23h

ANALYSIS OF VARIANCE FOR ZINC IN SEDIMENT.....

Source of variation:	df.	ss.	Ms.	F.	
Replication (6).	5	6192.66	1238.53	13.105	x
Stations (5).	4	144.828	36.207	.383	N
Seasons (2).	1	186.914	186.914	1.978	N
Station by Seasons.	4	1722.45	430.611	4.556	x
Months (12).	11	8633.24	784.84	10.240	x
Residual.	34	4380.392	128.8350		
Total.	59	21260.48			

** Highly Significant ($P < 0.01$).
* Significant ($P < 0.05$).
NS. Not Significant ($P > 0.05$).

recorded for dry and rainy seasons respectively. The difference was highly significant with station by seasons ($P < 0.01$), but insignificant between stations and seasons ($P > 0.05$).

4.20.4.5 MANGANESE:

The monthly variation in sediment Mn is shown in Fig. 12 . The concentration was observed to exhibit highly significant difference with station by seasons, seasons and months ($P < 0.01$), without significant difference between stations ($P > 0.05$). The correlation with temperature, suspended solid, CO_2, alkalinity, surfacewater Mn; sediment Cr, Ni, Cd, and macro-invertebrates was positive ($P < 0.05$). Significant negative correlation with DO, hardness, Cl, PO_4-P, Mg in surfacewater; sediment K, Na, Fe, and Zn was established.

4.20.4.6 CHROMIUM:

Significant positive correlation between sediment Cr concentration and surfacewater Cu, Cr, sediment Pb, Fe, Cu, Zn, Mn and Ni, with negative correlation between sediment Cr, K, air temperature, sediment pH, water pH, alkalinity, PO_4-P, chlorophyll 'a', surfacewater Mg, and Zn was recorded ($p < 0.05$). Mean seasonal concentration of 14.25ppm for dry season and 12.18ppm for rainy season was recorded (Table 23k). Highly significant difference between months ($P < 0.01$) was observed. The difference between seasons was significant ($P < 0.05$) while those between stations and station by season were insignificant ($P > 0.05$).

Table 23.I

VARIATION IN CONCENTRATIONS OF MANGANESE IN SEDIMENT (PPM)

		STATIONS				
		1	2	3	4	
General Station	$\bar{x}$	27.07	31.94	32.98	34.93	37.
Dry Season	$\bar{x}$ 37.07					
Rainy Season	$\bar{x}$ 28.50					
S.E.D. $\bar{x}$ between months		3.29317				
S.E.D. $\bar{x}$ between stations		3.64813				
S.E.D. $\bar{x}$ between seasons		2.30728				
S.E.D. $\bar{x}$ between season by station		5.15924				

Station by Seasons $\bar{x}$:	1	2	3	4	
Dry Season .	39.15	15.33	50.93	20.15	5
Rainy Season.	14.98	48.55	15.03	49.7	1

Table 23 J

ANALYSIS OF VARIANCE FOR MANGANESE IN SEDIMENT

Source of variation:	df.	ss.	Ms.	F.	s
Replication (6).	5	1859.23	371.846	4.657	x
Stations (5).	4	672.085	168.021	2.104	N
Seasons (2).	1	1101.67	1101.67	13.796	x
Station by Seasons.	4	16670.9	4167.72	52.192	x
Months (12).	11	20299.9	1845.44	28.36	x
Residual.	34	16706.405	491.36		
Total.	59	57310.19			

** Highly Significant ($P<0.01$).
* Significant ($P<0.05$).
NS. Not Significant ($P>0.05$).

Tab e 23 K

VARIATION IN CONCENTRATIONS OF CROMIUM IN SEDIMENT (PPM)

		STATIONS				
		1	2	3	4	
General Station	$\bar{x}$	13.27	11.68	14.48	13.98	1
Dry Season	$\bar{x}$ 14.25					
Rainy Season	$\bar{x}$ 12.18					

S.E.D. $\bar{x}$ between months .....981675.....

S.E.D. $\bar{x}$ between stations .....1.74704.....

S.E.D. $\bar{x}$ between seasons .....1.1[illegible].....

S.E.D. $\bar{\bar{x}}$ between season by station .....2.47128.....

	1	2	3	4	
Station by Seasons $\bar{x}_s$					
Dry Season .	13.72	11.10	16.68	15.50	14
Rainy Season.	13.03	12.25	12.28	12.47	10

Table 23 L

ANALYSIS OF VARIANCE FOR CROMIUM IN SEDIMENT .....

Source of variation:	df.	ss.	Ms.	F.	S
Replication (6).	5	629.11	125.822	6.868	xx
Stations (5).	4	60.1674	15.0418	.821	N.
Seasons (2).	1	64.2735	64.2735	3.509	x
Station by Seasons.	4	60.8507	15.2127	.83	N.
Months (12).	11	1235.98	112.365	19.43	xx
Residual.	34	411.521	12.10357		
Total.	59	2461.90	52		

** Highly Significant (P< 0.01).
* Significant (P< 0.05).
NS. Not Significant (P>0.05).

4.20.4.7 NICKEL:

Highly significant difference between seasons, station by seasons and months was observed ($P< 0.01$). The difference was significant between stations ($P< 0.05$). The mean dry season concentration of 11.05ppm and rainy season mean of 8.39ppm were recorded. Seasonal variation (Fig. 12) indicates a concentration range between 4.8 to 19.4ppm. Significant positive correlation between sediment Ni, and water temperature, Pb, Mn, Cr, Ni, sediment Pb, Cu, Mn, Cr and Ca was recorded ($P<0.05$). The correlation with oxygen saturation, Cl, PO_4-P, chlorophyll 'a' and surfacewater Mg was however negative.

4.20.4.8 CADMIUM:

Mean seasonal concentrations of 0.22 and 0.19ppm were recorded for dry and rainy seasons respectively. Station 2 shows the highest concentration of 0.61ppm in April, while the lowest concentration of 0.01ppm was recorded in station 1 in October. Highly significant difference between months and station by season was observed ($P<0.01$). The difference between stations, and seasons was however not significant ($P>0.05$).

Positive correlation was established between cadmium concentration in sediment and water temperature, suspended solid, COD, surfacewater K, Mn, sediment Na, Fe, Mg, Cr and Ni ($P<0.05$). Negative correlation was however noted to exist with sediment pH and DO ($_p<0.05$).

Table 23 M

VARIATION IN CONCENTRATIONS OF NICKEL IN SEDIMENT (PPM)

		STATIONS				
		1	2	3	4	
General Station	$\bar{x}$	10.08	8.93	10.81	9.19	9.
Dry Season	$\bar{x}$ 11.05					
Rainy Season	$\bar{x}$ 8.39					

S.E.D. $\bar{x}$ between months .....0.600764.....

S.E.D. $\bar{x}$ between stations .....0.651507.....

S.E.D. $\bar{x}$ between seasons .....0.412049.....

S.E.D. $\bar{x}$ between season by station .....0.92137.....

	1	2	3	4	
Station by Seasons $\bar{x}$:					
Dry Season .	12.48	7.5	13.83	9.53	11
Rainy Season.	7.67	10.37	7.78	8.85	7

Table 23 N

ANALYSIS OF VARIANCE FOR NICKEL IN REDIMENT.....

Source of variation:	df.	ss.	Ms.	F.	
Replication (6).	5	244.762	48.9524	19.2 1	
Stations (5).	4	26.6993	6.67483	2.621	
Seasons (2).	1	106.667	106.667	41.8 3	
Station by Seasons.	4	163.663	40.9158	16.06	
Months (12).	11	475.785	43.2532	19.973	
Residual.	34	361.1803	10.62295		
Total.	59	1378.7566			

** Highly Significant ($P < 0.01$).
* Significant ($P < 0.05$).
NS. Not Significant ($P > 0.05$).

Table 23. 0

VARIATION IN CONCENTRATIONS OF CADMIUM IN SEDIMENT (PPM)

		STATIONS				
		1	2	3	4	5
General Station	$\bar{x}$	0.17	0.17	0.28	0.20	0.2
Dry Season	$\bar{x}$ 0.22					
Rainy Season	$\bar{x}$ 0.19					

S.E.D. $\bar{x}$ between months ..... 4.025148-02 .....

S.E.D. $\bar{x}$ between stations ..... 5.084313-02 .....

S.E.D. $\bar{x}$ between seasons ..... .032156 .....

S.E.D. $\bar{x}$ between season by station ..... .071903 .....

		1	2	3	4	5
Station by Seasons	$\bar{x}$i					
Dry Season .		0.20	0.08	0.38	0.19	0.1
Rainy Season.		0.15	0.25	0.18	0.21	0.1

Table 23. P

ANALYSIS OF VARIANCE FOR CADMIUM IN SEDIMENT .....

Source of variation:	df.	ss.	Ms.	F.	S
Replication (6).	5	.159895	.031979	2.062	N.
Stations (5).	4	.100177	2.50E-02	1.615	N.
Seasons (2).	1	7.93E-03	7.73E-06	.512	N.
Station by Seasons.	4	.276323	5.71E-05	5.87%	*.
Months (12).	11	.628365	2.05E-05		
Residual.	34	0.069595			
Total.	59	1.19229			

** Highly Significant ($P < 0.01$).
* Significant ($P < 0.05$).
NS. Not Significant ($P > 0.05$).

Table23q : Seasonal variations and the relationship of surfacewater metals to sediment metal concentrations (ppm).

Metals	Surfacewater		Sediment		Correlation	
	D	R	D	R	Coefficient	Relationship
K	3.11	4.15	339.47	585.10	.400	Positive
Ca	4.22	5.17	383.47	448.00	.397	Positive
Mg	2.69	3.46	50.78	51.92	.175	NS
Na	3.11	3.68	36.69	40.58	-.039	NS
Pb	0.98	0.92	155.06	136.37	.312	Positive
Fe	0.36	0.57	68.69	74.81	.116	NS
Cu	0.58	0.51	58.53	41.18	.381	Positive
Zn	0.76	0.66	34.13	37.66	-.018	NS
Mn	0.43	0.38	37.07	28.50	.615	Positive
Cr	0.01	0.01	14.25	12.18	.253	Positive
Ni	0.04	0.04	11.05	8.39	.246	Positive
Cd	0.001	0.001	0.22	0.19	-.140	NS

D = Dry season mean

R = Rainy season mean

NS = insignificant correlation

Values above critical (2-tail, = 0.05) ± .21574 significant

Values below critical (2-tail, = 0.05) ± .21574 insignificant

4.20.5.0 BIOLOGICAL CHARACTERISTICS:

Four major groups of organisms namely: Macroinvertebrates in surfacewater, zooplankton, phytoplankton and benthic macroinvertebrates were studied on seasonal, monthly and individual group variations per station.

4.20.5.1 MACROINVERTEBRATES IN SURFACEWATER:

Three groups of macroinvertebrates were recorded. The Hamipterans made up 56.55% of the surfacewater macroinvertebrates, while Coleopteras (23.45%) and Dipterans constitute 20.00% respectively (Fig. 15). Station 5 was found to contain 43.99% of the total surfacewater macroinvertebrates, while stations 2, 3 and 4 were found to contain 4.12%, 17.87% and 34.02% respectively. Station 1 was found to contain none (Fig. 13).

Higher density was recorded in rainy season, with a mean of 8 organisms per litre as compared to that of dry season (1.30) recorded. Analysis of variance (Table 24b) shows highly significant difference between stations, seasons and station by seasons ($P < 0.01$), while the difference between months was found not to be significant ($P > 0.05$).

Correlation coefficient analysis indicates that the relationship between macroinvertebrates in surfacewater and DO, BOD, chlorophyll 'a', surfacewater K, Ca, Mg, Fe; sediment Ca, Mn, zooplankton and benthic macroinvertebrates was positive ($P < 0.05$). Significant negative correlation was however observed with water pH, hardness, oil, phenol, surfactant; sediment K, Na, Pb and Cu concentrations.

