BIOLOGICAL AND PHYSICO-CHEMICAL QUALITY OF RURAL WATER SOURCES IN ZARIA, NIGERIA.

BY

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DEDICATION

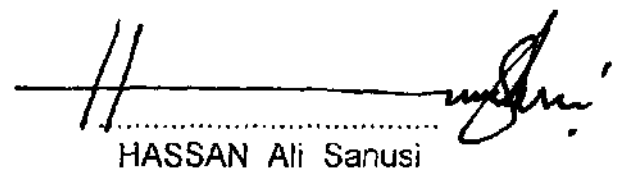
This work is dedicated to my Parents for the care,

Teachers for the Knowledge

and Family for the love.

DECLARATION

This thesis has been my personal work, and has not been presented in any form for any other qualification at any other time, in any other University or Institution. Information derived from other sources have been duly acknowledged.



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CERTIFICATION

This thesis entitled **"BIOLOGICAL AND PHYSICO-CHEMICAL QUALITY OF RURAL WATER SOURCES IN ZARIA, NIGERIA"** by HASSAN, Ali Sanusi satisfies the regulations governing the award of Doctor of Philosophy degree in Environmental Biology, of Ahmadu Bello University, Zaria, and is approved for its contribution to knowledge and literary presentation.

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ABSTRACT

This work examined water samples from sources in selected rural communities of Zaria, Kaduna State, Nigeria for biological and physico-chemical quality of the water from June, 1993 to May, 1995. The biological quality parameters measured indicate widespread *E. coli* and S. *faecalis* contamination with the on-set of rainy season; and widespread physico-chemical restriction of the relative abundance and life diversity on the inhabiting biota. However, S. *faecalis* appeared to be exclusively related to close proximity to liquid point sources. The biological index of pollution (BIP) indicates that the sources ranged from moderate decomposition (beta-saprobic) to being poly-saprobic during 5 out of 24 periods of sampling. Water quality was significantly affected by rainfall in addition to proximity of water sources to liquid point sources (Pit latrine and gutters) as well as surface run-off during the rainy season, which all were associated with significant increases in the concentration of faecal coliform and faecal streptococci, COD, and $P0_4$-P were above the recommended limits set for water quality intended for human consumption. With the exception of Pb, Fe, BOD, pH, TS, all parameters varied with season ($P < 0.01$). The variation in COD and Temperature was mild ($P < 0.05$). Significant positive correlation between biological and physico-chemical parameters were recorded. The phytoplankton species made up of 15 genera were positively correlated with macrinvertebtrates, BOD, Mg, Mn and specific conductivity of the water ($P < 0.0$). Zooplankton species made up of 8 genera were found to increase with corresponding increase in TS, SS, Ca, Mg, Mn, DO, pH, water hardness, macronutrients and BOD ($P < 0.01$). The indicator MPN-indices correlated positively with increase in hardness, conductivity, OD, macronutrients, BOD and zooplankton species ($P < 0.01$). Further, the E cpji correlated with SS, TS, St faecalis correlated negatively with increase in pH ($P < 0.01$). Temperature, pH, SS, TS and metal concentrations were within the acceptable limits of water quality.

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ABBREVIATION & SYMBOLS.

DHSS	=	Dept. of Health and Social Security.
AWWA	=	American Water Works Association
WHO	=	World Health Organisation
MPN	=	Most probable Number
AWQS	=	Australian Water Quality Standards
OWS	=	Open Water Sources
RWS	=	Restricted Water Sources
EWPHLSWS	=	England and Wales Public Health Labour Service Water Sub-Committee.
SAS	=	Statistical Application in Sciences.
ANOVA	=	Analysis of Variance.
SPSS	=	Statistical Package for Social Sciences.
AC	=	Average Concentration.
NAFF	=	Ministry of Agriculture, Food and Fisheries.
UNICEF	=	United Nation International Children's Educational Fund.
EEC	=	European Economic Community
DNHW	=	Department of Health and Walfare
APHA	=	American Public Health Authority.
RWATSAN	=	Rural Water Sanitation
DFRRI	=	Directorate of Food Road and Rural Infrastructure.
IMR	=	Infants Mortality Rate.
OPL	=	Organisms per Litre
TS	=	Total Solids
SS	=	Suspended Solids.
OD	=	Optical density
COD	=	Chemical Oxygen Demand
BOD	=	Biochemical Oxygen Demand
DO	=	Dissolved Oxygen
USEPA	=	United State Environmental Protection Agency.
GSM	=	General Station Mean
RSM	=	Rainy Season Mean
DSM	=	Dry Season Mean
FYGM	=	First Year General Mean
SYGM	=	Second year General Mean.
/L	=	Per Litre

µgm	=	Microgramme
gm	=	gramme
kg	=	kilogramme
ppm	=	parts per million
mm	=	millimetre
cm	=	centimetre
m	=	metre
km	=	kilometre
pH	=	Hyrogen ion concentration
°C	=	Degree centigrade
PO_4-p	=	Phosphate phosphurous
No_3-N	=	Nitrate - Nitrogen
Cl	=	Chloride ion
O_2	=	Oxygen
CO_2	=	Carbondioxide
K	=	Potassium
Ca	=	Calcium
Na	=	Sodium
Mg	=	Maggaesium
Pb	=	Lead
Zn	=	Zinc
As	=	Arbsenic
Cd	=	Cadcium
Mn	=	Maganrin
Cu	=	Cupper
CO_3	=	Calcium Carbonate

CHAPTER ONE

1.0 INTRODUCTION

The total amount of water available in the world is sufficient to meet the demands if human populations ensure efficient and rational use. Present estimates show that the total volume of water on earth is 1.4×10^9 Km^3, 97 percent of which is saline water which cannot be used for direct human consumption; 2.7 percent is freshwater of which 77.2 percent is stored in polar ice-caps and glaciers, 22.4 percent as groundwater and soil moisture (with about 2/3 deeper than 750 meters below the surface), 0.35 percent in lakes and swamps, 0.04 percent in the atmosphere and 0.01 percent in streams (Biswas, 1981).

Much emphasis has been placed in recent years on assessing and analyzing water availability to satisfy human needs. With rising global populations and increases in standards of living, it is not surprising the level of importance placed on water availability studies. The availability of water, however, does not only necessarily address the quantity of water alone, but also its quality. The quality and quantity of water are closely interrelated, and both must be considered simultaneously for all water management purposes (ibid). As a major constituent of human body, the largest item of diet and the most widely used natural medium, there is no denying that freshwater and its quality are of vital significance to mankind everywhere, the nature of freshwater as a medium, the plant and animals which inhabit it, and the use to which it is put by man are of importance to everyone concerned with this limited, but fortunately re-cycling resource (Maitland, 1978). The inter-play among the physical, chemical and biological components of a given water body determine its quality . Changes in water quality exert selective action

on the flora and fauna which constitute the living population of water, and the effects produced in them could be used to establish biological indices of water quality (Palmer,1980).

During the last two decades it became increasingly evident that pollution was impairing different uses of water in many parts of the world, and that in certain cases it even destroys possible utilization of important sources of water. With accelerated and uncontrolled developments, increasing number of waste products are being discharged in to water sources. In many cases not enough is known (with any degree on reliability), about the impacts of these pollutants on human health and the inhabiting biota.

A lot of work has been done on the effects of industrial and municipal point sources on water quality. Since it is comparatively easier to control point sources of pollution, much of the emphasis in recent years has been placed on this aspect. The report of the United States National Commission for Water Quality (1971) however, indicates that 92 percent of suspended solids, 37 percent of the biochemical oxygen demand and 98 percent of coliform bacteria would still remain uncontrolled in natural surface water, even when all discharges from point sources have been eliminated because of agricultural activities. Agriculture is the dominant activity in the rural settlements of Nigeria, where potable water supply is lacking and increased agricultural activity is encouraged.

In recent years, concern has risen about the rapidly deteriorating state of freshwater bodies with respect to trace metal pollution (Jaleel et al., 1991), from solid domestic waste sanitary landfills (Radenkova-Yeneva et al., 1995), water quality with respect to water mutagenicity and toxicology (Daniel and Carlos, 1996), groundwater as source of contamination for water supply (Rahman, 1996), the

relationship between indicator, pathogen and water quality (Ferguson et al., 1996), among others, to highlight on the importance of water quality as a criterion for human health. Little or no data exist with respect to our rural areas.

1.0.1 WATER QUALITY:-

Water during its movement and storage on the earth, acquires increased amounts of dissolved and suspended constituents. The chemistry and hence the quality change, and this may impair its use for one purpose or another (Ezeigbo,1988). The term "water quality" is widely used expression which has an extremely broad spectrum of meaning depending on vested intention in the water for particular use (Borchadt and Walton, 1971). At present, based on sampled results in the global perspective, water quality acquires increasing significance and man's need to articulate more exactly those parameters that clearly define water quality for anthropogenic use becomes paramount, particularly as human population appears to be more vulnerable to dangers associated with water contamination and its pollution. According to Kulsky (1983), the properties of water, and therefore, its quality are determined by the concentrations of particular impurities, Such quality can be determined in terms of physical indices (temperature, suspended matter, colouration, odour, flavour, atc); chemical indices (hardness, alkalinity, reactivity, oxidation susceptibility, dry residue, etc); biological indices(hydrobionts), and bacteriological indices (total concentration of bacteria, coli index, etc). The quality of water is determined, according to Nikoladze et al (1984), by the chemical, biological and technological analyses carried out in the periods which are the most typical of a given water source.

The general intention and concern for water quality is to have, for public consumption, water that is inter alia (wholesome), DHSS (1970). Safe water with predominant amounts of its nitrogenous matter in the oxidized form (AWWA, 1971); water from which hazardous non-living contaminants have been controlled or removed (Hopkins and Gullans,1960); free from organism capable of causing disease and from mineral and substances producing adverse physiological effects, aesthetically acceptable, free from apparent turbidity, colour, odour, and from any objectionable taste, at reasonable temperature, which will be consumed in any desired amount without concern for adverse effects on health (Borchadt and Walton, 1971); proper organoleptic properties and suitable for domestic use.

1.0.2 BACTERIOLOGICAL INDICES OF WATER QUALITY:

When a source of water is being considered for anthropogenic purposes, it is important that a full bacteriological examination be carried out. According to WHO (1971), such examination should include colony counts of micro-organisms on non-selective media and the examination for faecal streptococci and possibly also for *Clostridium perfringens* , *Clostridium welchii* as well as faecal coliforms including *Eschericia coli* . Such procedure is imperative in view of the great danger associated with drinking water that may have been contaminated by sewage or by human excrement. Even the danger of animal pollution cannot be overruled. The health hazard associated with the intake of such contaminated water is of great health consequences. According to WHO(1963,1971) if such contamination occurred recently and sourced by carriers of such infectious diseases as enteric fever or dysentery, the water may contain the living pathogens of these diseases.

Despite the common knowledge of the existence and mode of transmission of pathogenic bacteria (water born),it is not practicable to detect these pathogens in water samples for anthropogenic use. According to WHO(1971)despite the fact that modern bacteriological methods have made it possible to detect these pathogenic bacteria in sewage and sewage effluents, it is not practicable to attempt to isolate them as routine procedure from samples of drinking water. According to Smith (1977),two factors are responsible for this : The relative low ratio of number of pathogens to volume of water samples, and the inability of the pathogens to multiply rapidly in water. Routine analysis would produce results on the presence or otherwise of indicator organisms rather than the index of pathogens directly. Such an indicator index has been accepted world-wide as a reliable method of indirect detection of pathogenic micro-organisms in water due to the existing correlation between indicators and pathogens. According to WHO (1971),when pathogenic organisms are present in water, they are almost always greatly outnumbered by the normal excremental organisms, and these normal excremental organisms are easier to detect in the water. The absence of the indicator organisms in water sample, could lead to the general inference that disease-producing organisms are also absent, and the use of normal excremental organisms as indicators of faecal pollution in itself, produces a margin of safety. The search for organisms indicative of faecal pollution instead of the pathogens in particular is universally accepted for monitoring the microbial contamination of water supplies. The detection of these indicator bacteria denotes the presence of intestinal pathogens (DHSS,1983).

The organisms most commonly used as indicators of faecal pollution are the coliform group, especially the *Escherichia coli,* which is undoubtable of faecal

origin. The use of these indicators started from the work of Escherich in 1884, who isolated from the stool of cholera patients organisms which he originally thought to be the cause of the cholera. Further investigations, however, revealed that similar organisms also were present in the intestinal tracts of healthy individuals. These organisms were later called the "coliforms". The coliform group has been recognised as the inherent characteristics of the faeces of man. Perhaps one-third (1/3) to one-fifth (1/5) of the weight of an average individual's faeces are active viable coliform organisms (Borchadt and Walton,1971). In terms of population equivalent, this amounts to $200x10^9$ coliform cells per gram of faeces per day. The presence of coliform organisms in water may be interpreted to mean that such water has been contaminated with faecal matter. Smith-Theoball (1892) established a procedure for inoculating fermentation tubes with measured volumes of water being tested. The New York State Board of Health first applied this procedure in their study of pollution of the Mohansk and Hudson Rivers. Following such applications, series of tests based on the method have been performed, leading to the standardisation of water quality with respect to microbiological indices. According to American Water Works Association, AWWA (1971), an acceptable drinking water must not show presence of coliforms (*E. coli*) in more than one of the five 10 ml. portions of the sample tested. Standard Methods for the Examination of Water and Waste Water (APHA,1980) defines coliform group as to include all of the aerobic and facultative anaerobic Gram-negative, non-spore forming rod-shaped bacteria which ferment lactose with gas formation within 48 hours at 30°C.

Other indicator organisms include Faecal Sterptococci, of which the most common characteristic member is *Streptococcus faecalis*, which has been attributed by WHO(1963)to be of value in confirming the faecal nature of pollution in doubtful

cases. The role of *Streptococcus faecalis* as an indicator bacteria is emphasised (WHO,1963,1971.,DHSS,1983). They occur in smaller numbers in faeces compared to *E. coli;* and there is high probability that their death rate and the rate of disappearance are similar to those of *E. coli.* When found in water, therefore, becomes an important confirmatory evidence of the faecal source of water contamination. According to Wagner and Lenoix (1959), standard demands that coliform organisms must be absent from each 100 ml of water entering distribution system; in 90% of the samples examined throughout any year, coliform bacteria should not be detected or the Mean Probable Number (MPN)index of coliform micro-organisms should be less than 1.0; none of the samples should have MPN index of coliform bacteria in excess of 1.0; an MPN index of 8-10 should not occur in consecutive samples. In untreated water, in 90% of the samples examined throughout any year, the MPN index of coliform micro-organisms should be less than 10; none of the samples should have an MPN index greater than 20 and an MPN index of 15 or more should not be permitted(Accepted) in consecutive samples (ibid).

1.0.3 PHYSICO-CHEMICAL INDICES OF WATER QUALITY

The Chemical substances that affect water quality are classified into four categories: (a) those that affect potability (b) those having definite effects upon health (c) those components that are definite toxins and whose presence in greater than limiting amounts would be sufficient grounds for rejecting the water as a source of public water supply, and (d) chemical indicators of pollution. The International Standard for Drinking water, WHO(1963,1971) recommended standards for each of the above.

Chemical analysis of water supplies has been envisaged by WHO(1971) to have a wide range of uses, particularly that of protecting the users of water supplies from dangers associated health wise. It is therefore recommended that water supplies should be examined for physico-chemical, and aesthetic characteristics. A number of chemical substances, if present in certain concentrations in supplies of drinking water, may constitute danger to health. Limits for toxic substances in drinking water have been set by WHO (1971) and those limits are found to be related to the daily intake of drinking water (assumed average daily intake of 2.5 litres by a man weighing 70kg). Tentative limits for arsenic, cadmium, lead, selenium, copper, zinc, manganese, alkaline earth metals, and a number of substances affecting potability, and other water quality indices have been articulated. According to WHO (1971), the intake of toxic substances from the environment cannot be completely avoided. However, possible control of fractions associated with drinking water has been proposed (ibid) to safeguard the public against deleterious consequences.

High concentration of oxygen in water tends to remove undesirable tastes and increase the palatability of water (McKee and Wolf, 1963), and minimum concentration of 5 mg/L appears to be a satisfactory limit for water intended for domestic use. (AWRC, 1974).

The reactivity (pH) of domestic water sources is recommended to be within the range of 6.5 to 9.0 (ibid) and 7.0-8.5 (WHO,1971). Departing from this range may cause water to have a sour taste and tend to be corrosive to metals.

Despite the fact that the consumption of water characterised by high level of hardness may not be detrimental to health, high level of water hardness may present undesirable effects which include incrustations on kitchen utensils and poor

laundry. It is recommended that the hardness of water for domestic use should not exceed 100 mg/L and concentrations up to 500mg/L may be acceptable where no o8ther suitable water is available WHO,1971; AWRC,1974).

The role of solids in increasing optical density, hence reducing the dept of light penetration, the euphotic zone, clarity of the water and general effects on potability has been stressed. The maximum allowable limits for total solids in water has been set at 1500 mg/L (WHO,1971).

Environmental concern over the effects of nitrogen and phosphate in aquatic systems are centred on two issues; the eutrophication of water bodies and the possible health risks associated with the consumption of nitrates (Addiscot et al.,1991; McEldowney et al.,1993). The suggested maximum limit of PO_4-P is 0.2 mg/L (AWRC,1974). The concentration of NO_3-N is limited at 10 mg/L (WHO,1971).

The biological and chemical oxygen demands (BOD and COD) influence the oxygen content of water hence its potability. These parameters are being regarded 2as chemical indicators of water pollution. The measurement of BOD and COD has been regarded as basic means of determining the degree of water pollution (Hach,1990). Biochemical Oxygen Demand limit of 6 mg/L and COD of 10 mg/L 2have been set by WHO (1963, 1971) for acceptable quality of water for domestic use.

1.0.4 BIOLOGICAL INDICES OF WATER POLLUTION:

The use of aquatic fauna and flora for the detection pollution is currently being researched into. Numerous techniques have been proposed for biological detection of organic pollution in raw wat8ers. Liebmann (1951)advocated concentration upon

micro-organisms in the detection of water pollution. Huet (1949) advanced the use of microscopic invertebrates to determine the pollution status of water. According to WHO (1963), micro-organisms undoubtedly have special importance in determining the degree of water pollution as many of their species are cosmopolitan and their greater ratio of surface area to volume renders them more rapidly responsive to chemical changes in the aquatic environment, in addition to their being the bulk of the inhabitants of the more heavily polluted waters.

Kolkwitz and Marsson (1908, 1909); Kolkwitz (1935, 1950); Liebmann (1951,1962) proposed the principle of the saprobity system (Saprobiensystem). Accordingly, a body of water that has received a heavy load of sewage undergoes self purification. This results in a series of zones of decreasing pollution namely : Polysaprobic, alpha-mesosaprobic, beta-mesosaprobic and oligosaprobic, with each zone containing characteristic plants and animals, and for each zone peculiar indicator organisms exist. These indicator organisms serve as means of identifying the various levels of pollution.

There is now a growing realization that conclusion can be based upon the relative abundance of the species within the association of organisms for the quality evaluation of polluted waters. Some methods have been developed by Knopp (1945), Pantle and Buck (1955a and 1955b), Zelinka and Marvan (1961), Zelinka et al (1959) and Dittmar (1959). Breitig (1961) indicated that the method of Pantle and Buck (op cit) has already been adopted as a preliminary standard procedure in East Germany.

Expansion of the saprobity system was done by Sladecek (1961). His work classified all fresh waters under four broad headings: Katharobity (very pure water), lomnosaprobity (polluted surface and ground water),eusaprobity (sewage and

industrial wastes undergoing becterial decomposition), and trans-saprobity (wastes inaccessible to bacteriological decomposition), which become useful for the classification of different types of domestic and industrial wastes.

Fjerdingstad (1960) established a saprobic system based on the decomposition of benthic communities of micro-organisms. The reducers-producers-consumers (R-P-C) system based on the numerical values of the reducers, producers and consumers in the system was established by Gabriel (1946).

The Artenfehlbetrag method, which provides useful picture of the consequence of waste water discharge into water system was published by Kothe (1962).

The biomassentiters index method based on physiological procedures where organisms are subjected to test-samples and their reactions studied was proposed by Brigmann and Kuhn (1956, 1958a,1958b and 1962).

Horasawa (1942) proposed the biological index of pollution (BIP). This method is based on the relative abundance of the most pollution sensitive zooplankton communities in relation to the corresponding phytoplankton. The method has been adopted by Palmer (1980) and serves as a promising biological method of detecting water pollution in relation to its quality.

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1.0.5. HISTORICAL RELATIONSHIP BETWEEN WATER AND HEALTH:

A relationship between water and health has been recognized from the time of Hippocrates, and probably earlier, in the association of marshy places with fever. Snow (1855) was the first to establish a precise relationship between water and diseases in his studies of cholera, and was closely followed by Budd, who

demonstrated the spread of typhoid through water supplies (Bradley, 1972). The spread of filariasis was first shown to be transmitted by mosquitoes which larvae lived in and depended on surface water . The spread of guinea-worm and schistosomiasis were shown to depend on freshwater invertebrates, and the present day knowledge as indicated by the various epidemiological studies has shown that access to water determines the incidence of several infectious diseases (ibid).

While water is an absolute necessity for life, little was recorded by ancient historians regarding the quality of drinking water. Certain brief references were made to boiling, filtering, sedimentation, and treatment of water with salts. Since man knew relatively little about diseases, it must be concluded that (at times under reference), any treatment had as its objectives the improvement of the appearance or taste of the water. No definite standards of water quality other than the general clarity or palatability were recorded.

Hippocrates, the father of medicine (460-354 B.C) stated that "water contributes much to health," and asserted that rainwater should be boiled and strained, for otherwise it would have bad smell and cause hoarseness. Historical records indicate that standards of water quality, except for infrequent references to aesthetics, were notably absent up to and including much of the 19th century. Even today most people will first look at the water in a glass to see if it is crystal clear and sparkling then, taste it to determined its palatability. If the water is agreeable in these basic respects, then assumption is made that it is of high quality (AWWA,1971).

Many examples exist to illustrate how man's sense of taste and smell failed him resulting in serious health consequences. One example is that of Broad street

well cholera epidermic reported to be prevalent with high intensity in the district of Broad street, London in 1854 (Rosenau, 1935). No less than 700 deaths occurred in St. James Parish in the 17 weeks that the cholera raged. John Snow made a very detailed study of the situation and associated the epidemic with the Broad street well and a leaky sewer that passed adjacent to the well, bringing infection (infectious agent) from the original cholera case in the house at No 46 Broad Street. Snow's inquiry showed that most of the victims had preferred or had access to water from the Broad Street well. Apparently its contamination with the sewage did not impair its flavor. Hence, the use of clarity or taste as indices of water quality was proved to be deceptive in quality assessment of drinking water. The outstanding point of concern in developing countries is that the use of taste and clarity in water quality assessment is still prevalently in use, most especially in rural communities.

Prior to 1950, public health had been the primary field for water and sewer investigations. In the mid 19th century, following the establishment of the relationship between water from Broad Street well and cholera epidemic (London) and shortly afterwards, it was postulated that typhoid also could be spread by contaminated water (Wolman and Bosh,1963). The value of public water supplies in the reduction of typhoid fever was raised even before the use of chlorine was in use. Since that time, the United States' national death rate due to typhoid had decreased from 35.8 per 100,000 in 1900 to 2.5 per 100,000 in 1936, and to zero in the 1960s, especially in large cities and the increase in the number of municipal water supplies has closely paralleled the decline in typhoid death for more than half a century (Wolman and Bosch, 1963). According to AWWA (1971), typhoid fever had now been practically eliminated (in developed countries) as a water-borne disease through appropriate bacteriological control of finished water quality and

immunology.

Since 1952, the death rate from typhoid fever in the United States of America has been less than 0.1/100,000. Generally, statistics show that the death rate from typhoid fever has paralleled the advent of water purification practice and the coliform bacteria examination has served as a satisfactory measure of microbial safety of water and

the incidence of a disease-producing organisms in raw water is related to the endemic level of the particular disease within the tributary population (AWWA,1971). Available evidence indicates that each of such epidemics resulted from pollution introduced through cross connection between potable and contaminated water system (Miller,1962). Rosenau's text cited by Borchadt and Waltan (1971) revealed that typhoid epidemics at Butler, Plymouth New Haven, Nanticoke and Reading, involving 39,029 cases with 361 deaths, were caused in each case, by the careless treatment of the discharges of one individual patient.

In an exploratory study into the effect of improved water and sewer system upon rural community development in The United States of America, Warner and Dajani (1975)showed that a majority of homes in US at that time, where without sanitary facilities. The water supply problem was among the most difficult to resolve, water systems were inadequate, their accessibility was minimal, and disposal of sewage was yet an unsolved problem in most places, health conditions were reflected by an infant mortality rate of one in every four live births with many of those deaths were attributed to dysentery resulting from the lack of adequate potable water: "Harsh as it might sound, and hard as it might be to believe, that was a picture of a sample of rural existence in the twentieth - century United States of America. While the picture does note necessarily portray a typical rural

community, it does portray a significant number of real communities found in one of most affluent nations in the world." (ibid).

In the developed countries, perhaps twenty four out of a thousand babies die shortly after birth, and the vast majority survive through childhood and early adult life , with only occasional tragedies of cancers such as Leukaemia, and road accidents (Bradley, 1978). Most people survive into their forties when mortality from diseases of the arteries become a major health problem, followed by the rapidly increasing death rate among people in their seventies and eighties. The general conclusion was that these relatively affluent people all enjoy excellent water supplies and sewage systems, and so the incidence of water-bone or water related diseases is rare, except for a possible effect of water softness on health (ibid).

On the other hand, the picture in developing countries is Gloomy: According to Bradley (1978), human health in most tropical developing countries is poor. General statistics reveal that in the third Wold countries, development of rural water sources is used as an index of level of civilisation (Abibo,1988). It is also observed that traditional water sources in these countries are easily contaminated with organic pollutants. For many people in Africa for example, water supply is dwindling while demand is rising, in many countries, soil and gully erosion is evident, and the gullies draw shallow aquifers and traditional wells become dry. In addition, surface run-off is increased while base flow is reduced, and thus many formerly perennial sources now flow only seasonally. The risks to health are not just drinking contaminated water, but also in collecting the water: bilharzia, scabies and other skin diseases are most prevalent where there is shortage of water for washing. Under these circumstances many faecal diseases are transmitted directly without even involving water(Richardson,1989).

The predicament of the rural communities has been projected by the work of Sangodoyin and Osunji (1990). Accordingly, the governments of many developing nations often promise a conventional water supply system to both urban and rural dwellers, however, far to many, especially in the rural areas, are without adequate and hygienic water supply, and there has been plenty of evidence of outbreak of water-borne diseases. Consequent upon governments' inability to provide sufficient potable water for all needs, most residents resort to other sources amongst which are the boreholes, springs, shallow dug wells, streams, village ponds, etc. Bradley (1978) indicated that out of a thousand babies, a quarter (two hundred and fifty fail to reach their fifth birth day. About a hundred and fifty die in the first year of life, and perhaps another seventy in the second year. The second year's death rate may be a hundred times than observable in developing countries. According to Bradley (ibid) 5% to 10 % of the overall death in the developing countries is attributed to water-related diseases, and particularly among the very young children when malnutrition and infection work together tragically. Intestinal infections related to water further increase malnutrition in such group. It has been estimated (ibid) that over 10 % of the infections among in-patients are related to water in developing countries.

A Survey by the World Health Organization,(1963) revealed that only one half of the urban population in developing countries had safe drinking water supply in their homes, and only 12 per cent of the rural dwellers had reasonable access to safe drinking water. These factors, together with the inadequate waste treatment facilities and the general low level of personal hygiene were attributed by WHO (1968) to result in high level of enteric diseases. Also, in developing countries the evidence of typhoid fever, bacillary dysentery, amoebiasis, infectious hepatitis and

other enteric infections that may be transmitted by water is often 10 to 100 times more than in advanced countries of the world. According to UNICEF Report (1985),which shows that in Nigeria, only 18% of the population living in rural areas had access to potable water in 1983; and that infant mortality rate (IMR) was 115 per 1000 live birth, due to diarrhoeal diseases associated with defective sanitation and water pollution. This figure was confirmed by the World Health Organization's figure for 1988 which shows that overall 32% of the people in developing countries, numbering about 1200 million, lack adequate water supply, with Nigeria falling within the group where only 0-20% of its rural population have access to safe water of acceptable standard.

According to Bradley (1978), village dwellers in Northern Nigeria collect water from polluted wells, where structurally it becomes possible for surface drainage to flow into the wells and carry along pathogens contained in human faeces resulting into cholera, schistosomiasis, dracunculiasis and various enteric infections becoming prevalent. In this area, diarrhoeal diseases have been found to be the major causes of infant mortality (ibid). In the study of microbiological criteria of tropical water quality, Evison and James (1982) stated that the presence of faecal material in water presents the most immediate health hazard, since faecal material from human or animal sources might contain pathogenic micro-organisms.

Adequate literature on the direct effects of inorganic chemicals that are randomly found in water on health is yet unattainable. However, the existing reports regarding the role of these substances tend to suggest their toxicity to animals. The ultimate effects on man cannot be ruled out. The carcinogenic effect of the heavy metals, the role of nitrates in causing methaemglobinaemia and gastric cancer(DHSS,1979), the potability effect iron has been stressed by the

International Standard for Drinking Water , (WHO,1971), and the toxicity of iron to aquatic organism (Petter,1980), the effect of lead most especially as it was reported to inhibit the biosynthesis of haem, affect membrane permeability in kidney, liver and brain cells (MAFF,1975), the inverse relationship between water hardness and cardiovascular diseases (Pecock et al, 1980) and its rendering of water non acceptable for domestic use (WHO,1971), The gastrointestinal, skin liver, and nerve tissue effect due to long term ingestion of arsenic contaminated drinking water (Zaldiva, 1974), the production of nephrotoxic cardiovascular effects in animals due cadmium ingestion (WHO,1971), The negative effects of cadmium on morphological, biochemical and physiological processes as well as the reduction in biovolume, abundance and bioaccummulation (Novillo,1996) are some of the existing references regarding the problems associated with pollution of water by inorganic substances.

It is obvious that "progress towards improving man's health and welfare could result from better control of his environment, and the provision of yet better quality water is one logical step in this direction (Borchadt and Walton,1971).Man's reliance on taste and smell has not been an infallible means of quality judgement and acceptability of water; more stringent quality criteria become necessary (AWWA,1971).

1.0.6 SOURCES OF WATER FOR THE RURAL COMMUNITIES:-

The communities being devoid of conventional pipe borne water source, have their sources of water from the rains, surface water and ground water via the hand dug wells.

Rain water:-

This is seasonal and collectable from metal or asbestos roof during the rainy season. it is relatively pure and available close to the users. However, the rural houses are roofed mostly with other materials such as thatch, and rain pattern may require large expensive storage tanks to guarantee supply all the year round. Hence cannot be relied on as stable source of water for the rural communities.

Surface water :-

Is readily available from impoundments (Bomo lake, Shiga Dam and the University Dam along Kubanni river). The control of water quality in these impoundment appears difficult due to the nature of their unprotected banks and close proximity to agricultural land, anthropogenic settlements and grazing animals. In most locations streams, lakes and ponds are subject to substantial faecal pollution.

Ground water:-

Where it can be extracted with reasonable ease, the ground water is normally preferred, reason being that it is purified by filtering action of the soil through which it flows. Nevertheless, ground water in some areas may contain iron, manganese, salts, fluoride, or other substances which raider its use undesirable or unpleasant.

The existing waste disposal, system of the settlements are principally pit latrines, open space waste dump and gutters. These may have profound negative effects on the quality of the ground water.

Hand-dug wells are the most common means of obtaining water from the ground source. Its construction is cheap and technology of construction very much simplified to the use of "Dagi", bucket and pulling rope. The hand-dug well has the very important advantage of water being drawn from it by container and rope, if pump cannot be provided. Most of the wells are however left unprotected hence are

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1.0.6.1 JUSTIFICATION

Report by the United Nations Children"s Fund (UNICEF,1985) indicates that in 1983, 68% of the urban populate and only 18% of the rural dwellers had access to safe quality water supply in Nigeria, with infant mortality rate (IMR) of 15 per 1000 live births. The situation may not differ much from the above in children and adults. Same report indicates that 75% of the urban dwellers and only 25% of the rural populace in Nigeria had access to health care facilities. Greater percentage of Nigerian's population (over 70%) live in the rural areas where potable water supply is virtually non-existing (Bradley, 1978). The greater rural communities are cut off 8from the urban treated water schemes, consequently they do not benefit from the p8ortable water projects contained in the various developmental plans. Additional concern to this is the general attitude of waste disposal system : In the rural communities the use of shallow dug traditional latrines close to open hand-dug wells and other water sources is a common practice. In most respects, these latrines are sunk at random without any due regard to the minimum ten meter distance between latrines, gutters and water sources, thereby subjecting the water source to massive bacteriological , organic and inorganic pollution. The problem is further compounded by the open-space free squatting methods of getting rid of faeces. The corresponding inhabitants of the area are therefore subjected to high rate of infections by water borne diseases, high morbidity and mortality rates. treatment.

The incidence of water-borne and water-related diseases in Zaria area is remarkably high. Despite the apparent problem of moderate percentages of such diseases obtainable from the Health Statistics, routine monthly disease notification data obtained from the Government Health Office, Zaria reveals that in 1989, a total number of recorded cases for nineteen diseases was 21,889 covering Zaria, Sabon

gari, and Giwa areas under the then Zaria Local Government Area. In 1990 the total number of reported cases was 7,866. Urinary Schistosomiasis, filariasis, dysentery, typhoid and paratyphoid fever constituted 8.059 % in 1989 and 4.71 % in 1990 out of the total number of cases reported for the respective years. Malaria, a water-related disease was 58 % in 1989 and 61.89 % in 1990.

A total of 13,796 cases of cholera was recorded in 1991 and 1,827 in 1992. Schistosomiasis, diarrhoea, typhoid and paratyphoid fever representing 13.87 % and 63.76 % in 1991 and 1992 respectively. Malaria represented 71.34 % in 1991 and 14.01 % in 1992.Urinary schistosomiasis, filariasis, dysentery, typhoid and paratyphoid fever constitute 1.3% in the selected rural communities in the year 1998 and 0.7% in 1990. In 1991 and 1992, schistosomiasis, diarrhoea, typhoid and paratyphoid fever represented 3.8% and 15.1% respectively.

The selected communities are also located mainly as farm settlements where their sources of water are being surrounded by hectares of farmland and pesticides, artificial fertilizers and various agro-chemicals are being applied in large quantities. The communities' sources of water finally end up being the 2ultimate recipients of these substances are of known effects to both health and water quality, and the magnitude have been evaluated.

1. Hence the need to study the sources of water for the rural communities, for the purpose of control and prevention of possible contamination and pollution, most especially alternative sources of water have not been made available to the rural communities. This may lead to reduction in incidence of water-borne diseases, high morbidity and mortality of the rural population that constitute greater percentage of the human potentials and work force of the area.

2. This work will also provide knowledge and presedure for water quality creteria assessement in the the area, which will serve as a necessary prerequisite for strategy required towards improvement in the quality of water available for human consumption and other domestic uses.

3. Serve as base-line data needed to formulate criteria to assess the long -and short- term consequencies of pollutants in the area. This information is vital for the setting up of realistic standards monitoring techniques paculiar to the communities for the protection of the water sources, the environment and the human population resident in the rural settlements.

4. Improvement in water quality contributes to the reduction of health hazards due to water borne diseases such as cholera, typhoid fever, infectious hepatitis and bacillary dysentry, which are frequently incident in the area. Consequently mobidity and infant motality rates could be reduced.

1.0.6.2 OBJECTIVES:

1. To identify the sources of drinking-water for the communities and assess the impact of the catchment area on the water quality.
2. To determine the type and effectiveness of water treatment methods (if any), as well as the potability of the water.
3. To determine the monthly and seasonal variations in the bio-physico-chemical quality of the water sources.
4. To determine the level of correlation between physical, chemical and biological components of the water sources.

5. To investigate and determine any possible faecal contamination, point and level of such contamination using the Most Probable Number(MPN)of organisms indicative of faecal contamination.

1.0.6.3 WORKING HYPOTHESES:

1. The catchment area has not influence on the quality of water in the selected sources.
2. Variations in terms of month, season and year has no significant effect on the variation in bio-physico-chemical parameters of the water
3. The physical, chemical and biological properties are not dependent on each other.

1.0.7 GEOLOGY OF ZARIA AREA:

Zaria is situated in Northern part of Nigeria where the geological structure is largely of pre-cambrian igneous metamorphic rocks of the Basement complex that is characterised by lesser degree of porosity and permeability to water (Buchanan and Pugh, 1969., Acheampong ,1988). According to Kowal and Omolokun (1970), the Basement complex rocks are principally metamorphic and igneous characterised by high resistance to weathering, with thin mantle of weathered material, irregular and often discontinuous. The weathered material is of average depth between 15 and 60 maters (Du-Preez and Barber, 1965). It contains much clay, which makes it to serve as efficient aquifer (Kowal and Omolokun, 1970).

According to Wright and McCurry (1970), retrogressive metamorphism may also have occurred, which could explain the presence of both chlorite - and biotite - bearing assemblages in the rocks. Olowu (1967)reported that alluvial deposits post-dating Older laterite and broadly contemporaneous with young laterite overlie most of the area. Accumulation of fine gray-brown sands, clays, red sands, and gravels reach thickness of 15 to 40 feet (4.18 to 11.15 maters).

A complex depositional history was indicated by the work of Wright and McCurry (1970), viz:-

(a) Scattered exposures of laterite, some gravelly, which may be either underlain by the alluvium,

(b) Local discontinuity marked by layers of quartz fragments and

(c) ancient drainage channels filled by stream deposits and now re-exposed in present day erosion gullies.

1.0.8 HYDROLOGY:

The present knowledge of the quality, quantity and pattern of distribution of ground water in the country is still far from satisfactory. Available data, however, show that the country is deficient in ground water resources. Mitchell-Thome's (1961) estimates that the country has about 9,500 billion litres of ground water, that represents 0.2. percent of the worlds total. Whereas the deficiency of this resources may be attributed to the geology of the country, Acheampong (1988), highlighted that the availability of ground water in Nigeria is dependent directly or indirectly on the weather and climate, most especially rainfall, particularly as over half of the country is underlain by crystalline rocks of the Basement complex. The rocks being igneous and metamorphic, and are neither porous nor permeable, rainwater can, penetrate or percolate directly downwards.

The work of Wright and McCurry (1970)reveals that the superficial deposits of underground water rest almost everywhere on weathered basement. The thickness of this weathered zone is not certain but there is evidence that it can attain 50 feet (13.94 maters) or more in places, especially beneath areas where Older Laterite is still preserved. Thirty feet (8.36 maters) thickness of alluvial deposits appear to be common place. Extensive areas are underlain by unconsolidated material 80 to 100 feet (27.30 to 27.88 maters), in thickness, which accordingly should hold large volumes of water. The underground flow of such water terminates in rivers, both seasonal and permanent, which according to Wright and McCurry (ibid)offer the most reliable source of underground water supply.

Available data indicate that surface water is unevenly distributed and subject to large seasonal and climatic variations in the arid northern part of the country,

where Zaria is located, and where rainy season is short, the network of rivers is less dense Acheampong (1988). How much surface water is actually available each year in Zaria area is uncertain, however, observations made during preliminary survey suggest that there is enough for the present use in the area (Wright and McCurry, 1970). Except for Galma river, all streams in the area are seasonal, flowing only during and after the rains, although the larger ones have surface water along their stretches for much of the year. Dams across valleys filled with undissected Younger Alluvium, have been successful in a few places. Shika dam Bomo lake and ABU-Kubanni dam are a few examples. Away from the rivers and dam sites, wells are dug to the water table, which falls depending on the location. The fall is mainly attributed to sub-surface percolation of water through the larger river valleys (Olowu, 1967).

1.0.9 VEGETATION

Zaria lies in Northern Guinea Savanna Zone, with a woodland vegetation type characterised by the presence of *Isoberlinia doka, I. tomentosa* and *Uapaca toqoensis*, with well developed grass layer of tufted *Andropoqoneae.*

The most common trees associated with *I.doka* in the Savanna woodland are *Termilinia avicenniodes. Combretum binderianum, Piliostiqma thonninqii, Bridelia ferruqinia, Butyrospermum paradoxum, Vitex doniana, Parkia Clappertoniana, Acacia sieberiana,* and *Parinari Curatellifolia.* The smaller tress include *Ximonia americana, Stereospernum kunthianun, Nauclea Latifolia, Annona senegalensis* and *Dichrostachys cinerea.*

Some cryptophytes which include the bulbous and rhizomatous plants and

the very typical sub-shrubs (suffrutices) which include *Cochlospernum tinctorium* and *Andenodolichos paniculatus* are found.

The low ground cover and tufted grasses include *Andropogoneae* such as *Hyparrhenia spp: Andropogon Spp: Schizachyrium semiberbe,* and *Monocymbium ceresiiforae.* Other plants includes *Ceiba Parkland, Ceiba pentandra, Tamarindus indica, Adansonia digitata* and *Manqifera indica.* The more recently planted communities are the result of Forestry Department. Plant such as *Daniella oliveri, Khaya senegalensis,* and *Dalbergia sissoo* .

Vegetation as a result of influence of undulating laterite include: *Monotes kerstinqii, Uapaca togoensis, Afroremosia laxiflora, Parinari curatellifolia, Pterocarpus erinaceus, Ficus spp.* and *Diospyros mespiliformis.* Dwarf shrubs such as *Detarrium microcarpum* and *Cambretum binderianum, Isoberlina tomentosa, Steganotaenia araliacea. Dichrostachys cinerea, Terminalia glaucescens, T. avicennioides* and *Anogeissus leiocarpus* (ibid).

1.0.10 RELIEF AND DRAINAGE:

Zaria is located North of Niger and Benue rivers within the vast area of high plains of Hausa land. The topography is fairly representative of the surrounding plains: undulating with very broad and gentle slope lying at an altitude of 609.9 to 731.5 meters above sea level (Kowal and Omolokun, 1970). The high plains represent the major exposure of crystalline rocks in the North. The plains are not uniform throughout, and sub-divided into a number of erosion surfaces separated by scraps

or by belts of youthful topography (Buchanan et al., 1969). The widespread (African surface) lies at 2,000 to 2,400 feet (557.56 to 669.07 meters), with the lower section at 1,600 to 2,000 feet (446.05 to 557.56 meters).

These surfaces give wide plains of little relief crossed by mature streams. The latter flow in broad, shallow valleys separated by inconspicuous watersheds. The plains rise kopjes and inselbergs, some by over a thousand feet (278.78 meters) above the general level (ibid).

The eastern part of the area is drained by the southward flowing Galma River and its tributaries. The western limit of the Galma catchment basin crosses from the middle of the southern boundary to the north-west corner (Wright and McCurry, 1970).

1.0.11 WEATHER AND CLIMATE :

According to Hore (1970), Zaria is characterised by typical continental climate, which is more pronounced during the dry season, especially in December and January. The mean daily maximum temperature shows a major peak in April and minor one in October. The daily maximum temperature raises gradually from January and attains its highest value in April. This is followed by by a rapid drop to its lowest value in August. It raises again to its secondary peak in October. The mean minimum temperature rises from its lowest value in December- January, to its highest in July-August.

Zaria is characterised by a tropical savanna climate in the high sun period and the dry season is practically rainless (ibid).The total annual rainfall is low, with mean of about 430 inches. such low and seasonal character of rainfall is reflected

on the vegetation which assumes various shades of green in wet season and turns brown or pale yellow in the dry season. According to Thornthwaites's moisture index, the climate of Zaria is dry-sub-humid type (Mortimore,1970).

Zaria is invaded by two distinct air-masses, one being north-dry continental (sahara airmass), and the other from the Atlantic ocean in the south, which is moist, cool and equatorial maritine in nature. The weather depends to a large extent, on the airmass which covers the area and its depth (Hore, 1970). On the basis of relative importance of the dry continental north-easternly otherwise regarded as easternly, and the humid southernly air ,and the consequent weather, the year in Zaria can be divided into dry season (November to February), which includes harmattan period, hot season (March to June), and the wet season (July to October). The month of October is being regarded as transitional month when normally the wet season ends and the dry season begins (Hore, 1970).

CHAPTER TWO

2.0. LITERATURE REVIEW :-

The monitoring of biological and physico-chemical characteristics of a given water body serve as important measures in evaluation of both short and long term trends in its hydrological regime by enabling appropriate decision to be made and remedy application geared towards minimizing deleterious effects (Stern, 1981).

2.1.0 PHYSICO-CHEMICAL PARAMETERS

Water temperature, reactivity (pH),dissolved oxygen(DO), nutrients, total solids (TS), suspended solids (SS), amount of light penetration, concentration of inorganic and organic elements, fauna and flora fluctuation under the autochthonous and allocthonous influence, among others, cause remarkable changes in physico-chemical and general biological characteristics of water, hence its quality for the purpose which it is intended (Palmer,1980).

2.1.1 TEMPERATURE

Temperature changes are considered to be more important than any other environmental factor in influencing diatom growth (Patrick, 1948). Generally, the various classes as well as individual species of algae have minimum, optimum and maximum temperatures for growth (Smith, 1951). According to Cairns (1956), the diatom- Gomphonema parvulum grew best at 22°C but still showed growth at 34°C, while Nitzschia grew best at 22

°C and showed little or no growth at 30°C. Water at 10°C is reported to be palatable and above 15°C it may be objectionable with increase in unpleasant taste and odour (McKee and Wolf,1963). The Canadian Department of National Health and Welfare,,CDNHW (1968) reported that certain taste and odour producing organisms grow more readily at higher water temperature. The type of algae found in a particular stream may be a good indication of the range of temperature that the water has experienced (Stein and Amudsen, 1967; Prescott, 1968). Water temperature is known to influence the biomass composition, nutrient requirement and nature of biota (Pirt, 1971).The work of Esener et al (1981) revealed that aquatic micro-organisms lack the ability to regulate their internal temperature. By increasing water temperatures up to 30°C , pronounced effect on the multiplication of Vibrio cholerae was shown, as was attachment of the cells to live Copepods (Huq et al, 1984).The inability of the biota to regulate their internal temperatures may in turn affect their growth and substrate utilisation rate (Mayo and Noike, 1996).

2.1.2 REACTIVITY OF WATER (pH)

According to Bukley (1975), pH influences the toxicity of contaminants. Its increase may increase the toxicity of ammonia and decrease in pH may increase the toxicity of hydrogen sulphide, copper and cyanide. Hudson and Sprague(1975) reported that temperature modifies the lethal effects of heavy metals in animals exposed to metal pollution. Godfery (1980) observed that increased acidity decreases the diversity of species in aquatic environments. Changes in pH of water due to industrial waste or to natural causes greatly modifies the algal population (Palmer, 1980). Mine waste tend to lower pH drastically and reduce the algal flora to a few acid-tolerant forms such as Euglena mutabilis, Ulotrix zonata, among others (ibid).

An alkaline pH (8.5) was found to be optimal both for attachment and multiplication of V. cholerae, as compared with pH 6.5 and 7.5 (Ibid). Winger (1981) reported the pH range of 5 to 9.5 as being suitable for aquatic life. Borg(1983) reported the decrease in pH to have favoured the retention time of some metals in freshwater bodies in Sweden. According to Guffani et al (1984), the pH of the algal-bacterial system is known to influence the biomass regulation and ion transport system . (Mayo and Noike 1994) highlighted the role of pH in the regulation of metabolic rate of biota. pH in stabilization ponds located in the tropical and sub-tropical climates has been shown to correlate to water temperature (Mayo, 1995). pH exceeding 10.0 were significantly found to be detrimental to a number of heterotrophic bacteria, and glucose metabolism decreased significantly at high pH values particularly above 7.0. In studying the quality of well waters in two districts of Conackry (Republic of Guinea), Gelinas et al (1996) reported values of pH being weakly acidic and associated the reason to the location of the wells in highly populated centres and hence their being subject to a variety of anthropogenic inputs of pH lowering pollutants.

According to Mayo and Noike (1996), temperature and pH were among the important environmental parameters governing the activities and growth rate of algae and heterotrophic bacteria in stabilization ponds. The AWRC (1974) reported that the pH of domestic water supplies should be in the range of 6.5 to 9.0 and outside this range water may have sour taste and become corrosive to metals.

2.1.3 OXYGEN,LIGHT AND OPTICAL DENSITY:

Biswass (1966) reported the increase in phosphate, decrease in nitrate and increase in ammonia content of Volta lake (Ghana) due to O_2 depletion at depths

below five metres, which in turn appeared to be due to poor light penetration caused by opalescence of water during flood season with consequent effects on the distribution as well as photosynthetic activity of the phytoplankton. Physical factors such as light and turbulence play their part in determining the particular algal flora that develop or remain in water (Palmer, 1980).In water quality assessment of Sebeel water, Hammad and Dirar (1982), recorded OD range of 0.005 to 0.015, which turned out to be low and attributed such low OD to location and low pollution load. Plankton and inorganic suspended materials reduce light penetration into the water body, thus reducing the depth of the euphotic zone (Kemdirim, 1987).

2.1.4 BIOCHEMICAL AND CHEMICAL OXYGEN DEMANDS

According to Hach et al (1990), measurement of BOD has long been the basic means for determining the degree of water pollution. Biological Oxygen demand (BOD) and Chemical Oxygen Demand (COD) have been recognised as being specific chemical indicators of pollution and limits of 6 mg/L and 10 mg/L have been set respectively by the World Health Organisation (WHO, 1963,1971). While BOD is the amount of oxygen bacteria utilise from water on the oxidation of organic matter, COD measures the oxygen equivalent of the organic content of water sample that is susceptible to oxidation by strong chemical oxidant (APHA, 1985).

2.1.5 WATER HARDNESS

Elevated hardness renders water unsuitable for domestic use (hard-water does not lather well with soap). Hence, the standard of total hardness is set at 7mg-eq/l while the maximum permissible limit is 10 mg.eq/L (Nikoladze et al, 1989). Highest desirable level of 10 mg/L and maximum permissible level of 500 mg/ L has been

adopted by WHO (1971). Retrospective studies in several countries, including the United Kingdom, suggest that there exists an inverse relationship between the hardness of drinking water and cardiovascular diseases, with the death rates from cardiovascular diseases recorded being high in towns supplied with very soft water (1-10%) than in towns supplied with very hard water (Pocock , 1980) and this relationship holds true for most towns studied. Related studies showed that mortality due to gastric cancer was also high in soft water areas (ibid) and results of intensive epidemiological investigations is still uncertain whether the differences in mortality due to intake of soft water is associated with a toxic factor in the soft water, prospective factors in hard water or whether some other environmental factors are involved that are yet to be understood. As a general principle, however, it has been recommended, for good health, to drink hard water, despite the drawback of using such water for domestic and industrial purposes.

World Health Organisation, WHO (1971) listed high water hardness as one of the factors affecting the acceptability of water for domestic use and set 100mg/L. $CaCO_3$ as the highest desirable level and 500 mg/L. $CaCO_3$ as the maximum permissible level in drinking water quality.

2.1.6 MACRONUTRIENTS

Heckey and Kling (1980) noted that both PO_4-P and NO_3-N were limiting nutrients in phytoplankton productivity. Kemdirin (1987) reported that among the factors controlling phytoplankton abundance, considerable attention has been given to nutrients especially nitrate-nitrogen and phosphate-phosphorus.

2.1.7 NITRATES

Nitrates occur in water due to the decomposition of organic substances which gain access to water by seepage or drainage, from land application of chemical fertilizers, from subterranean mineral deposits and from reclaimed water. The proportion in any particular instance is dependant on season, and climate (Ewing and Mayo-Whik, 1951). Excessive nitrate in water is considered dangerous by sanitary standards due to its effects on health. Concentrations of nitrates up to a fe8w thousands milligrams per litre in artesian wells were reported by Nikoladze et al (1989). Potable water containing nitrstes in excess of 50 mg/L NO_3 affects the oxygen bearing capacity of blood, a condition known as methaemoglobinaemia (ibid). The allowable concentration of nitrates in potable water is limited to 45 mg/L (WHO,1971).

The role of nitrate in gastric cancer has been researched into, DHSS (1979). Laboratory experiments were conducted in a series of studies to explore the hypothesis that the ingestion of nitrate or nitrite may be responsible for gastric cancer as a result of its conversion to nitro-compounds, a conversion that could, in appropriate circumstances be brought about by bacterial action (ibid). DHSS (1977) described the deterioration in the quality of drinking water, and hinted at the possibility of methaemoglobinaemia in infants due to high levels of nitrates in drinking water, which developed with rains and predicted upward trend due to changing agricultural practice, most especially as agro-chemicals may take many years to reach the deeper ground water. In many sources of potable water there are reported cases of general upward trend in nitrate concentration in recent years (Ewing and Mayo-Whik, op cit). Water containing nitrates in excess of the 50 mg/L has been reported to be lia2ble for producing methaemoglobinaemia in young

artificially fed babies, although such water my be safe for older children and adults to drink (up to a 4limit of 100 mg/L). "Well water cyanosis" is believed to be a rare condition, with 10 cases having been reported since 1950, one death occurred in may,1950 in a baby whose feeds were made from well water containing 880 mg/L nitrate (ibid). Increased concentrations of nitrate were frequently found in shallow farm 8and rural community wells, often due to inadequate protection from barn yard drainage or from septic tanks, and high nitrate concentrations in streams were recorded due to farmland drainage in areas of intense application of fertilizers. Observations similar to the above were made and attributed such increased nitrate concentration to input from agricultural land (Comin et al ,1983). Gelinas et al (1996) re8corded high levels of nitrate with maximum of 51.8 mg/L in wells located in urban areas, and linked nitrate origin to inadequate disposal of human excreta and domestic sewage, particularly coupled with high soil permeability and depth of the wells.

Nitrate contamination has long been considered a major threat to health in highly agricultural areas where ground water is used as drinking water source (Franco et al, 1993; Power, 1993; Jemison and Fox,1994). In developing countries, high nitrate levels in aquifers were generally associated with unsewered sanitation (Lewis et al, 1981; Hughes and Van Ginkel ,1994), and high nitrates in water is regarded as suitable quality indicator of anthropogenic impact on the ground water (Kumaru-Swamy and Venkata Rao, 1991., Zahn and Grimm, 1993). According to Gelinas et al (1996), the leaching effect of the rain becomes more pronounced where the ground is more permeable and the wells are shallow and observed that after long periods of drought (about 6 months) , high quantities of nitrogen were 8accumulat2ed in the superficial layers of the ground.

The World Health Organization, WHO (1971) reported that in some circumstances, nitrates present health hazards to infants, and possibly older children, if present in drinking water at concentrations greater than 45 mg/L. It is als2o emphasised, (ibid) that nitrates, after reduction to nitrite could cause methaemoglobinaemia.

2.1.8 PHOSPHATE:

Water containing excess phosphate may be undesirable for use in food preparations because of the buffering action on the stomach acids (McKee and Wolf, 1963). Phosphate concentrations in excess of 0.02 mg/L have been reported by Vollenweider (1968) to be associated with eutrophication of lakes . An objective limit of less than 0.02 mg/L phosphate and acceptable limit of 0.2 mg/L has been set (DNHW, 1968).

2.1.9 CHLORIDE

The concentration of chloride ion is often used as indicator of pollution and considered symptomatic of a variety of anthropogenic effects. Enrichment of lakes with chloride to high levels have been reported several workers. The biological imp8act of chloride pollution has been described as subtle, probably influencing the assemblages of various organisms (Gorham,'1961 and gibbs, 1970). In quality investigation of well water in Guinea, Gelinas et al (1996), reported chloride level in traditional wells with minimum concentration of 22.5 mg/L and maximum concentration of 284 mg/L. Reason for the recorded high level was attributed to ground water contamination through agriculture, precipitation and other sources.

2.2.0 METALS:

Base-line research by many authors have identified elevated levels of certain trace metals in freshwater system, especially rivers and lakes (Ashraf and Jaffar, 1990, Ashraf et al, 1991, 1992, Jaffar et al, 1988, Jaleel et al, 1991, 1996) in Pakistan, arising mainly from unregulated agricultural and industrial sewage and effluent.

2.2.1 CALCIUM AND MAGNESIUM:

Hardness in water has been attributed to the presence of calcium and magnesium ions in water (Lind, 1979). There has not been direct link between hardness of water and its harmful effect to the health of man. To the contrary, calcium promotes the removal of cadmium, an element that can adversely affect the cardiovascular system(Pocock . , 1980). Jop and Wajton (1981) associated low water hardness to low levels of Ca and Mg ions. Nikoladze et al (1989) directly linked water hardness to the presence of Ca and Mg ions in water.

2.2.2 SODIUM

Drinking water normally provides only a small proportion of dietary intake of sodium, which is about 4 to 8 grams per day in adults. About 9% of large town supplies in the United Kingdom contain on average less than 50 milligrams per litre of sodium and increases in its concentrations in river-derived supplies have been reported during droughts. Some wells in a few areas contained as high as 1000 mg sodium per litre (Department of Environment, 1980). When concentration of sodium exceeds 200 mg/L, the water begins to have noticeable taste. The major point of concern regarding sodium content of drinking water revolves around three points :

a. On the basis of animal studies and international comparisons, that high dietary intake of salts (rich in sodium) has a role to play in development of high blood pressure.

b. Drinking water could be an important source of sodium in infants and the ability of the kidney to excrete sodium is not fully developed in the first few weeks of life. Consequently, an excessive sodium intake in artificially fed infants, when combined with water loss due to diseases such as darrhoea could lead to brain damage and consequent death (Department of Environment, ibid), and treatment by diuretics or salt restriction of patients with heart failure or high blood pressure has been reported to be limited by water with high sodium content.

Following the report of the expert committee (EEC, 1971), it was concluded that water with up to 150 or 200 mg/L sodium is acceptable for the above category of patients. The European Economic Community (EEC) directive on quality of water for human consumption provides that in general, sodium concentrations be restricted to 175 mg/L in 1984; 150 mg/L in 1987 and to 120 mg/L afterwards (Council of the European Communities, 1980).

2.2.3 POTASSIUM

Potassium in waters originate naturally from the dissociation of evaporated salts and the decomposition of silicates; and is therefore highly correlated with other cations and anions responsible for both water mineralisation and conductivity (Zamora-Munoz et al, 1995). Introduction of K_+ into freshwater bodies as a result of the use of chemical fertilizers has been reported in Makwaye lake, Zaria (Balarabe, 1989); Romi stream, Kaduna (Hassan, 1989). Specific conductance of water in bicarbonate dominated lakes and stream has been closely proportional to

the concentration of major cations - Ca, Mg and Na (Kemdirim, 1987). According to2 Golterman (1975), conductivity of water is proportional to the concentration of its dissolved elements and high conductance was significant if the buffering capacity of water is to limit toxic effects of pollutants.

22.2.4 ARSENIC

The tentative limit for arsenic in drinking water has been set by WHO (1971) at 0.05 mg/L. Some epidemiological studies have suggested that arsenic is carcinogenic. However, substantive proof of arsenic carcinogenicity via drinking water in man has not been established (ibid). According to WHO (1971), figures higher than 0.05 mg/L were found in water in a number of Latin American countries and same reports indicate that levels as high as 0.20 mg/L were known to have caused some difficulties in man.

Long term ingestion of arsenic contaminated drinking water was found to produce gastrointestinal, skin, liver, and nerve tissue injuries in Taiwan, where widespread occurrence of "Black Disease" resulted from high levels of arsenic in ground waters in concentrations up to the maximum of 2.5 mg/L (Wittman,1979). Chronic arsenic poisoning ws Iso reported in a Mexican village, Toreon, in which 60 % of the inhabitants showed varying degrees of chronic intoxication from drinking water contaminated with arsenic up to the levels of 4-6 ppm arsenic (ibid).

2.2.5 CADMIUM

Results of animal studies suggest that very small amounts of cadmium could produce nephrotoxic cardiovascular effects in the reproductive organs of animals which were specifically effected cadmium salts. The toxicity of cadmium may depend on the presence of other trace elements such as zinc and selenium (WHO, 1971). The upper limit of concentration of cadmium in drinking water has been set at 0.01 mg/L (ibid).

Cadmium has been identified as one of the most toxic heavy metals and is considered non-essential for living organisms, found at low concentrations in natural environment, but with human activities attributed as the major factor for increased cadmium concentration in the environment (Fernando-Laborans and Novillo, 1996). High concentrations of cadmium have recently been reported in kidneys of penguin from the Antarctic region (Elinder, 1992). Studies carried out so far, with respect to cadmium toxicity using protozoa, algae and cyanobacteria (Fernando- Laborans and Novillo, 1996), show effects on morphological, biochemical and physiological processes induced by the presence of cadmium: Reduction in biovolume, significant reduction in cell number, 71-80 % reduction in abundance and ability for bioaccummulation of cadmium were reported.

2.2.6 LEAD

According to the Ministry of Agriculture, Fisheries and Food, MAFF (1975), the important biochemical changes that may follow prolonged absorption of lead has been found to be obscure. High affinity of lead for thiol and phosphate containing ligands has been found to inhibit the biosynthesis of haem, affect membrane permeability in kidney, liver and brain cells, resulting in either reduced functioning

or complete break-down of the mentioned tissues, because lead is a cumulative poison (Wittman,1979). Nikoladze at al (1989) recommended that the concentration of lead in potable water should not exceed 0.1 mg/L. World Health Organization, WHO (1963,1971) set the maximum allowable concentration at 0.05 mg/L. The tentative level of Pb in drinking water has been reviewed by WHO (1971), from 0.05 mg/L to 0.01 mg/L following intake of water for many years in many countries with Pb concentration up to 0.1 mg/L without apparent health effect. In studying ground water as source of contamination for water supply in Pakistan, Rahman (1996), reported Lead (Pb) in high concentrations from samples of ground water collected throughout the city of Karachi, Pakistan with the maximum amount detected being above any standard set for water intended for domestic use .

2.2.7 IRON

Probably most characteristic of ground water in Nigeria is the relatively high iron content, in significant parts of particularly all states in the country. Commonly found in many of the rocks and soil in Nigeria, iron occurs in igneous rocks in the ferromagnesia or dark magnetic mineral and in derived (ferragnised) sedimentary rocks or soils, lateritic soils. Ferrous iron is a common constituent of bog and swamp deposits, lignites and coal, with ground water in contact with such strata, frequently containing between 1-10 mg/L of ferrous iron (Mandel and Shiftan, 1981) . Details of geological studies of Zaria reveals that the geological structure is largely underlaid by pre-cambrian igneous metamorphic rocks of the basement complex with a thin mantle of weathered material (Buchanan and Pugh , 1969; Acheampong, 1988). Such weathered material has been described by DuPree and Barber (1965) as having average depths of about 5 to 60 meters. Kowal and

Omolokun (1970) described the set up as that of efficient aquifer.

The work of Mandel and Shiftan (op cit) associated high iron content in ground water to lateritic soils. Olowu (1967) reveals that Zaria contains alluvial deposits post-dating older laterite and broadly contemporaneous with young laterite overlie most of the area. Iron in drinking water or house-hold supplies water imparts ametallic taste at concentrations up to 1.8 mg/L, while concentration exceeding USEPA (1976) limits of 0.3 mg/L could stain surfaces of clothing, cooking utensils, etc. According to Petter (1980), iron has been found to be toxic to some aquatic species at concentrations of between 0.32 and 1.0 mg/L. Ezeigbo (1988) reported that excessive iron in water imparts brown colouration to water upon storage, due to the oxidation of ferrous to insoluble ferric form. Some of the undesirable effect that may be produced by iron in water were outlined by WHO (1971) and they include negative effects on taste, discolouration, stimulation of growth of iron bacteria and affecting turbidity. The maximum permissible level of iron in drinking water is set at 1.0 mg/L, the highest desirable level being 0.1 mg/L (WHO,1971).

2.2.8 MANGANESE

Excessive manganese in water comes from the soil and sediments with biotite and hornblendes. These are the major furnishing minerals in igneous rocks (Ezeigbo,1988). Even minute amounts of Mn in Solution are objectionable for the same reason as iron (ibid). The USEPA (1976) limit for manganese in water is put at 0.05 mg/L (Ezeigbo, 1988). According to Gelinas et al (1996), this limit was established as a norm mainly because of organoleptic considerations : Only 3-4 % of total ingested manganese is absorbed by the digestive tract, its toxicity begins

at much higher concentrations.

2.3.0 BIOLOGICAL INDICES OF WATER POLLUTION

Numerous techniques have been proposed for biological detection of organic pollution in raw waters. Liebmann (1951)advocated concentration upon micro-organisms in the detection of water pollution. Huet (1949) advanced the use of micrsocopic invertebrates to determine the pollution status of water.

Kolkwitz and Marsson (1908, 1909); Kolkwitz (1935, 1950); Liebmann (1951, 1962) proposed the principle of the saprobity system (Saprobiensytem) comprising of series of water quality zones ranging from polysaprobic, alpha-mesosaprobic, beta-mesosaprobic to oligosaprobic, with each zone containing characteristic plants and animals, and for each zone parculiar indicator organisms exist.

Fjerdingstad (1960) established a saprobic system based upon the decomposition of benthic communities of micro-organisms. The reducers-producers-consumers (R-P-C) system based on the numerical values of the reducers, producers and consumers in the system was established by Gabriel (1946).

The use of relative abundance of the species within the association of organisms for the quality evaluation of polluted waters have been developed by Knopp (1945), Pantle and Buck (1955a and 1955b), Zelinka and Marvan (1961), Zelinka et al (1959) and Dittmar (1959).

Horasawa (1942) proposed the biological index of pollution (BIP). This method is based on the relative abundance of the most pollution sensitive zooplankton communities in relation to the corresponding phytoplankton. The method has been adopted by Palmer (1980) and serves as a promising biological

method of detecting water pollution in relation to its quality.

2.3.1 MICROBIOLOGICAL PARAMETERS

The prolonged survival of coliform and possibly other faecal bacteria in sediments and the likelihood of their being desorbed by dilution and thus becoming resuspended has been stressed by Geldreich (1970) and Grimes (1975).Several studies have highlighted the importance of sediments as potential reservoirs for microorganisms in the aquatic environment (Hendricks, 1971; Grimes, 1975; Erkenbrecher, 1981). Hammad and Dirar (1982) enumerated some factors controlling microbial population in homes and at public watering stands (Sebeel)in Sudan, among which warm water temperature, dust storms, more frequent use by humans and possible regrowth of bacteria in water, as well as the presence of coliform of non-faecal origin.

Gelinas et al (1996) analysed water from open wells in Conackry and reported the widespread well water contamination with faecal bacteria especially faecal coliform and *Faecal streptococci*). Reason for this was linked with insufficient well maintenance, high permeability of the soil and shallow water table of the area sampled. Lewis et al (1981) referred to the above situation as to have corresponding to one in which pit latrines, sanitation and shallow aquifer exploitation for drinking purpose were in direct conflict because of the facilitated migration of contaminants, both bacteriological and chemicals, through the soil. Kindler (1992) attributed sewage as being a dominant factor contributing to the contamination of ground water.

Ferguso et al (1996) studied the relationship between indicators, pathogens and water quality in an estuary system and found that rainfall and sewage overflows

caused significant increases in the number of all the indicator organisms and some pathogenic ones tested. They (ibid), also reported a significant increase in faecal coliform density in sediments after rainfall. The total organic matter was associated with a significant increase in the density of both faecal coliform and Faecal streptococci. Gerba and McLeod (1976) earlier reported similar findings.

CHAPTER THREE

3.0 METHODOLOGY

3.0.1 STUDY AREA :-

The study areas lie between 11° 00'N to 11° 13'N and 7° 30'E to 7° 47'E (Fig.1). The study areas are devoid of electricity supply, good access roads, pipe-borne water supply and bore-hole. In one of the study areas (Kurmin Bomo), only one hand-dug well was seen. It was sunk by DIFRRI in 1991. There is however a proposal for pipe borne water supply in due course.The typical source of water for domestic use in the area is the well water which is obtainable from hand- dug wells. Occassionally, water from the impoundments (Bomo lake, Shika dam and University-Kubanni dam) are used.

The wells are sunk without adhering to the minimum 10 meter distance fron source of contamination such as pit- latrine, gutter and refuse dump.They are often un-protected with concrete The well water levels are under the influence of water table, with high water table resulting in maximum volume of water during the late rainy season (August to September), followed by rapidly submerging water table with increase in the period of drought (Months of November to April).