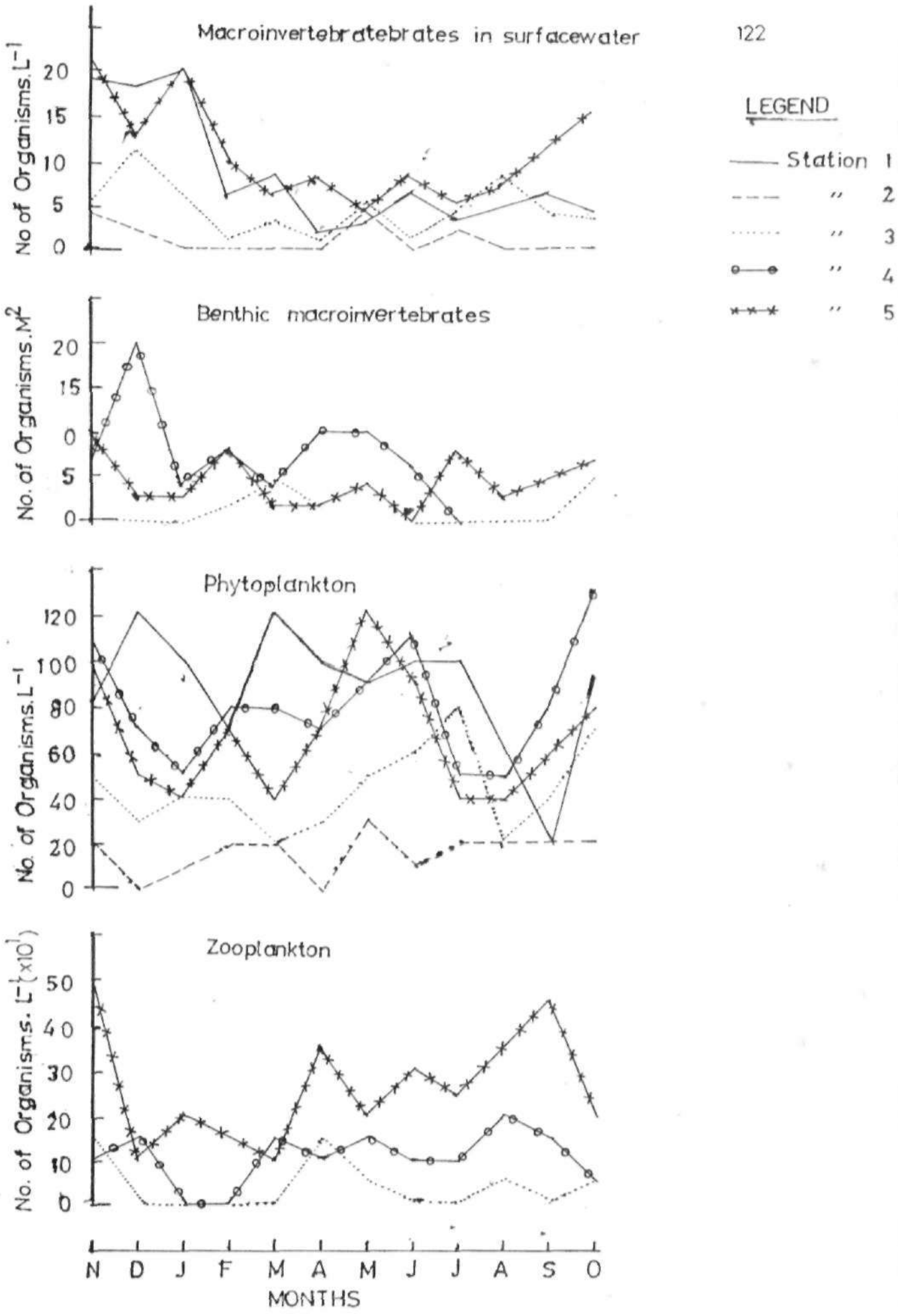


FIG.13 MONTHLY VARIATION IN SURFACEWATER MACROINVERTEBRATES, BENTHIC MACROINVEBRATES PHYTOPLANKTON AND ZOOPLANKTON TOTAL DENSITY

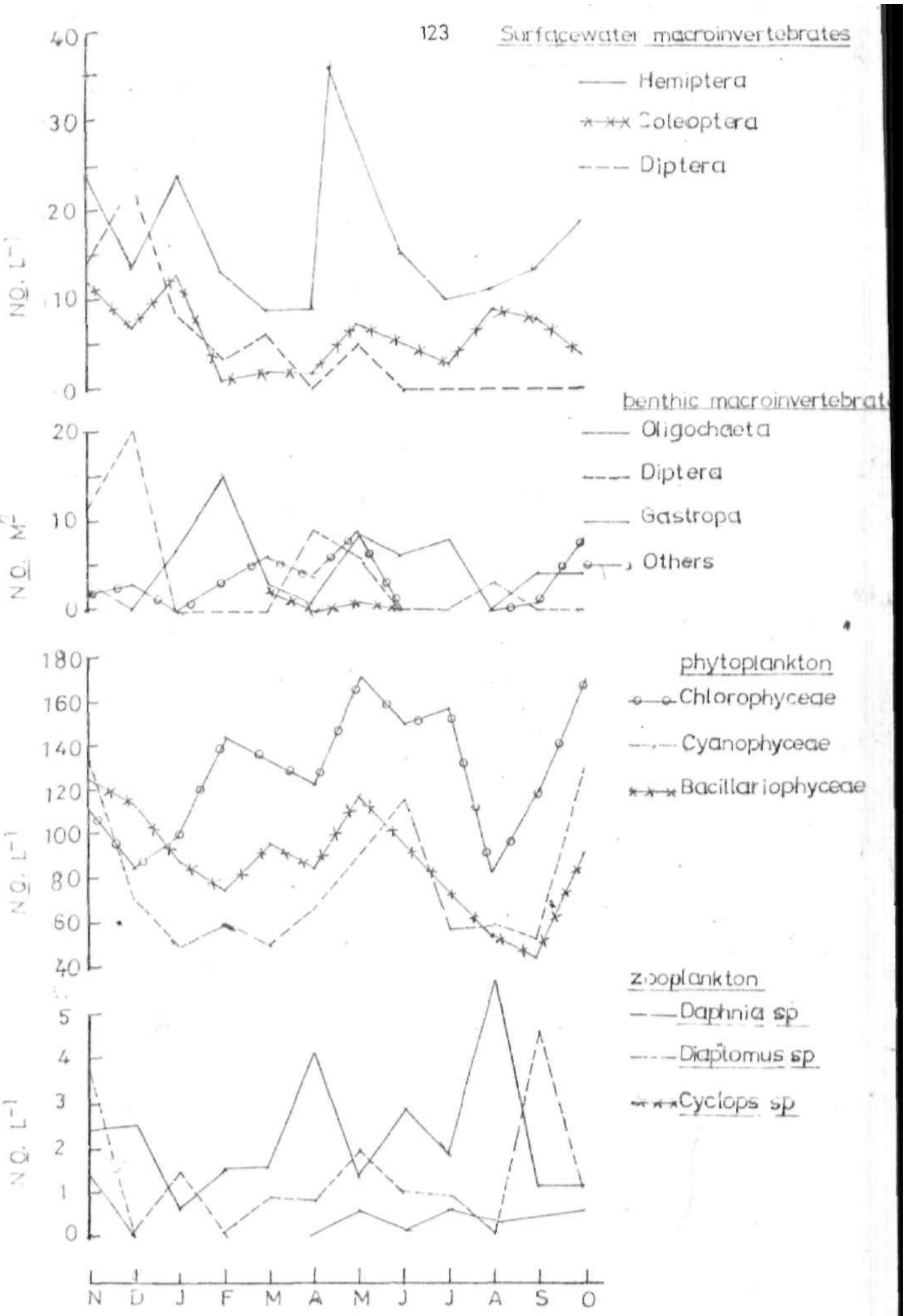


FIG 13. MONTHLY VARIATION IN SURFACEWATER AND BENTHIC MACROINVERTEBRATES, ZOOPLANCTON AND PHYTOPLANKTON DENSITY.

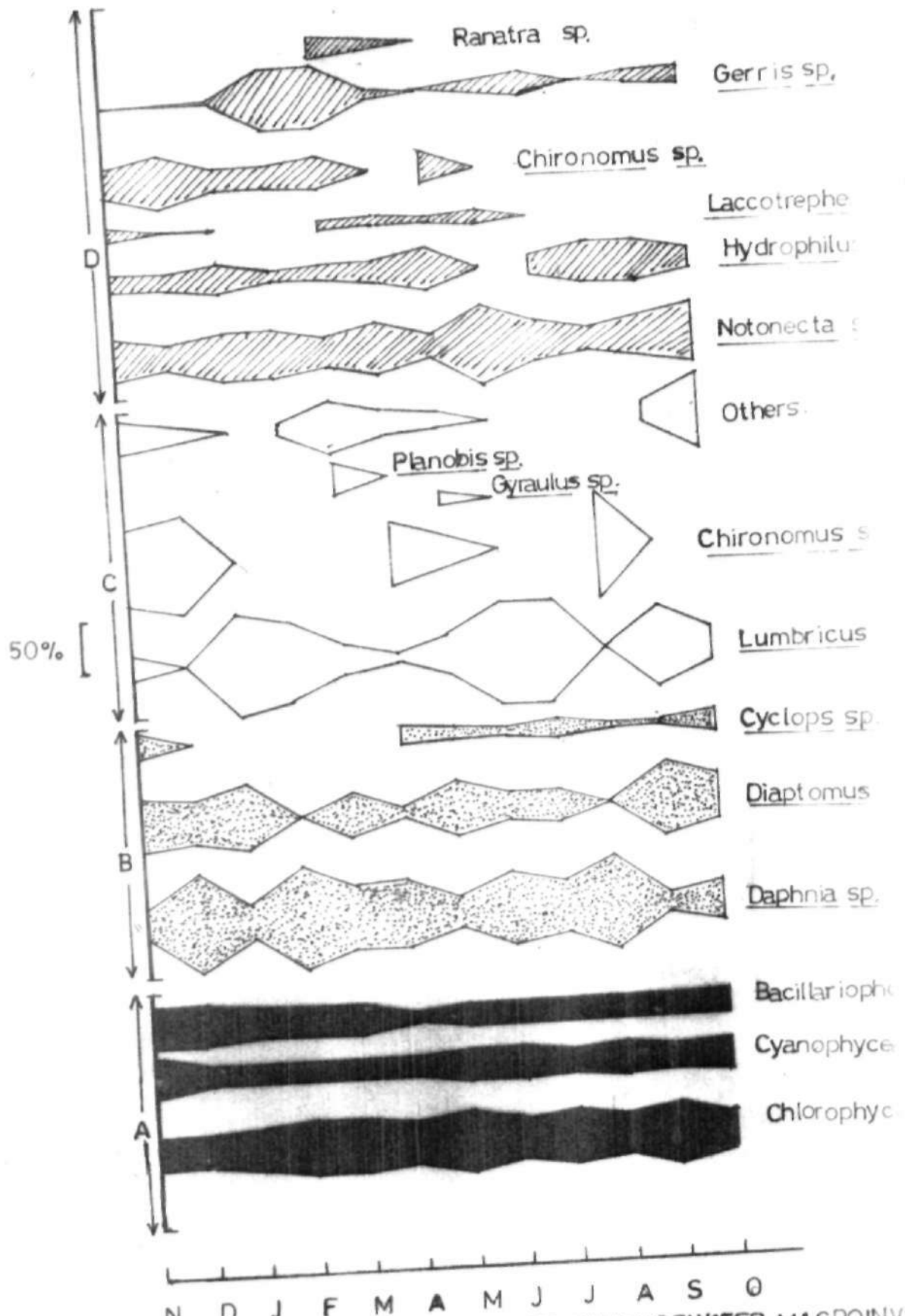


FIG 15. RELATIVE ABUNDANCE OF SURFACEWATER MACROINV
BENTHIC MACROINVERTES(C) ZOOPLANKTON(B)&PHYTOPLANKTO

Table 24a

VARIATION OF MACROINVERTEBRATES IN SURFACE WATER (ORGANI.M. L

		STATIONS				
		1	2	3	4	
General Station	$\bar{x}$	4.08	6.00	2.75	7.00	6.
Dry Season	$\bar{x}$ 1.30					
Rainy Season	$\bar{x}$ 8.37					
S.E.D. $\bar{x}$ between months		1.43324				
S.E.D. $\bar{x}$ between stations		1.50694				
S.E.D. $\bar{x}$ between seasons		0.95307				
S.E.D. $\bar{x}$ between season by station		2.13113				

		1	2	3	4	
Station by Seasons	$\bar{x}_i$					
Dry Season		0	0	1.00	1.00	4
Rainy Season.		4.12	12.00	4.50	13.00	8

Table 24 b.

ANALYSIS OF VARIANCE FOR MACROINVERTEBRATES IN SURFACE WATER.....