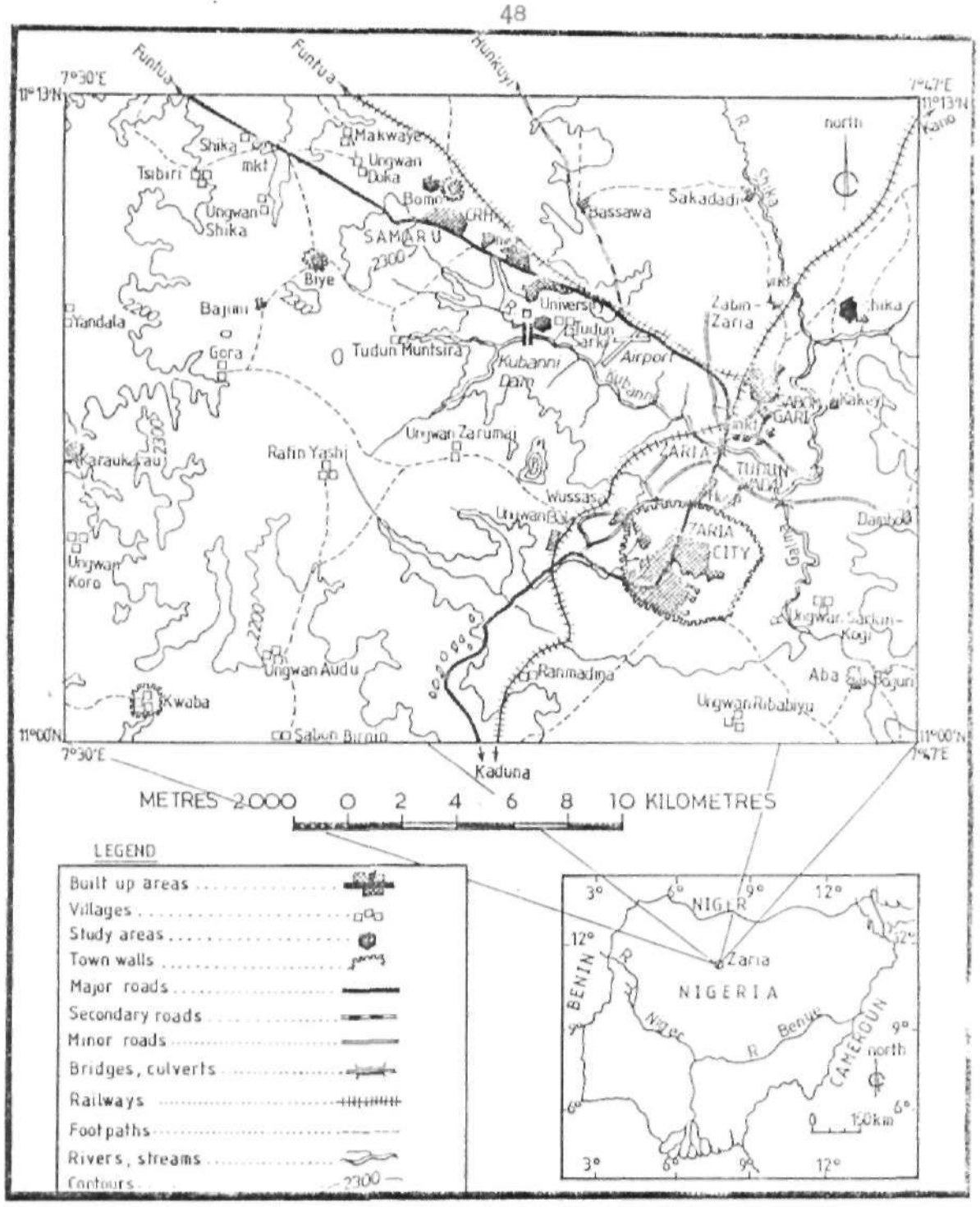


Figure 1. Zaria and its Environs showing the study area.

Brief Description of the Sampling areas:

Bomo Area:

Is located on the northern bank of the lake. It is an agricultural area with most of the population being predominantly farners. A few of the inhabitants are civil servants with strong base in farming and animal husbandry.

The area comprise of Bomo and Kurmin Bomo clusters. The division between the two is basically on the clusters of settlements, They share Bomo lake ,a man made lake. The residential houses are constructed with mud, which is readily obtainable from the surface and sub-surface soils. Some of the houses are roofed with iron sheets, but the most popular roofing is the traditional type called "Soro", wich is made up of mud and wood or a special timber called "azara".

The water sources are principally the hand-dug wells (see S1-S6). These wells are sunk without any concrete lining and often are unproteted from dust. The location of such well is based on the posssible shallow water table without regard for its closeness to liquid point sourcesof pollution (see S2, and S4). The DIFRRI constructed well (S6) constructed in 1991, is the most modern of its type in the area. It is located in the midst of cultivated land. Bomo lake serves as the only available open water source for the dry season irrigated farming and occasional use by the people. In both the wells and the lakes, water obtained is directly used without any treatment. A dispensary/clinic serves the two clusters.

Shika Settlement and Tudun Sarki:

The two settments are basically similar to the former in aspects of



Plate i Bomo and Kurmin Bomo Area

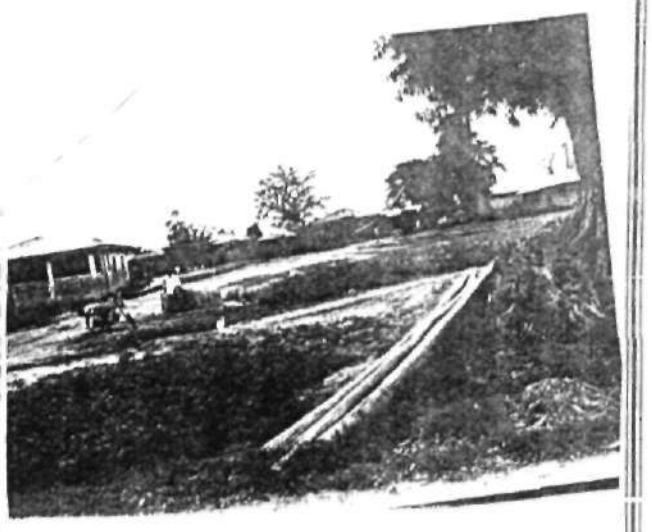


Plate ii Kofar Fada (S1)

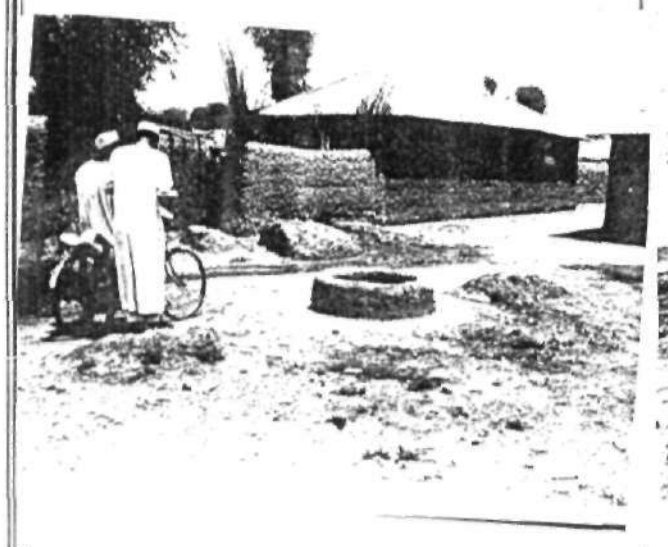


Plate iii Gidan Tanimu Rasha (S2)



Plate iv Gidan Tanimu Rasha (S2)



Plate v Gidan Mal. Musa (S3)



Plate vi Gidan Mal. Musa (S3)



Plate vii Gidan Mal. Zailani (S4)



Plate viii Gidan Alaramma (S5)



Plate ix Gidan Mal. Zailani (S4)



Plate x Rijiyar DFRRI (S6)



Plate xi Gidan Mal. Zailani (S4)



Plate xii Bomo Lake (S7)

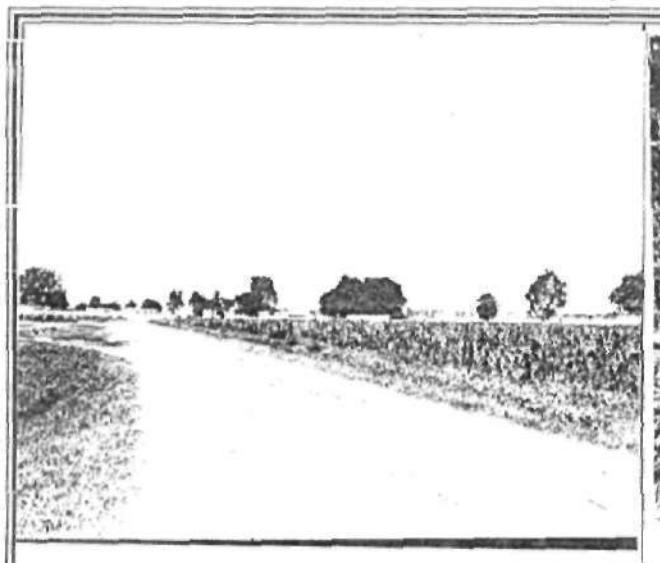


Plate xiii Shika Dam Settlement



Plate xiv Gidan Mal. Sani (S8)



Plate xv Gidan Mal. Sani (S8)

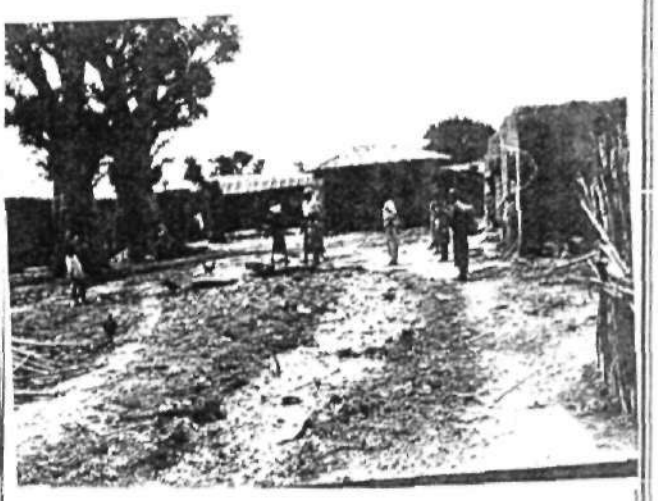


Plate xvi Babban Gida (S10)



Plate xvii Babban Gida (S10)

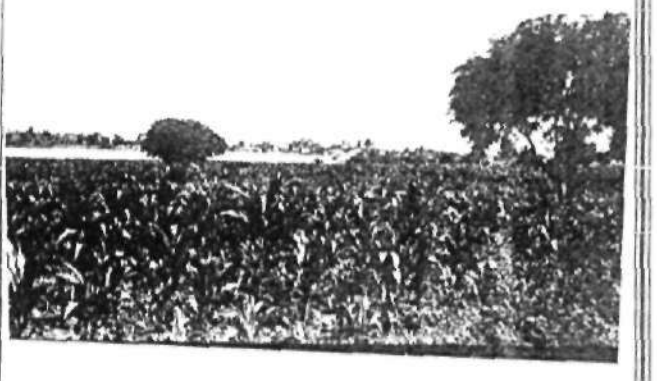


Plate xviii Shika Dam Reserviour (S11)



Plate xix Tudun Sarki Settlement

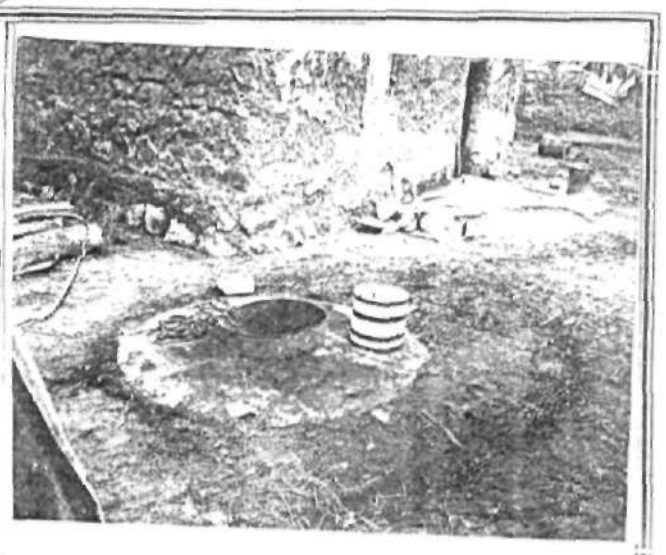


Plate xx Gidan Mal. Magaji(S12)

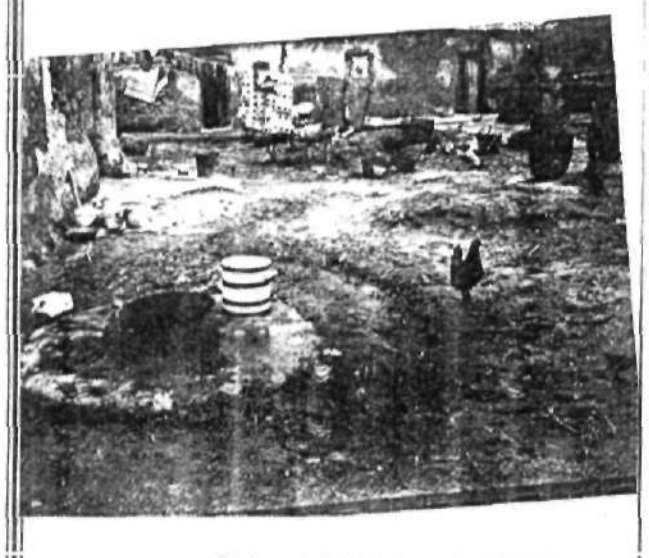


Plate xxi Gidan Mal. Magaji (S12)



Plate xxii Gidan Alh. Musa (S13)

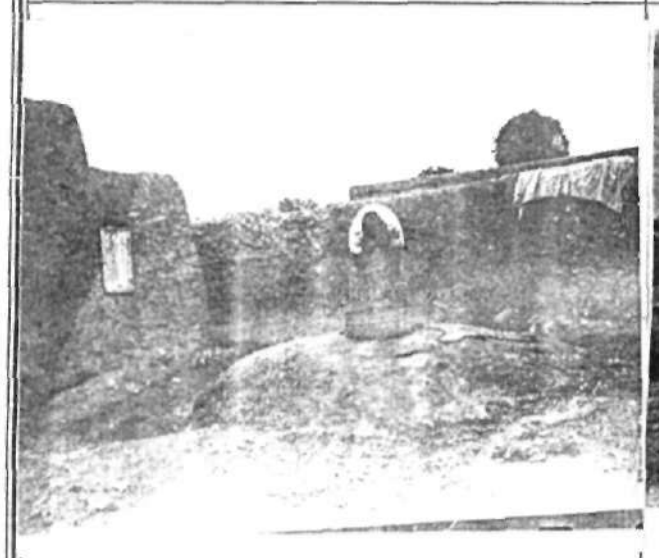


Plate xxiii Gidan Alh. Idrisu (S14)

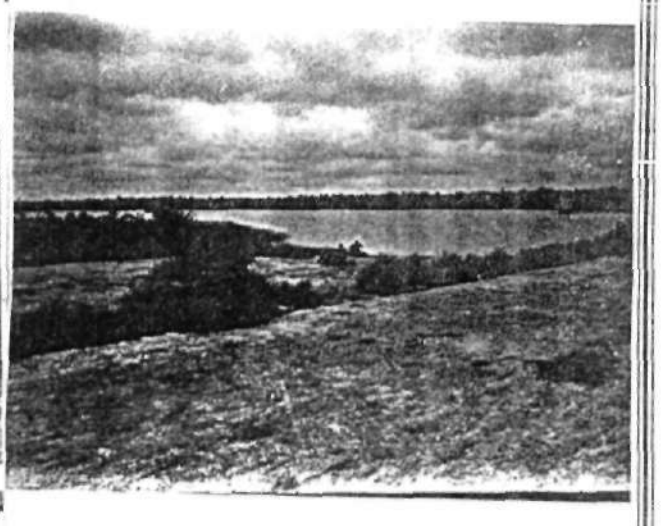


Plate xxiv ABU-Kubanni Dam (S15)

housing,occupation and the nature of the water sources.Shika settlement is located on the norhtern bank of Shika Dam, while Tudun sarki is on the western bank of the ABU-Kubanni dam.The two communities in addition to farming and cattle rearing, carry out small scale fishing. Stations 7 to 15 are the selected water sorces in the two areas.

Four (4) rural settlements around Zaria that had not linked with pipe borne water supply were selected, namely:-

a. Bomo:

Kofar Fada (S1)

Gidan Tanimu Rasha (S2)

Gidan Mal. Musa (S3)

b. Kurmin Bomo:

Gidan Mal. Zailani (S4)

Gidan Alramma (S5)

Rijiyar DFRRI (S6)

Bomo Lake (S7)

c. Shika-Dam:

Wajen Gidan Mal. Sani (S8)

Cikin Gidan Mal. Sani (S9)

Babban Gida (S10)

Shiga-Dam ,the main water reserviour (S11)

d. Tudun Sarki:

Gidan Mal. Magaji (12)

Gidan Alh. Musa (S13)

Gidan Alh. Idrisu (S14)

A.B.U. Kubannin Dam (S15)

Quality Standards for International StandardS for Drinking-water (WHO,1971,AWQRC,1974)quality specificationS were used for comparison .

3.0.1 Parameters:

The following parameter were tested:-

3.1. Physico-chemical parameters:

i. Water Temperature

ii. Optical Density of the Water

iii. Suspended Solids

iv. Total Solids/residue on evaporation

v. Water Hardness

vi. Water pH

vii. Electrical conductivity

viii. Nitrate-Nitrogen

ix. Phosphate-Phosphorus

x. Biochemical Oxygen Demand (BOD)

xi. Chemical Oxygen Demand (COD)

xii. Chloride ion concentration

xiii. Dissoved Oxygen

xiv Akaline-earth metals (K, Ca, Na and Mg)

xv. Heavy metals (Pb, Cu, Cd, Zn, Fe, As and Mn)

3.2. Biological Parameters:

(i) Pytoplankton

(ii) Zooplankton

(iii) Bacteriological examination for Faecal coliform, Faecal streptococci anaerobic sore-forming organisms

3.3. METHODS FOR THE DETERMINATION OF PHYSICO-CHEMICAL PARAMETER:

a. Determination of Water temperature :

This was measured on the spot, using thermometer calibrated to measure range of temperature from -10 °C to 110 °C. The thermometer was immersed into the water for 5 minutes, after which the water temperature was recorded (°C).

(WHO,1963; Lind,1979; APHA,1980)

b. Determination of Optical density of Water:

This was determined by Spectrophotometry, using model S101 spectrophotometer, setting the wavelength at 430 nm (blue filter) Distilled water was used as blank (Hammad and Dirrar, 1982). The optical density

(OD) was thus calculated as:

$$OD = LOG\frac{1}{\%TRANSMITTANCE}$$ (Lee, 1978)

c. Determination of Suspended Solids:

One hundred ml of water sample was filtered through 0.45 µm 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 (DS) on drying at 103 °C (DS,103 °C) was thus calculated as :

$$DS,103\ °C = \frac{W_2 - W_1}{Vol.\ of\ Sample} X\ 1000(mg/L)$$

where,

W2 and W1 represent the final and initial weight of dish respectively.

d. <u>Determination of Total Solids/Residue on Evaporation</u>:

One hundred ml of water sample was thoroughly shaken and introduced to a clean, dry, pre-weighed evaporating dish. Re-weighing and evaporation was followed. After the evaporation to dryness, the dish and content were further dried to constant weight at 103 °C for two hours, cooled in a desiccator for 90 minutes. The dish was reweighed and the amount of solid (S) thus calculated as total solid on drying at 103°C (TSS 103 °C).

$$TSS,103\ °C = \frac{W_2 - W_1}{Vol.\ of\ Sample} x\ 1000(mg/L)$$

(WHO,1963; Lind,1979).

where,

W2 = Final weight of dish and content

W1 = Initial weight of dish and content.

e. <u>Determination of Water Hardness</u> :

Twenty-five ml of water sample was diluted to 50 ml using distilled water. This was followed by the addition of 1 ml NH4OH(buffer); 2 drops of Erichrome-black-T-

indicator and titrated against 0.01M EDTA till light blue coloration was observed.

$$\text{Water Hardness(mg/L.CaCO3)} = \frac{Vol.\ of\ EDTA\ (titrant)}{Vol.\ of\ sample} \times 1000\ (mg/L)$$

(Lind,1979).

f. Determination of Water pH

This was determined on the spot, using portable pH meter. The electrode was immersed into the water for few seconds to obtain stable reading on the pH scale.

g. Determination of Electrical Conductivity of Water :

This was determined on the spot using EBA/10 portable conductivity mater. The electrolytic conductivity cell (K=0.1) of the meter was rinsed with the water sample. This was followed by the introduction of water sample into the cell, with the temperature of the meter's scale adjusted to read the corresponding water temperature.Conductivity (in Micro ohms/cm^3) was thus recorded from the calibration of the meter.

APHA(1980).

h. Determination of Nitrate- Nitrogen content of water:

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 10 ml distilled water and 5 ml strong ammonia solution. setting the spectrophotometer at the wavelength 410 mU, absorbance of the treated sample (above) was obtained from the scale against distilled water (used as Blank). Nitrate-Nitrogen concentration was obtained from a calibration curve in mg/L(APHA,1980).

I. Determination of Phosphate-Phosphorus content:

To 100 ml of water sample, 1 ml ammonium molybdate and 5 drops of stannous chloride solution were added, and allowed to stand for 10 minutes. Absorbance was taken at 690 mU. using Spectrophotometer. Thus, PO_4 -P concentration was obtained from a calibration curve in mg/L(APHA,1980).

j. Determination of Biochemical Oxygen Demand (BOD) :

After the initial dissolved oxygen (DO) of the water sample was determined by the Modified Winkler's Method (above), water sample was incubated in 250 ml BOD bottles at 20 C for five days.

BOD(mg/L) was calculated as : $DO_1 - DO_5$ (mg/L).

where,

DO_1= Dissolved oxygen concentration prior to incubation,

DO_5= Dissolved oxygen concentration after 5 days incubation

(APHA,1980).

K. Determination of Chemical Oxygen Demand (COD):

The water sample was filtered through glass fibre and 10 ml of it was transferred into 250 ml conical flask. To this, 40 ml distilled water was added, followed by the addition of 5 ml 0.1N potassium permanganate ($KMNO_4$) solution and covered with beaker. The flask was placed in water bath at 80 ^{0}C for 60 minutes, cooled for 10 minutes, and 5 ml potassium iodide(KI), 10ml 4N H_2SO_4 were afterwards added and titrated against 0.1N sodium thiosulphate till pale yellow coloration appeared. One ml 1% starch indicator was added and the content was further titrated to end point

(the appearance of colourless solution). Three blanks (50 ml distilled water, 5 ml 0.1N $KMNO_4$, 5 ml 1% KI and 5 ml H_2SO_4) were prepared and titrated as the former.The average value was determined and designated (a).

COD (mg/L) was thus calculated as : (a-b) x N x 1000 (mg/L).

(Golterman,1970)

Where,

a = vol. of Sodium thiosulphate for the blank,

b = vol. of Sodium thiosulphate for sample,

N = Normality of the titrant used.

I. **Determination of Dissolved Oxygen (DO):**

Dissolved oxygen was determined by the modified Winkler's method (Lind,1979). Water sample was collected from the marked sampling stations in 250 ml. amber sampling bottles, filled up to the neck. Twenty ml. standard $MnSO_4$ solution and 2 ml alkaline-iodide-azide solution 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 shaken again for few seconds till the precipitate dissolved. samples were then transported to the laboratory.

In the laboratory, 100 ml of the sample was transferred into 250 ml conical flask then titrated against standardised 0.0124N sodium thiosulphate. As the colour changed to pale yellow, 2 ml starch solution (indicator 0 was added and further titrated to end- point (appearance of colourless solution).

The dissolved oxygen(ml/L) was thus obtained using 1:1ration, 0.0124N

titrant to 1 ml/L Oxygen (Lind,1979).

m. Determination of Chloride ion concentration :

One hundred ml of the water sample transferred into an Elenmeyer flask. Two drops of potassium chromate solution wad added(indicator). Titration against 0.014N silver Nitrate was followed till an end-point was obtained.

Chloride ion (mg/L) = vol. of $AgNO_3$ used x 10

(APHA,1980).

n. Determination of Metals:

200 ml water sample was collected using polythene container previously washed with acid. This was followed by the digestion of 50 ml of the water sample in 10 ml concentrated nitric and hydrochloric acids in ration 1:3 in a water bath at 90 °C for 60 minutes. Spectral characteristics of alkaline earth metals (K,Ca,Na,Mg) were determined using flame photometer and their concentrations (µg/L) were obtained using standard curves.

Heavy metals (Pb,Zn,Cd,Fe,Mn,Cu and As) were determined by Atomic absorption Spectrophotometer (AAS), Model 180-80. Corresponding concentrations were obtained from standard curved (APHA,1980).

3.4.0 METHODS FOR DETERMINATION OF BIOLOGICAL PARAMETERS:

The biological parameters sampled were the phytoplankton,zooplankton and bacteriological indicators (*faecal coliforms and faecal streptococci)*

3.4.1 Collection,Preservation, Identification and Numerical count of Phytoplankton and Zooplankton Genera:

(a) Collection from open water source :-

i. Phytoplankton samples:

Phytoplankton collection was done by the use of plankton net of 70 meshes/cm and radius of 25 cm. This was dragged just below the water surface for the distance of 3 meters. The collected volume of water, now concentrated in 50 ml collection bottle attached to the net. The content of the bottle was preserved in Lugol's solution.

(b) Collection from restricted water source :-

Ten litre container was used in fetching the water from source and concentrated in 50 ml collection bottle attached to the plankton net.

ii Zooplankton samples :

Zooplankton samples were collected by the same method (Above) over the same distance, and preserved in 40 % formalin (WHO,1963; APHA,1980).

3.3.0.2 Identification:

Identification of the collected organisms from the samples was made with the aid of reference texts: [Edmonsen,1957(ed); Hynes,1963 (ed); Hutchinson,1967 (ed); Pennack,1978 (ed); Whitton,1975 (ed); Needham and Needham, 1975 (ed)]; Prescott, 1972 (ed); Palmer (1980) and the Identification Guide of the Standard Method for the Examination of Water and Waste water (APHA,1985). The organisms were identified to generic level.

3.3.0.3 Deferential counting :

Differential count of phytoplankton : This involved the counting and recording of any identified phytoplankton and zooplankton communities of each kind quantitatively (WHO,1963). By means of mechanical stage , the entire content of 1 ml. concentrate sample placed on Sedwick Rafter Counting Cell is moved past the low power objective of a light microscope for enumeration.

The number of organisms per litre from the lakes was thus calculated as :

$$N = NX\left[\frac{ab}{bd}\right] x\ 1000\ (\text{Org./L})$$

Where,

N = number of organisms per litre

NX= number of organisms recorded in the 1000 fields of standard Sedwick-rafter cell(1 ml deep) i.e. from 1 ml. concentrate sample.

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

b = number of fields counted (1000)

c = ml. of concentrate sample (50 ml.)

d = ml. of original sample vol. (πr^2 x 3m) for open sources

and for samples collected from wells, the computation was as follows:

$$N = NX\ 1\ x\left[\frac{50}{10}\right]$$

where,

N = number of organisms per litre

NX= number of organisms recorded in the 1000 fields of standard Sedwick-rafter cell(1 ml deep) i.e. from 1 ml. concentrate sample.

3.3.0.4 Calculation of relative abundance :-

Calculation of relative abundance of organisms: The relative abundance of each genus was determined on individual basis by calculating its monthly percentage composition:

$$\frac{\text{Number of members of a genus in a month}}{\text{Total number of all the genera in a month}} \times \frac{1000}{1}$$

(Expressed as percentage)

3.3.1 Collection Of Samples For Bacteriological Examination:

Samples were collecte on a monthly basis in 250 ml sterilised glass bottles with ground-glass stoppers after the addition of 0.1 ml 3% Sodium thiosulphate (England and Wales,Public Health Laboratory Service Water Sub-Committee, EWPHLSWSS, 1953; DHSS, 1983)The bottles were filled up to the neck without rinsing and care was taken to avoid contamination and fouling of the water or contamination of samples by surface scum. The stoppers and the neck of the bottles were protected with thin aluminium foil.

Bacteriological examination was carried out immediately after collection (within 24 hours). The temperature of the samples was maitained as closely as possible to that of the source of water at time of sampling using ice blocks. Time and temperature of of the samples during storage were recorded (WHO,1963,1971,DHSS,1983,APHA,1985).

Frequency of sampling was based on WHO(1963, 1971) specification for untreated water serving a population up to 20,000 has been recommended to be once a month.

3.3.2 Bacteriological Examination

Organisms Indicative of Faecal Pollution:Pathogenic micro- organisms in water are almost always outnumbered by the normal excremental organisms, and these normal intestinal organsims are easily detectable in water as compared to the pathogenic ones. According to WHO (1963,1971), modern bacteriological methods have made it possible to detect pathogenic bacteria in sewage and effluent, it is however, not possible to attempt to isolate them as a routine procedure from samples of drinking water. If normal excremental organisms are found in water it can be inferred that the water is contaminated with disease producing micro-organisms. Thus the use of excremental bacteria as indicators of faecal pollution introduces a margin of safety (WHO,1963,1971;DHSS,1983).

3.3.3 Faecal coliform (*Escherichia coli*):

All organisms of the coliform group are foreign to water and most be regarded as indicators of faecal pollution. The most common being Eschericia coli According to DHSS(1983), the test for E. coli is most sensitive routine bacteriological examination carried out on drinking water, as it provides the most sensitive method for detecting faecal contamination

Presumptive Test : This test is based on the fact that coliform bacteria ferment Lactose with the production gas.According to DHSS (1983) E. coli is thermotolerant coliform organism which produces acid in 24 hours at 44°C.The World Health Organisation,WHO(1971) recommends the use of MacConkey broth for the incubation, with bromocresol purple as an indicator and a standardised concentration of bile salts.The bile component is inhibitory to the growth of other

organisms (DHSS,1983).

Five set each of MacConkey broth fermentation tubes were inoculated with 10 ml portion of the test water and incubated for 24-48 hours +/-2 hours at 35 °C +/- 0.5 °C. The presence of gas and acid formation mark the presumptive evidence that coliform bacteria were present and suggests faecal contamination (WHO, 1963, 1971, Smith,1977).

Confirmatory Test: Presumptive positive tubes (tubes in which gas formation was observed) were sub-cultured into 2 tubes each containing MacConkey broth, one of which was incubated at 35 °C for 48 hours (for confirmation of the presence of other coliform organisms) and the other at 44 °C and inspected after 6 and 24 hours to confirm the presence of E. coli, WHO(1963,1971). If on incubation at 37 °C +/- 0.5 °C, MacConkey broth shows gas formation at the end of 48 +/-3 hours,the confirmatory test for thermotolerant coliform organism becomes positive (Smith, 1977, DHSS,1983).

Completed Test : This was done by streaking MacConkey agar plates with presumptive positive content and incubated at 35°C +/-0.5 °C for 24 +/-2 hours.From these plates colonies typical of or similar to coliform bacteria were transferred to another fresh MacConkey broth fermentation tube at 35 +/-0.5 °C and incubated at the end of 24 +/-2 hours and 48 +/- 3 hours respectively. This was followed by microscopic examination for gram negative bacteria) and indol production (Smith,1977).

3.3.4 Faecal streptococci (*Streptococcus faecalis*): This occurs regularly in faeces in varying number that are usually smaller than that of E. coli. In human faeces they rarely exceed 1 million per gram (DHSS,1983). In water,their probability of survival is approximately of the same rate as that of E. coli. Streptococci are regarded as indicators of faecal pollution and the main use of faecal streptococcus test is to assess the significance of coliform organisms in the absence of E. coli. and to help in distinguishing between human and other animal sources in water pollution (DHSS,1983).

Presumptive Test for Faecal Streptococcus: Five 10-ml portions of water samples were placed into sodium azide broth (Hannay and Norton,1974; EWDHSS,1969; WHO,1963,1971; DHSS,1983). and incubated for 72 hours at 37 °C to observe growth and acid formation.

Confirmatory Test: As soon as acidity was observed,a heavy inoculum was sub-cultured into tubes of the broth and incubated for 48 hours at 45 °C. Tubes showing acidity at this temperature were therefore confirmed to contain faecal streptococcus (WHO,1963,EWDHSS,1969 and DHSS,1983). Tubes being positive were indicated by the growth and acid formation at 45 °C.

The appearance of black/brown colour in the inoculum within a few hours excludes the possibility of other gram-positive organisms and confirms the presence of faecal streptococci(WHO,1971; DHSS,1983).

Further,microscopic examination of positive tubes for presence of gram-negative stained films was confirmatory (Fjerdistad,1970)

3.3.5 MOST PROBABLE NUMBER:

It was based on the following assumptions :

(a) That the organisms are distributed randomly in the water,

(b) That a positive reaction is obtained if, and only if, the portion of water tested contains one or more of the organisms (WHO,1963).

MPN INDEX AND 95% CONFIDENCE LIMITS WITHIN WHICH IT CAN LIE, FOR VARIOUS COMBINATIONS OF POSITIVE AND NEGATIVE RESULTS, WHEN FIVE 10 ml PORTIONS ARE USED :

Number of tubes giving positive reaction	MPN index	95% Confidence limits (lower limit)	95% Confidence limits (upper limit)
0	0	0	6
1	2.2	0.1	12.6
2	5.1	0.5	19.2
3	9.2	1.6	29.4
4	16.2	3.3	52.9
5	Infinity	8	Infinity

Swaroop (1951), adopted by WHO (1963 and 1971), APHA (1985).

3.4.0 Statistical Analysis:

Two-way analysis of variance (ANOVA) and Duncan's Multiple Range Test were used out to determined significant differences in all the parameters with seasons, sampling stations,stations by seasons, and months, at 0.01 (1%), and 0.05 (5%) levels of significance *using Statistical Analysis for Sciences (SAS)Computer soft ware package*

Rank correlation analysis was used in determining the relationship between parameters as they affect each other, using 0.01(1%) and 0.05 (5%) confidence limits, two-tailed test (SPSS/PC=4.0) .

CHAPTER FOUR

4.0 RESULTS:

The parameters measured had their values analysed statistically in addition to the graphic representations of the variations . Each parameter had 360 values from 15 different stations over 24 months sampling period. a total of 28 different parameters were sampled, giving 10,080 values. Analysis of results based on two-way analysis of variance (ANOVA) and Duncan's Multiple Range Test using Statistical Application for Sciences (SAS), and Rank Correlation analysis using Statistical Application for Social Sciences (SPSS/Pc+4.0), and Graphic representations using Lotus 1-2-3 release 5 for Windows soft ware packages reveal wide range of fluctuations in the bio-physico- chemical parameters accompanied with varied interaction effects among parameters.

4.1.1 Water Temperature:-

Water temperature over the 2-year period ranged from 18.0 °C to 32.5 °C, giving a range of gradual fluctuations of 14.5 °C (Fig.2). The rainy season mean (RSM) of 28.121 ° C which was higher than the dry season mean (DSM) of 225.134 °C. Two-way analysis of variance (Table 1a) indicates slightly significant temperature fluctuation between seasons

($P < 0.05$). Duncan's Multiple Range Test (Table 1b) reveals station 4 general station mean (GSM) of 35.442 °C to be the highest, while station 3 GSM was 24.229 ° C (the lowest). The open water sources (OWSs) had fairly uniform range of temperature from 26.079 °C to 27.142 °C. Correlation analysis (Table 1c) shows increase in water temperature to correspond positively with decrease in copper($P < 0.01$),conductivity and manganese

($P < 0.05$).

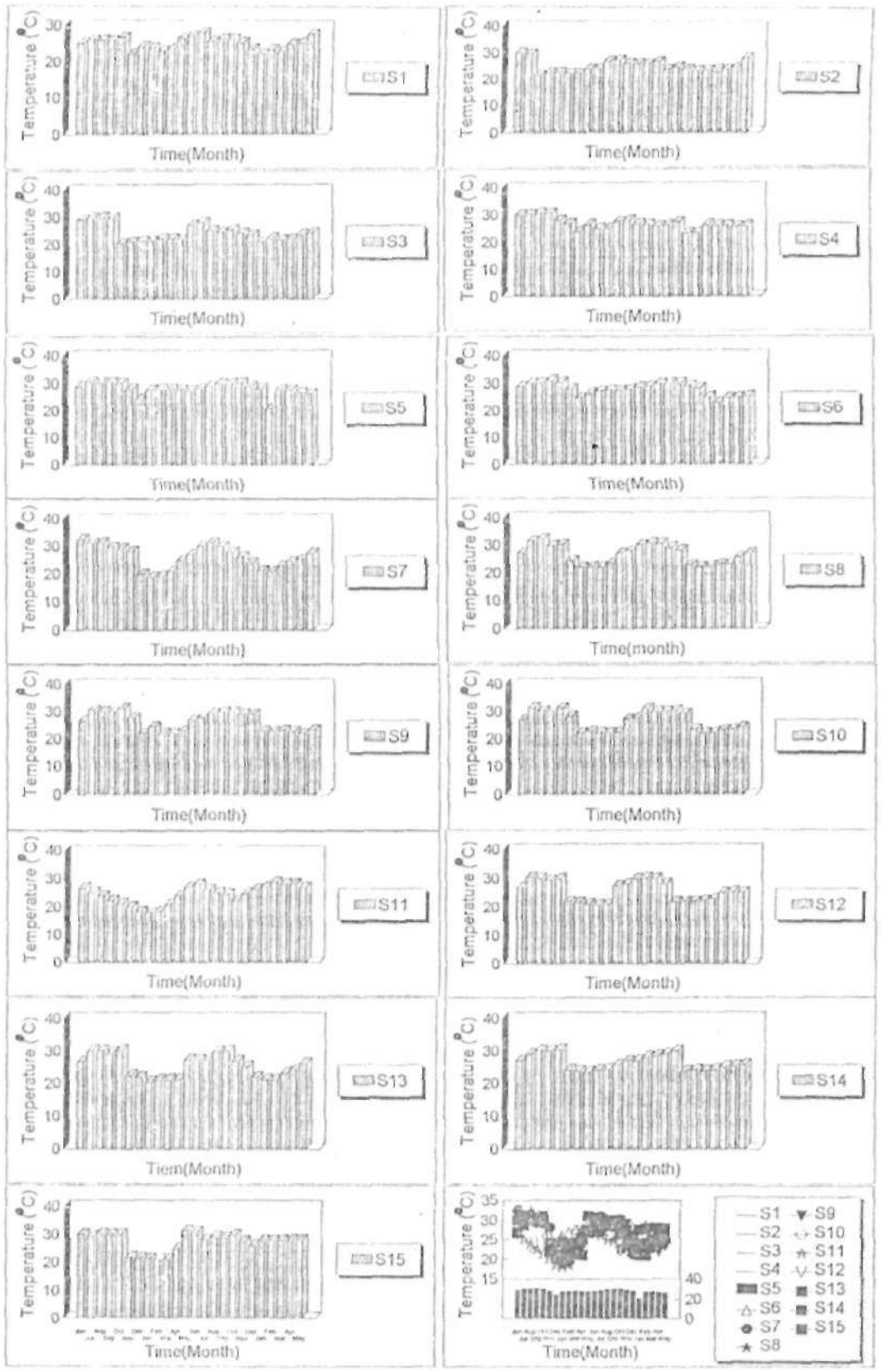


Fig.2 monthly variation in water temperature (°C).

TABLE 1a VARIATION IN WATER TEMPERATURE.

Dry Season Mean	25.134
Rainy Season Mean	28.121
First Year General Mean	26.121
Second Year General Mean	26.018

ANALYSIS OF VARIANCE (ANOVA)

Procedure

Source of Variation	DF	Sum of Squares	Mean Square	F Value	Pr > F
REP.	5	566.419583	113.283917	0.92	0.4671
YEAR	1	133.834028	135.834028	1.09	0.2975
REP(YEAR)	5	561,595806	112.319161	0.91	0.4722
SEASON	1	803.114694	803.114694	6.54	0.0111
STATIONS	14	2437.392333	174.099452	1.42	0.1440
SEASON BY STATIONS	14	2338.413222	167.029516	1.36	0.1724
SEASON BY YEAR	2	389.168028	389.168028	3.17	0.0762
YEAR BY STATIONS	14	1463.093889	104.506706	0.85	0.6137
SEASON BY YR. BY STS.	14	1884.069889	134.576421	1.10	0.3615

alpha = 0.01.

TABLE 1b DUNCAN'S MULTIPLE RANGE TEST

DUNCAN'S GROUPING	MEAN	N	STATION
A	35.442	24	4
B	28.192	24	5
B	27.796	24	6
B	27.142	24	15
B	26.454	24	8
B	26.342	24	14
B	26.296	24	10
B	26.212	24	9
B	26.079	24	7
B	25.625	24	12
B	25.200	24	13
B	25.071	24	1
B	24.975	24	2
B	24.358	24	11
B	24.229	24	3

alpha = 0.05

Table 1c. Correlation table for all the parameters.

	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17	V18	V19	V20	V21	V22	V23	V24	V25	V26	V27	V28	V29	V30	V31	V32
																									0.30	0.24	0.08	0.96
V5	p=																								p= 0	p= 0	p= .13	p= 0
V6	p= .8[illegible]	p=																							p= 01	p= 0	p= 0	p= .46
V7	p= 0	p= [illegible]	p=																						p= 0	p= 0	p= 07	p= 0
V8	p=0	p= .[illegible]2	p= .0	p=																					p= 0	p= 0	p= 0	p= 0
V9	p= .21	p= .[illegible]2	p= .012	p= .14	p=																				p= 0	p= 0	p= 0	p= .19
V10	p= 0	p= [illegible]	p= 0	p= 0	p= .46	p=																			p= 0	p= 0	p= 0	p= 0
V11	p= 0	p= [illegible]	p= 0	p= 0	p= 0	p= C	p=																		p= 0	p= 0	p= 0	p= 0
V12	p= 0	p= [illegible]	p= 0	p= 0	p= .44	p= C	p= C	p=																	p= 0	p= 0	p= 0	p= 0
V13	p= 0	p=0	p= 0	p= 0	p= .18	p= C	p= C	p= 0	p=																p= 0	p= 0	p= 0	p= 01
V14	p= .20	p= [illegible]	p= 0	p= 0	p= 0	p= C	p= C	p= 0	p= 0	p=															p= 0	p= 0	p= 33	p= 17
V15	p= .0	p=0	p= 0	p= 0	p= 0	p= [illegible]	p= C	p= 0	p= 0	p= C	p=														p= 0	p= 0	p= 29	p= 0
V16	p= 0	p=0	p= 0	p= 0	p= 0	p= C	p= C	p= 0	p= 0	p= C	p= 0	p=													p= 0	p= 0	p= 01	p= 0
V17	p=0	p=0	p= 0	p= 0	p= 0	p= C	p= C	p= 0	p= 0	p= C	p= 0	p= 0	p=												p= 0	p= 0	p= 0	p= 0
V18	p= .22	p=0	p= 0	p= 0	p= 0	p= C	p= C	p= 0	p= 0	p= C	p= C	p= 0	p= 0	p=											p= 0	p= 0	p= 53	p= 20
V19	p= 0	p=0	p= .13	p= 0	p= .81	p= 0	p= C	p= 0	p= .102	p= [illegible]9	p= .339	p= 0	p= .32	p= 56	p=										p= 02	p= 0	p= 0	p= 0
V20	p= .56	p= [illegible]2	p= 0	p= 0	p= 0	p= [illegible]1	p= C02	p= 0	p= 0	p= 03	p= C	p= 94	p= 0	p= 0	p= 93	p=									p= 0	p= 0	0.45	0.70
V21	p= 0	p= [illegible]8	p= 01	p= 0	p= 0	p= [illegible]2	p= C08	p= 0	p= .245	p= C	p= C95	p= 0	p= 0	p= 0	p= 0	p= 0	p=								p= 0	p= 0	p= 0	p= 0
V22	p= 0	p= [illegible]2	p= 60	p= 0	p= 0	p= C	p= .597	p= .234	p= 308	p= [illegible]0	p= 012	p= 08	p= 53	p= 73	p= 03	p= 0	p= C	p=							p= 22	p= 20	p= 0	p= 0
V23	p= .78	p= [illegible]9	p= 85	p= 39	p= 66	p= [illegible]8	p= .564	p= .541	p= .433	p= 06	p= 121	p= 01	p= 65	p= 03	p= 80	p= 62	p= 7[illegible]	p= 51							p= 03	p= 96	p= 31	p= 53
V24	p= 0	p= [illegible]3	p= 0	p= 21	p= 0	p= C	p= 6.45	p= 351	p= 054	p= [illegible]4	p= C02	p= 03	p= 63	p= 73	p= 43	p= 0	p= C	p= 0	p= 48	p=					p= 03	p=43	p= 0	p= 0
V25	p= 0	p= [illegible]	p= 0	p= 0	p= 0	p= C	p= C	p= 0	p= 012	p= [illegible]5	p= C58	p= 87	p= 0	p= 22	p= 04	p= 0	p= C	p= 01	p= 34	p= 0	p=				p= 0	p= 0	p= 0	p= 0
V26	p= 0	p=[illegible]0	p= 0	p= 0	p= 01	p=[illegible]8	p= C	p= 0	p= 0	p= 02	p= C	p= 0	p= 0	p= 0	p= 24	p= 0	p= C	p= 0	p= 22	p= 15	p= C	p=			p= 0	p= 0	p= 0	p= 0
V27	p= 0	p= [illegible]	p= 0	p= 0	p= 0	p= C	p= C	p= 0	p= 0	p= C	p= C03	p= 0	p= 0	p= 0	p= 0	p= 0	p= C	p= 14	p= 65	p= 56	p= C	p= C[illegible]	p=		p= 0	p= 0	p= 0	p= 0
V28	p= 0	p= [illegible]	p= 0	p= 0	p= .75	p= C	p= C	p= 0	p= 0	p= C	p= C	p= 0	p= 0	p= 0	p= 0	p= 0	p= C	p= 04	p= 35	p= 0	p= C	p= C[illegible]	p= 0	p=	p= 0	p= 0	p= 01	p= 0
V29	p= 0	p= [illegible]1	p= 0	p= 0	p= 0	p= C	p= C	p= 0	p= 0	p= C	p= C	p= 0	p= 0	p= 0	p= 02	p= 0	p= C	p= 22	p= 03	p= 03	p= C	p= C[illegible]	p= 0	p= 0	p=	p= 0	p= 0	p= 0
V30	p= 0	p= [illegible]	p= 0	p= 0	p= 0	p= C	p= C	p= 0	p= 0	p= C	p= C	p= 0	p= 0	p= 0	p= 0	p= 0	p= C	p= 20	p= 96	p= 43	p= C	p= C[illegible]	p= 0	p= 0	p= 0	p=	p= 0	p= 0
V31	p= .13	p= [illegible]	p= 02	p= 0	p= 0	p= C	p= C	p= 0	p= 0	p= [illegible]3	p= 29	p= 01	p= 0	p= 55	p= 0	p= 45	p= C[illegible]	p= 0	p= 31	p= 00	p= C	p= C[illegible]	p= 0	p= 0[illegible]	p= 0	p= 0	p=	p= 25
V32	p= 0	p= [illegible]6	p= 0	p= 0	p= .19	p= C	p= C	p= 0	p= 01	p= [illegible]7	p= C	p= 0	p= 0	p= 20	p= 0	p= .70	p= C	p= 0	p= 53	p= 00	p= C	p= C[illegible]	p= 0	p= 0	p= 0	p= 0	p= 25	p=

Interpretation of table 1c (Correlation analysis).

Suspended solids..... represented by V5
Water hardness .....represented by V6
Calcium..... represented by V7
Magnesium.....represented by V8
Sodium .....represented by V9
Iron..... represented by V10
Zinc..... represented by V11
Arsenic..... represented by V12
Lead .....represented by V13
Copper .....represented by V14
Potassium .....represented by V15
Electrical conductivity..... represented by V16
Cadmium ..... represented by V17
Manganese ..... represented by V18
Optical density ..... represented by V19
Dissolved Oxygen .....represented by V20
Chloride ion..... represented by V21
Chemical Oxygen Demand.....represented by V22
Water temperature.....represented by V23
Water pH/reactivity..... represented by V24
Phosphate-phosphorus..... represented by V25
Biochemical Oxygen Demand.....represented by V26
Nitrate-nitrogen..... represented by V27
Zooplankton..... represented by V28
Phytoplankton..... represented by V29
Eschericia coli..... represented by V30
Streptococcus faecalis..... represented by V31
Total solids .....represented by V32

4.1.2 Optical Density :

The optical density (OD) of the water sampled, ranged from $0.05x10^{-2}$ to 8.71×10^{-2} (Fig.3). The DSM was $0.8111x\ 10^{-2}$, with higher RSM of $1.2880\ x10^{-2}$. The first year general mean (FYGM) was higher than the second year general mean (SYGM) recording 1.1249×10^{-2} and 0.9744×10^{-2} respectively (Table 2a).

Analysis of variance (Table 2a) indicates highly significant difference between seasons, stations, season by year, year by stations and season by year by stations

($P< 0.01$).

Multiple range test (Table 2b) shows that the highest GSM was in station 15, being 2.017×10^{-2} and the lowest GSM was 0.562×10^{2} at station 7. Increase in optical density was accompanied by increase in the amount of suspended solids (SS), water hardness, concentration of magnesium (Mg), iron (Fe), zinc (Zn) and arsenic (As) as well as the increase in conductivity chemical oxygen demand (COD), nitrate-nitrogen (NO_3-N) concentration of the water and chloride (Cl) ion($P< 0.01$).The correlation with phosphate-phosphorus was significant ($P < 0.05$).

4.1.3.0 Suspended Solids :

The amount of suspended solids (SS) ranged from 27 mg/L to 391 mg/L, with peaks in early rainy season and late dry season (Fig.4).The seasonal means for the amount of SS (Table 3a) indicates high DSM of 102.344 mg/L, with lower RSM of 111.622 mg/L. The FYGM was 114.650 mg/L which turned out to be higher than the SYGM of 99.317 mg/L. There was significant difference between years, stations, seasons, season by stations, year by stations and season by year by stations at 1 % level of significance (Table 3a).

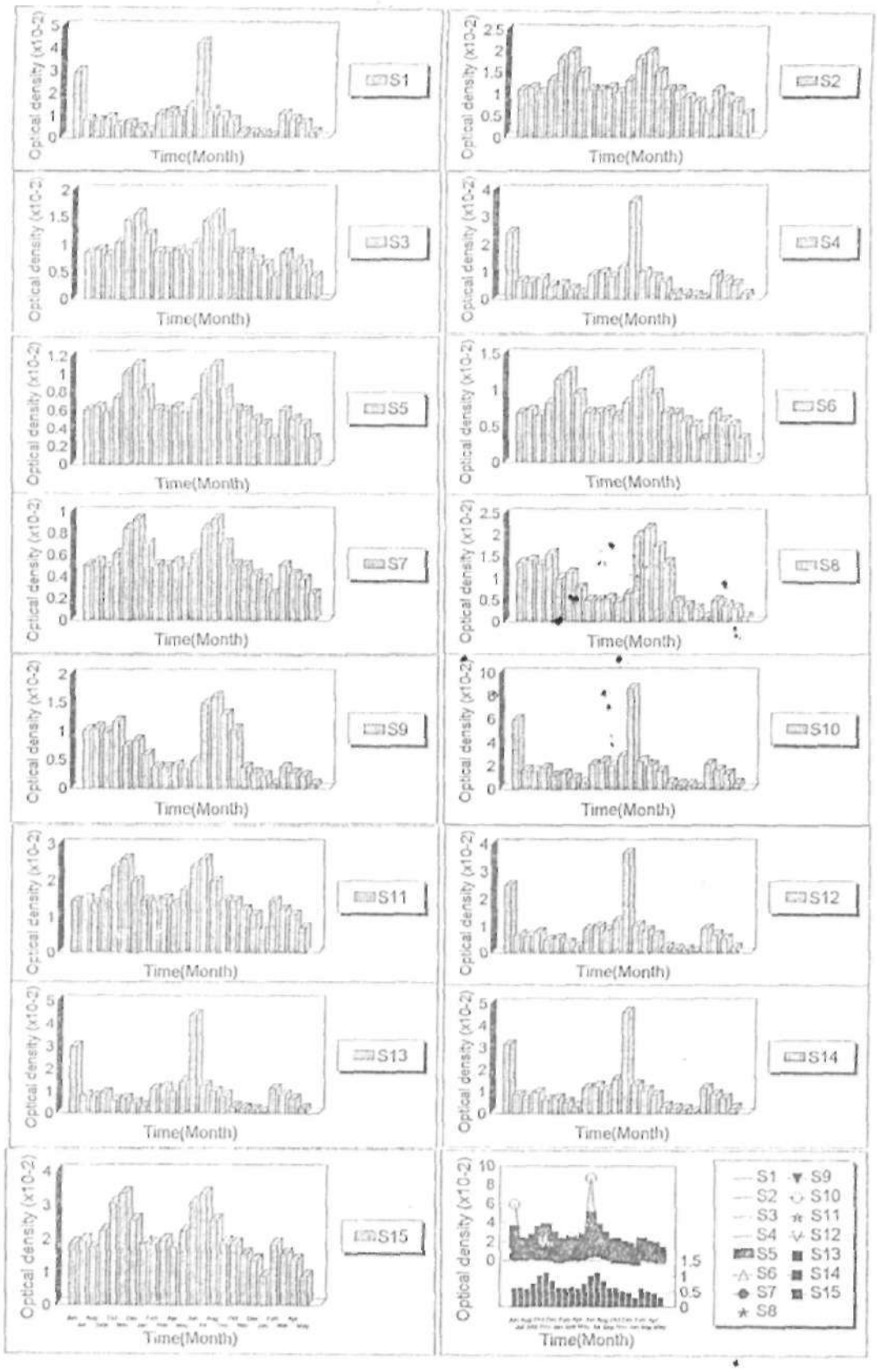


Fig.3 monthly variation in optical density of the water .

TABLE 2a VARIATION IN OPTICAL DENSITY OF THE WATER.

Dry Season Mean	0.8111
Rainy Season Mean	1.2882
First Year General Mean	1.1249
Second Year General Mean	0.9744

ANALYSIS OF VARIANCE (ANOVA)

Procedure

Source of Variation	DF	Sum of Squares	Mean Square	F Value	Pr > F
REP.	5	22.56287472	4.51257494	9.52	0.0001
YEAR	1	2.03852250	2.03852250	4.30	0.0390
REP(YEAR)	5	13.40106583	2.68021317	5.65	0.0001
SEASON	1	20.49192250	20.49192250	43.22	0.0001
STATIONS	14	64.26419889	4.80458563	10.13	0.0001
SEASON BY STATIONS	14	8.24124000	0.58866000	1.24	0.2442
SEASON BY YEAR	2	4.15810028	4.15810028	8.97	0.0033
YEAR BY STATIONS	14	0.5233233	0.03733024	0.08	1.0000
SEASON BY YR. BY STS.	14	0.71822889	0.05130206	0.11	1.0000

alpha = 0.01.

TABLE 2b DUNCAN'S MULTIPLE RANGE TEST

DUNCAN'S GROUPING	MEAN	N	STATION
A	2.017	24	15
B A	1.906	24	10
B C	1.578	24	11
D C	1.197	24	2
D E	1.025	24	14
D E	0.966	24	13
D E	0.954	24	1
D E	0.943	24	3
D E	0.882	24	8
D E	0.818	24	12
D E	0.791	24	4
D E	0.758	24	6
E	0.668	24	5
E	0.659	24	9
F	0.562	24	7

alpha = 0.05

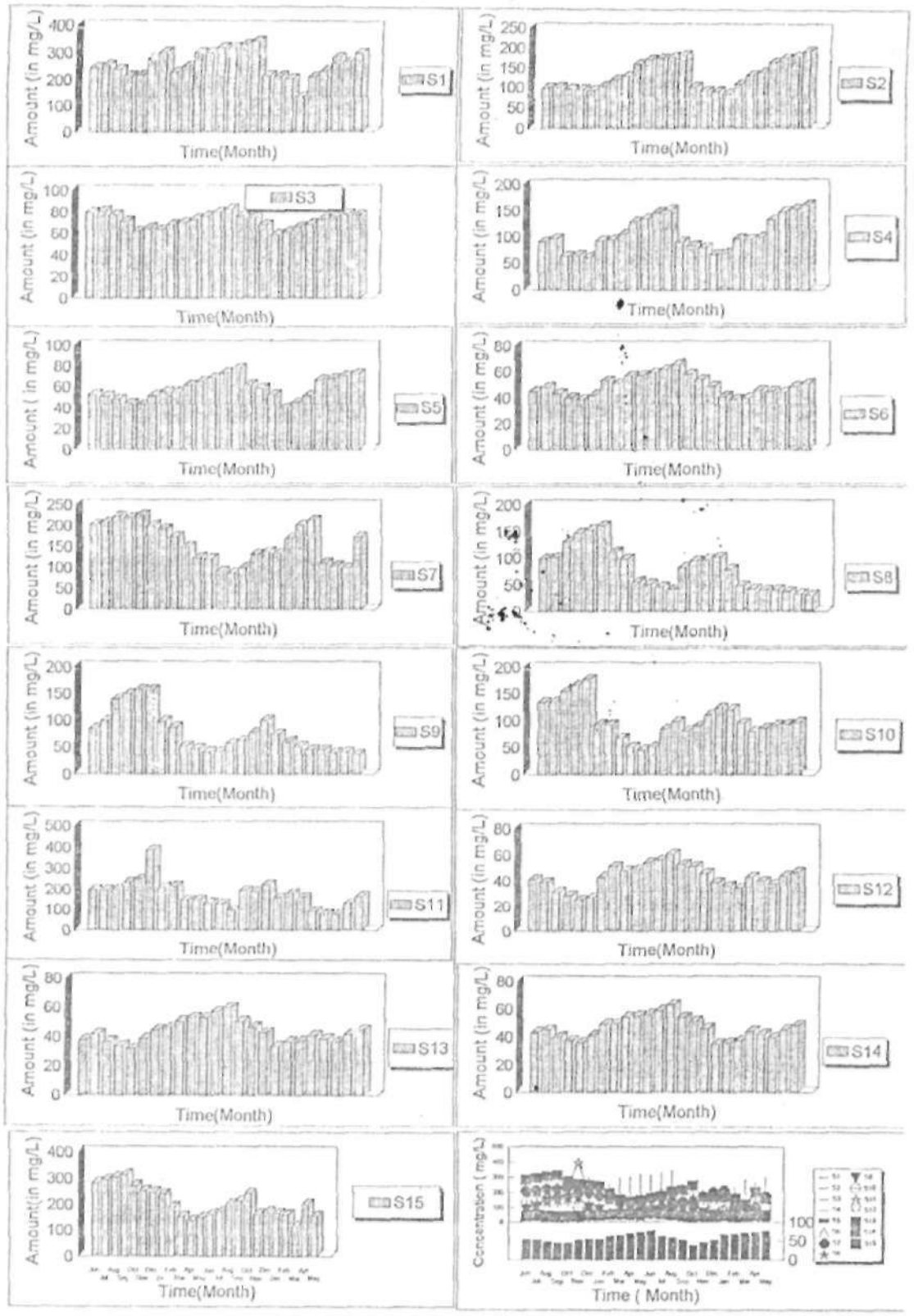


Fig.4 Monthly variation in concentration of suspended solids in water (mg/L)

TABLE 3a VARIATION IN SUSPENDED SOLIDS.

Dry Season Mean	102.344
Rainy Season Mean	111.622
First Year General Mean	114.650
Second Year General Mean	99.317

ANALYSIS OF VARIANCE (ANOVA)

Procedure

Source of Variation	DF	Sum of Squares	Mean Square	F Value	Pr > F
REP.	5	1131.333	226.267	0.22	0.9544
YEAR	1	21160.000	21160.00	20.44	0.0001
REP(YEAR)	5	547.233	109.447	0.11	0.9909
SEASON	1	7746.944	7746.944	8.49	0.0066
STATIONS	14	1466465.067	104747.505	101.21	0.0001
SEASON BY STATIONS	14	42204.889	3014.635	2.91	0.0004
SEASON BY YEAR	2	547.600	547.600	0.53	0.4676
YEAR BY STATIONS	14	48113.333	3436.667	3.32	0.0001
SEASON BY YR. BY STS.	14	34264.067	2447.433	2.36	0.0040

alpha = 0.01.

TABLE 3b DUNCAN'S MULTIPLE RANGE TEST

DUNCAN'S GROUPING	MEAN	N	STATION
A	258.125	24	1
B	206.333	24	15
C	175.958	24	11
C	157.958	24	7
D	131.208	24	2
E	104.833	24	4
E	101.125	24	10
F	80.375	24	8
F	76.875	24	9
G F	71.833	24	3
G H	59.000	24	5
H	49.083	24	6
H	46.042	24	14
H	43.333	24	13
H	42.667	24	12

alpha = 0.05

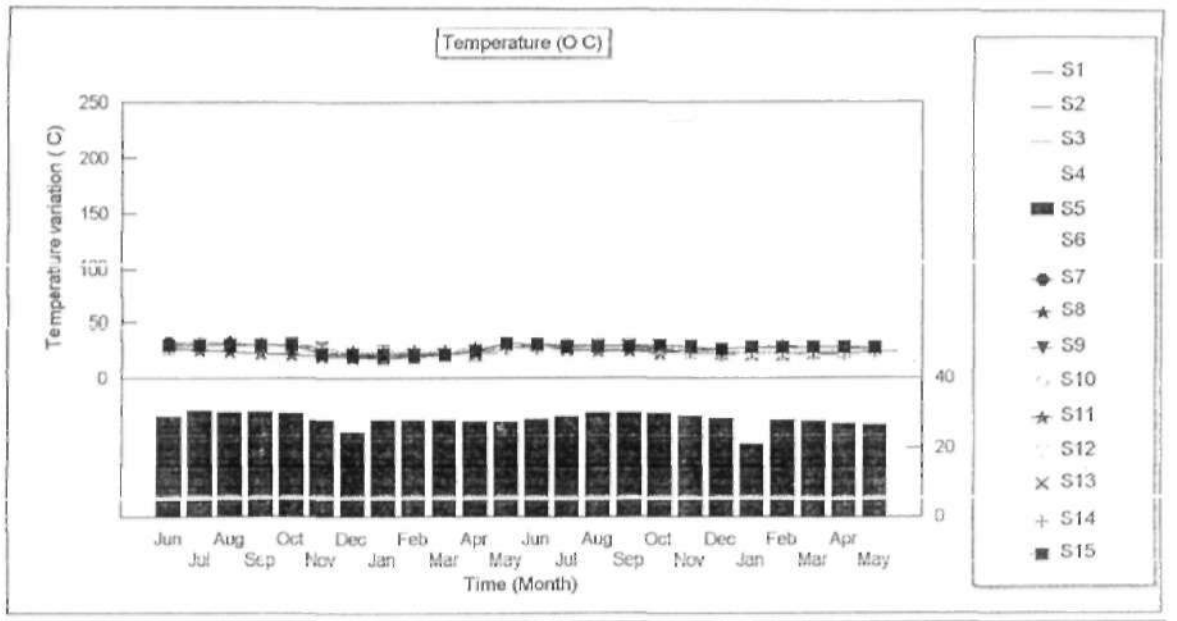
Multiple range test (Table 3b) indicates the GSM for station 1 to be the highest (258.125 mg/L) as compared to that of station 12 (42.667 mg/L) being the lowest. The interaction among variables using correlation analysis (Table 1c) reveals positive correlation between the amount of SS and Ca, Mg, Fe, Zn, As, Pb, conductivity, Cd, optical density (OD), Cl, COD, PO_4-P, BOD, and NO_3-N ($P < 0.01$).

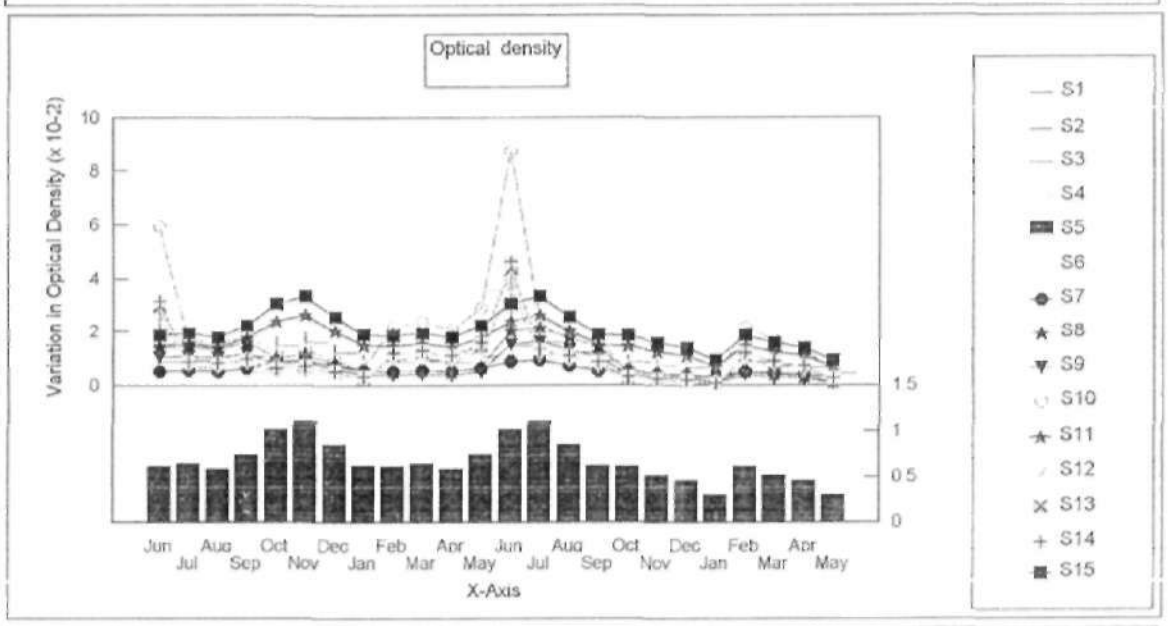
Figure 4b shows the range of variations in water temperature, Optical density and amounts of suspended solids.

4.1.3.1 Total Solids :

The amount of total solids (TS) was higher during the rainy season with RSM of 398.59 mg/L as compared to that of the dry season with DSM of 376.89 mg/L. The FYGM was 412.02 mg/L which turned out to be higher than the SYGM of 363.46 mg/L.

Analysis of variance (Table 4a) shows that the variation in TS was highly significant with year, stations, season by stations, year by stations and season by year by stations ($P< 0.01$). Station 1 had the highest GSM of 955.75 mg/L. This was followed in declining order by the OWSs (Stations 15, 11, and 7). Station 13 recorded the lowest GSM of 155.67 mg/L. There was highly significant positive correlation ($P< 0.01$) between the amount of TS and SS, Ca, Mg, Fe, Zn, As, Pb, conductivity, Cd, Cl, OD, COD, PO_4-P, BOD, NO_3-N, zooplankton and phytoplankton population, as well as the *Eschericia coli* index. The correlation was negative with K and pH ($P< 0.01$).