Source of variation:	df.	ss.	Ms.	F.	
Replication (6).	5	95.[illegible]	19.1067	1.40	
Stations (5).	4	242.5	60.625	4.44	x
Seasons (2).	1	749.067	749.067	54.97	x
Station by Seasons.	4	244.1	61.025	4.47	x
Months (12).	11	405.533	36.8667	2.991	N
Residual.	34	207.5967	6.19579		
Total.	59	195.33			

** Highly Significant ($P < 0.01$).
* Significant ($P < 0.05$).
NS. Not Significant ($P > 0.05$).

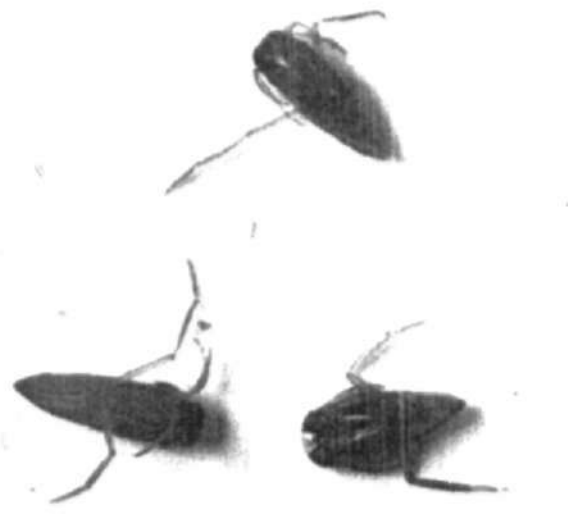


PLATE 1. *Notonecta sp.*



PLATE 2. *Hydrophilus sp.*

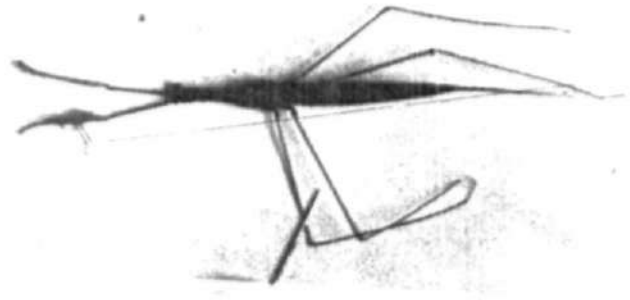


PLATE 3. *Ranatra sp.*

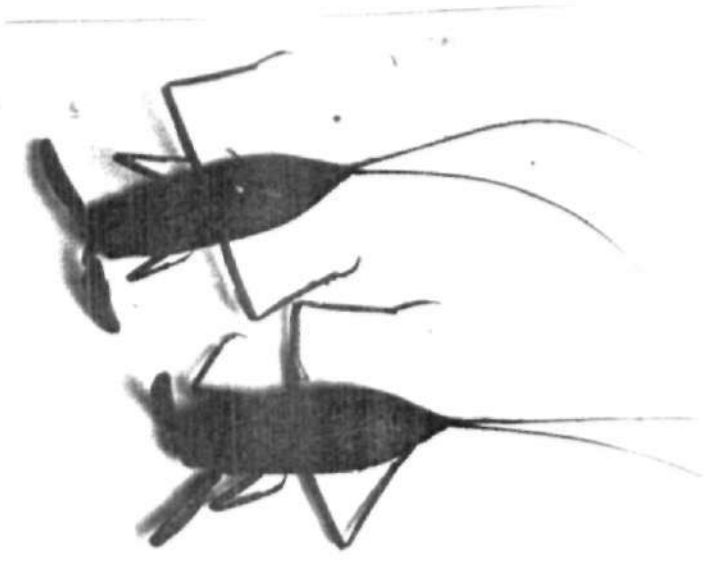


PLATE 4. *Laccotrephes sp.*

Decrease in Hemipterans was observed as dry season progressed. However, gradual rise in abundance was observed with the onset of rainy season. The dipterans were however found to be more abundant during the dry season but diminished as rainy season set in, with the highest relative abundance of 44.0% at station 5 (Fig. 15). The various taxa were represented by Notonecta sp., (Plate 1) (Plate 2), Hydrophilus sp. (Plate 2), Chironomus sp., Gerris sp. Ranatra sp. (Plate 3) and Laccotrephes sp. (Plate 4).

4.20.5.2 ZOOPLANKTON:

Crustaceans were found to constitute the only zooplankton group. The 3 genera recorded, 1 belongs to the Cladocera group, which include Daphnia sp. (55.60%). The copepods were made up of Cyclops sp. (10.60%) and Diaptomus sp. (33.80%). A decline in abundance was observed as dry season progressed.

Variation in seasonal composition of zooplankton was observed to be higher during the rainy season with a mean 116.00 organisms per litre as compared with the dry season mean of 10.00 (Table 24c). The lowest number of zooplankton recorded was 50 organisms per litre in station 3 (in August and October), and station 4 (in October). The highest was 500 organisms per litre in station 5 in November. Stations 1 and 2 were mostly found to be devoid of zooplankton species.

Analysis of variance (Table 24d) shows highly significant difference in zooplankton density between stations, seasons, and station by seasons ($P < 0.01$), while the difference between months was found to be insignificant ($P > 0.05$).

Significant positive correlation was observed between zooplankton and DO, BOD, NO_3-N, chlorophyll 'a', surfacewater K, Ca, Mg, Na, Fe: sediment Ca, macroinvertebrates in surfacewater and the density of

Table 24c.

VARIATION IN ZOOPLANKTON COMPOSITION (ORGANISM. L^{-1})

		STATIONS				
		1	2	3	4	
General Station	$\bar{x}$	12.50	41.67	62.50	116.	1
Dry Season	$\bar{x}$ 10.00					
Rainy Season	$\bar{x}$ 151.67					
S.E.D. $\bar{x}$ between months		26.5346				
S.E.D. $\bar{x}$ between stations		28.806				
S.E.D. $\bar{x}$ between seasons		18.2185				
S.E.D. $\bar{x}$ between season by station		40.7378				

		1	2	3	4	5
Station by Seasons	$\bar{x}i$	0	0	0	0	50.0
Dry Season .		25.00	83.33	125.00	233.33	291.
Rainy Season.						

24c

ANALYSIS OF VARIANCE FOR ZOOPLANKTON COMPOSITION

Source of variation:	df.	ss.	Ms.	F.	s.
Replication (6).	5	22208.3	4441.67	.89	NS
Stations (5).	4	191083	47770.8	9.595	XX
Seasons (2).	1	301042	301042	60.4	XX
Station by Seasons.	4	107083	26770.8	5.377	XX
Months (12).	11	80458.3	7314.39	1.75	NS
Residual.	34	143583.4	4223.04		
Total.	59	845458			

** Highly Significant ($P \leq 0.01$).
* Significant ($P < 0.05$).
NS. Not Significant ($P > 0.05$).



PLATE 5 *Daphnia sp.*

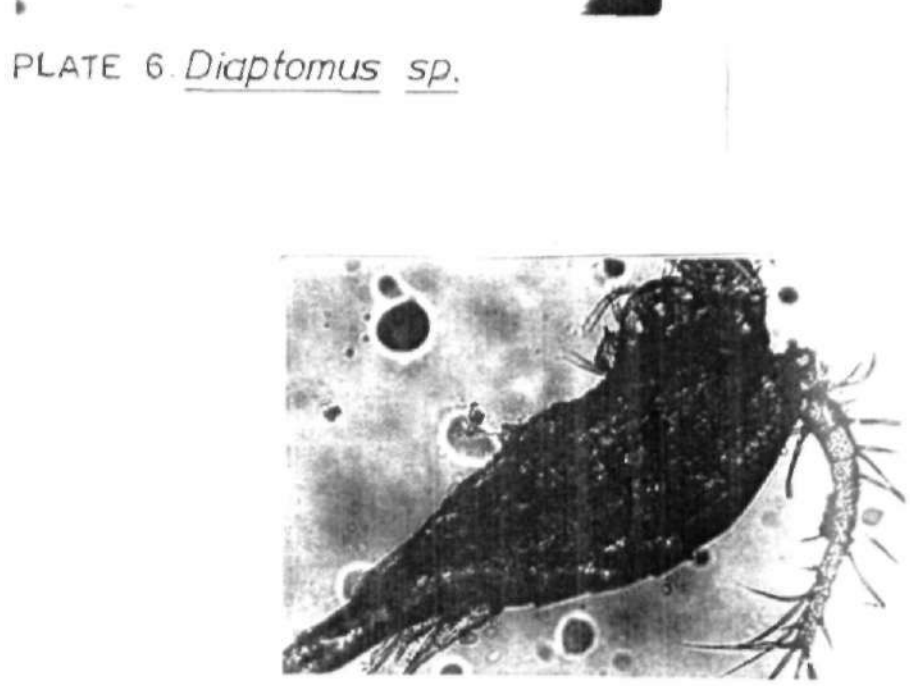


PLATE 6 *Diaptomus sp.*

PLATE 7 *Cyclops sp.*

benthic macroinvertebrates ($P < 0.05$). Significant negative correlation was observed with the amount of suspended and dissolved solids, CO_2, H_2S, Oil, phenol, surfactant, and sediment Cu concentrations ($P < 0.05$).

4.20.5.3 PHYTOPLANKTON

The groups of phytoplankton identified were members of the family Chlorophyceae, Cyanophyceae and Bacillariophyceae. Monthly variations in phytoplankton density is represented in Fig. 11c.

The relative abundance of phytoplankton groups (Fig. 15) indicates Chlorophytes to constitute 38.95%, Cyanophytes 28.49% and Bacillariophytes 32.50% of the total Phytoplankton density. The various genera were Spirogyra sp., Closterium sp., Ulotrix sp., Zygnema sp., Euderina sp., Selanastrum sp., Nivacula sp., Phormidium sp., Oscillatoria sp., Nostoc sp., Gyrosigma sp., Cymbella sp. and Pinnularia sp.

Phytoplankton density was observed to be high during the rainy season with a seasonal mean of 70 organisms per litre as compared to relatively lower mean of 48 organisms per litre observed in dry season. The highest population of Phytoplankton was recorded in stations 1 and 2 with a general station mean of 76 organisms per litre (Table 24e).

Positive correlation between phytoplankton density and water pH, sediment pH, DO, BOD, zooplankton and benthic macroinvertebrates was observed ($P < 0.05$), with significant negative correlation between conductivity, CO_2, alkalinity, Cl,

Table 24 e

VARIATION IN PHYTOPLANKTON COMPOSITION. (ORGANISM. L^{-1})

		STATIONS				
		1	2	3	4	5
General Station	$\bar{x}$	75,83	75.83	48.33	40.83	53.33
Dry Season	$\bar{x}$ 48.00					
Rainy Season	$\bar{x}$ 69.67					
S.E.D. $\bar{x}$ between months		8.48126				
S.E.D. $\bar{x}$ between stations		8.46379				
S.E.D. $\bar{x}$ between seasons		5.35297				
S.E.D. $\bar{x}$ between season by station		11.9696				

Station by Seasons $\bar{x}$:	1	2	3	4	5
Dry Season .	98.33	75.00	11.67	20.00	35.00
Rainy Season.	53.33	76.67	85.00	61.67	71.67

Table 24f

ANALYSIS OF VARIANCE FOR PHYTOPLANKTON COMPOSITION

Source of variation:	df.	ss.	Ms.	F.	s.
Replication (6).	5	550.833	110.167	25.63	xx
Stations (5).	4	1251.0	312.75	72.76	xx
Seasons (2).	1	704.167	704.167	163.83	xx
Station by Seasons.	4	2441.67	610.417	142.08	x
Months (12).	11	921.833	83.803	19.41	xx
Residual.	34	1012.327	29.774		
Total.	59	6881.83			

** Highly Significant ($P < 0.01$).
* Significant ($P < 0.05$).
NS. Not Significant ($P > 0.05$).

COD, surfacewater K, Ca, Fe, Cu, Mn, Na, Pb, and phytoplankton. Highly significant difference between stations, seasons, station by seasons and months was recorded ($P < 0.01$).

4.20.5.4 BENTHIC MACROINVERTEBRATES:

The population of benthic macroinvertebrates comprised of 40.14% Oligochetes, 33.33% Dipterans, 2.04% Gastropods, and various developmental stages of Odonatans, Nematodes and tadpoles that are collectively referred to as 'others', which constitute 24.49%. The genera include Lumbricus sp., Chironomus sp., Gyranlus sp., and Planorbis sp.

Benthic macroinvertebrates were found to be absent throughout the year from stations 1 and 2; scanty in stations 3 and 4. Station 5 was however noted to contain benthic macroinvertebrates throughout the year (Fig. 13).

Mean seasonal values of (Table 24e) indicates higher density during the rainy season. The difference between seasons was observed to be highly significant ($P < 0.01$), while the difference between stations, station by season and between months was significant ($P < 0.05$). Positive correlation between BOD, surfacewater Ca, Na; sediment Cu, macroinvertebrates in surfacewater, zooplanktons and benthic macroinvertebrates was observed ($P < 0.05$). A decrease in density was however recorded with increasing concentrations of H_2S, oil, phenol, and sediment Pb ($P < 0.05$).

Table 24 g

VARIATION ..IN BENTHIC..MACROINVERTEBRATES.(ORGANISM. M^2)

		STATIONS				
		1	2	3	4	5
General Station	$\bar{x}$	0.75	4.33	1.33	2.33	3.00
Dry Season	$\bar{x}$ 0.30					
Rainy Season	$\bar{x}$ 4.40					

S.E.D. $\bar{x}$ between months 1.30054

S.E.D. $\bar{x}$ between stations 1.20853

S.E.D. $\bar{x}$ between seasons ..... .764344

S.E.D. $\bar{x}$ between season by station 1.70913

	1	2	3	4	5
Station by Seasons $\bar{x}$:					
Dry Season .	0	0	0	0	1.50
Rainy Season.	1.50	9.67	2.67	4.67	4.50

Table 24 h

ANALYSIS OF VARIANCE FOR BENTHIC MACROINVERTEBRATES

Source of variation:	df.	ss.	Ms.	F.	s.
Replication (6).	5	28.15	5.63	.642	NS
Stations (5).	4	95.4	23.85	2.722	NS
Seasons (2).	1	252.15	252.15	28.773	xx
Station by Seasons.	4	93.6	23.4	2.67	NS
Months (12).	11	84.05	7.6409	.752	NS
Residual.	34	310.3	9.1264		
Total.	59	863.65			

** Highly Significant ($P < 0.01$).
* Significant ($P < 0.05$).
NS. Not Significant ($P > 0.05$).

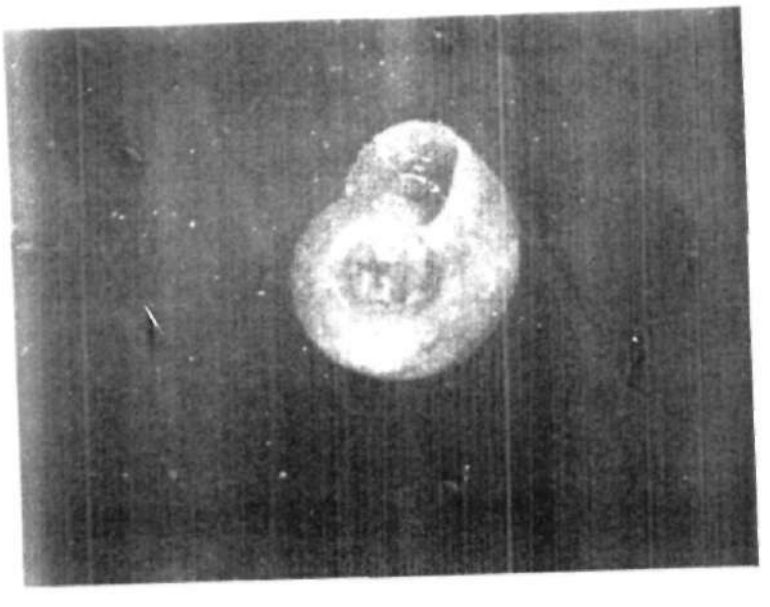


PLATE 8 *Gyraulus sp.*

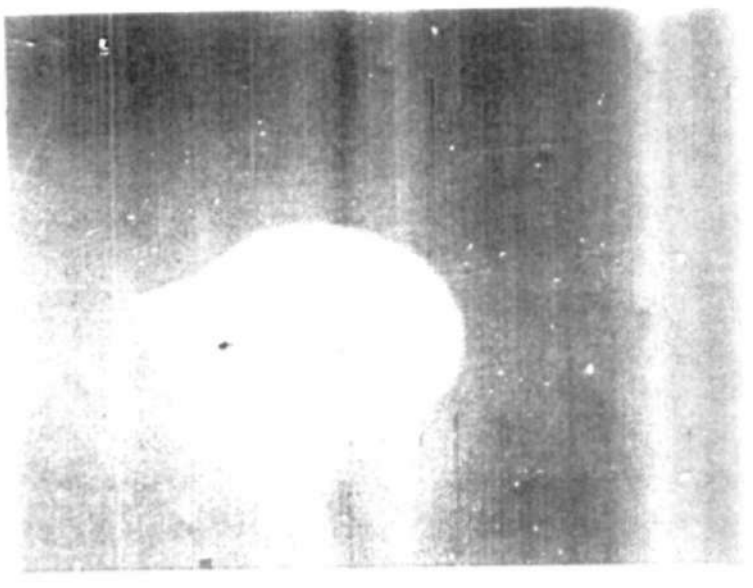


PLATE 9 *Planorbis sp.*

CHAPTER FIVE

5 .0 D I S C U S S I O N

This research was carried out to determine the extent to which the distribution and abundance of zooplankton, phytoplankton, benthic macroinvertebrates, surface-water macroinvertebrates, physico-chemical parameters and productivity of Romi stream (Kaduna) are affected by the effluent discharge from the Nigerian National Petroleum Corporation (NNPC) Kaduna refinery.

The relative abundance and diversity of the biota may be regarded as indication of the stream potential in terms of fisheries and the degree of pollution that it is subjected to as a result of the refinery effluent discharge.

5 .1 PHYSICO-CHEMICAL PARAMETERS

5 .1.1 WATER TEMPERATURE:

Temperature of the surfacewater was observed to be fairly stable with stations 1 and 2 relatively higher than other stations (3, 4 and 5). This could be due to the inflow of effluent with a higher temperature than the stream water. Being a lotic habitat, the water is constantly agitated and as such temperature fluctuation was minimal all year-round. According to Cote (1976), cooling water system of petro-chemical refineries may create problems associated with the discharge of thermal effluents. The extent of the problem is however dependent upon the volume of the discharge as a function of the capacity of the receiving water body. The relatively low temperatures recorded away from the outfall (stations 3, 4 and 5) could be due to dilution, heat loss to the atmosphere and to the substratum. Hynes (1960) reported that water temperature declines as distance is increased downstream from

point of discharge of heated effluents, partly due to dilution, loss to the atmosphere and river bed, in which turbulance, wind speed and temperature difference between water and its surroundings play significant roles.

Rainy season temperature was observed to be slightly lower than that of dry season. This could be attributed to hign dilution and increased turbulance.

5 .1.2 WATER AND SEDIMENT pH:

Water pH remains fairly stable throughout the sampling period ranging from weak acidity to weak alkalinity (6 to 8). This may be due to the hardness of the body of water receiving the effluent. Hynes (1963) observed that hard waters are alkaline and their pH does not change readily. As a result, any addition of acid may be neutralized. Slight shift to alkaline pH was however observed during the rainy season. A similar circumneutral pH condition with slight increase in pH during the rainy season was reported by (Kemdirim (1987) in some water bodies in Plateau State, Nigeria. They attributed the slight fluctuation in pH to the good buffering capacity of the water, which is related to the nature of the bedrock. Increased carbondioxide production as a result of vegetation decay, allocthonous and autochthonous organic matter could have contributed to the lowering of pH observed during the dry season.

The acidic pH of the sediment observed at all the stations could be due to increased microbial activity and carbondioxide production. Kemdirim (1987) reported a similar decrease in pH due to high allochthonous input of organic matter in Shendam reservoir,

Plateau State (Nigeria). This phenomenon may be responsible for the acidic pH observed in sediments of the stream.

5.1.3 HYDROGEN SULPHIDE AND MERCAPTAN (RSH):

Level of H_2S and RSH was above the refinery effluent quality specification, set at $0.20mg.L^{-1}$ (Lolomari, 1983), with the exception of station 5 where the level was below detection. The presence of sulphides in refinery effluents has been reported by a number of workers: Cote (1976) indicates that sulphides originate from the desalting distillation hydrotreatment and hydrocracking of crude oil. Concentration of sulphides of $0.20mg.L^{-1}$ has been reported by Lolomari (1983) to be the desired effluent concentration from the Linear-Alkyl-benzene plant of the NNPC Kaduna refinery. However, analysis of predischarged effluent of the refinery conducted by Onwumere (1987) revealed the highest concentration of H_2S and RSH to be 20.50 while 4.60 wt. % was at station 1, indicating effluent enrichment and occasional spills to contribute to such high enrichment, particularly as crude oil has been reported to contain sulphur (0.19% to 2.50%), which could be converted to H_2S by the action of microbes (Dean, 1968). Further increase in the level of sulphides could be due to water-borne H_2S, as similarly reported by Korting (1970).

5.1.4 SURFACTANT (Dispersant):

The highest concentration of surfactant recorded (0.60ppm) was in station 1. It has been reported that surfactants in refinery effluent originate from cooling water system (Cote, 1976). In an analysis of predischarged effluent of the refinery (Onwumere, 1987),

levels up to 0.40ppm was recorded. This indicates that the prediscbarged effluent contains low level of surfactant as compared to values recorded in this work. The disparity could be due to the occasional addition of surfactant during the period of spills to disperse oil slicks, as well as accumulation (adsorption) by sediments over a long period following such addition. The sediment may subsequently serve as reservoir of occasional surfactant desorption to the surfacewater.

.1.5 PHENOL:

The presence of phenolic compounds in refinery effluent is traceable to thermal and catalytic cracking of crude oil. Field and laboratory studies undertaken by Zoulalian et al. (1974) on the levels of phenolic compounds below an oil refinery outfall indicated the presence of phenolic substances beyond 300 meters downstream. At Romi stream, phenol was detected in stations 1 to 3, and non-detectable in stations 4 and 5. The absence of phenol in these stations (4 and 5) could be due to excessive dilution, and biophysico-chemical degradation. Zoulalian et al. (1974) demonstrated that biodegradation of phenols by 10% occurred within 200 minutes after discharge into St. Lawrence river (Ontario, Canada), and noted dilution to have a major influence on the decreasing concentration of phenol. It has also been reported (Laws, 1981) that phenols in aquatic system were degraded by combination of biological, physical and chemical processes.

on Shendam and Pankshin reservoirs, Nigeria (Kemdirim, 1987); Kaduna river (Awanda, 1987); Chesa Peake Bay, U.S.A. (Beardly, 1988) attributed nutrient enrichment to surface input mainly from agricultural land, and desorption from bottom sediments.

5 .1.8 CHLOROPHYLL 'a':

A peak in chlorophyll 'a' concentration was observed during the later part of rainy season. This could be related to the high phosphates and nitrate enrichment period. Similar increase in chlorophyll 'a' concentration with corresponding increase in phosphate-phosphorus and nitrate-nitrogen has been reported by several workers. Hecky and Kling (1980), Kemdirim (1987), Awanda (1987) observed covariation in chlorophyll 'a' concentration, phosphate-phosphorus and nitrate-nitrogen maxima.

5 .1.9 DISSOLVED OXYGEN:

Station 2 was observed to contain very low level of oxygen throughout the dry season period with a steady re-oxygenation as rainy season progressed. Both dissolved oxygen and percentage saturation were observed to be higher during the rainy season. The oxygen content was observed to be on the increase with increasing chlorophyll 'a' concentration, phytoplankton and zooplankton abundance. Increased turbulance during the rainy season could be responsible for water-air-reoxygenation and low oxygen during the dry season may be due to reduction in water level during this period with a consequent reduction in water velocity and mixing. According to Maitland (1978), dissolved oxygen in water depends on the extent of water-air contact, water

velocity and mixing. Biswass (1966) and Adeniji (1973) reported a similar increase in oxygen concentration in two water bodies, (Volta Lake, Ghana and Lake Kainji, Nigeria respectively) and attributed such increase to increased phytoplankton activities, which was observed to coincide with the period of phytoplankton bloom.

The general low oxygen content of the stream could be due to high oxygen demand of the water body associated with the biodegradation of organics and a variety of reductants associated with refinery wastes. Similar observation was made with respect to Canadian refinery effluents (Cote, 1976). Meynell (1973) in hydrological survey of Rio Ojaile river (Spain) reported that pollution by a refinery effluent had reduced DO level to $1mg.L^{-1}$, however, he observed that downstream reoxygenation had increased the level to $8mg.L^{-1}$ at 1kkm distance, and $12mg.L^{-1}$ at 8kkm distance downstream from point-source. Such reduction in oxygen content with a more pronounced effect during the dry season following reduction in water level, flow rate and turbulence was recorded in Romi stream.

5.1.10 CARBONDIOXIDE:

Increase in CO_2 concentration as dry season progressed was observed. This could be due to decreased water level, reduction in oxygen concentration during the dry season, slight increase in water temperature and microbial degradation of organics. Kemdirim (1987) reported similar increase in CO_2 concentration in Shendam reservoir (Nigeria) during the dry season, and attributed the extent of organic decomposition to account for such increase. According to USEPA (1979), differences in CO_2 concentrations with season is related to differences in anaerobic decomposition of organics and the uptake of CO_2 by phytoplankton for phytosynthesis.

5.1.11 **BIOCHEMICAL OXYGEN DEMAND:**

Mean seasonal BOD values were observed to be high during the rainy season as compared to dry season. This could be related to high impact of oxygen demanding chemicals as a result of occasional oil spills, surface run off during the rainy season, effluent discharge and the corresponding increase in aquatic fauna. According to Cote (1976) refinery effluents have average BOD of over 94kg from every 1000 barrels of crude oil processed. High BOD discharge might therefore be associated with Kaduna refinery effluent which processes crude oil beyond 100,000 barrels per day (Anon., 1989).

5.1.12 **CHEMICAL OXYGEN DEMAND:**

Seasonal variations in COD appears to exhibit similar trend observed in BOD. The COD loading for every 1000 barrels of crude oil processed has been reported to exceed 1,300kg (Wilber, 1969).

Allocthonous input of inorganic reducing agents could be another reason for the observed high COD.

5.1.13 **ALKALINITY:**

Alkalinity was observed to be high during the dry season with a gradual decline as rainy season progressed. This could be attributed to low water level and soil type. Decrease in

alkalinity during the rainy season was similarly reported by Awanda (1987) in Kaduna river to be related to dilution effect by rain. Soil taking up the bicarbonate ion resulting in a corresponding decrease in alkalinity was reported by Sprenger et al. (1987) in studies of some selected elements concentrations in some acidic lakes.