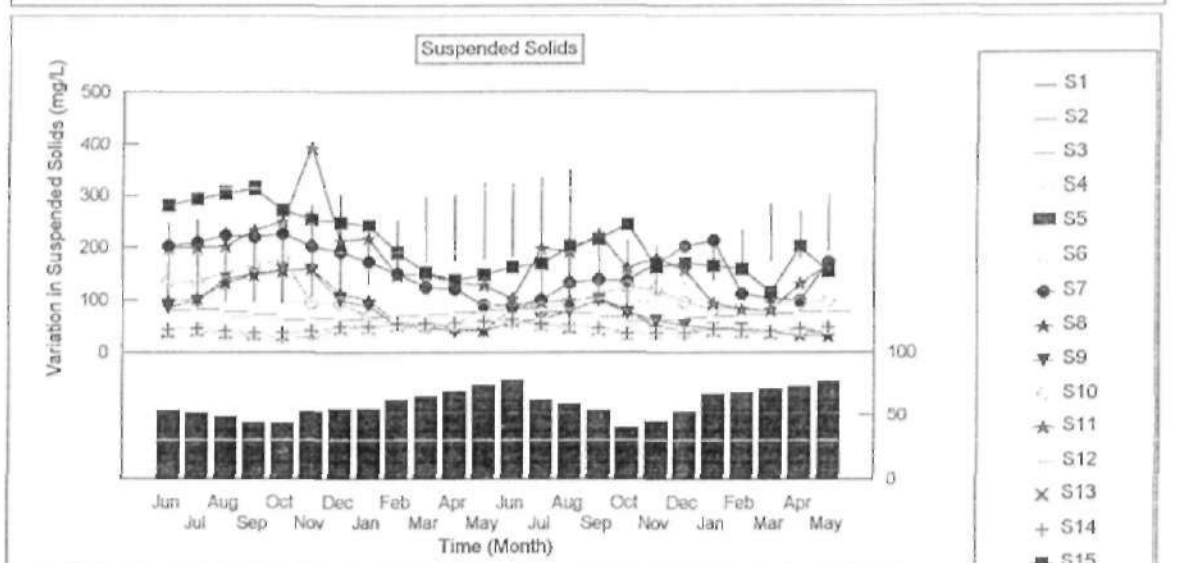


Fig. 4b Monthly Variations in Temperature, Optical Density and Amount of Suspended Solids.

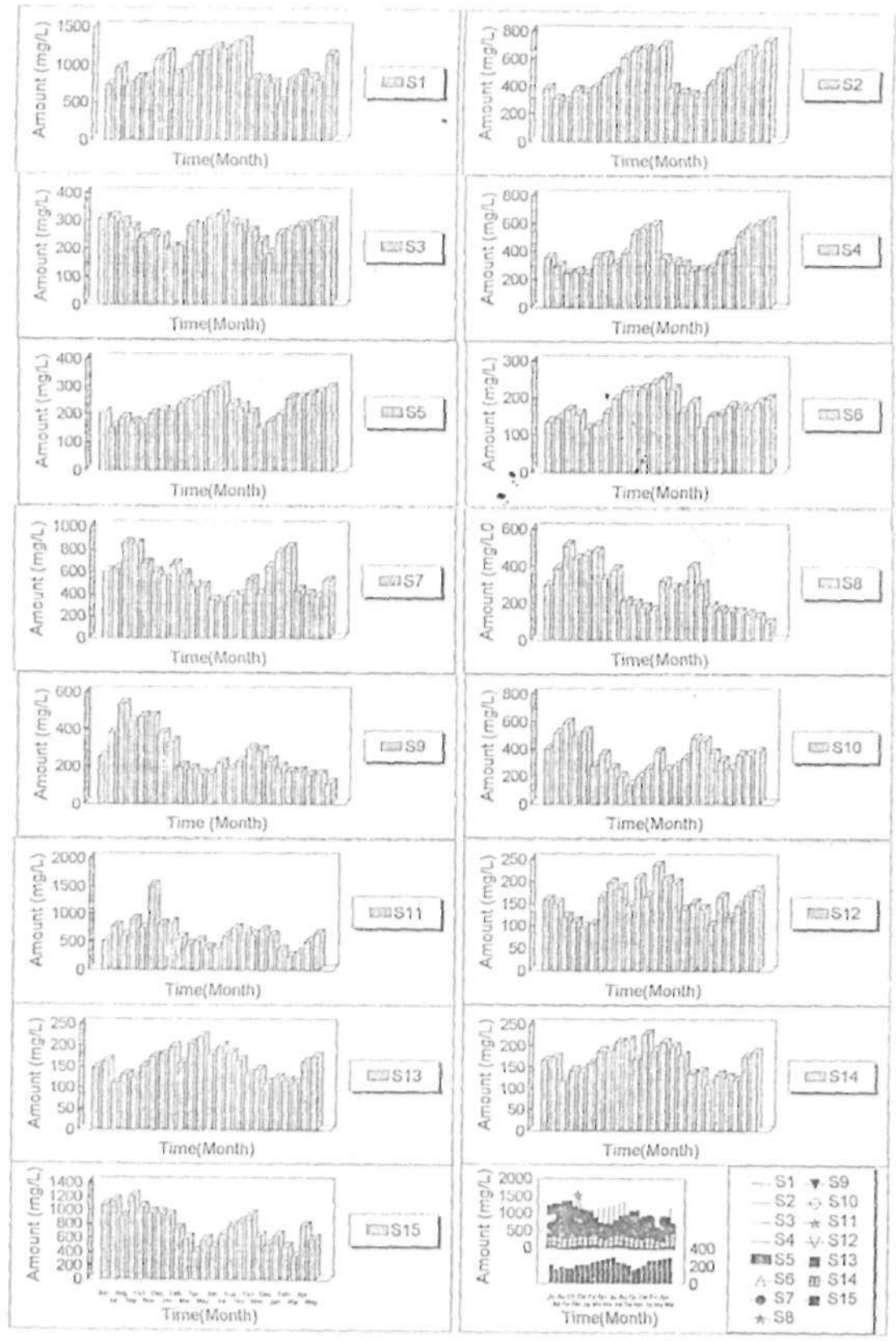


Fig.5. monthly variation in amount of total solids (mg/L).

TABLE 4a VARIATION IN TOTAL SOLIDS.

Dry Season Mean	376.89
Rainy Season Mean	398.59
First Year General Mean	412.02
Second Year General Mean	363.46

ANALYSIS OF VARIANCE (ANOVA)

Procedure

Source of Variation	DF	Sum of Squares	Mean Square	F Value	Pr > F
REP.	5	37173.92	7434.78	0.50	0.7798
YEAR	1	212236.34	212236.34	14.14	0.0002
REP(YEAR)	5	7196.35	1539.27	0.10	0.9916
SEASON	1	42401.80	42407.80	2.82	0.0939
STATIONS	14	19763020.35	1411644.31	94.02	0.0001
SEASON BY STATIONS	14	1523862.24	37418.73	2.49	0.0023
SEASON BY YEAR	2	33466.23	33466.23	2.23	0.1365
YEAR BY STATIONS	14	626886.04	44777.57	2.98	0.0003
SEASON BY YR. BY STS.	14	703739.48	50267.11	3.35	0.0001

alpha = 0.01.

TABLE 4b DUNCAN'S MULTIPLE RANGE TEST

DUNCAN'S GROUPING	MEAN	N	STATION
A	955.75	24	1
B	756.00	24	15
C	622.08	24	11
D C	554.87	24	7
D	497.54	24	2
E	387.75	24	4
E	350.46	24	10
F	277.08	24	8
F	269.17	24	3
F	266.17	24	9
G F	225.12	24	5
G	225.12	24	6
G	177.04	24	14
G	156.00	24	12
G	155.67	24	13

alpha = 0.05

4.1.4 Water Hardness:

Water hardness was recorded to be within the range of 52 mg/L to 289 mg/L, with stations 1, 2, 3, 4, 5 and 6 being relatively softer as compared to the other stations (Fig.6). Hardness was higher during the rainy season with RSM of 151.106 mg/L $CaCO_3$. The DSM was 132.306 mg/L. $CaCO_3$. The FYGM and SYGM were 144.678 mg/L. $CaCO_3$ and the SYGM was 138.733 mg/L.$CaCO_3$. respectively.

Water hardness did not show much variation as compared to the sources of variations (Table 5a). There were significant differences with seasons and stations ($P < 0.01$). Station 11 recorded the highest GSM (189.42 mg/L. $CaCO_3$.), while station 5 was the lowest with GSM of 81.87 mg/L $CaCO_3$. (Table 5b). There was highly significant positive correlation ($P< 0.01$) between harness and Ca, Mg, Fe, Zn, As, Pb, electrical conductivity, Cd, OD, Cl, COD, PO_4-P, BOD and NO_3-N (Table 1c).

4.1.5 Water pH:

Water reactivity ranged from weakly acidic (6.0) to weakly alkaline (8.3). Fluctuations in pH were fairly minimal within the range of 2.3 (Fig.7). There were little difference between the seasons. The RSM was 7.0611 and the DSM was 7.0761. The FYGM was 7.0878 and the SYGM 7.0490. Analysis of variance (Table 6a) reveals highly significant difference in pH values between stations, season by stations, and year by stations ($P < 0.01$). Station 6 recorded the highest GSM of 7.7875 and station 1 recorded the lowest GSM of 6.2458 within the range of weak acidity . The average pH value was 7.0684.

Correlation analysis (Table 1c) shows that the reactivity of the water had significant positive correlation with Fe, K, PO_4-P and Ca, with. negative correlation

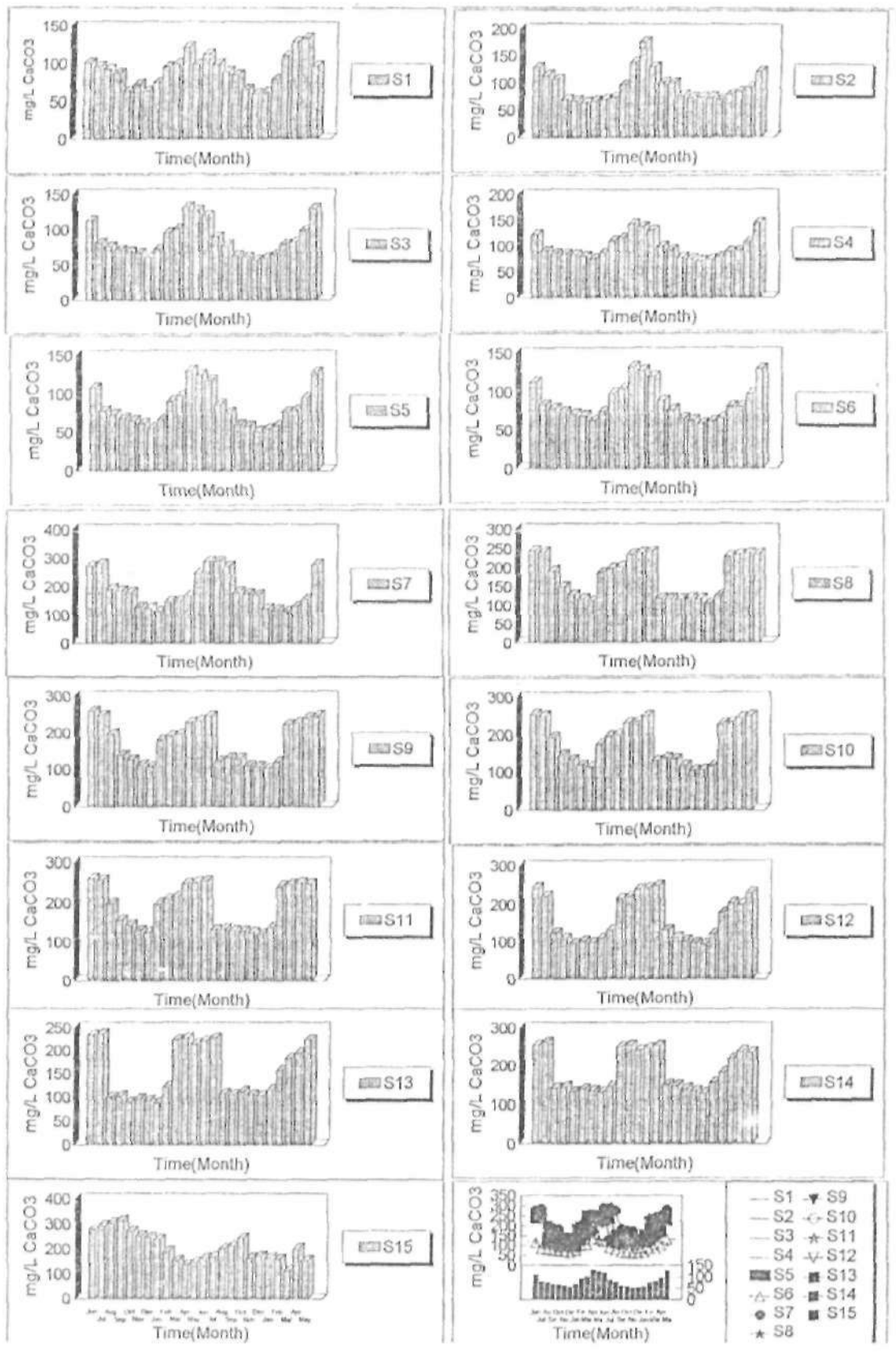


Fig.6 Monthly variation in hardness of water (mg/L) $CaCO_3$

TABLE 5a VARIATION IN WATER HARDNESS.

Dry Season Mean	132.306
Rainy Season Mean	151.106
First Year General Mean	144.678
Second Year General Mean	138.733

ANALYSIS OF VARIANCE (ANOVA)

Procedure

Source of Variation	DF	Sum of Squares	Mean Square	F Value	Pr > F
REP.	5	5833.2889	116.6578	0.52	0.7619
YEAR	1	3180.2778	3180.2778	1.41	0.2353
REP(YEAR)	5	5046.4222	1009.2849	0.45	0.8139
SEASON	1	31809.6000	31809.600	14.15	0.0002
STATIONS	14	691518.7056	49394.19335	21.97	0.0001
SEASON BY STATIONS	14	41164.1500	3368.8679	1.50	0.1104
SEASON BY YEAR	2	376.1778	376.1778	0.17	0.6828
YEAR BY STATIONS	14	7931.3056	566.5218	0.25	0.9975
SEASON BY YR. BY STS.	14	10599.5722	757.1123	0.34	0.9887

alpha = 0.01.

TABLE 5b DUNCAN'S MULTIPLE RANGE TEST

DUNCAN'S GROUPING	MEAN	N	STATION
A	189.42	24	11
A	189.33	24	7
A	185.96	24	14
B A	180.12	24	15
B A	179.54	24	10
B A	176.33	24	8
B A	176.25	24	9
B A	161.33	24	12
B	153.75	24	13
C	97.42	24	4
C	93.04	24	2
C	91.25	24	1
C	86.42	24	6
C	85.54	24	3
C	81.87	24	5

alpha = 0.05

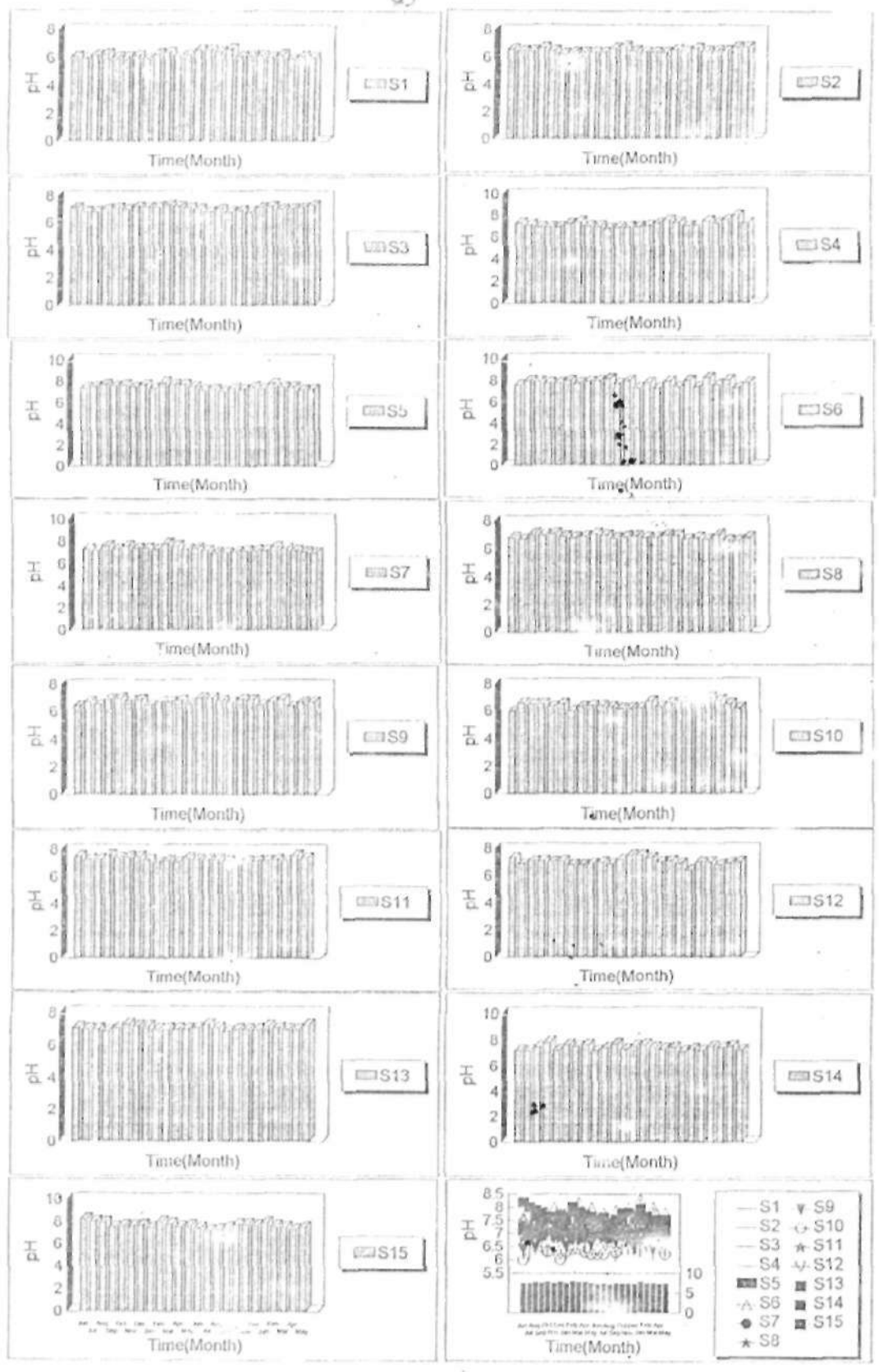


Fig.7 monthly variation in reactivity of the water (pH).

TABLE 6a VARIATION IN pH OF THE WATER.

Dry Season Mean	7.0761
Rainy Season Mean	7.0611
First Year General Mean	7.0878
Second Year General Mean	7.0494

ANALYSIS OF VARIANCE (ANOVA)

Procedure

Source of Variation	DF	Sum of Squares	Mean Square	F Value	Pr > F
REP.	5	0.08980556	0.01796114	0.55	0.7401
YEAR	1	0.13225000	0.13225000	4.03	0.0456
REP(YEAR)	5	0.25691667	0.05138333	1.57	0.1694
SEASON	1	0.02025000	0.02025000	0.62	0.4327
STATIONS	14	66.4782222	4.74844444	144.78	0.0001
SEASON BY STATIONS	14	1.33766667	0.09554762	2.91	0.0004
SEASON BY YEAR	2	0.00136111	0.00136111	0.04	0.8387
YEAR BY STATIONS	14	2.07066667	0.147904476	4.51	0.0001
SEASON BY YR. BY STS.	14	0.97655556	0.06975397	2.13	0.0107

alpha = 0.01.

TABLE 6b DUNCAN'S MULTIPLE RANGE TEST

DUNCAN'S GROUPING	MEAN	N	STATION
A	7.7875	24	6
B	7.6417	24	15
C	7.4875	24	5
D C	7.4000	24	14
D	7.3083	24	11
D	7.3042	24	7
E	7.1458	24	4
F E	7.0750	24	13
F E	7.0417	24	3
F	7.0208	24	12
G	6.8667	24	8
H	6.7375	24	9
I	6.5333	24	2
I	6.4333	24	10
J	6.2458	24	1

alpha = 0.05

between pH and Na, SS, Cl and COD (P< 0.01); electrical conductivity (P<0.05). Figure 7b shows the range of variations in total solids, water hardness and pH.

4.1.6 Electrical conductivity :

Specific conductivity of the water ranged from 8 to 197 micro ohms/cm^2, with increased conductivity in the late dry season (Fig.8).The RSM of 44.489 micro ohms/cm^2 was lower than the DSM (60.144 micro ohms/cm^2) . The FYGM (58.894) was higher than the SYGM (45.739).

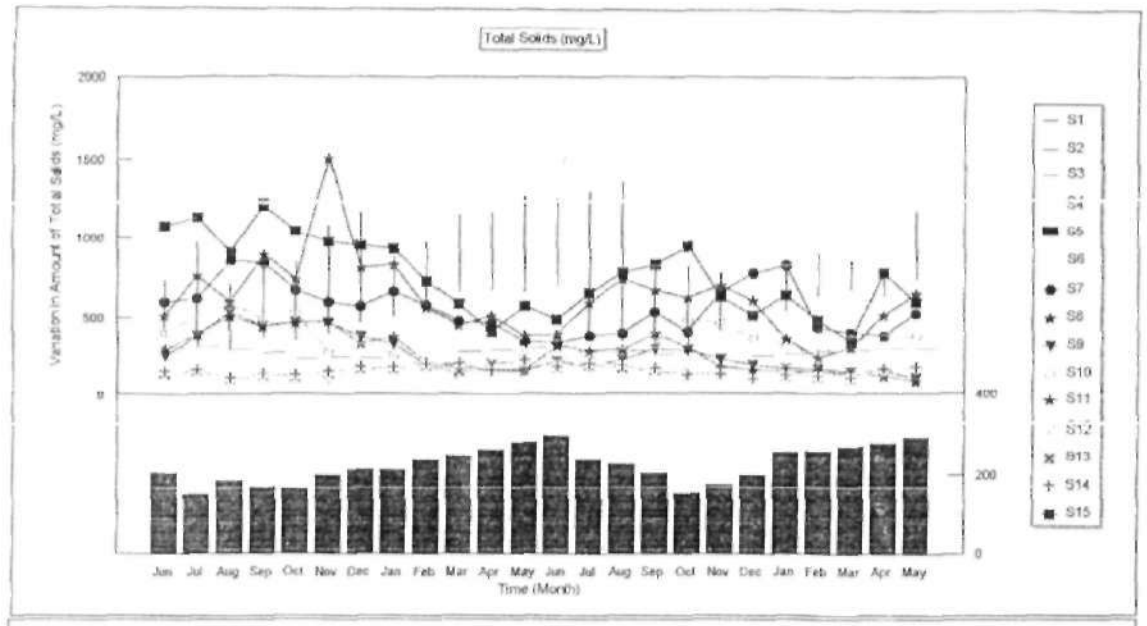
Table 7a (analysis of variance) indicates highly significant variation in conductivity of the sampled water between years, seasons and station by seasons (P < 0.01).

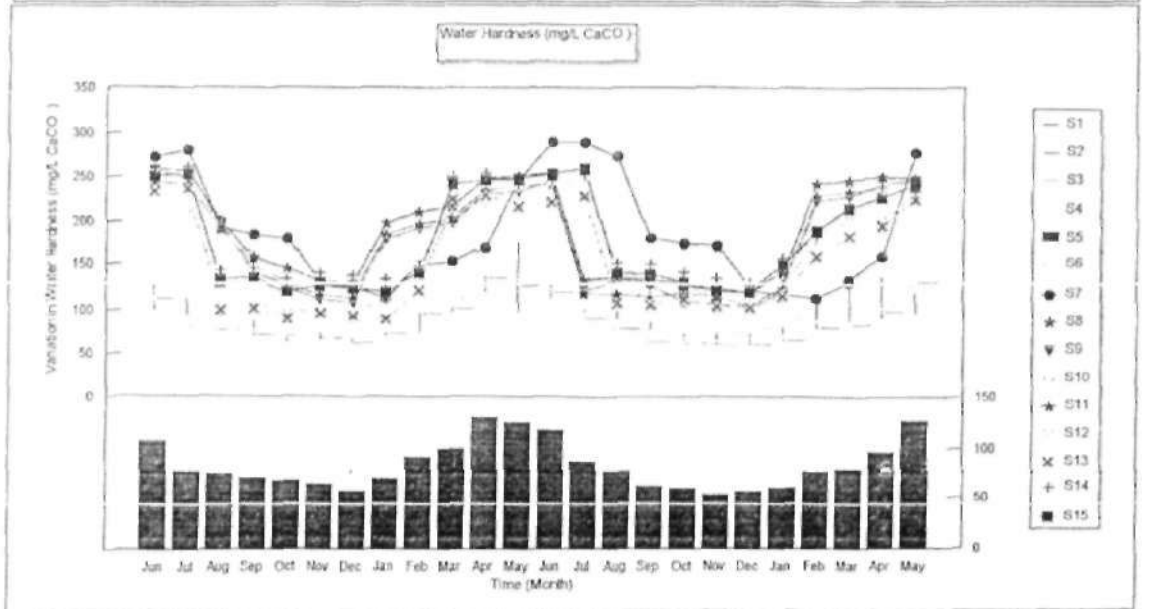
Multiple range test (Table 7b) shows that station 9 had the highest GSM of 90.417 and station 6 had the lowest of 21.750.There was highly significant increase in most of the chemical parameters with increase in SS, hardness, Ca, Mg, Na, Fe, Zn, As, Pb, Cu, K, Cd, Mn, OD, Cl, BOD, NO_3-N with increase in electrical conductivity (P < 0.01).

4.1.7.0 Nitrate-Nitrogen:

General station mean (GSM) for the nitrate form of nitrogen in water sampled (Table 8a) indicates that station 10 had the highest average of 5.904 mg/L and station 13 contained the lowest mean of 1.367 mg/L. The RSM was 3.321 mg/L, which was higher than the DSM of 2.8083 mg/L. The FYGM (3.1822 mg/L) was higher compared to the SYGM of 2.9472 mg/L .

Analysis of variance (Table 8b) shows highly significant variation (P < 0.01) in nitrate-nitrogen content with year, seasons, stations, season by stations and year by stations. Correlation analysis (Table 1c) reveals positive correlation (P < 0.01)





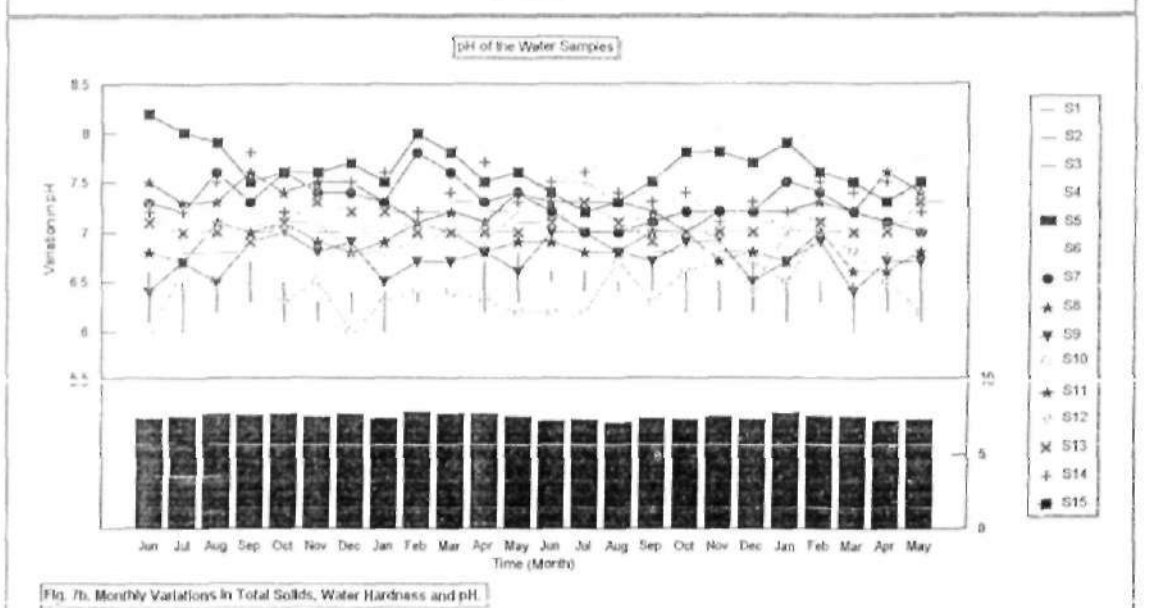


Fig. 7b. Monthly Variations in Total Solids, Water Hardness and pH.

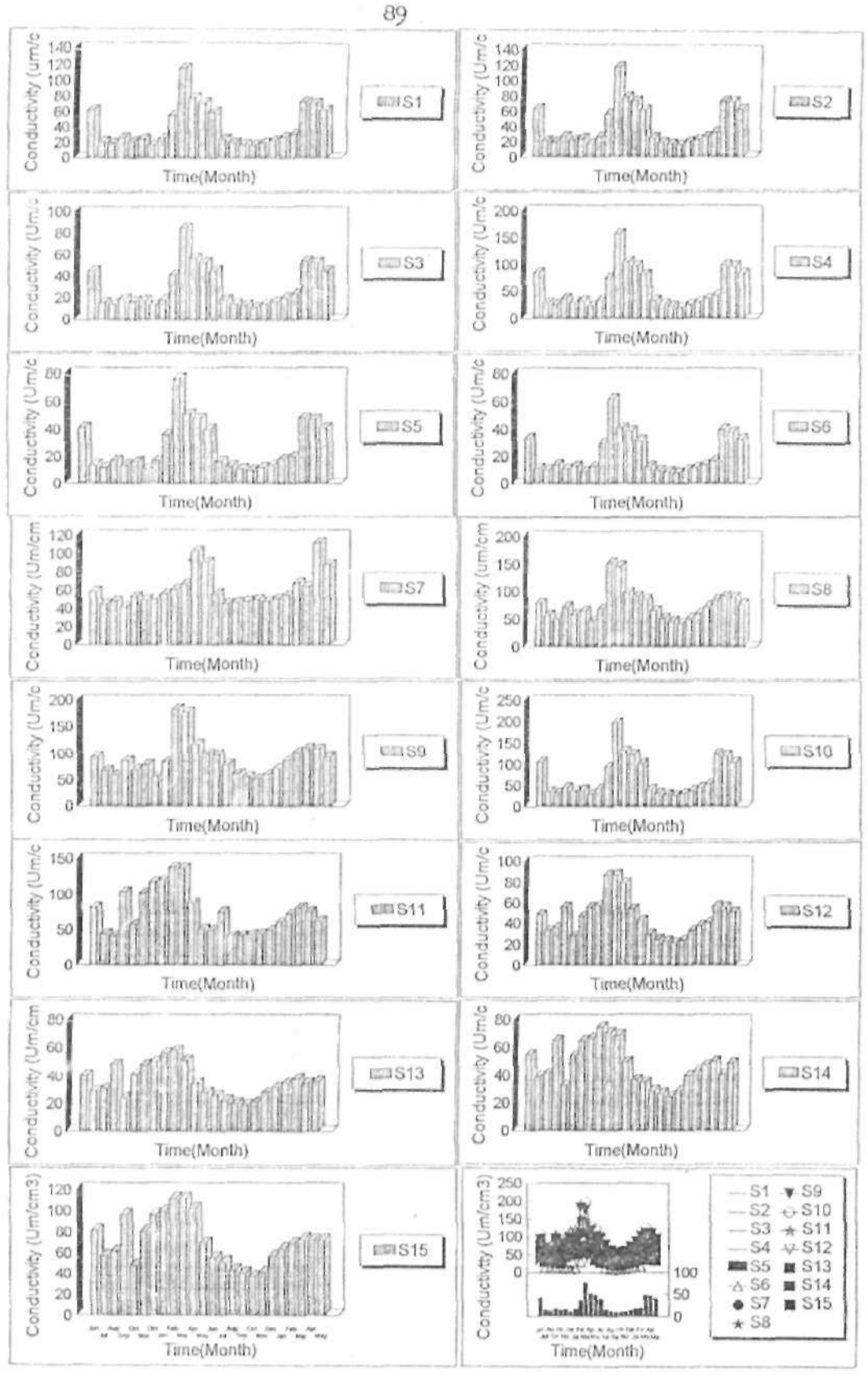


Fig.8 monthly variation in electrical conductivity of the water (UΩ/cm3) .

TABLE 7a VARIATION IN ELECTRICAL CONDUCTIVITY OF THE WATER

Dry Season Mean	60.144
Rainy Season Mean	44.489
First Year General Mean	58.894
Second Year General Mean	45.739

ANALYSIS OF VARIANCE (ANOVA)

Procedure

Source of Variation	DF	Sum of Squares	Mean Square	F Value	Pr > F
REP.	5	17676.0333	3535.2067	6.41	0.0001
YEAR	1	15576.1776	15576.1778	28.25	0.0001
REP(YEAR)	5	7575.4889	1515.0978	2.75	0.0192
SEASON	1	22058.6778	2058.6778	40.00	0.0001
STATIONS	14	139484.4833	9963.1774	18.04	0.0001
SEASON BY STATIONS	14	4763.0722	340.2194	0.62	0.8506
SEASON BY YEAR	2	3534.4000	3534.4000	6.41	0.0119
YEAR BY STATIONS	14	6723.7389	480.2671	0.87	0.5911
SEASON BY YR. BY STS.	14	2149.6833	153.5488	0.28	0.9957

alpha = 0.01.