5.1.14 HARDNESS:

The water has been noted to remain fairly hard throughout the year. The high levels of Ca^{2+}, Mg^{2+} and other alkaline earth metals recorded in surfacewater and sediment samples might play a significant role in maintaining fairly high level of hardness throughout the year. Jop and Wojtan (1981) associated low hardness to low levels of Ca^{2+} and Mg^{2+}.

5.1.15 CHLORIDE ION:

The high level of chloride ion observed during the rainy season could be related to chloride enrichment by rains. Gorham (1958, 1961) measured the influence of atmospheric precipitation on the supply of ions to natural waters in English Lake District, and associated the supply of chloride to rain, with a range of about 0.1mg.L^{-1} (Minnesota) and 8.9mg.L^{-1} in Newfoundland. Gibbs (1970, 1972) reported that the chloride of the Rio Tefe (a tributary of the Amazon) has the rain as its major source.

5.1.16 ELECTRICAL CONDUCTIVITY:

Gradual rise in conductivity was recorded as dry season progressed. Similar increase was reported in some water bodies, Jos, Nigeria, (Kemdirim, 1987) and the increase was attributed

to higher content of bivalent cations (Ca^{2+} and Mg^{2+}), and high sediment Pb^{2+}. According to Green (1960), Biswas (1966a) and Imovbare (1970) low conductivity of water bodies during the rains could be due to dilution effect. Significant drop in conductivity was observed in station 1. This could be due to the nature of the bottom (rocky) coupled with increased slope which lead to increase in water speed and did not provide soft underlaying substratum for accumulation of ions.

5.1.17 SUSPENDED SOLID:

The decline in amount of suspended solid following the commencement of rains, with the gradual decrease with increasing distance from the refinery effluent outfall could be due to increased water volume and speed noticed during the rainy season and the setting out of the suspended material with increase in distance. Similar decrease in suspended matter was reported by Lynes (1960) and it was attributed to increased rate of setting out, high water level and microbial decomposition.

5.1.18 DISSOLVED SOLID:

The rainy season was characterised by low concentration of dissolved solid. Increase in water level might have accounted for this. The significant positive correlation observed between the amount of dissolved solid and water temperature seems to suggest that the solubility of substances is influenced by temperature, which was observed to be higher during the dry season.

The low conductivity recorded during the rainy season seems to indicate that the contribution of rains to increase in

conductivity was insignificant. According to Hynes (1960), conductivity is related to the amount of dissolved solid, which in turn is influenced by effluent discharge, leaching and autochthonous contributions.

5.2.0. **METALS:**

Metal enrichment of the water body could be attributed largely to surface input, effluent discharge and occasional spills. The nature of sediment and organic decay could contribute to such enrichment. There was a marked disperity, with higher concentration of metals in sediment as compared with that of surfacewater. The role of sediments as natural sinks for most metallic species has been studied by Groot et al. (1973) who observed sediments to bear large amount of heavy metals. Reimer and Krent (1973) studied the sorption phenomenon of organics of bottom sediments and reported that such sorption, is dependent on a number of factors among which low pH is important. The low sediment pH observed year round could be responsible for the sediment sorption of metals and the consequent higher metal concentrations in sediment throughout the year as compared to the surfacewater concentrations.

The slight elevation of alkaline-earth metals at the beginning of rainy season and the heavy metals maxima observed during the same period (with the exception of Mn and Zn) could be related to surface flow input. According to Sprenger et al. (1987), soil type and surface flow could have influence on trace-elements, while Caldwell (1975) suggested that certain heavy metals of plant origin may occur in natural waters. Rainwater could also account for metals enrichment of water bodies. Skoczen (1982) reported increased

lead loads at time of great precipitation in Vistula river (Poland).

5.3 . 0 BIOLOGICAL CHARACTERISTICS:

Literature on oil pollution and its impact on freshwater has been scanty. However, the fate of oil and its effects on the biota have been widely studied with respect to marine environments, possibly due to concern about oil spills which occur mostly in the marine environment. In a number of laboratory studies, the effects of oil have been studied, of recent being the work of Linden et al. (1987) on the effect of North sea oil and oil dispersant.

Despite the limited literature on freshwater-related studies, oil impact can be assessed in inland waters using the available literature on marine-related studies, particularly as the toxicity of oil has been reported by several workers including Blumer (1969), Nelson-Smith (1972) and Laws (1981), to be largely dependent on the nature of oil, concentration and the nature of organisms.

5 .3.1 MACROINVERTEBRATES IN SURFACEWATER:

Hemipterans and Chironomus sp. constitute the surfacewater macroinvertebrates of Bomi stream. Considerable reduction in abundance, particularly with regard to the Hemipterans was observed during the dry season. This might be due to the recorded increasing oil, phenol and surfactant concentrations with increasing period of dry season. Increase in surfacewater macroinvertebrates with increasing distance from the refinery outfall downstream was recorded, with maxima at station 5. Report by Kerr (1977) on the study of circumstances controlling oil impact in ocean, attributed distance from point-sauce to diminish in both quantity and effect.

Review of toxicity studies by Laws (1981) indicates that most aquatic communities are adversely affected by oil concentration above 10ppm. Similar effect was reported by Linden et al. (1987) on studies of oil effect on littoral ecosystem of Baltic sea, suggesting clear inhibitory effect of oil on the growth of macrofauna. No surfacewater macroinvertebrates was recorded at station 1 throughout the year. Only 4.12% recorded at station 2, while station 5 was found to contain over 40% of the invertebrate population. The disappearance of surfacewater macroinvertebrates at station 1 could be attributed to high levels of effluent components particularly oil, phenol and surfactant. The same reason may account for the great reduction in the abundance at station 2. The higher abundance recorded at station 5 might be due to significant recovery of the stream, particularly as no hydrogen sulphide, oil, phenol, surfactant was detected at station 5. The presence of oil components in water as it affects surfacewater organisms has been illucidated by Kerr (1977). Accordingly, most components of oil being less dense than water, usually tend to float on the water surface thus come in contact with surfacewater organisms to exert deleterous effect, particularly in period of less turbulence.

5 .3.2 ZOOPLANKTON:

The density of zooplankton was observed to be higher during the rainy season with Daphnia sp., Diaptomus sp. and Cyclops sp. being dominant. High water level, upsurge in phytoplankton density, decrease in oil and its related components coupled with increased re-oxygenation rate due to high tubulence

could account for this. A few field studies in connection with oil spills have indicated similar effects. The work of Gilfillan et al. (1976) on oil spill in Marine, Thomas (1978) on 'Arrow' spill at Chedabucta Bay, Nova Scotia (Canada) show reduction in plankton communities and the growth of many other components of the biota following the spills.

5 .3.3 PHYTOPLANKTON:

The phytoplankton dominated by chlorophytes, cyanophytes and Bacillariophytes, were more abundant during the rainy season and recorded in high number all year round. Tolerance of algae to pollution effect could account for this to certain degree. Study carried out by Scott and Glooschenka (1984) indicates no discernible short- or long-term effects on phytoplankton in ponds exposed to crude oil. Blue-green algae (Cyanophytes) have been reported by Nelson-Smith (1972) to show apparent resistance to oil pollution from both refinery effluent and trackling filters designed to remove oil from the effluent. Similar report on Phytoplankton tolerance to oil pollution has been made available by Sauthward and Southward (1978) following "Torey Caryon" spill, Elmgren et al. (1980) and Vargo (1982) using model system exposed to number 2 oil, Connell and Miller (1980) on phytotoxic effects of petroleum hydrocarbon.

5 .3.4 BENTHIC MACROINVERTEBRATES:

No benthic macroinvertebrates was recorded in station 1 throughout the year. Possible reason could be the concrate nature of the effluent basin. According to Dicks (1983) benthic communities in water bodies polluted with oil tend to be influenced

by sediment nature. Thus soft sediments tend to support a wider range of community types.

The year round absence of benthic macroinvertebrates in station 2 might be due to high levels of contaminants, particularly the subsediment layer of oil covering the sediment. Similar observation was made when oil was found to penetrate into sediment, killing virtually all benthic communities, following Buzzards Bay Oil spill case study (Blumer et al., 1971). Further studies by Krebs and Burns (1977) revealed that toxic components such as napthalene from oil persists in sediment for years following the spill.

According to Laws (1981), low molecular weight hydrocarbons evidently find their way into sediments and persist to kill organisms for several months after spill incidence. This indicates the possibility that a single oil spill from the Kaduna refinery, as one evident in August, 1988, which was reported to persist for some years (Anon., 1988) could account for detrimental effects on aquatic communities for years to follow.

CHAPTER SIX

6.0 S U M M A R Y

The physico-chemical characteristics, distribution, abundance, seasonal variation of surfacewater and benthic macroinvertebrates; zooplankton and phytoplankton groups of Romi stream (Kaduna) were studied monthly for a period of twelve months (from November, 1987 to October, 1988).

Water samples were collected in 1 litre capacity acid-washed plastic bottles from 5 stations downstream from NNPC Kaduna refinery effluent outfall. Methods of Lind (1979) and APHA (1980) were used.

Water temperature, pH, conductivity were measured on the spot using mercury thermometer, portable pH and conductivity meters respectively. Sediment pH was determined using 1:1 sediment-water ratio of Black (1966). Optical density of the water was measured by Spectrophotometric method of Lee (1978); dissolved and suspended solids by method of Lind (1974), Hardness, CO_2, Cl, titration (APHA, 1980). DO by modified Winker's azide method, O_2 saturation was calculated using the formula of Golterman (1970), Alkalinity and BOD by Methylorange-phenolphthalien and BOD-5 day methods respectively (APHA, 1980). COD by titration (Golterman, 1970), NO_3-N and PO_4-P contents were determined by spectrophotometry using Deniges and phenol-disulphonic acid methods (APHA, 1980). Chlorophyll 'a' was by the method of Talling and Driver (1963) using 90% acetone as extraction medium. Metal analysis by APHA (1980) methods respectively. Alkaline-earth metals by flame photometry (WHO, 1963) and APHA (1980).

Concentrations of oil in water, H_2S and RSH, surfactant and phenol were determined by the NNPC Kaduna Water Laboratory.

Plankton samples were collected using 25cm radius and 70 meshes/cm^2 plankton net. Zooplankton was preserved in 4% formalin and phytoplankton in Lugol solution (WHO, 1963) and APHA (1980). Macroinvertebrates in surfacewater were collected using the sweep net, and benthic macroinvertebrates and sediment samples by using Ekman's grab of 300cm^3 area.

The relationship between parameters was determined by correlation analysis and 2-way analysis of variance using computer at 0.05, and 0.01, 0.05 levels of significance respectively.

Significant seasonal variations were observed in water temperature, H_2S and RSH, Oil, Phenol, surfactant, PO_4-P, chlorophyll 'a', CO_2, BOD, Cl, suspended solid, alkaline-earth metals in surfacewater, Fe; sediment Ca, Pb, Cu, Mn, Cr and Ni. Highly significant difference in seasonal composition of surface-water and benthic macroinvertebrates, phytoplankton and zooplankton density ($P < 0.01$) was observed.

Significant difference between stations in terms of surfacewater macroinvertebrates, phytoplankton and zooplankton groups was recorded. Alkaline-earth metals in surfacewater, Mn and Fe concentrations; sediment Ni, Cu, Mg and Ca also varied significantly between stations. Similar difference was observed in amount of suspended solid, conductivity, Cl, hardness, alkalinity, chlorophyll 'a', COD, BOD, O_2 saturation, PO_4-P, phenol, oil, H_2S and RSH, and sediment pH.

Positive correlation was observed between surfacewater and sediment concentrations of K, Ca, Pb, Cu, Mn, Cr and Ni ($P< 0.05$). The correlation between surfacewater Mg, Na, Fe, Cd and sediment concentrations was insignificant ($P> 0.05$).

The surfacewater macroinvertebrates were composed of Hemiptera (56.55%), Coleoptera (23.45%), and Diptera (20.00%). Relative abundance was highest in station 5, with station 1 devoid of any. The genera recorded were Notonecta sp., Laccotrephes sp., Gerris sp., Ranatra sp., Hydrophilus sp., and Chironomus sp.

Increase in oil, phenol, surfactant, water hardness and pH was observed to have corresponding decrease in surfacewater macroinvertebrates density, while DO, surfacewater K, Ca, Mg, chlorophyll 'a', and zooplankton showed positive correlation ($P< 0.05$).

The Crustaceans were found to constitute the zooplankton species. 2 groups consisting of 3 genera were recorded. The Copepods made up of 66.20% and Cladocerans 33.80%, comprising of the following genera: Daphnia sp. (55.60%), Cyclops sp. (10.60%) and Diaptomus sp. (33.80%) respectively.

Decline in zooplankton density was observed as dry season progressed, with highly significant difference between stations and seasons (P 0.01). Stations 1 and 2 were mostly devoid of zooplankton species, while station 5 contained the highest zooplankton density.