TABLE 7b DUNCAN'S MULTIPLE RANGE TEST

DUNCAN'S GROUPING	MEAN	N	STATION
A	90.417	24	9
B	75.333	24	8
B	73.833	24	11
B	70.250	24	15
C B D	69.167	24	10
C B D	60.750	24	7
C E D	55.167	24	4
F E D	47.333	24	14
F E C	46.375	24	12
F E G	41.458	24	2
F E G	40.708	24	1
F H G	35.458	24	13
H G	29.958	24	3
H G	26.992	24	5
H	21.750	24	6

alpha = 0.05

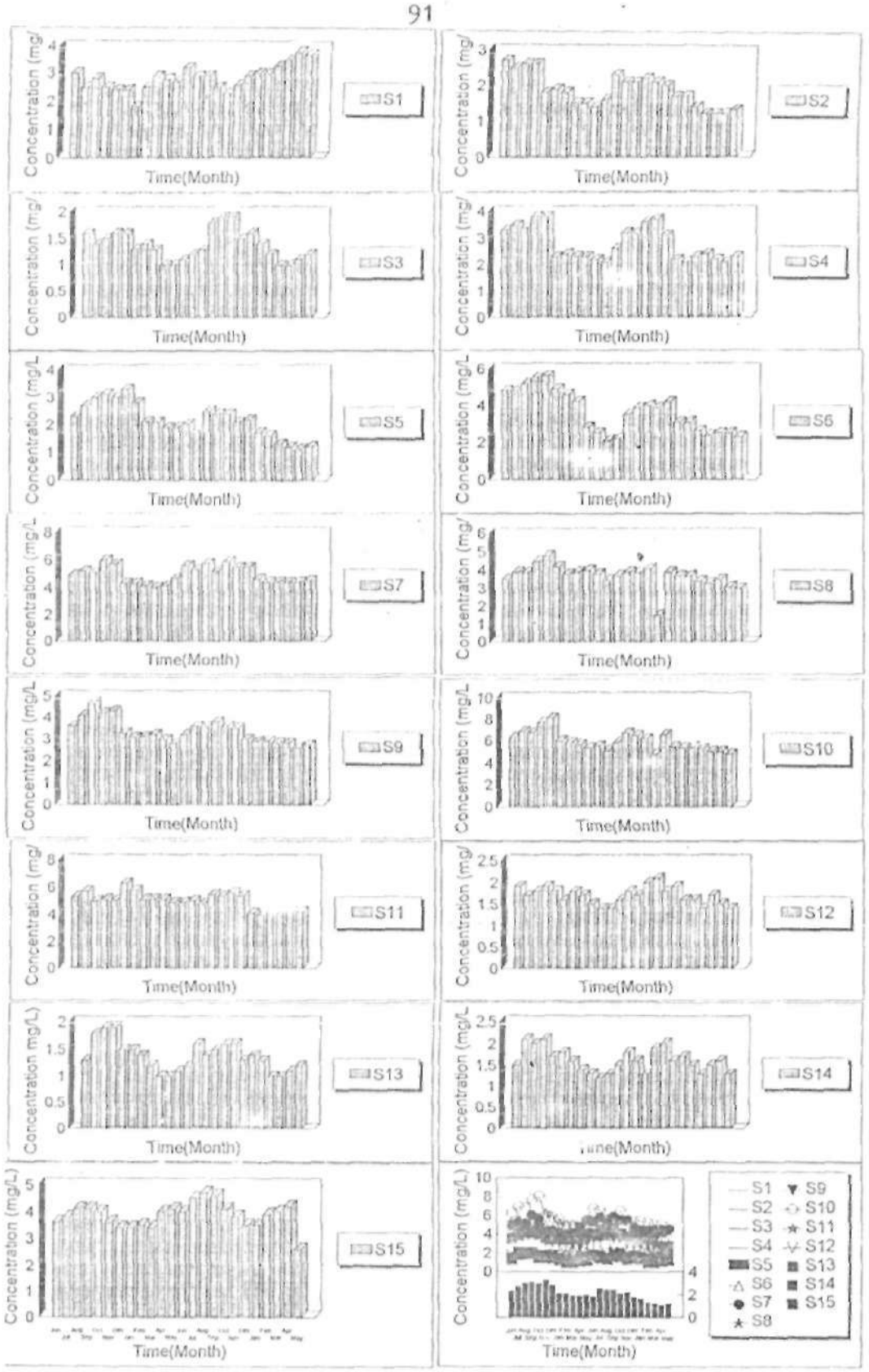


Fig 9 monthly variation in concentration of nitrate-nitrogen in water (mg/L).

TABLE 8a VARIATION IN NITRATE-NITROGEN CONTENT OF THE WATER.

Dry Season Mean	2.8083
Rainy Season Mean	3.3211
First Year General Mean	3.1822
Second Year General Mean	2.9472

ANALYSIS OF VARIANCE (ANOVA)

Procedure

Source of Variation	DF	Sum of Squares	Mean Square	F Value	Pr > F
REP.	5	1.0458056	0.2091611	0.99	0.4263
YEAR	1	4.9702500	4.9702500	23.44	0.0001
REP(YEAR)	5	0.5155833	0.1031167	0.49	0.7864
SEASON	1	23.6646944	23.6646944	111.60	0.0001
STATIONS	14	691.7548889	49.4110635	233.97	0.0001
SEASON BY STATIONS	14	12.4482222	0.8891587	4.19	0.0001
SEASON BY YEAR	2	0.4913611	0.4913611	2.32	0.1290
YEAR BY STATIONS	14	12.9726667	0.9266190	4.37	0.0001
SEASON BY YR. BY STS.	14	3.1215556	0.2229683	1.05	0.4023

alpha = 0.01.

TABLE 8b DUNCAN'S MULTIPLE RANGE TEST

DUNCAN'S GROUPING	MEAN	N	STATION
A	5.904	24	10
B	4.996	24	11
B	4.913	24	7
C	3.850	24	15
C	3.688	24	8
C	3.633	24	6
D	3.350	24	9
F	2.829	24	1
E	2.767	24	4
F	2.154	24	5
G	1.850	24	2
G	1.692	24	12
H G	1.608	24	14
H	1.371	24	3
H	1.364	24	13

alpha = 0.05

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between NO_3-N content and SS, hardness, all the alkaline earth metals, Fe, Zn, As, Pb, Cu, Cd, Mn electrical conductivity, , OD, Cl, PO_4-P, BOD.

4.1.7.1 Phosphate-phosphorus :

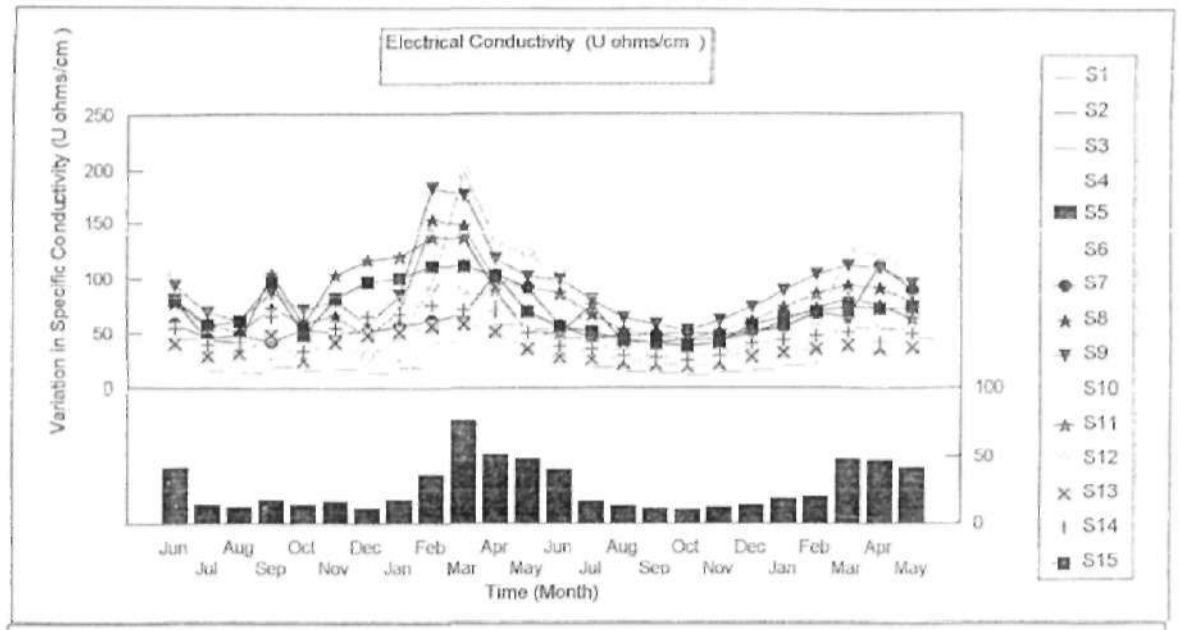
The RSM concentration of PO_4-P in water sampled was 74.717 mg/L, which was much higher than the DSM of 49.50 mg/L. The FYGM was 66.150 mg/L and the SYGM was 58.067 mg/L. Analysis of variance (Table 9a) indicates highly significant variations in PO_4-P with seasons, stations, season by station, year by stations, and between season by year by stations ($P < 0.01$).

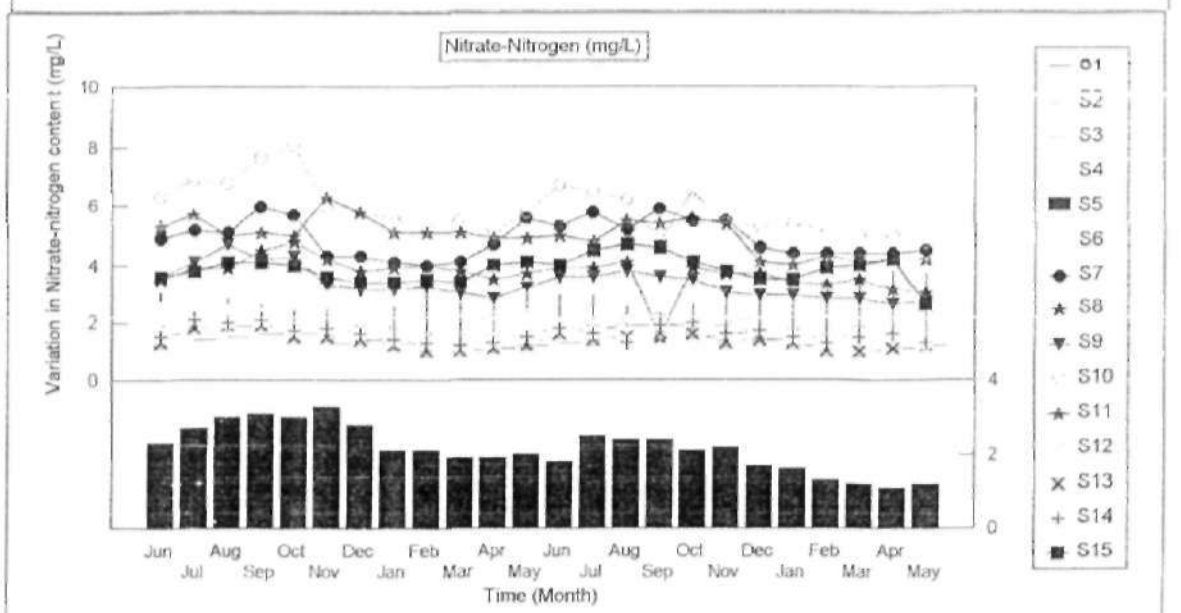
Duncan's Multiple Range Test (Table 9b) ranked station 7 to have the highest GSM of 153.625 mg/L, while station 3 had the lowest of 29.958 mg/L. Correlation analysis (Table 1c) reveals highly significant positive correlation between PO_4-P and SS, hardness, Ca, Mg, Fe, Zn, Cd, Cl, pH, BOD, and NO_3-N ($P < 0.01$). The correlation with OD, was significant at ($P < 0.05$). Significant negative correlation with COD was observed at 5% level of significant ($P < 0.05$).

Figure 10b. shows the range of variations in Specific conductivity, NO_3-N and PO_4-P.

4.1.8.0 Biochemical Oxygen Demand :

The BOD of the water sampled varied greatly with the OWSs (stations 7, 11 and 14) being having the highest general station means (GSMs).The lowest was station 12 (Table 10b). There was no much difference between the RSM and DSM, being 3.5545 mg/L and 3.6172 mg/L respectively. Analysis of variance (Table 10a) indicates highly significant differences with year, stations, season by stations, season by year and season by year by stations ($P < 0.01$).





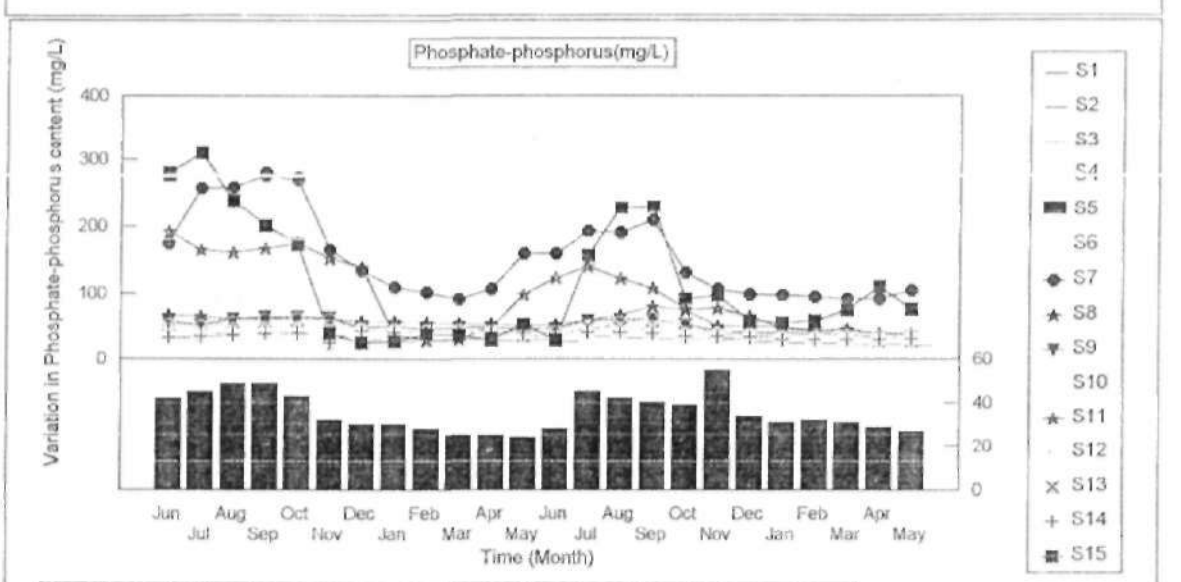


Fig. 10b Monthly Variations in Conductivity, Nitrate-nitrogen and Phosphate-phosphorus

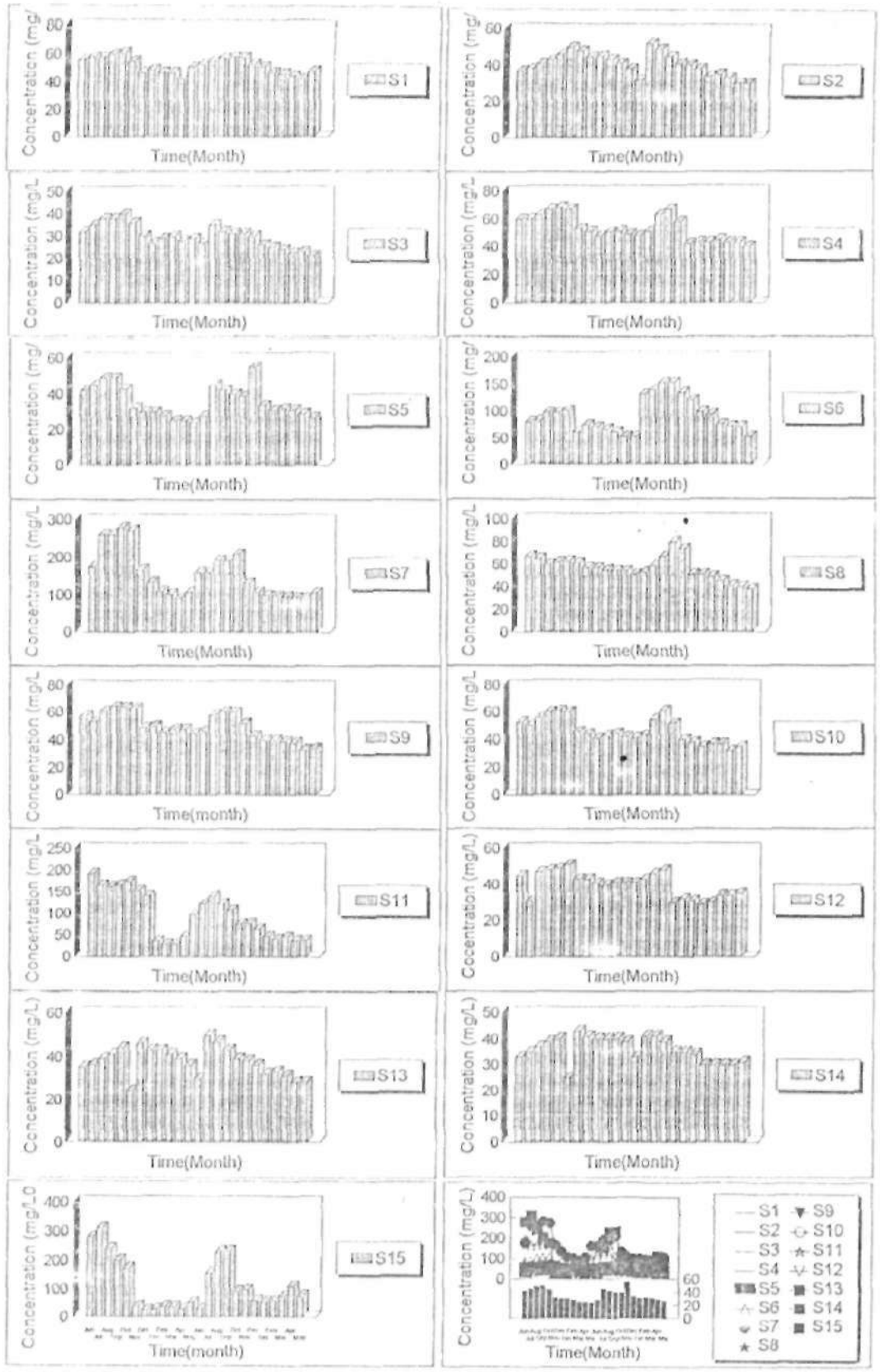


Fig.10 monthly variation in concentration of phosphate-phosphorus (mg/L).

TABLE 9a VARIATION IN PHOSPHATE-PHOSPHORUS CONTENT OF THE WATER.

Dry Season Mean	49.50
Rainy Season Mean	74.717
First Year General Mean	66.150
Second Year General Mean	58.069

ANALYSIS OF VARIANCE (ANOVA)

Procedure

Source of Variation	DF	Sum of Squares	Mean Square	F Value	Pr > F
REP.	5	5898.0917	1179.6183	2.33	0.0429
YEAR	1	5880.6250	5880.6250	11.60	0.0008
REP(YEAR)	5	2314.0917	462.8183	0.91	0.4731
SEASON	1	57229.2250	57229.2250	112.85	0.0001
STATIONS	14	424095.4000	30292.5286	59.73	0.0001
SEASON BY STATIONS	14	113872.0667	8133.7190	16.04	0.0001
SEASON BY YEAR	2	2088.0250	2088.0250	4.12	0.0434
YEAR BY STATIONS	14	26121.6667	1869.8333	3.68	0.0001
SEASON BY YR. BY STS.	14	25807.2667	1843.3762	3.64	0.0001

alpha = 0.01.

TABLE 9b DUNCAN'S MULTIPLE RANGE TEST

DUNCAN'S GROUPING	MEAN	N	STATION
A	153.625	24	7
B	113.125	24	15
C	96.708	24	11
C	91.708	24	6
D	56.417	24	8
D	53.042	24	4
E D	51.875	24	1
E D F	49.667	24	9
E G D F	46.125	24	10
E G H F	40.583	24	2
E G H F	39.798	24	12
G H F	37.583	24	13
G H	35.875	24	14
G H	35.625	24	5
H	29.958	24	3

alpha = 0.05

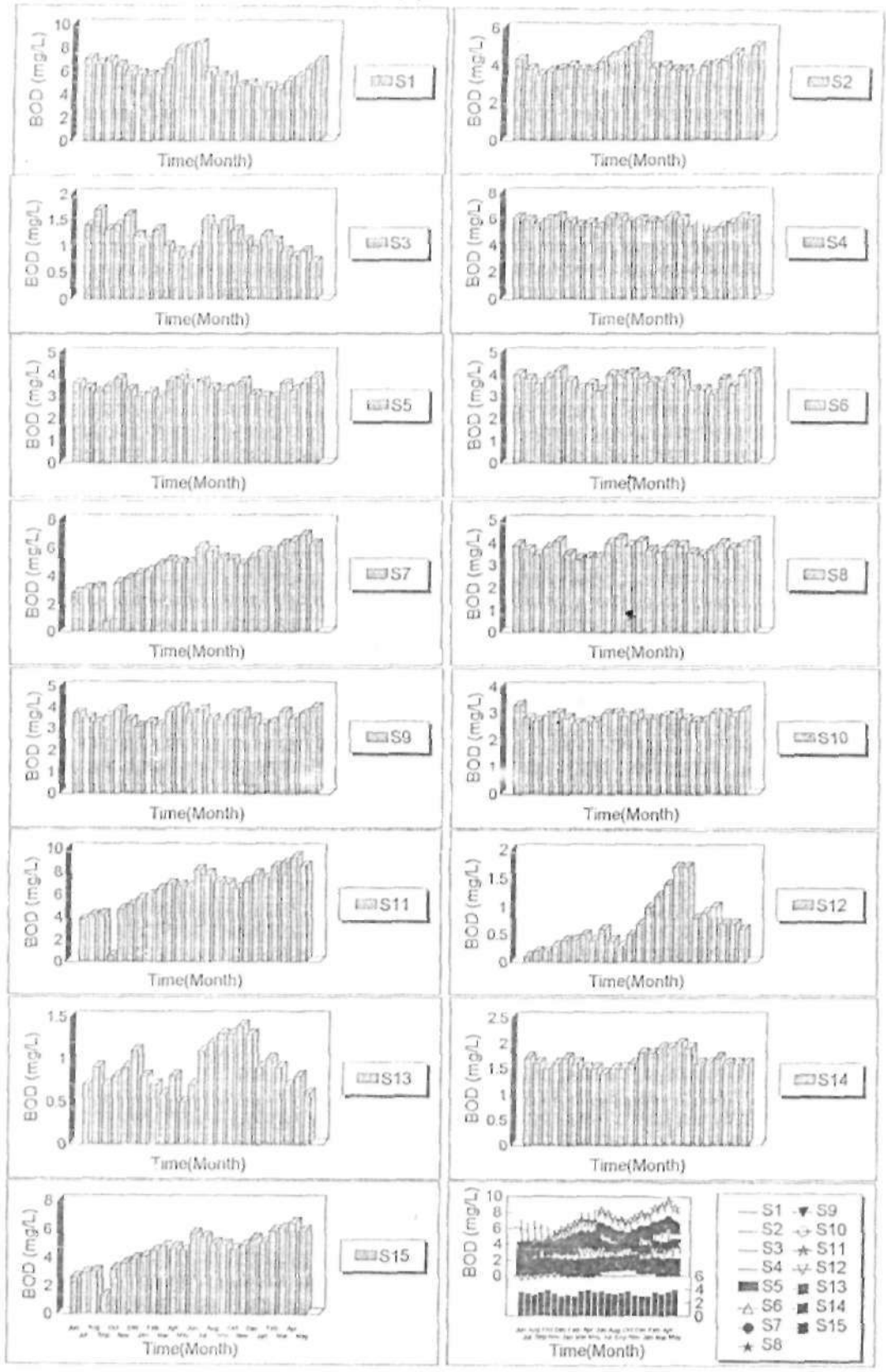


Fig.11 monthly variation in Biochemical Oxygen Demand of the water (mg/L).

TABLE 10a VARIATION IN BIOCHEMICAL OXYGEN DEMAND (BOD).

Dry Season Mean	3.6172
Rainy Season Mean	3.5545
First Year General Mean	3.1822
Second Year General Mean	3.8011

ANALYSIS OF VARIANCE (ANOVA)

Procedure

Source of Variation	DF	Sum of Squares	Mean Square	F Value	Pr > F
REP.	5	3.963335	0.792667	2.92	0.0136
YEAR	1	16.679723	16.679723	61.55	0.0001
REP(YEAR)	5	1.467446	0.293489	1.08	0.3699
SEASON	1	0.354067	0.354067	1.31	0.2540
STATIONS	14	1158.051371	82.717955	305.22	0.0001
SEASON BY STATIONS	14	25.211437	1.800817	6.64	0.0001
SEASON BY YEAR	2	2.383067	2.383067	8.49	0.0033
YEAR BY STATIONS	14	90.048615	6.432044	23.73	0.0001
SEASON BY YR. BY STS.	14	4.270771	0.305055	1.13	0.3346

alpha = 0.01.

TABLE 10b DUNCAN'S MULTIPLE RANGE TEST

DUNCAN'S GROUPING	MEAN	N	STATION
A	6.483	24	11
B	6.121	24	1
C	5.808	24	4
D	4.830	24	7
E	4.525	24	15
F	4.192	24	2
G	3.771	24	8
G	3.754	24	6
H G	3.575	24	9
H	3.425	24	5
I	2.879	24	10
J	1.654	24	14
K	1.171	24	3
L K	0.904	24	13
L	0.696	24	12

alpha = 0.05

The lowest value of BOD was recorded at station 12, being 0.01 mg/L. The highest was in station 11, being 8.00 mg/L. Correlation coefficient (Table 1c) reveals highly significant positive correlation between BOD and SS, alkaline earth metals, Zn, As, Pb, Cu, Cd, Mn, electrical conductivity, Cl, COD, PO_4-P and NO_3-N, with significant negative correlation between BOD and dissolved oxygen ($P < 0.01$).

4.1.8.1 Chemical Oxygen Demand :

The highest value of chemical oxygen demand (COD) was recorded in station 1, being 58.8 mg/L in June . The lowest being 1.3 mg/L was recorded in station 7 in November (Fig.12). Table 11a shows close values of both RSM and DSM of 20.951 mg/L and 20.226 mg/L respectively. . The analysis of variance indicates highly significant difference with years, stations, season by stations, and year by stations ($P < 0.01$).

Multiple range test (Table 11b) shows that the GSM for station 1 was the highest (37.846 mg/L) and that of station 6 was the lowest (7.954 mg/L). Open water sources were intermediate, while the RWSs (the wells) had their COD values depending on location and influence of point-sources of COD enrichment.

Correlation analysis (Table 1c) shows that there was highly significant positive correlation between COD and SS, Mg, Na, Cl and BOD ($P < 0.01$). The correlation with OD was significant at 5% ($P < 0.05$). There was highly significant negative correlation with DO, pH and Fe ($P < 0.01$).

4.1.8.2 Dissolved Oxygen :

There were recorded differences between stations and highly significant differences ($P < 0.01$) in dissolved oxygen (DO) concentrations with seasons and season by

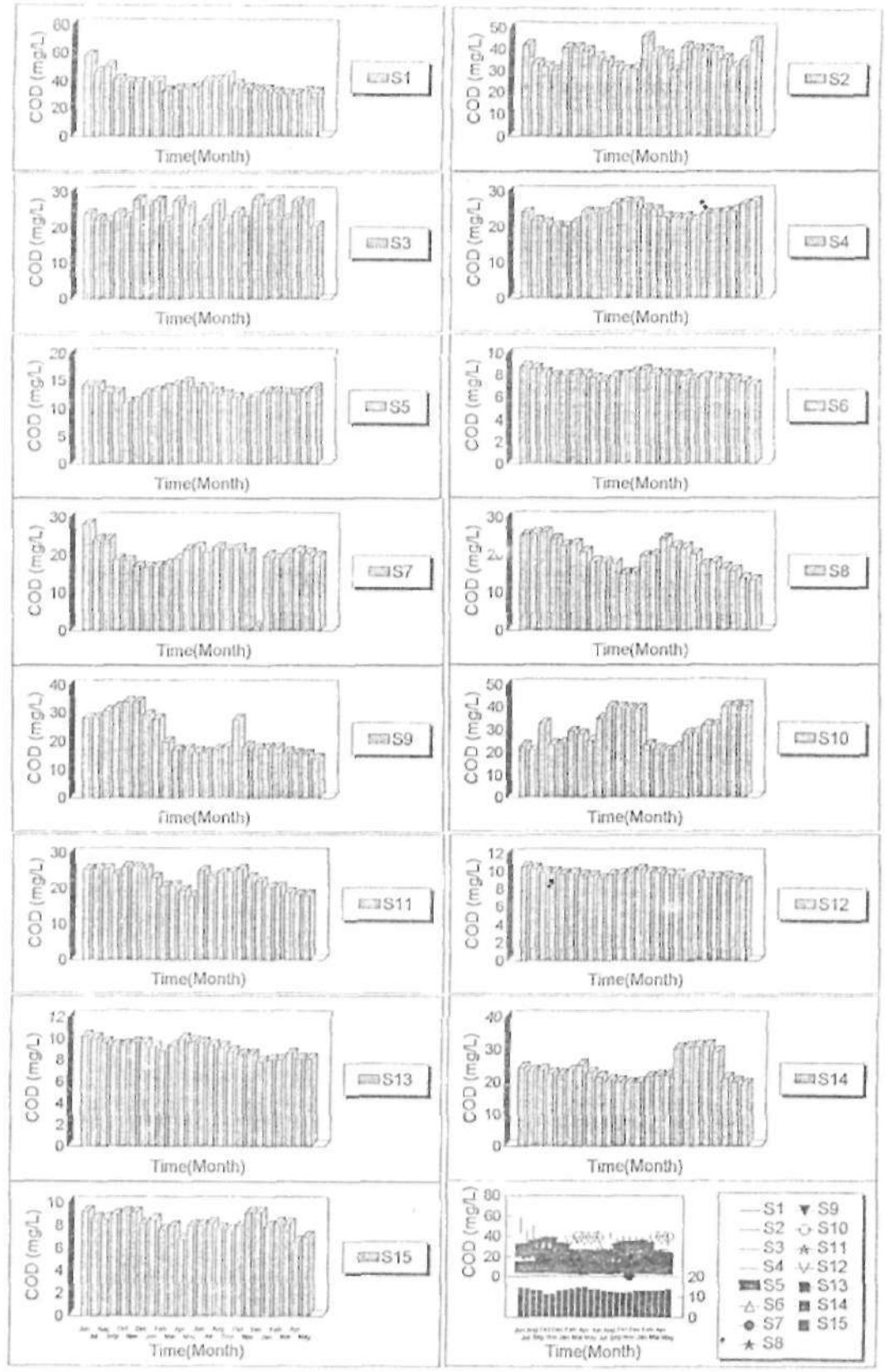


Fig.12 monthly variation in Chemical Oxygen Demand of the water (mg/L).

TABLE 11a VARIATION IN CHEMICAL OXYGEN DEMAND (COD).

Dry Season Mean	20.226
Rainy Season Mean	20.951
First Year General Mean	21.080
Second Year General Mean	20.097

ANALYSIS OF VARIANCE (ANOVA)

Procedure

Source of Variation	DF	Sum of Squares	Mean Square	F Value	Pr > F
REP.	5	127.84114	25,57423	2.08	0.0684
YEAR	1	86.92669	86,92669	7.08	0.0083
REP(YEAR)	5	14.04247	2,80849	0.23	0.9502
SEASON	1	47.30625	47.30625	3.84	0.0510
STATIONS	14	31784.33456	2270.30961	184.28	0.0001
SEASON BY STATIONS	14	867.59333	61.97095	5.03	0.0001
SEASON BY YEAR	2	1.23669	1.23669	0.10	0.7516
YEAR BY STATIONS	14	744.01956	53.14425	4.31	0.0001
SEASON BY YR. BY STS.	14	86.32789	6.16628	0.50	0.9321

alpha = 0.01.

TABLE 11b DUNCAN'S MULTIPLE RANGE TEST

DUNCAN'S GROUPING	MEAN	N	STATION
A	37.846	24	1
A	36.883	24	2
B	30.346	24	10
C	24.671	24	3
D C	23.733	24	4
D C	23.479	24	14
D C	22.646	24	11
D	21.896	24	9
E	19.762	24	8
E	19.704	24	7
E	13.017	24	5
G	9.663	24	12
G	9.063	24	13
G	8.167	24	15
G	7.954	24	6

alpha = 0.05

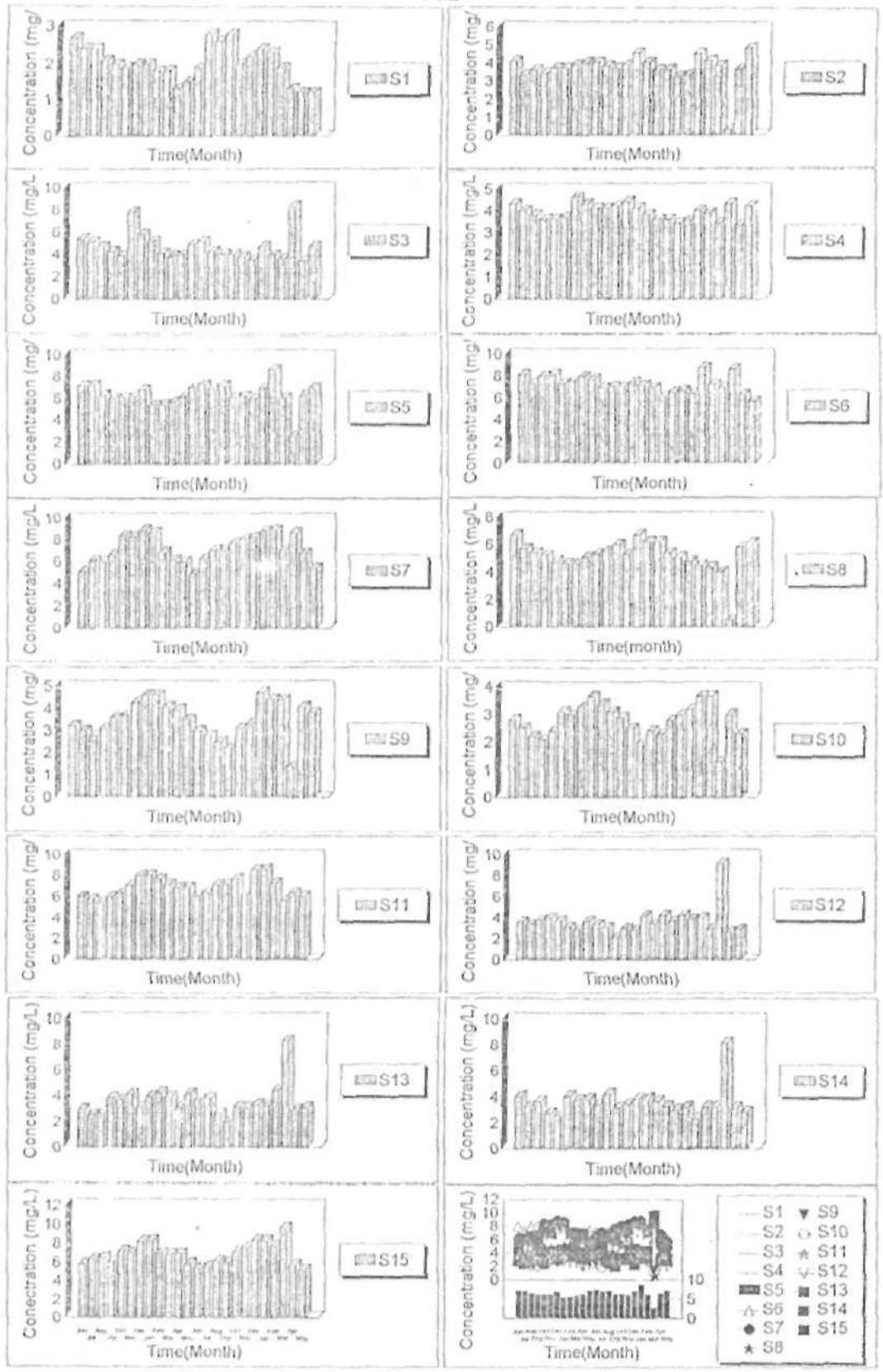


Fig.13 monthly variation in concentration of oxygen in water (mg/L).