Positive correlation was observed between zooplankton and DO, BOD, NO_3-N, alkaline-earth metals in surfacewater, while increase in H_2S and RSH, Oil, Phenol and surfactant

was observed to cause significant drop in zooplankton density ($P < 0.05$).

The various taxa of phytoplankton recorded were represented by the Chlorophytes (38.95%), Cyanophytes (28.94%) and Bacillariophytes (32.50%). The various genera were Spirogyra sp., Closterium sp., Ulotrix sp., Zygnema sp., Euderina sp., Selanastrum sp., Nivacula sp., Gyrosigma sp., Cymbella sp., Pinnularia sp., Phormidium sp., Oscillatoria sp., and Nostoc sp with station 1 containing the highest density.

Phytoplankton density was observed to be higher during the dry season with highly significant difference between seasons, station by season and months ($P < 0.01$).

Benthic macroinvertebrates comprised of Oligochaetes (10.14%), Dipterans (33.33%), Gastropods (2.04%) and various developmental stages of Odonatans, Nematodes and tadpoles (54.49%). The recorded genera were Limbricus sp., Chironomus sp., Graulus sp., and Planorbis sp.

Stations 1 and 2 were found to be completely devoid of benthic macroinvertebrates, with year round high abundance in station 5.

Higher density was observed during the rainy season, with significant difference between stations and months ($P < 0.05$). A decrease in benthic macroinvertebrates with increasing concentrations of H_2S and RSH, Oil, Phenol and sediment Pb was observed ($P < 0.05$).

.1 CONCLUSION

The distribution and relative abundance of surfacewater nd benthic macroinvertebrates, zooplankton and phytoplankton mmunities of Romi stream, Kaduna, are influenced by the mbined effects of seasons and physico-chemical characteristics the stream. Chemical quality of the stream is influenced rgely by the input of oil and related components into the ter body via occasional spills and pipeline leakages and to lesser extent by the effluent discharge.

High oxygen demand of the stream drastically reduces the ygen concentration of the water to levels too low to ustain high aquatic fauns, resulting in high O_2 saturation lue at low O_2 concentration.

High phytoplankton density is due to tolerance of aquatic nts, particularly algae to pollution load. The low density aquatic fauna, low O_2 content, coupled with high organics, solved and suspended solid, less species diversity haracterized the stream to be unproductive.

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APPENDIX.

AIR TEMPERATURE (°C)

SITE	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
Rs 1	27.5	31.1	28.9	31.0	29.7	30.1	32.4	24.4	29.0	28.1	23.4	22.8
Rs 2	23.1	32.0	30.0	30.7	30.2	29.9	30.7	27.0	27.2	32.0	23.4	21.5
Rs 3	26.0	29.7	31.3	28.3	27.9	31.0	29.3	23.6	24.8	27.0	22.7	23.0
Rs 4	23.2	30.2	29.6	28.8	31.0	29.5	30.1	28.1	21.9	33.0	23.1	22.9
Rs 5	21.5	31.3	28.4	30.1	29.8	30.3	31.4	27.5	22.3	34.8	22.9	25.7

Water Temperature (^{o}C)

	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
SITE												
Rs 1	31.5	29.0	30.1	29.8	34.0	28.6	31.2	29.2	27.8	33.0	21.6	23.7
Rs 2	31.8	27.0	31.3	30.2	33.2	30.1	28.0	27.8	24.4	35.0	20.4	22.5
Rs 3	31.5	24.0	28.6	30.0	34.0	27.9	30.7	22.6	23.1	24.2	19.7	20.4
Rs 4	30.1	22.1	29.0	31.7	29.3	31.4	30.1	25.1	25.0	26.3	20.1	21.3
Rs 5	30.3	22.0	31.1	29.9	32.1	29.0	29.7	22.7	25.3	28.0	21.3	21.7

WATER pH

SITE	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
Rs 1	7.90	6.80	7.20	7.40	7.2	7.90	7.30	7.10	7.2	6.3	7.1	7.40
Rs 2	7.00	6.80	6.90	6.70	6.90	6.70	6.60	7.30	6.80	6.40	7.0	6.6
Rs 3	6.70	6.00	7.00	6.90	7.00	7.30	7.10	7.90	7.00	6.80	7.30	7.10
Rs 4	6.40	6.70	7.10	7.30	8.00	7.10	7.50	7.70	7.00	6.50	7.10	7.30
Rs 5	6.30	6.70	7.30	7.10	7.70	7.1	6.80	7.10	7.60	6.30	6.80	6.80

SEDIMENT pH

SITE	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
Rs 1	8.9	7.3	7.1	7.6	7.7	7.9	8.1	8.4	8.3	8.5	7.1	7.7
Rs 2	3.8	3.8	3.9	4.9	5.2	6.0	5.3	5.1	3.9	4.1	3.8	4.0
Rs 3	6.0	5.8	6.5	6.8	6.7	5.9	6.0	5.9	5.7	5.8	6.0	5.6
Rs 4	5.5	5.8	6.0	6.6	5.9	5.8	5.8	5.9	5.6	5.6	5.9	5.7
Rs 5	7.1	6.9	6.9	7.2	7.0	6.9	7.1	7.3	7.4	6.9	7.1	7.3

HYDROGEN SULFIDE (WT.%)

	N	D	J	F	M	A	M	J	J	A	S	O
Rs 1	0.72	0.83	0.19	0.46	0.32	0.48	2.56	0.43	0.36	4.60	0.49	0.72
Rs 2	0.33	0.52	0.17	0.19	0.37	0.36	1.32	0.25	0.30	3.49	0.41	0.50
Rs 3	0.29	0.30	0.10	0.12	0.20	0.25	0.30	0.10	0.25	1.16	0.36	0.48
Rs 4	0.20	0.17	0.10	0.16	0.21	0.12	0.30	0.21	0.11	1.11	0.29	0.30
Rs 5	-	-	-	-	-	-	-	-	-	-	-	-

OIL IN WATER (PPM)

	N	D	J	F	M	A	M	J	J	A	S	O
Rs 1	4.50	3.81	6.00	7.10	5.49	6.35	9.69	8.72	7.01	10.42	5.50	4.00
Rs 2	3.93	3.29	3.08	6.44	2.36	5.04	3.72	3.14	3.00	9.33	4.92	4.40
Rs 3	1.87	1.82	2.11	2.00	1.81	4.10	2.08	1.41	2.73	3.85	3.98	3.42
Rs 4	0.91	1.00	1.36	0.49	1.43	1.51	1.03	0.61	0.71	1.06	0.32	0.27
Rs 5	-	-	-	-	-	-	-	-	-	-	-	-

PHENOL CONTENT ($\mu g.L^{-1}$)

	N	D	J	F	M	A	M	J	J	A	S	O
Rs 1	0.89	0.79	0.53	0.54	0.46	0.48	1.20	2.66	0.52	4.06	1.10	0.81
Rs 2	0.27	0.35	0.23	0.48	0.22	0.17	0.29	0.23	0.08	1.13	0.21	0.62
Rs 3	0.05	0.10	0.05	0.09	0.17	0.10	0.05	0.10	0.05	0.16	0.04	0.02
Rs 4	-	-	-	-	-	-	-	-	-	-	-	-
Rs 5	-	-	-	-	-	-	-	-	-	-	-	-

SURFACTANT (PPM)

	N	D	J	F	M	A	M	J	J	A	S	O
Rs 1	0.40	0.20	0.30	0.41	0.20	0.30	0.42	0.30	0.30	0.60	0.40	0.42
Rs 2	0.20	0.10	0.20	0.03	0.10	0.01	0.10	0.06	0.04	0.51	0.03	0.01
Rs 3	0.03	0.02	0.02	-	0.02	-	-	0.02	0.02	0.13	0.01	0.01
Rs 4	-	-	-	-	-	-	-	-	-	-	-	-
Rs 5	-	-	-	-	-	-	-	-	-	-	-	-

DISSOLVED OXYGEN ($MG.L^{-1}$)

SITE	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
Rs 1	3.6	3.4	3.8	4.0	3.7	3.1	2.8	3.7	3.4	3.1	2.1	3.0
Rs 2	1.7	1.6	1.4	1.4	1.3	2.8	2.9	3.5	3.1	3.4	2.0	2.8
Rs 3	2.3	3.2	3.0	3.2	3.6	2.7	2.5	4.0	3.7	3.8	3.4	4.2
Rs 4	4.6	3.2	3.3	3.1	3.1	2.0	2.6	3.8	3.7	4.1	3.1	3.9
Rs 5	3.8	2.9	3.1	2.8	2.6	2.8	2.9	4.0	3.9	4.3	3.7	4.3

% SATURATION OF OXYGEN

SITE	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
Rs 1	49.18	44.50	50.46	53.12	51.99	40.58	37.74	48.43	44.50	42.94	24.62	36.36
Rs 2	23.22	20.36	18.97	18.59	18.91	37.10	37.40	45.16	37.58	48.29	22.62	33.41
Rs 3	31.42	38.70	38.17	42.49	54.49	34.93	33.59	47.73	44.15	46.96	38.46	47.51
Rs 4	61.00	37.51	43.19	42.34	40.58	26.95	34.52	46.86	45.62	51.31	35.07	44.93
Rs 5	50.46	33.99	41.77	37.18	35.52	36.55	38.51	47.73	48.00	55.40	42.63	50.41

DISSOLVED CARBONDIOXIDE (Mg. L^{-1})

SITE	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
Rs 1	26	56	47	62	22	28	23	28	31	30	20	23
Rs 2	37	60	60	71	48	39	31	47	30	28	26	21
Rs 3	26	34	49	50	38	41	37	24	26	14	41	19
Rs 4	19	53	38	48	18	38	33	19	29	14	37	22
Rs 5	17	30	44	39	4	25	30	21	25	13	30	32

DISSOLVED CARBONDIOXIDE (Mg. L^{-1})

SITE	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
Rs 1	26	56	47	62	22	28	23	28	31	30	20	23
Rs 2	37	60	60	71	48	39	31	47	30	28	26	21
Rs 3	26	34	49	50	38	41	37	24	26	14	41	19
Rs 4	19	53	38	48	18	38	33	19	29	14	37	22
Rs 5	17	30	44	39	4	25	30	21	25	13	30	32

BIOCHEMICAL OXYGEN DEMAND (B.O.D.) $mg.L^{-1}$

SITE	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
Rs 1	1.0	1.8	2.0	1.8	2.7	2.1	1.8	1.9	2.4	2.7	1.3	1.9
Rs 2	0.1	0.2	0.3	0.1	0.1	0.5	0.3	0.8	1.6	1.9	1.6	2.0
Rs 3	1.6	1.6	2.7	3.1	3.4	1.1	1.9	1.6	2.0	2.0	2.4	2.3
Rs 4	4.4	3.1	2.6	2.6	3.3	1.8	2.0	1.5	2.0	2.0	2.0	2.1
Rs 5	3.1	0.4	2.6	2.0	2.0	1.2	2.0	1.9	1.9	1.8	2.3	2.1

CHEMICAL OXYGEN DEMAND (C.O.D.) x 10^{-1} mg.L^{-1}

SITE	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
Rs 1	312	136	240	224	240	320	296	240	336	296	320	232
Rs 2	392	520	464	384	448	480	388	494	408	392	408	280
Rs 3	360	200	320	264	360	328	312	296	376	376	376	264
Rs 4	384	392	392	416	416	456	360	328	392	388	392	376
Rs 5	376	224	376	312	408	336	320	312	392	304	376	320

NITRATE-NITROGEN (PPM)

SITE	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
Rs 1	5.95	4.20	2.09	2.45	2.09	1.75	2.27	2.45	5.95	5.25	3.68	3.15
Rs 2	7.70	1.92	3.32	3.68	3.68	2.79	3.45	3.32	5.43	5.78	4.20	4.00
Rs 3	7.70	3.32	3.68	4.20	5.25	3.32	3.68	2.97	5.25	4.38	4.03	3.50
Rs 4	4.90	2.79	4.55	4.55	4.90	3.85	4.55	4.20	4.55	4.90	5.25	4.37
Rs 5	7.00	3.45	4.03	4.55	5.08	4.38	4.55	3.85	4.90	5.25	5.78	4.55

PHOSPHATE-PHOSPHOROUS IN WATER (PPM)

SITE	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
Rs 1	69.58	62.99	82.95	96.34	82.95	56.21	56.21	62.99	56.21	56.21	56.21	76.26
Rs 2	82.95	76.26	96.34	123.05	109.68	82.95	76.26	109.68	136.42	149.79	136.42	102.99
Rs 3	49.52	109.68	69.58	116.37	136.42	96.34	109.68	129.74	163.16	116.37	149.79	123.05
Rs 4	82.95	89.63	76.26	149.79	102.99	69.58	109.68	129.74	149.79	156.48	149.79	143.11
Rs 5	56.21	82.95	76.26	149.79	102.99	76.26	96.34	129.74	143.11	156.48	149.79	143.11

CHLOROPHYLL 'a' IN WATER (PPM)