TABLE 13a VARIATION IN DISSOLVED OXYGEN CONTENT OF THE WATER.

Dry Season Mean	4.8950
Rainy Season Mean	4.5672
First Year General Mean	4.7433
Second Year General Mean	4.7189

ANALYSIS OF VARIANCE (ANOVA)

Procedure

Source of Variation	DF	Sum of Squares	Mean Square	F Value	Pr > F
REP.	5	10.012222	2.002444	2.33	0.0423
YEAR	1	0.058778	0.053778	0.06	0.8025
REP(YEAR)	5	3,154222	0.630844	0.74	0.5975
SEASON	1	9.669444	9.669444	11.27	0.0009
STATIONS	14	1018.468222	72.747730	84.79	0.0001
SEASON BY STATIONS	14	44.073889	3.148135	3.67	0.0001
SEASON BY YEAR	2	0.000111	0.000111	0.00	0.9909
YEAR BY STATIONS	14	12.206222	0.871873	0.00	0.1369
SEASON BY YR. BY STS.	14	14,636556	0.045468	1.22	0.2607

alpha = 0.01.

TABLE 13b DUNCAN'S MULTIPLE RANGE TEST

DUNCAN'S GROUPING	MEAN	N	STATION
A	7.225	24	6
A	7.192	24	7
B A	6.867	24	11
B A	6.825	24	15
B	6.362	24	5
C	5.163	24	8
C	4.675	24	3
D	3.908	24	4
D	3.683	24	2
D	3.658	24	12
D	3.558	24	13
D	3.542	24	14
D	3.508	24	9
E	2.779	24	10
F	2.021	24	1

alpha = 0.05

stations (Table 13a). The RSM was 4.5672 mg/L and the DSM was 4.8950 mg/L. There was significant variation in DO content between the FYGM and SYGM.

Multiple range test (Table 13b) indicates that the GSM for station 6 was the highest (7.225 mg/L), while station 1 recorded the lowest GSM of 2.021 mg/L.

Correlation analysis, (Table 1c) reveals highly significant correlation with most of the metals, pH, and macro-nutrients ($P < 0.01$). The correlation between DO and temperature was negative but not significant ($P > 0.05$), where as that of DO with COD, Na, and Cl was highly significant and negative ($P < 0.01$).

Figure 14b shows the range of variations in BOD, COD and dissolved oxygen.

4.1.9 Chloride ion :

The lowest value recorded was 22 mg/L. The highest was 280 mg/L. The RSM was 83.822 mg/L and the DSM was 77.767 mg/L (Fig.13). The FYGM was 83.594 mg/L, and higher than the SYGM of 77.994 mg/L.

Station 10 had the highest GSM of 196.375 mg/L, and station 13 recorded the lowest of 34.167 mg/L (Table 12b). There were significant differences between seasons, stations, season by stations and season by year by station ($P < 0.01$). There was also highly significant positive correlation (Table 1c) between chloride ion concentration and SS, Ca, Mg, Na, Zn, As, Cd, Mn, electrical conductivity, OD, COD, PO_4-P, BOD, and NO_3-N ($P < 0.01$). The correlation with dissolved oxygen (DO) and pH was negative ($P < 0.01$).

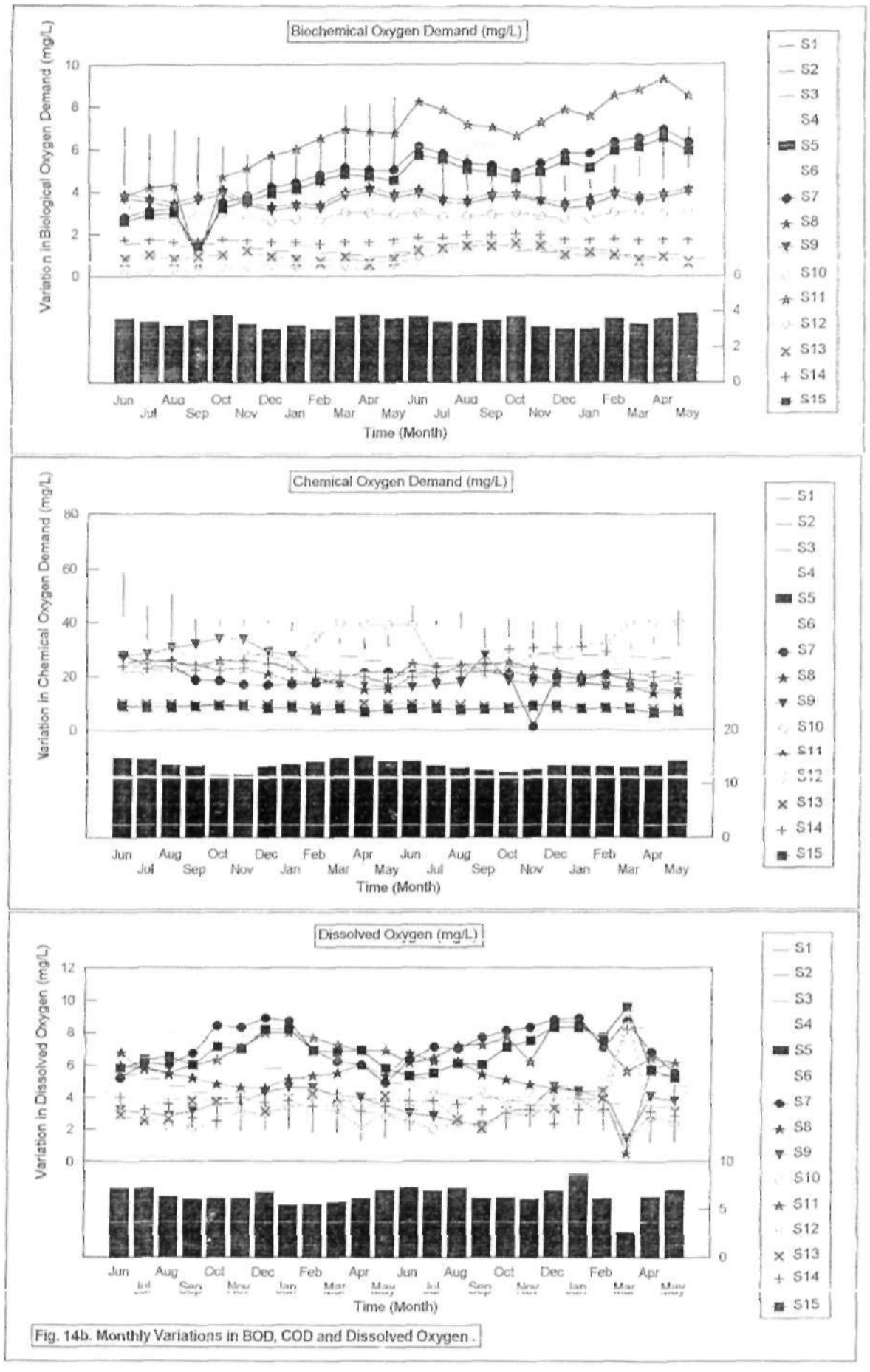


Fig. 14b. Monthly Variations in BOD, COD and Dissolved Oxygen .

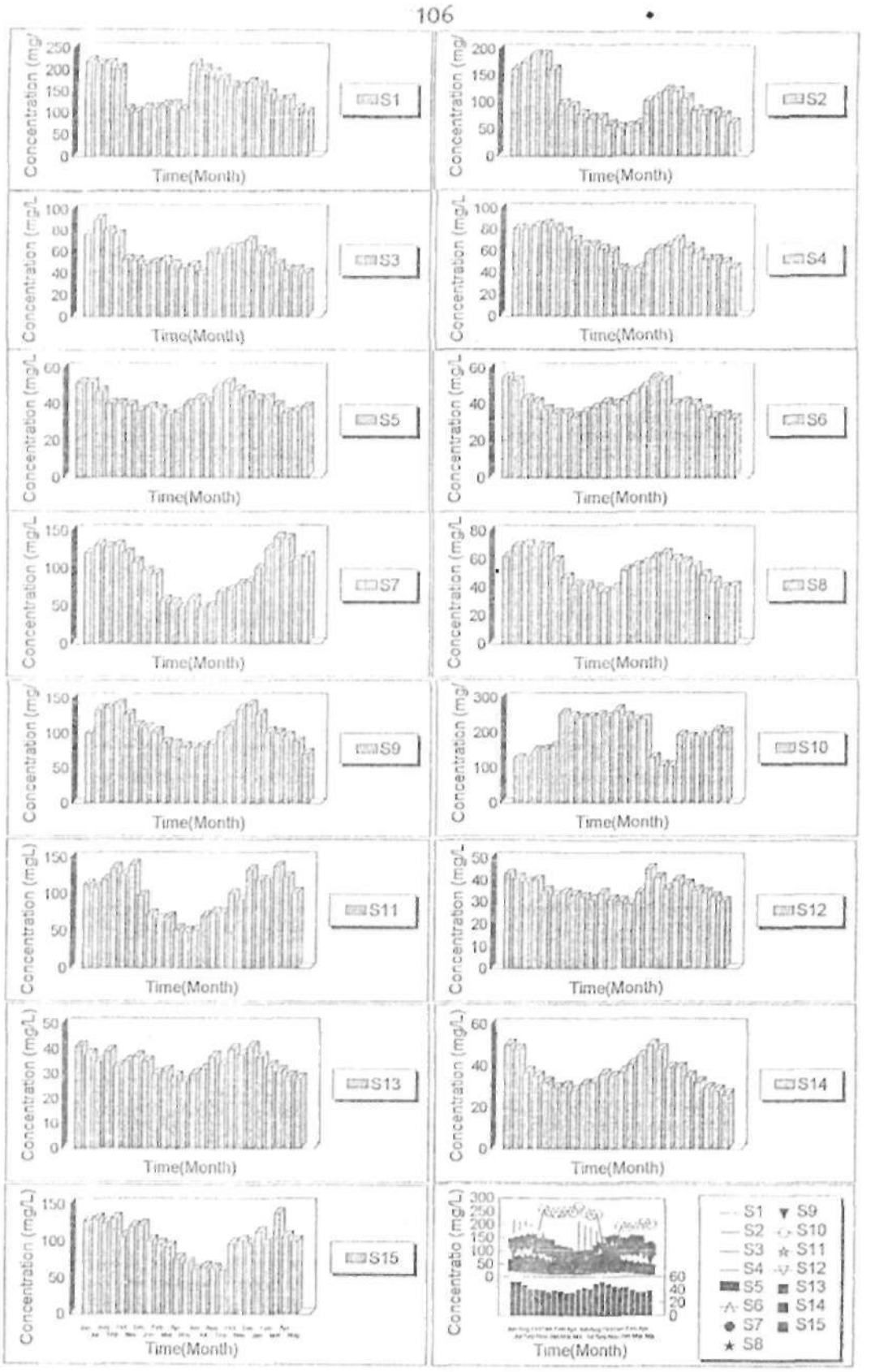


Fig.14 monthly variation in concentration of chloride ion in water (mg/L).

TABLE 12a VARIATION IN CHLORIDE ION CONCENTRATION.

Dry Season Mean	77.767
Rainy Season Mean	83.822
First Year General Mean	83.594
Second Year General Mean	77.994

ANALYSIS OF VARIANCE (ANOVA)

Procedure

Source of Variation	DF	Sum of Squares	Mean Square	F Value	Pr > F
REP.	5	2770.1222	554.0244	1.28	0.2929
YEAR	1	2822.4000	2822.4000	6.52	0.0112
REP(YEAR)	5	1182.8000	236.5600	0.55	0.7412
SEASON	1	3300.2778	3300.2778	7.62	0.0061
STATIONS	14	752204.6222	53728.9016	124.04	0.0001
SEASON BY STATIONS	14	33484.5556	2391.7540	5.52	0.0001
SEASON BY YEAR	2	11696.4000	11696.4000	27.00	0.0001
YEAR BY STATIONS	14	8584.6007	613.1857	1.42	0.1445
SEASON BY YR. BY STS.	14	43120.9333	3080.0667	7.11	0.0001

alpha = 0.01.

TABLE 12b DUNCAN'S MULTIPLE RANGE TEST

DUNCAN'S GROUPING	MEAN	N	STATION
	196.375	24	10
	152.375	24	1
	105.792	24	9
	101.500	24	2
	100.333	24	15
	98.083	24	11
	95.005	24	7
	62.833	24	4
	57.333	24	3
	53,375	24	8
	41.750	24	5
	41,250	24	6
	36.333	24	14
	35.417	24	12
	34.167	24	13

alpha = 0.05

4.2.0 Alkaline Earth Metals in Water:

4.2.1 Potassium:

The concentration of potassium (K) in water sampled shows variation between seasons. The RSM was 3.952 µg/L as compared to the DSM which was higher (5.357 µg/L).The differences between the FYGM and the SYGM was less than 1 µg/L

Analysis of variance (Table 14a)indicates highly significant differences between seasons and stations ($P < 0.01$). Duncan's Multiple Range Test (Table 14b) shows that the GSM for station 11 was the highest (9.083 µg/L), while station 14 had the lowest GSM of 1.839 µg/L. Correlation analysis (Table 1c) reveals highly significant positive correlation ($P < 0.01$) between K and water hardness, Ca, Mg, Na, Zn, As, Pb, Cu, Cd, Mn, pH, BOD, NO_3-N and electrical conductivity. The correlation with SS was negative ($P < 0.01$).

4.2.2 Calcium :

The lowest concentration of calcium (Ca) recorded was 1.1 µg/L. The highest was 8.12 Ug/L with peaks during the early rains and late dry season (Fig.16). The RSM was 3.6739 µg/L and the DSM was slightly higher (4.1289 µg/L). There was little difference between the FYGM and the SYGM, being 3.9367 and 3.9661 µg/L respectively. Analysis of variance (Table 15a) indicates highly significant difference with respect to Ca concentration in water between seasons, stations, season by stations and season by year ($P < 0.01$).

The highest GSM was recorded in station 11 (6.587 µg/L) and the lowest at station 9 (1.892 µg/L). The OWSs were found to rank higher as compared to the wells (Table 15b). Calcium shows highly significant positive correlation with SS,

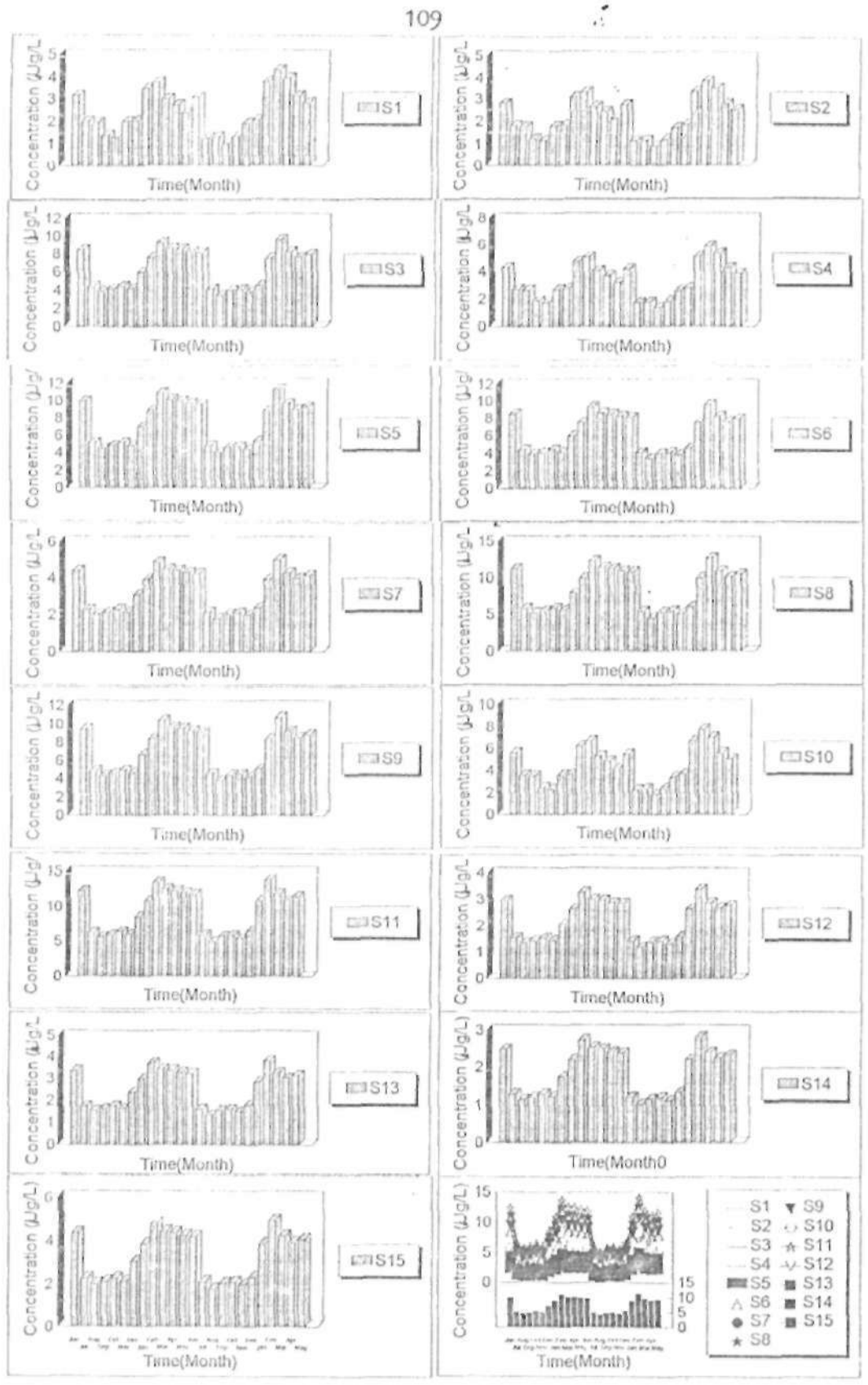


Fig.15 monthly variation in concentration of potassium in water (µg/L) .

TABLE 14a VARIATION IN CONCENTRATION OF POTASSIUM IN WATER.

Dry Season Mean	5.357
Rainy Season Mean	3.952
First Year General Mean	4.760
Second Year General Mean	4.549

ANALYSIS OF VARIANCE (ANOVA)

Procedure

Source of Variation	DF	Sum of Squares	Mean Square	F Value	Pr > F
REP.	5	19.902598	3.980520	1.24	0.2915
YEAR	1	4.009000	4,009000	1.25	0.2652
REP(YEAR)	5	2.413225	0.482645	0.15	0.9799
SEASON	1	177.676300	177.676300	55.24	0.0001
STATIONS	14	2078.989091	148.499221	46.17	0.0001
SEASON BY STATIONS	14	34.552537	2.468038	0.77	0.7045
SEASON BY YEAR	2	0.236647	0.236647	0.07	0.7864
YEAR BY STATIONS	14	4.609154	0.329225	0.10	1.0000
SEASON BY YR. BY STS.	14	3.423374	0.244527	0.08	1.0000

alpha = 0.01.

TABLE 14b DUNCAN'S MULTIPLE RANGE TEST

DUNCAN'S GROUPING	MEAN	N	STATION
A	9.083	24	11
B A	8.283	24	8
B C	7.403	24	5
D C	7.039	24	9
D	6.304	24	6
D	6.286	24	3
E	4.400	24	10
F	3.328	24	4
F	3.267	24	7
F	3.231	24	15
G F	2.494	24	13
G F	2.480	24	1
G F	2.195	24	12
G F	2.191	24	2
G	1.839	24	14

alpha = 0.05

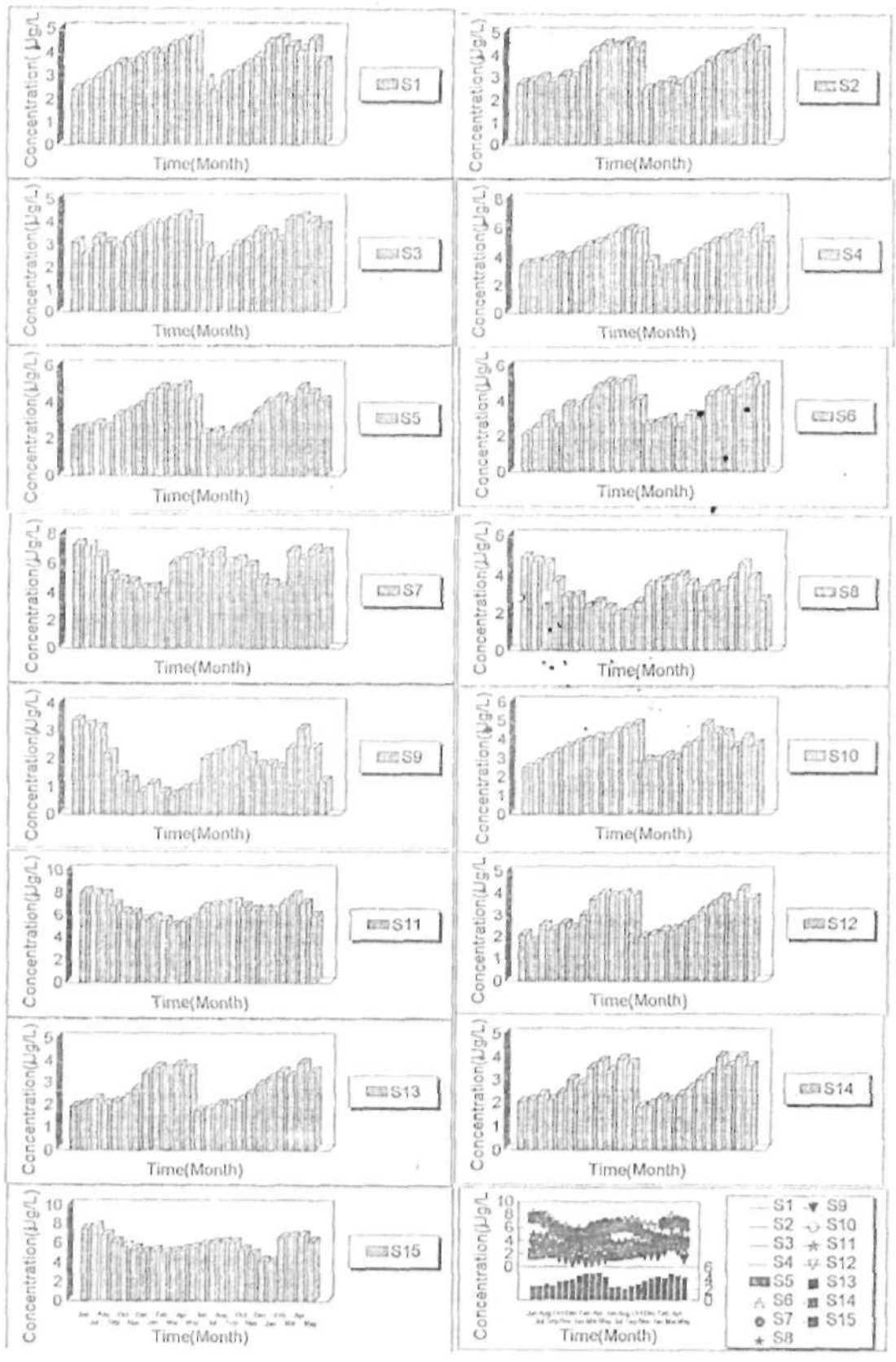


Fig.16 Monthly variation in concentration of calcium in water (µg/L) .

TABLE 15a VARIATION IN CONTRATION OF CALCIUM IN WATER.

Dry Season Mean	4.1289
Rainy Season Mean	3.6739
First Year General Mean	3.9367
Second Year General Mean	3.8661

ANALYSIS OF VARIANCE (ANOVA)

Procedure

Source of Variation	DF	Sum of Squares	Mean Square	F Value	Pr > F
REP.	5	7.5751389	1.5150278	3.78	0.0025
YEAR	1	0.4480278	0.4480278	1.12	0.2911
REP(YEAR)	5	0.27271389	0.5454278	1.36	0.2387
SEASON	1	18.6322500	18.6322500	46.52	0.0001
STATIONS	14	554.9705556	39.6407540	98.92	0.0001
SEASON BY STATIONS	14	72.1406667	5.1529048	12.87	0.0001
SEASON BY YEAR	2	6.2146944	6.2146944	15.52	0.0001
YEAR BY STATIONS	14	5.4315556	0.3879683	0.97	0.4856
SEASON BY YR. BY STS.	14	9.4598889	0.6757063	1.69	0.0575

alpha = 0.01.

TABLE 15b DUNCAN'S MULTIPLE RANGE TEST

DUNCAN'S GROUPING	MEAN	N	STATION
A	6.587	24	11
B	5.850	24	7
B	5.792	24	15
C	4.629	24	4
D	3.821	24	6
E D	3.713	24	10
E D	3.650	24	1
E D	3.571	24	5
E D	3.538	24	2
E D	3.442	24	3
E	3.388	24	8
F	3.017	24	12
F	2.892	24	14
F	2.742	24	13
G	1.892	24	9

alpha = 0.05

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hardness, Mg, K, Fe, Zn, As, Cu, Cd, Mn, conductivity, DO, Cl, pH, PO_4-P, BOD and NO_3-N ($P < 0.01$).

Figure 16b shows the range of variations in Cl, K, and Ca.

4.2.3 Sodium :

Sodium concentration was observed to be higher during the late dry season (Fig.17). the lowest concentration recorded was 31 µg/L and the highest was 361 µg/L. The RSM was 114.828 µg/L and the DSM was higher, being 142.194 µg/L. The difference between the FYGM and the SYGM was less than 1 µg/L (Table 16a).

The concentrations of Sodium (Na) varied significantly higher with season, stations, season by stations and season by year ($P < 0.01$). The highest GSM was recorded at station 10 (301.375 µg/L) and the lowest at station 14 (51.250 µg/L). Correlation analysis (Table 1c) indicates highly significant increase in the concentrations of Zn, Cu, K, Cd, Mn, Cl, COD, BOD, NO_3-N and conductivity with increase in the concentrations of sodium ($P < 0.01$). There was highly significant decrease in concentrations of DO, PO_4-P and pH with increase in Na ($P < 0.01$).

4.2.4 Magnesium :

The concentrations of magnesium (Mg) was observed to increase with the on-set of rainy season (Fig.18). The concentrations ranged from 0.8 µg/L to 6.4 µg/L with fluctuation values of between 0 to 6 µg/L (Fig.17a).The RSM was 3.7811 µg/L and the DSM was 3.5200 µg/L

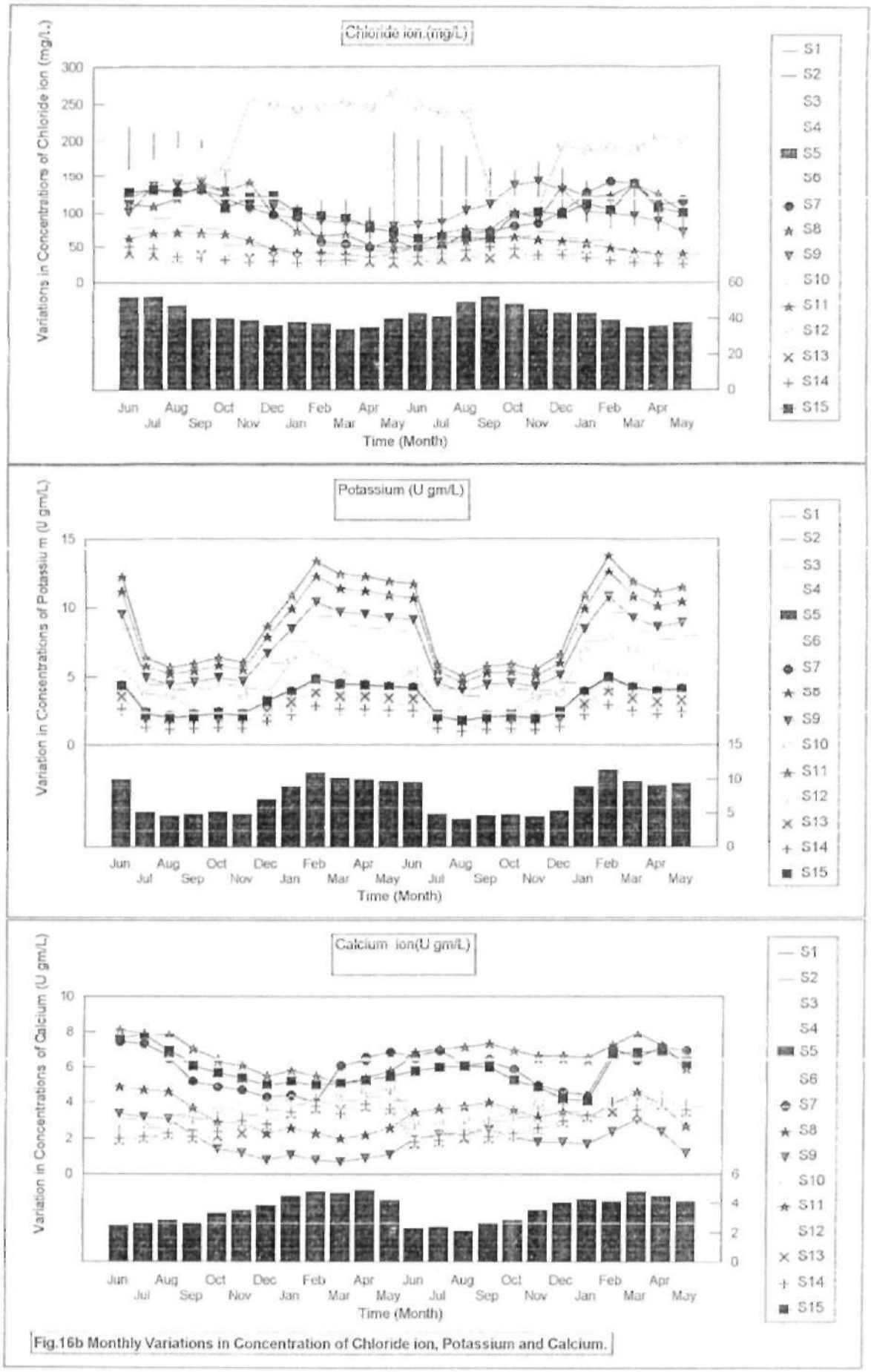


Fig.16b Monthly Variations in Concentration of Chloride ion, Potassium and Calcium.

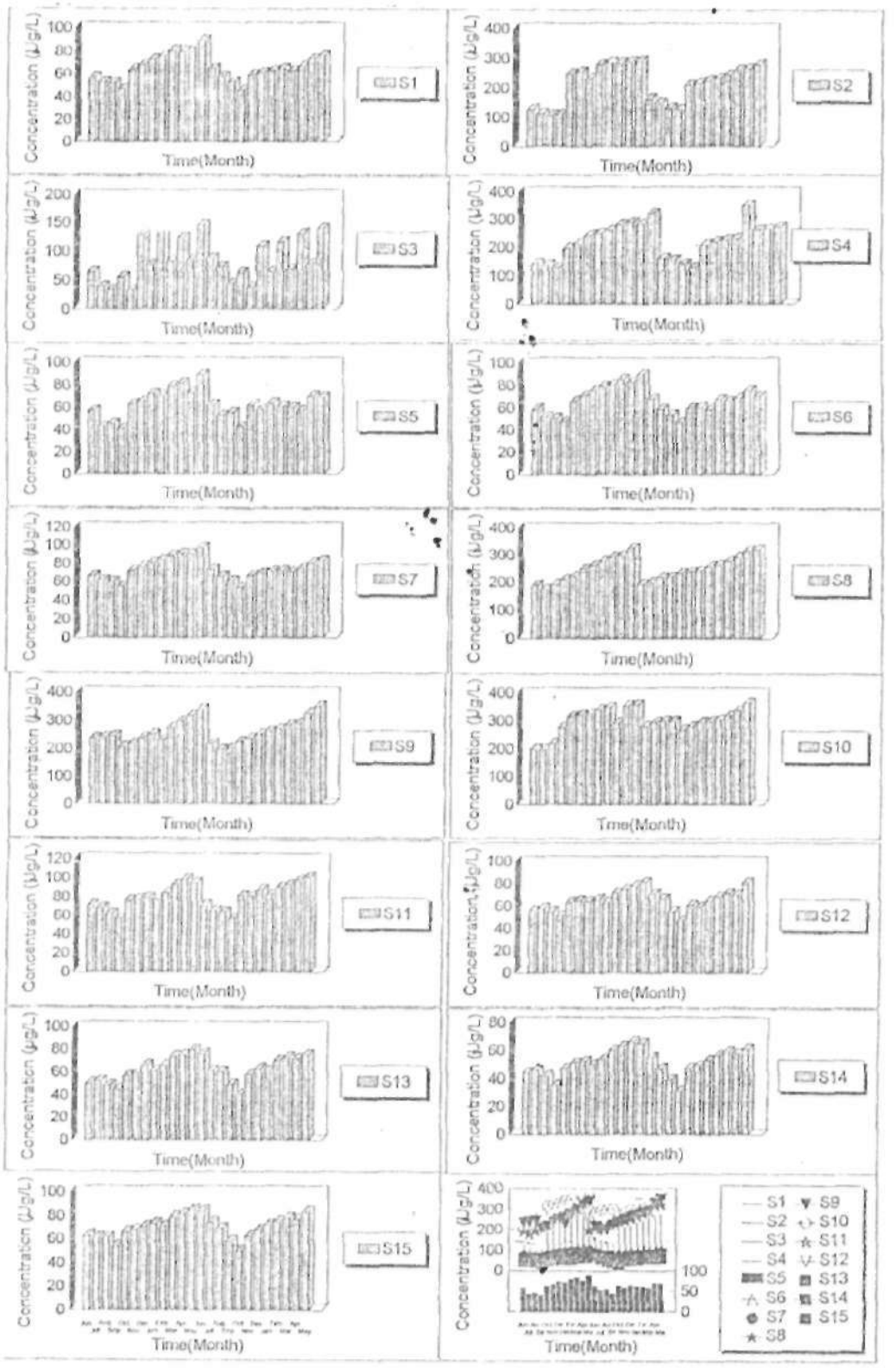


Fig.17 Monthly variation in concentration of sodium in water (µg/L) .