SITE	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
Rs 1	0.952	1.190	0.952	1.190	1.190	0.152	0.952	1.190	1.190	1.428	0.952	0.714
Rs 2	3.570	8.330	4.522	3.570	2.856	2.380	3.332	3.570	2.856	3.808	0.476	0.952
Rs 3	3.570	7.140	5.474	8.568	9.520	5.236	6.426	7.140	10.948	12.614	2.856	3.332
Rs 4	9.520	6.188	4.522	9.044	9.044	4.760	6.426	8.330	11.662	14.994	3.332	3.808
Rs 5	6.902	4.046	2.618	9.044	9.282	8.568	6.188	7.854	11.424	14.756	2.856	4.046

CONDUCTIVITY ($X\ 10^3$) K = 0.1

SITE	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
Rs 1	1.00	1.00	1.30	1.90	1.12	1.90	1.40	1.30	1.10	1.35	1.01	1.20
Rs 2	3.45	4.35	6.80	6.20	4.60	7.70	6.50	7.10	6.80	8.10	6.70	6.15
Rs 3	2.45	2.65	6.00	5.80	4.60	4.80	2.80	5.30	5.40	6.20	6.25	2.00
Rs 4	0.86	3.00	3.40	4.10	5.00	2.40	2.70	5.50	5.90	6.25	5.25	2.55
Rs 5	0.89	0.40	3.10	5.30	6.00	2.70	2.10	4.20	5.70	6.80	4.80	1.50

SUSPENDED SOLID (Mg. L^{-1})

SITE	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
Rs 1	101	160	109	172	162	86	47	92	125	113	97	63
Rs 2	137	142	140	163	178	121	98	93	99	85	72	61
Rs 3	90	85	97	108	110	113	100	87	81	81	73	58
Rs 4	122	127	133	141	148	132	121	99	93	95	81	78
Rs 5	82	87	90	91	90	83	79	80	73	71	65	52

DISSOLVED SOLID (Mg. L^{-1})

SITE	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
Rs 1	692	680	792	684	597	620	572	650	662	627	613	591
Rs 2	781	920	933	1,021	1,009	1,314	922	802	790	648	620	523
Rs 3	630	827	896	9,003	9,940	1,277	916	720	601	625	613	519
Rs 4	981	953	978	1,101	1,162	961	940	787	692	673	663	521
Rs 5	718	723	737	831	860	744	638	591	576	520	564	511

ALKALINITY (PPM)

SITE	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
Rs 1	18	33	21	61	47	52	46	40	43	38	72	29
Rs 2	103	183	163	187	88	64	121	63	72	44	68	27
Rs 3	75	101	101	126	90	55	81	49	81	26	73	29
Rs 4	43	79	112	174	133	59	42	61	79	28	71	23
Rs 5	48	94	164	130	120	43	46	57	73	23	75	21

WATER HARDNESS ($Ca\ Co_3$ ppm)

SITE	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
Rs 1	60	60	68	92	116	92	112	44	36	52	52	68
Rs 2	60	52	56	72	76	68	88	72	52	72	72	84
Rs 3	60	40	72	52	116	80	64	96	80	92	84	92
Rs 4	12	52	36	68	88	76	76	84	68	116	92	108
Rs 5	36	48	40	36	72	52	84	80	80	68	108	100

CHLORIDE ION (PPM)

SITE	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
Rs 1	55	53	47	61	49	67	43	61	72	41	43	53
Rs 2	103	117	120	107	99	132	107	147	153	110	141	127
Rs 3	70	85	86	52	60	96	69	139	161	128	126	131
Rs 4	70	104	93	73	91	81	74	112	110	146	119	99
Rs 5	70	102	93	60	82	80	70	120	131	143	119	97

ALKALINE-EARTH METALS IN SURFACE-WATER (PPM)

SITE	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
Rs 1	2.41	2.00	1.79	2.11	2.14	1.90	2.62	1.88	1.32	1.83	2.00	2.11
Rs 2	4.97	3.84	3.36	4.00	4.60	3.61	3.70	3.90	4.61	4.71	3.43	3.60
Rs 3	3.47	3.40	3.61	3.22	4.97	4.11	4.66	4.70	4.60	4.58	3.01	3.21
Rs 4	3.44	3.42	3.51	3.47	5.20	4.97	4.69	4.80	4.72	4.76	3.45	3.50
Rs 5	3.48	3.97	3.51	3.51	4.97	4.82	4.82	5.22	4.72	4.82	3.42	3.50

CALCIUM

SITE	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
Rs 1	3.60	3.71	3.42	2.43	2.61	3.00	3.93	2.91	2.83	2.71	2.32	2.19
Rs 2	4.00	4.43	5.21	5.20	4.00	4.71	5.20	5.73	6.32	6.03	3.61	3.63
Rs 3	5.60	5.30	6.00	4.70	5.50	5.62	5.23	5.38	4.92	5.14	4.00	3.88
Rs 4	5.50	5.00	5.50	4.81	5.21	6.04	5.21	5.80	5.67	6.12	3.86	4.12
Rs 5	5.00	4.72	5.73	5.70	4.50	5.20	5.80	5.20	6.10	6.15	4.84	4.50

MAGNESIUM

SITE	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
Rs 1	2.90	2.01	3.12	2.14	2.37	2.60	2.11	2.01	1.93	1.08	1.87	1.99
Rs 2	2.08	1.82	3.30	3.30	2.54	3.41	3.46	3.60	4.02	4.30	2.36	2.49
Rs 3	2.50	2.07	3.55	3.43	3.12	3.33	3.61	3.81	3.81	3.80	3.14	2.28
Rs 4	3.37	2.27	3.89	3.76	2.92	3.78	3.82	4.00	4.31	4.42	3.32	3.17
Rs 5	3.50	2.09	3.77	2.86	3.00	3.82	3.80	3.93	4.28	4.38	3.30	3.32

SODIUM

SITE	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
Rs 1	2.14	2.17	3.91	3.00	3.13	2.88	1.96	2.00	2.73	2.38	1.89	2.00
Rs 2	3.01	3.53	5.28	2.84	3.00	2.92	4.21	4.31	3.66	3.90	2.96	2.82
Rs 3	3.91	3.00	4.62	3.28	2.87	2.90	4.30	4.70	3.48	2.82	2.14	2.63
Rs 4	3.80	4.01	4.17	4.35	2.10	3.10	4.36	4.72	3.59	3.41	2.80	2.98
Rs 5	3.59	3.99	4.30	4.41	3.10	3.41	4.35	4.81	3.43	3.38	3.43	3.61

ALKALINE EARTH METALS IN SEDIMENT (PPM)

POTASSIUM IN WATER

SITE	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
Rs 1	910	203	201	216	430	344	430	450	201	220	340	300
Rs 2	109	400	360	380	447	539	496	586	270	280	447	341
Rs 3	143	211	255	492	510	492	536	588	300	273	490	261
Rs 4	121	276	290	300	490	490	610	580	300	301	492	322
Rs 5	111	230	263	298	492	490	595	560	340	308	500	340

CALCIUM

SITE	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
Rs 1	206	371	297	388	326	445	397	263	312	260	390	310
Rs 2	217	363	310	482	482	518	410	310	326	263	486	360
Rs 3	543	355	601	517	482	516	517	355	375	263	462	370
Rs 4	360	413	516	445	516	510	560	411	486	490	440	450
Rs 5	373	471	445	510	512	512	560	400	488	360	510	480

MAGNESIUM

SITE	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
Rs 1	48.5	38.5	41.3	40.1	46.7	53.9	40.1	53.5	53.0	50.9	47.0	40.1
Rs 2	55.5	52.3	57.2	57.2	54.1	55.0	52.9	60.4	54.7	54.7	56.8	56.0
Rs 3	54.7	46.0	54.8	42.6	52.4	52.4	53.8	56.8	50.9	55.2	51.3	50.9
Rs 4	48.1	55.2	50.4	54.1	51.6	40.1	58.1	52.4	40.1	50.3	56.6	54.0
Rs 5	50.0	49.7	54.0	54.1	54.4	50.9	53.8	57.4	40.9	50.4	57.4	54.8

SODIUM

SITE	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
Rs 1	16.1	21.5	15.7	21.8	31.3	54.0	18.1	38.1	41.7	33.8	30.6	25.7
Rs 2	30.0	26.9	30.6	30.0	64.0	82.0	46.7	40.1	60.0	60.5	39.0	30.0
Rs 3	29.3	21.4	12.8	31.3	58.0	64.8	28.1	40.0	53.2	51.7	40.1	28.1
Rs 4	21.4	11.4	13.6	34.4	54.0	56.0	31.3	50.9	69.0	54.3	37.0	40.1
Rs 5	26.4	14.9	28.8	38.1	54.2	50.9	30.0	50.8	70.9	52.7	40.0	48.0

HEAVY METALS IN SURFACE WATER (PPM)

LEAD

SITE	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
Rs 1	1.147	1.073	1.10	1.07	0.93	0.90	0.82	0.63	0.43	0.36	1.62	1.57
Rs 2	1.150	1.101	1.26	1.12	0.88	1.14	0.77	0.61	0.69	0.72	1.80	1.72
Rs 3	0.094	0.988	0.94	0.93	0.81	0.92	0.73	0.52	0.53	0.53	1.71	1.61
Rs 4	0.913	0.860	0.89	0.91	0.83	0.97	0.68	0.55	0.68	0.67	1.83	1.79
Rs 5	0.902	0.820	0.89	0.90	0.78	0.93	0.57	0.52	0.71	0.68	1.51	1.05

IRON

SITE	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
Rs 1	0.11	0.13	0.10	0.17	0.13	0.11	0.10	0.13	0.09	0.12	0.08	0.06
Rs 2	0.35	0.40	0.84	0.06	0.81	0.32	0.72	0.80	0.66	0.69	0.71	0.69
Rs 3	0.27	0.38	0.51	0.47	0.62	0.29	0.43	0.48	0.71	0.52	0.63	0.60
Rs 4	0.39	0.46	0.60	0.49	0.69	0.41	0.52	0.55	0.73	0.69	0.74	0.66
Rs 5	0.34	0.44	0.52	0.52	0.71	0.38	0.52	0.57	0.73	0.71	0.70	0.63

COPPER

SITE	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
Rs 1	0.066	0.063	0.052	0.058	0.036	0.033	0.026	0.019	0.011	0.013	0.16	0.10
Rs 2	0.057	0.052	0.066	0.061	0.050	0.045	0.029	0.023	0.058	0.052	0.19	0.15
Rs 3	0.053	0.051	0.057	0.057	0.039	0.024	0.018	0.021	0.058	0.053	0.12	0.081
Rs 4	0.060	0.056	0.066	0.056	0.045	0.039	0.013	0.033	0.056	0.055	0.080	0.052
Rs 5	0.056	0.047	0.061	0.050	0.041	0.035	0.026	0.031	0.061	0.052	0.050	0.050

ZINC

SITE	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
Rs 1	0.039	0.33	1.02	0.96	1.00	0.99	1.30	1.30	0.10	0.08	0.13	0.11
Rs 2	0.048	0.52	1.17	1.70	1.60	1.23	1.70	1.80	0.19	0.16	0.26	0.24
Rs 3	0.039	0.30	0.96	1.00	1.40	1.01	1.30	0.80	0.13	0.10	0.21	0.20
Rs 4	0.042	0.39	1.33	1.31	1.30	1.72	0.90	0.93	0.17	0.09	0.23	0.23
Rs 5	0.045	0.31	1.20	1.30	1.30	1.60	0.80	0.90	0.16	0.08	0.23	0.20

MANGANESE

SITE	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
Rs 1	0.52	0.38	0.32	0.29	0.17	0.13	0.32	0.33	0.13	0.11	0.19	0.16
Rs 2	0.51	0.44	0.90	0.73	0.92	0.89	0.48	0.51	0.19	0.08	0.20	0.19
Rs 3	0.39	0.32	0.87	0.71	0.71	0.71	0.30	0.41	0.13	0.05	0.17	0.11
Rs 4	0.40	0.41	0.90	0.80	0.69	0.66	0.32	0.38	0.17	0.06	0.23	0.13
Rs 5	0.41	0.41	0.91	0.80	0.70	0.62	0.32	0.35	0.16	0.04	0.20	0.12

CROMIUM

SITE	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
Rs 1	0.007	0.005	0.004	0.004	0.003	0.006	0.007	0.004	0.003	0.004	0.010	0.009
Rs 2	0.013	0.009	0.012	0.010	0.011	0.013	0.009	0.011	-	0.001	0.018	0.016
Rs 3	0.009	0.006	0.009	0.009	0.009	0.008	0.006	0.009	-	-	0.016	0.013
Rs 4	0.011	0.008	0.006	0.008	0.10	0.007	0.012	0.008	0.001	-	0.019	0.018
Rs 5	0.008	0.006	0.008	0.008	0.008	0.007	0.007	0.008	-	-	0.018	0.016

NICKEL

SITE	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
Rs 1	0.039	0.030	0.029	0.031	0.025	0.033	0.039	0.028	0.012	0.010	0.038	0.017
Rs 2	0.021	0.074	0.068	0.070	0.061	0.064	0.051	0.044	0.021	0.024	0.099	0.031
Rs 3	0.050	0.052	0.052	0.051	0.044	0.042	0.032	0.032	0.013	0.011	0.068	0.040
Rs 4	0.059	0.052	0.056	0.053	0.051	0.053	0.036	0.041	0.011	0.016	0.066	0.053
Rs 5	0.057	0.049	0.054	0.045	0.051	0.050	0.036	0.041	0.010	0.013	0.066	0.036

CADMIUM

SITE	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
Rs 1	.00031	.00027	.00027	.00031	.00030	.00041	.00028	.0006	.0026	.0019	.0016	.0013
Rs 2	.00073	.00066	.00069	.00066	.00071	.00059	.00036	.0012	-	-	.0063	.0049
Rs 3	.00059	.00052	.00044	.00042	.00052	.00038	-	.0003	-	-	.0041	.0026
Rs 4	.00065	.00060	.00051	.00051	.00048	.00040	-	-	-	-	.0072	.0019
Rs 5	.00059	.00041	.00084	.00084	.00039	.00036	-	-	-	-	.0061	.0008

HEAVY METALS IN SEDIMENT (PPM)

LEAD

SITE	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
Rs 1	128.6	100.1	121.2	182.8	151.2	166.1	144.3	133.0	123.1	111.0	201.7	182.4
Rs 2	172.0	181.2	190.0	92.7	167.0	182.3	216.1	198.2	177.5	162.3	242.0	191.0
Rs 3	135.4	127.8	121.3	21.3	181.2	179.1	107.5	167.3	146.3	156.7	198.5	171.6
Rs 4	162.1	111.9	124.0	80.7	104.7	166.0	179.8	162.0	112.4	101.0	172.0	134.5
Rs 5	171.0	121.0	101.5	82.1	111.2	149.9	181.4	159.0	119.1	100.2	148.3	127.8

IRON

SITE	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
Rs 1	662.	48.0	32.7	37.8	39.1	82.2	71.8	68.3	62.4	62.1	86.6	77.5
Rs 2	94.6	78.7	45.3	52.1	61.3	91.6	96.3	82.1	91.6	87.3	79.3	79.2
Rs 3	81.3	76.2	51.0	48.8	56.9	82.3	101.1	88.5	87.1	88.1	63.5	81.8
Rs 4	94.5	91.1	39.8	30.1	51.0	81.7	99.7	89.2	82.3	82.5	61.0	79.5
Rs 5	87.3	86.6	40.1	32.2	49.7	79.6	96.3	79.9	79.5	80.0	61.0	80.1

COPPER

SITE	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
Rs 1	57.4	55.1	58.4	23.9	34.1	61.1	80.6	57.1	37.7	40.1	96.3	82.3
Rs 2	76.7	69.6	69.0	30.3	59.8	67.3	116.2	82.3	36.3	37.3	70.1	89.0
Rs 3	45.0	47.5	52.3	32.1	51.3	39.7	64.9	46.2	37.1	35.8	87.3	81.4
Rs 4	56.6	36.6	30.7	32.6	42.5	45.3	36.5	32.6	26.8	20.8	54.0	56.3
Rs 5	54.2	33.9	27.9	33.0	37.0	38.8	41.3	21.1	24.6	21.1	41.4	37.0

ZINC

SITE	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
Rs 1	31.9	22.7	12.3	9.1	31.4	41.0	47.8	41.9	23.3	22.1	51.2	36.9
Rs 2	42.3	30.0	21.7	10.8	39.8	47.9	61.5	57.8	34.8	33.6	43.0	40.1
Rs 3	39.8	42.1	8.9	8.3	39.3	58.6	42.1	53.3	36.0	38.9	48.2	42.5
Rs 4	49.2	43.5	20.1	5.7	39.4	57.0	66.5	51.6	29.1	34.4	31.3	30.0
Rs 5	51.0	48.3	29.3	15.1	36.7	11.3	58.0	42.8	30.5	25.0	33.0	30.0

MANGANESE

SITE	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.
Rs 1	47.2	42.0	42.3	41.4	31.8	30.1	19.9	12.1	13.7	12.2	20.7	13.4
Rs 2	73.8	60.3	56.7	43.8	38.7	32.3	22.1	19.8	16.8	15.3	26.0	20.9
Rs 3	68.9	57.9	48.5	45.7	48.7	39.1	19.5	17.6	13.4	9.8	11.6	18.0
Rs 4	70.2	48.9	41.8	43.3	46.9	40.2	17.8	13.8	14.8	9.8	17.4	16.6
Rs 5	73.7	51.3	43.8	42.7	46.7	40.0	17.6	11.0	14.1	10.0	16.8	16.0

NICKEL

SITE	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
Rs 1	13.8	8.7	11.6	9.5	16.2	15.1	7.3	5.3	6.9	5.1	9.3	11.1
Rs 2	14.0	10.1	13.2	9.7	19.4	16.6	9.6	7.1	8.2	9.8	11.9	11.6
Rs 3	13.3	9.6	9.8	7.7	17.7	13.4	9.1	6.6	6.0	6.9	8.4	9.0
Rs 4	12.7	8.8	10.1	4.8	15.9	9.9	8.7	6.3	6.0	6.3	8.6	9.8
Rs 5	12.0	8.3	10.1	5.1	8.3	9.3	8.7	5.9	5.7	6.1	8.4	8.8

CADMIUM

SITE	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.
Rs 1	0.06	0.10	0.15	0.11	0.24	0.54	0.06	0.08	0.15	0.12	0.06	0.01
Rs 2	0.41	0.18	0.19	0.14	0.33	0.61	0.14	0.18	0.23	0.18	0.19	0.21
Rs 3	0.31	0.10	0.13	0.19	0.26	0.30	0.15	0.14	0.24	0.19	0.10	0.07
Rs 4	0.28	0.13	0.20	0.17	0.21	0.43	0.35	0.18	0.21	0.17	0.17	0.10
Rs 5	0.22	0.16	0.18	0.17	0.20	0.35	0.24	0.19	0.19	0.17	0.11	0.12

OPTICAL DENSITY OF SURFACEWATER

SITE	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.
Rs 1	.01	.01	.02	.09	.09	.10	.15	.08	.07	.02	.03	.03
Rs 2	.02	.03	.03	.09	.10	.14	.17	.09	.07	.04	.09	.15
Rs 3	.42	.38	.35	.48	.66	.69	.22	.09	.14	.09	.14	.12
Rs 4	.24	.26	.28	.40	.59	.64	.68	.21	.22	.10	.10	.24
Rs 5	.16	.15	.17	.36	.59	.62	.59	.22	.17	.10	.12	.28

RELATIVE ABUNDANCE OF MACROINVERTEBRATES IN SURFACEWATER (%)

	N	D	J	F	M	A	M	J	J	A	S	O
Notonecta sp.	38.75	25.00	48.90	52.94	29.41	51.55	18.75	86.67	38.46	22.50	42.86	63.64
Hychrophilus sp.	24.49	15.90	28.89	5.88	11.76	18.18	43.75	0.00	23.08	45.00	38.09	18.18
Laccotrephes sp.	6.12	0.23	2.22	0.00	0.00	9.09	8.25	6.67	15.38	0.00	0.00	0.00
Chironomus sp.	26.53	52.27	17.78	17.65	35.29	0.00	31.25	0.00	0.00	0.00	0.00	0.00
Gerris sp.	4.08	4.54	2.22	58.82	58.82	9.09	0.00	6.67	23.08	1.00	14.29	18.18
Ranatra sp.	0.00	0.00	0.00	0.00	17.65	5.88	0.00	0.00	0.00	0.00	0.00	0.00

RELATIVE ABUNDANCE OF BENTHIC MACROINVERTEBRATES

	N	D	J	F	M	A	M	J	J	A	S	O
Lumbricus sp.	18.75	0.00	100.00	83.33	27.27	7.14	44.44	100.00	100.00	0.00	80.00	33.33
Chiranonus sp.	68.75	86.96	0.00	0.00	0.00	64.28	33.33	0.00	0.00	100.00	0.00	0.00
Gyraulus sp.	0.00	0.00	0.00	0.00	0.00	0.00	5.55	0.00	0.00	0.00	0.00	0.00
Planaorbis sp.	0.00	0.00	0.00	0.00	18.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00
* Others	25.00	13.04	0.00	16.67	54.54	28.57	16.67	0.00	0.00	0.00	20.00	66.67

* Others: Developmental Stages of Odonatan's Nematodes and some tadpoles

RELATIVE ABUNDANCE OF ZOOPLANKTON AND PHYTOPLANKTON (%)

	N	D	J	F	M	A	M	J	J	A	S	O
ZOOPLANKTON												
Daphnia sp.	34.28	100.00	30.00	100.00	62.40	69.66	35.75	72.00	54.85	95.00	19.00	38.66
Diaptomus sp.	51.43	0.00	70.00	0.00	57.60	13.33	50.00	25.00	26.57	0.00	74.33	42.00
Cyclops	21.42	0.00	0.00	0.00	0.00	17.00	14.25	3.00	18.57	5.00	6.66	19.33
PHYTOPLANKTON												
Chlorophyceae	30.83	32.22	42.08	51.07	47.50	45.55	61.42	38.37	54.14	44.21	59.00	43.33
Cyanophyceae	36.66	25.55	16.66	21.78	18.57	23.70	31.78	31.08	20.34	31.05	22.08	33.07
Bacillariophyceae	34.72	45.33	37.08	27.14	33.93	30.74	8.00	25.94	24.82	25.00	19.58	28.58

MONTHLY VARIATIONS OF SURFACEWATER AND BENTHIC MACROINVERTEBRATES GROUPS

SURFACEWATER	N	D	J	F	M	A	M	J	J	A	S	O
SURFACEWATER												
Hemiptera	24	14	24	13	9	9	4	15	10	11	13	18
Coleoptera	12	7	13	1	2	2	7	0	3	9	8	4
Diptera	13	23	8	3	6	0	5	0	0	0	0	0
Total	49	44	45	17	17	11	16	15	13	20	21	22
Benthic												
Oligochaeta	3	0	7	15	3	1	8	6	8	0	4	4
Diptera	11	20	0	0	0	9	6	0	0	3	0	0
Gastropoda	0	0	0	0	2	0	1	0	0	0	0	0
*Others	2	3	0	3	6	4	9	0	0	0	1	8

MONTHLY VARIATIONS OF PHYTOPLANKTON AND ZOOPLANKTON POPULATIONS

PHYTOPLANKTON	N	D	J	F	M	A	M	J	J	A	S	O
Chlorophyceae	111	87	101	143	133	123	172	149	157	84	120	169
Cyanophyceae	132	69	50	61	52	64	89	115	59	59	53	129
Bacillariophyceae	125	114	89	76	95	83	119	96	72	57	47	92
Total	360	270	240	280	280	270	370	290	190	240	390	
ZOOPLANKTON												
Daphnia sp.	240	250	60	150	156	418	143	288	192	570	114	116
Diaptamus sp.	360	0	140	0	94	80	200	100	93	0	446	126
Cyclops sp.	150	0	0	0	0	102	57	12	65	30	40	58
Total	700	250	200	150	250	600	400	400	350	600	600	300

MONTHLY TOTAL OF SURFACEWATER AND BENTHIC MACROINVERTEBRATES PER STATION

	N	D	J	F	M	A	M	J	J	A	S	O
Surfacewater												
Station 1	0	0	0	0	0	0	0	0	0	0	0	0
Station 2	4	2	0	0	0	0	4	0	2	0	0	0
Station 3	5	11	6	1	3	1	5	1	4	8	4	3
Station 4	19	18	19	6	8	2	3	6	3	5	6	4
Station 5	21	13	20	10	6	8	4	8	5	4	11	15
Benthic												
Station 1	0	0	0	0	0	0	0	0	0	0	0	0
Station 2	0	0	0	0	0	0	0	0	0	0	0	0
Station 3	0	0	0	2	5	2	4	0	0	0	0	5
Station 4	6	20	4	8	4	10	10	6	0	0	0	0
Station 5	10	3	3	8	2	2	4	0	8	3	5	7

MONTHLY TOTAL OF ZOOPLANKTON AND PHYTOPLANKTON PER STATION

	N	D	J	F	M	A	M	J	J	A	S	O
Zooplankton												
Station 1	0	0	0	0	0	0	0	0	0	0	0	0
Station 2	0	0	0	0	0	0	0	0	0	0	0	0
Station 3	150	0	0	0	0	150	50	0	0	50	0	50
Station 4	100	150	0	0	150	100	150	100	100	200	150	50
Station 5	500	100	200	150	100	350	200	300	250	350	450	200
Phytoplankton												
Station 1	80	120	100	70	120	100	90	100	100	60	20	90
Station 2	20	0	10	20	20	0	30	10	20	20	20	20
Station 3	50	30	40	40	20	30	50	60	80	20	40	70
Station 4	110	70	50	80	80	70	90	110	50	50	80	130
Station 5	100	50	40	70	40	70	120	90	40	40	60	80