TABLE 16a VARIATION IN CONCENTRATION OF SODIUM IN WATER.

Dry Season Mean	142.194
Rainy Season Mean	114.828
First Year General Mean	128.939
Second Year General Mean	128.083

ANALYSIS OF VARIANCE (ANOVA)

Procedure

Source of Variation	DF	Sum of Squares	Mean Square	F Value	Pr > F
REP.	5	33765.222	6753.044	9.58	0.0001
YEAR	1	65.878	65.878	0.09	0.7601
REP(YEAR)	5	2021.522	404.304	0.57	0.7205
SEASON	1	67404.100	67404.100	95.57	0.0001
STATIONS	14	2761881.456	197277.247	279.72	0.0001
SEASON BY STATIONS	14	61422.900	4387.350	6.22	0.0001
SEASON BY YEAR	2	5168.044	5168.044	7.33	0.0072
YEAR BY STATIONS	14	4060.622	290.044	0.41	0.9709
SEASON BY YR. BY STS.	14	10441.289	745.806	1.06	0.3975

alpha = 0.01.

TABLE 16b DUNCAN'S MULTIPLE RANGE TEST

DUNCAN'S GROUPING	MEAN	N	STATION
A	301.375	24	10
B	259.625	24	9
B	248.750	24	8
C	223.708	24	4
C	213.250	24	2
D	84.500	24	3
E D	79.583	24	11
E D	73.583	24	7
E D	70.250	24	15
E F	66.625	24	6
E F	65.500	24	1
E F	65.083	24	12
E F	62.417	24	5
E F	62.167	24	13
E F	51.250	24	14

alpha = 0.05

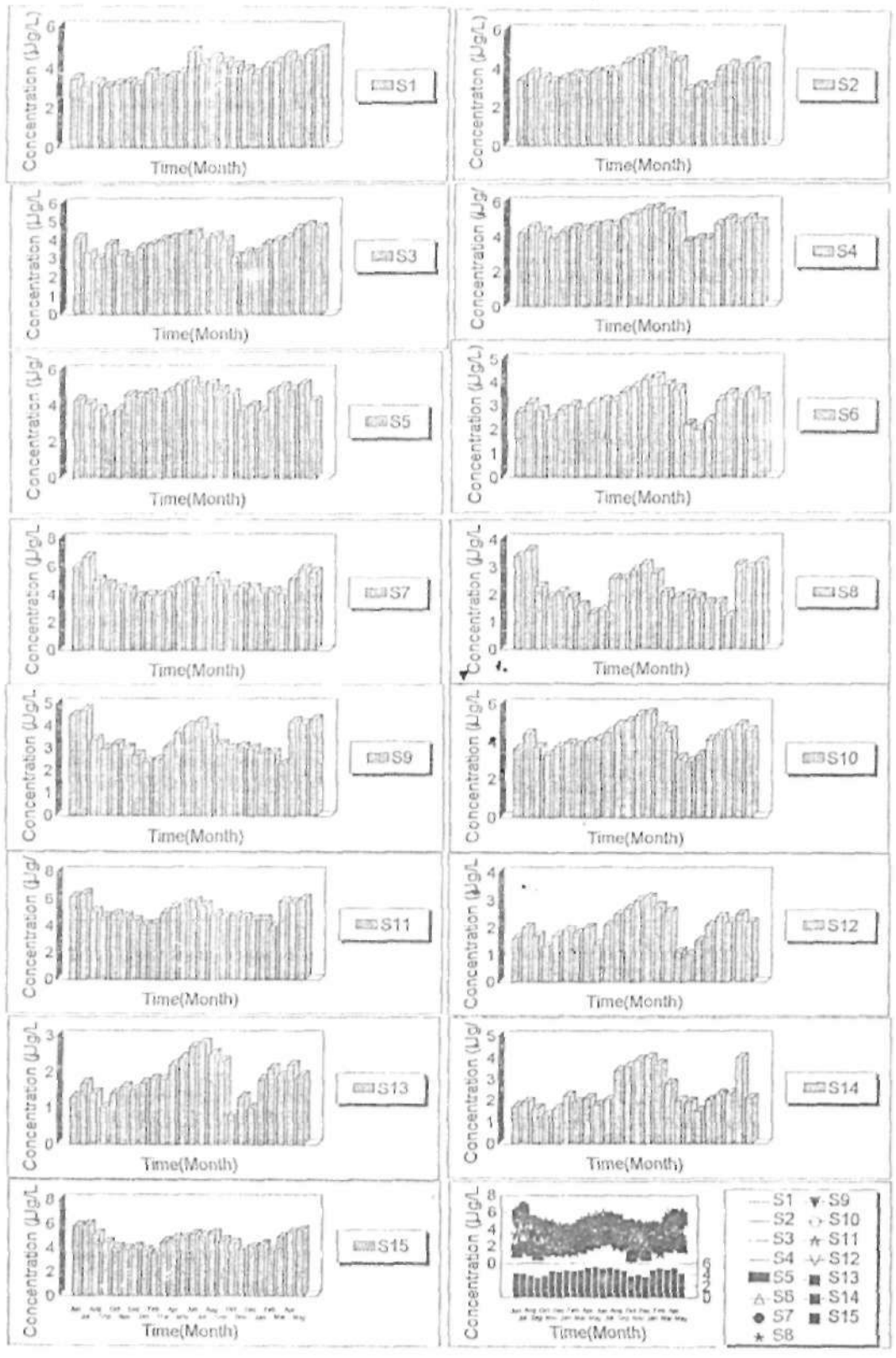


Fig.18 Monthly variation in concentration of magnessium in water (µg/L) .

TABLE 17a VARIATION IN CONCENTRATION OF MAGNESIUM IN WATER.

Dry Season Mean	3.5106
Rainy Season Mean	3.7811
First Year General Mean	3.5200
Second Year General Mean	3.7717

ANALYSIS OF VARIANCE (ANOVA)

Procedure

Source of Variation	DF	Sum of Squares	Mean Square	F Value	Pr > F
REP.	5	2.2589167	0.4517833	1.33	0.2503
YEAR	1	5.7002500	5.7002600	16.82	0.0001
REP(YEAR)	5	6.7182500	1.3436500	3.96	0.0017
SEASON	1	6.58802780	6.5880278	19.43	0.0001
STATIONS	14	391.2708333	27.9836310	82.55	0.0001
SEASON BY STATIONS	14	8.6857222	0.6204087	1.83	0.0340
SEASON BY YEAR	2	1.2840278	1.2840278	3.79	0.0526
YEAR BY STATIONS	14	3.8485000	0.274929	0.81	0.6571
SEASON BY YR. BY STS.	14	8.1747222	0.5839087	1.72	0.0506

alpha = 0.01.

TABLE 17b DUNCAN'S MULTIPLE RANGE TEST

DUNCAN'S GROUPING	MEAN	N	STATION
A	5.088	24	11
B A	4.796	24	7
B	4.683	24	4
B	4.612	24	15
B C	4.533	24	5
D C	4.217	24	10
D	3.912	24	1
D	3.887	24	2
D	3.862	24	3
E	3.379	24	9
E	3.167	24	6
F	2.400	24	14
F	2.304	24	8
G F	2.050	24	12
G	1.796	24	13

alpha = 0.05

4.2.5.0 Heavy Metals :

4.2.5.1 Iron

Elevated levels of iron in water were observed in late dry and early rainy seasons (Fig. 19). The concentrations ranged from 0 to 10.2 µg/L and varied within the range of 0 to 4 µg/L. The RSM was 3.311 and the DSM was 3.096 µg/L. The difference between the FYGM and the SYGM was 0.191 µg/L . Analysis of variance (Table 18a) reveals significant variation in concentrations of Fe between stations, season by stations, and year by stations ($P< 0.01$). Multiple range test (Table 18b) indicates that the highest GSM was recorded in an open water source (Station 15), being 6.054. The lowest (2.046) was recorded at station 6. There was highly significant positive correlation between Fe and SS, water hardness, Ca, Mg, Zn, As, Pb, Cu, Cd, Mn, OD,PO_4-P, NO_3-N and electrical conductivity ($P< 0.01$). The correlation with COD was negative ($P < 0.01$). Fig.19b shows the range of variations in concentrations of Na, Mg and Fe.

4.2.5.2 Lead:

The concentrations of Pb in water increased significantly ($P< 0.01$) with the increase in SS, Hardness, concentration of Ca, Mg, Fe, Zn, As, Cu, Cd, Mn, K, electrical conductivity, BOD, and NO_3-N. The mean concentration with respect to rainy and dry season means were slightly higher than 0.1 µg/L (Table 19a). Maxima were recorded in early rains and during the harmattan period (Fig.20).

Variations between stations, months, and season by stations (Table 19a) were observed to be highly significant ($P < 0.01$). The open water sources (stations 11, 15 and 7), generally ranked highest with GSMs of 0.3683, 0.2367 and 0.1833 µg/L respectively. The lowest was station 14 with GSM of 0.0575 µg/L.

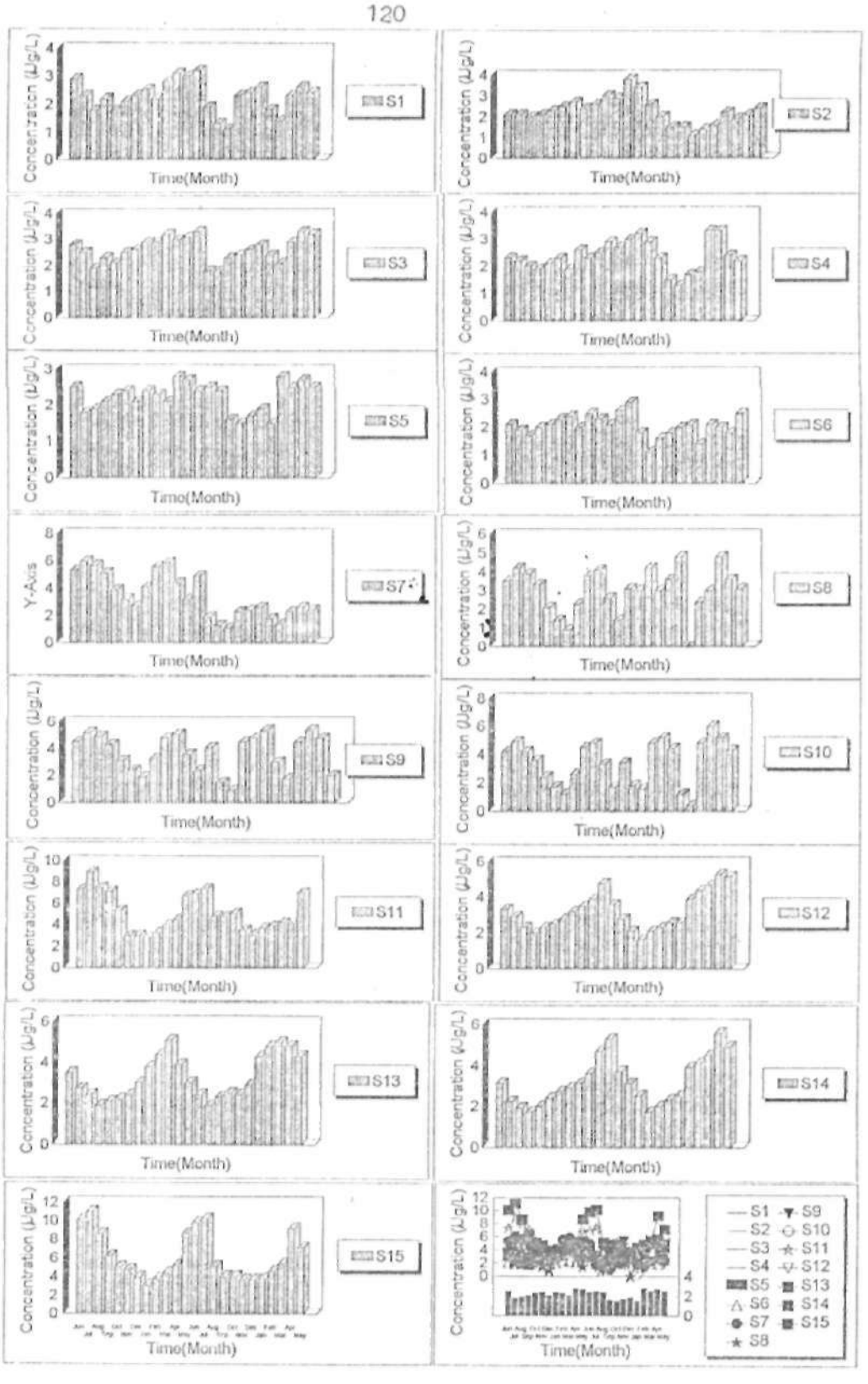


Fig. 19 Monthly variation in concentration of iron in water (µg/L) .

TABLE 18a VARIATION IN CONCENTRATION OF IRON IN WATER.

Dry Season Mean	3.096
Rainy Season Mean	3.311
First Year General Mean	3.299
Second Year General Mean	3.108

ANALYSIS OF VARIANCE (ANOVA)

Procedure

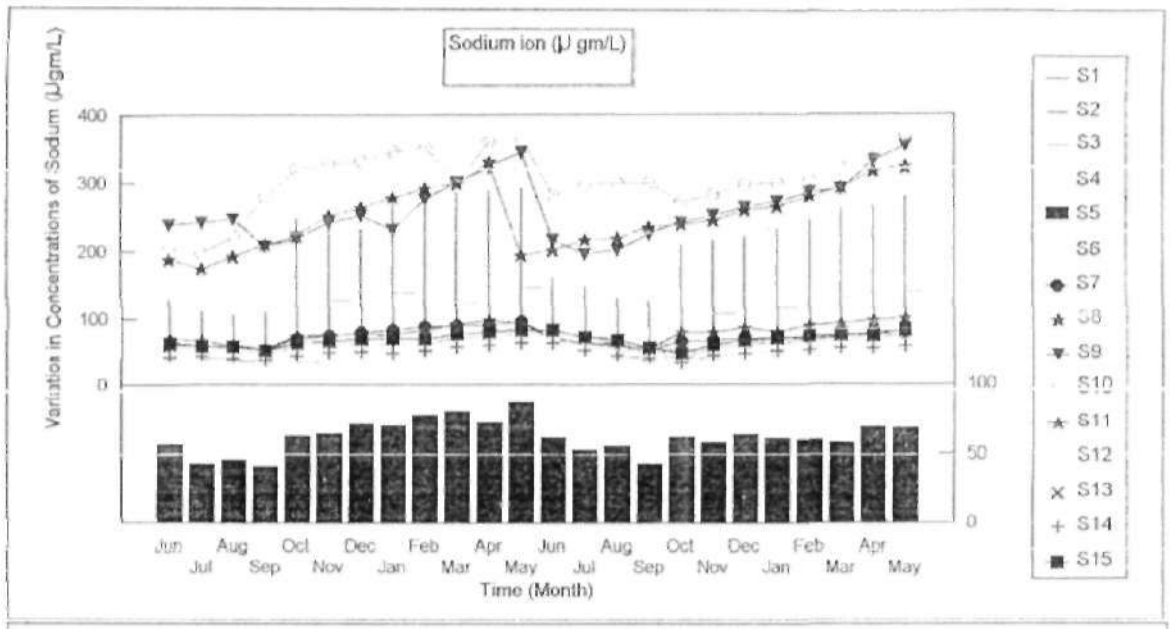
Source of Variation	DF	Sum of Squares	Mean Square	F Value	Pr > F
REP.	5	2.6804722	0.5360944	0.45	0.8100
YEAR	1	3.2630278	3.2680278	2.77	0.0971
REP(YEAR)	5	11.2944722	2.2588944	1.91	0.0919
SEASON	1	4.1602500	4.1602500	3.53	0.0614
STATIONS	14	411.8665556	29.4190397	24.93	0.0001
SEASON BY STATIONS	14	115.6410000	8.2600714	7.00	0.0001
SEASON BY YEAR	2	4.3780278	4.3780278	3.71	0.0551
YEAR BY STATIONS	14	38.2065556	2.7290397	2.31	0.0050
SEASON BY YR. BY STS.	14	15.7898889	1.1278492	0.96	0.4991

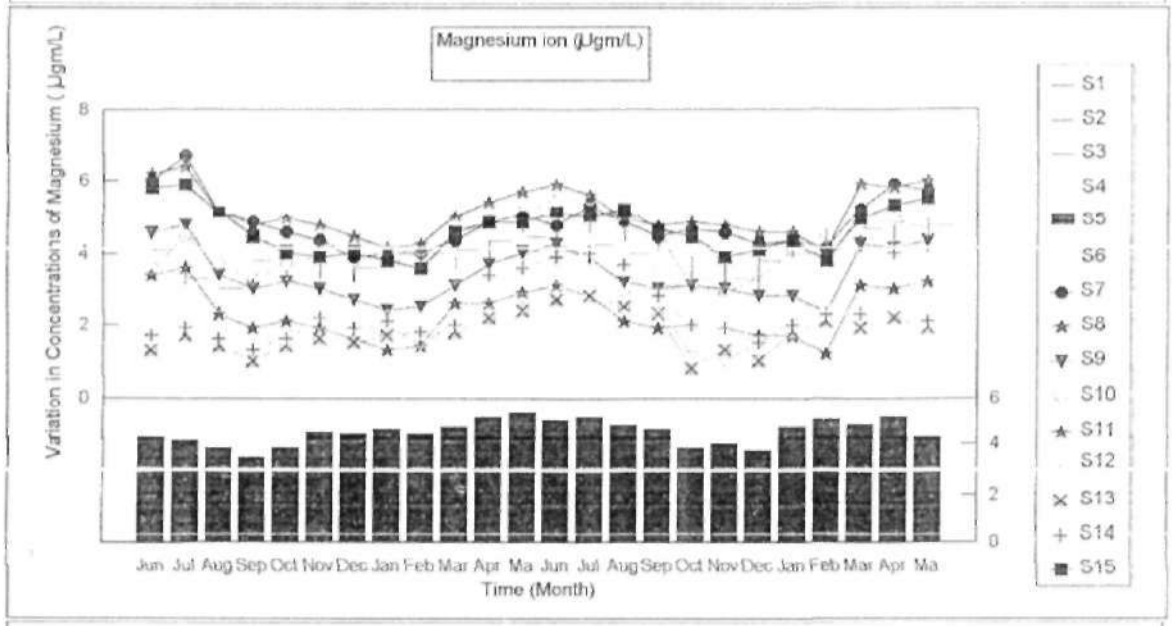
alpha = 0.01.

TABLE 18b DUNCAN'S MULTIPLE RANGE TEST

DUNCAN'S GROUPING	MEAN	N	STATION
A	6.054	24	15
B	5.083	24	11
C	3.675	24	9
C	3.425	24	10
C	3.421	24	7
D C	3.250	24	13
D C	3.196	24	12
D C	3.183	24	14
D C E	3.004	24	8
D F E	2.612	24	3
F E	2.358	24	4
F	2.262	24	1
F	2.258	24	2
F	2.225	24	5
F	2,046	24	6

alpha = 0.05





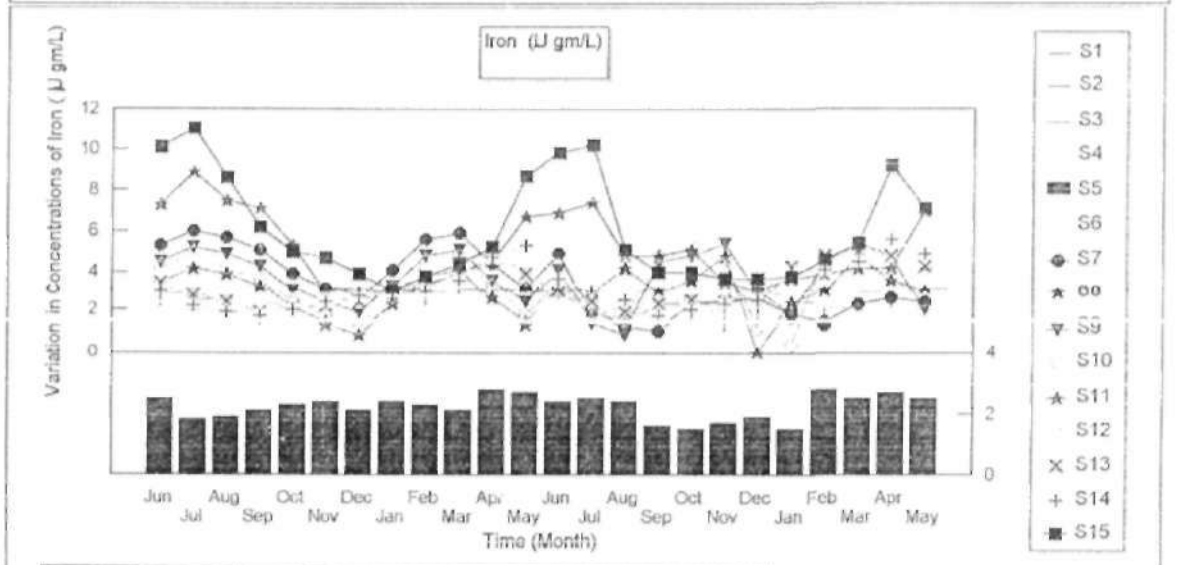


Fig. 19b. Monthly Variations in Concentrations of Sodium, Magnesium and Iron.

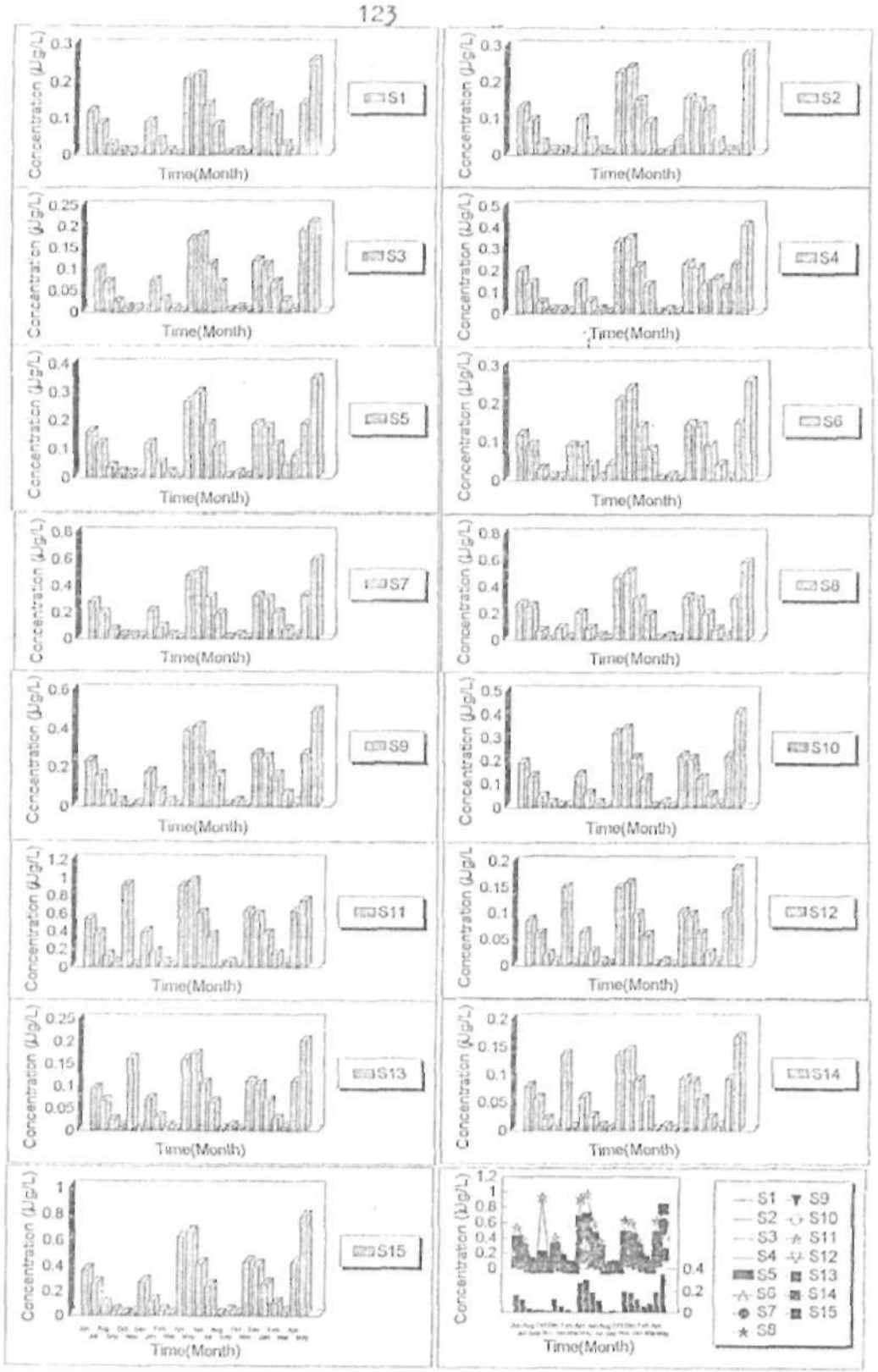


Fig.20 monthly variation in concentration of lead in water (µg/L) .

TABLE 19a VARIATION IN CONCENTRATION OF LEAD IN WATER.

Dry Season Mean	0.1235
Rainy Season Mean	0.1343
First Year General Mean	0.1231
Second Year General Mean	0.1347

ANALYSIS OF VARIANCE (ANOVA)

Procedure

Source of Variation	DF	Sum of Squares	Mean Square	F Value	Pr > F
REP.	5	2.36956889	0.47391378	35.13	0.0001
YEAR	1	0.01201778	0.01201778	0.89	0.3460
REP(YEAR)	5	0.34360869	0.06872178	6.09	0.0002
SEASON	1	0.01045444	0.01045444	0.77	0.3774
STATIONS	14	2.33814722	0.16701052	12.38	0.0001
SEASON BY STATIONS	14	0.03202056	0.00228718	0.17	0.9997
SEASON BY YEAR	2	0.11736111	0.11736111	8.70	0.0034
YEAR BY STATIONS	14	0.08167389	0.00583385	0.43	0.9635
SEASON BY YR. BY STS.	14	0.15444722	0.01103194	0.82	0.6497

alpha = 0.01.

TABLE 19b DUNCAN'S MULTIPLE RANGE TEST

DUNCAN'S GROUPING	MEAN	N	STATION
A	0.3683	24	11
B	0.2367	24	15
C B	0.1833	24	7
C D	0.1504	24	9
C D E	0.1354	24	8
C D E	0.1350	24	4
C D E	0.1221	24	10
C D E	0.1100	24	5
D E	0.0854	24	6
D E	0.0775	24	2
D E	0.0742	24	1
E	0.0675	24	3
E	0.0671	24	13
E	0.0629	24	12
E	0.0575	24	14

alpha = 0.05

4.2.5.3 Arsenic:

The recorded values of arsenic were generally less than 0.4 µg/L. The concentrations were higher during the rainy season, with mean value of 0.1344 µg/L as compared to that of the dry season (0.09572 µg/L). The FYGM and SYGM were similar with respect to their mean values of 0.10375 and 0.12439 µg/L respectively (Table 20a).The range of variation was between 0.0 to 0.2 µg/L (Fig. 21). Analysis of variance (Table 20a) reveals highly significant variations in concentrations of As with months, year, season, stations, and season by stations ($P < 0.01$). Station 7 ranked highest with GSM of 0.2696 µg/L, followed by station 15. The lowest GSM of 0.0208 µg/L was recorded at station 13 (Table 20b).

4.2.5.4 Zinc :

The open water sources were found to contain the highest amount of Zn in the following order: Station 7 with GSM of 0.8737 µg/L, station 15 with GSM of 0.8283 µg/L, and station 11 with the GSM of 0.8100 µg/L. the lowest GSM was recorded at station 6 (Table 21b).

The difference between seasons and stations (Table 21a) was observed to be highly significant ($P < 0.01$).

The concentration of Zn showed peaks in early rains with maxima in June and May (Fig. 22). The RSM was higher (0.5206 µg/L) than that of the dry season (0.3673), while the difference between the FYGM and the SYGM was only 0.0333 µg/L (Table 21b). There was significant positive correlation ($P < 0.01$) between concentration of Zn and SS, hardness, Ca, Mg, Na, Fe, As, Pb, Cu, K, Cd, Mn, OD, DO, Cl, PO_4-P, NO_3-N and conductivity ($P< 0.01$)

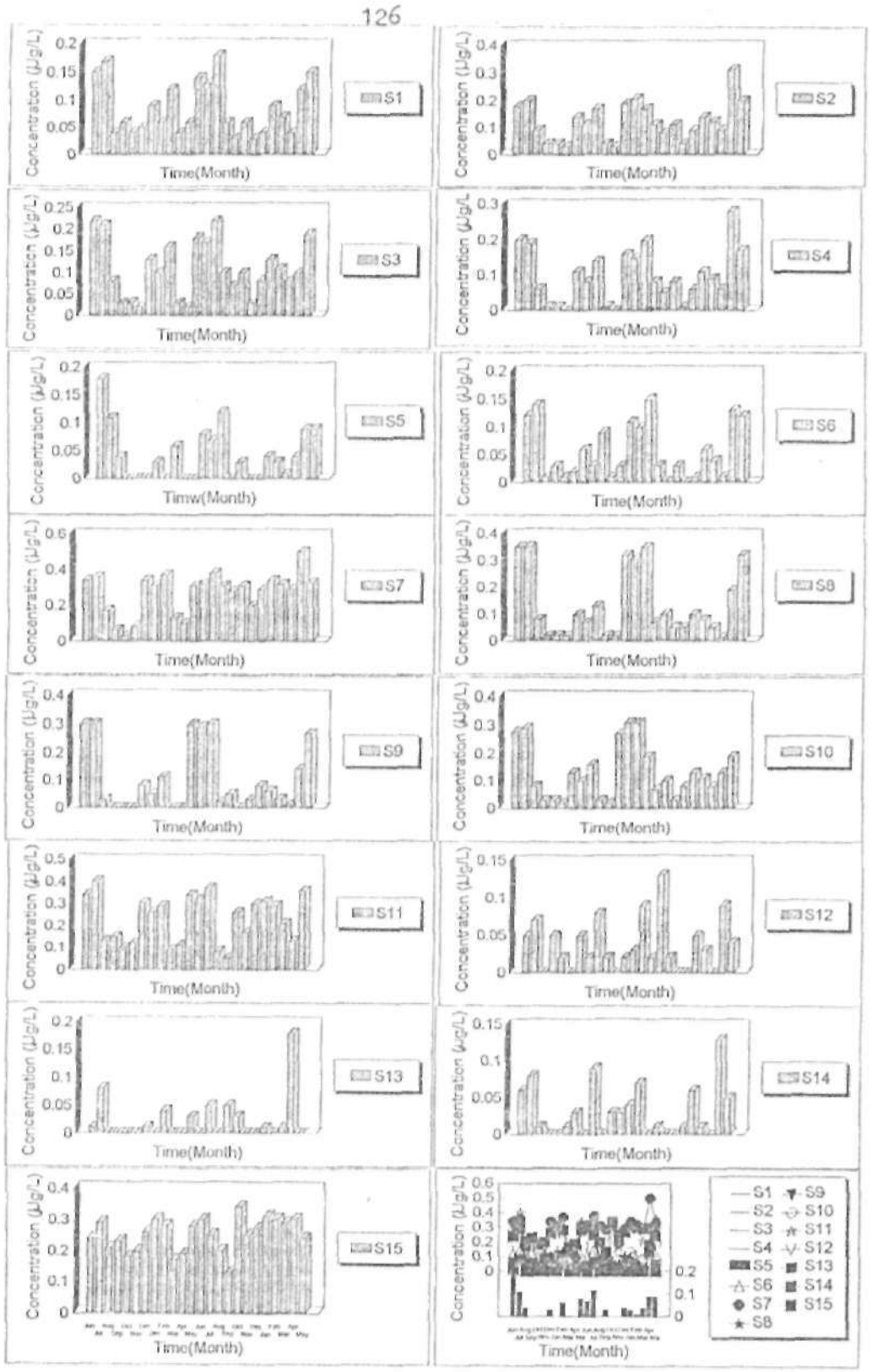


Fig.21 monthly variation in concentration of arsenic in water (µg/L x 10-1) .

TABLE 20a VARIATION IN CONCENTRATION OF ARSENIC IN WATER.

Dry Season Mean	0.09572
Rainy Season Mean	0.13244
First Year General Mean	0.10378
Second Year General Mean	0.12439

ANALYSIS OF VARIANCE (ANOVA)

Procedure

Source of Variation	DF	Sum of Squares	Mean Square	F Value	Pr > F
REP.	5	0.44488583	0.08897717	21.94	0.0001
YEAR	1	0.03823361	0.03823361	9.43	0.0023
REP(YEAR)	5	0.16454806	0.03290961	8.11	0.0001
SEASON	1	0.12136694	0.12366944	29.92	0.0001
STATIONS	14	2.11724333	0.15123167	37.29	0.0001
SEASON BY STATIONS	14	0.14707889	0.01050563	2.59	0.0015
SEASON BY YEAR	2	0.00342250	0.00342250	0.84	0.3591
YEAR BY STATIONS	14	0.05724556	0.00408183	1.01	0.4467
SEASON BY YR. BY STS.	14	0.00959000	0.00068500	0.17	0.9997

alpha = 0.01.

TABLE 20b DUNCAN'S MULTIPLE RANGE TEST

DUNCAN'S GROUPING	MEAN	N	STATION
A	0.2696	24	7
B A	0.2504	24	15
B	0.2283	24	11
C	0.1325	24	8
C	0.1321	24	10
D C	0.1221	24	2
D C	0.1079	24	3
D C	0.1021	24	9
D E	0.0963	24	4
D E	0.0842	24	1
F	0.0558	24	6
F	0.0425	24	5
F	0.0367	24	12
F	0.0300	24	14
F	0.0208	24	13

alpha = 0.05

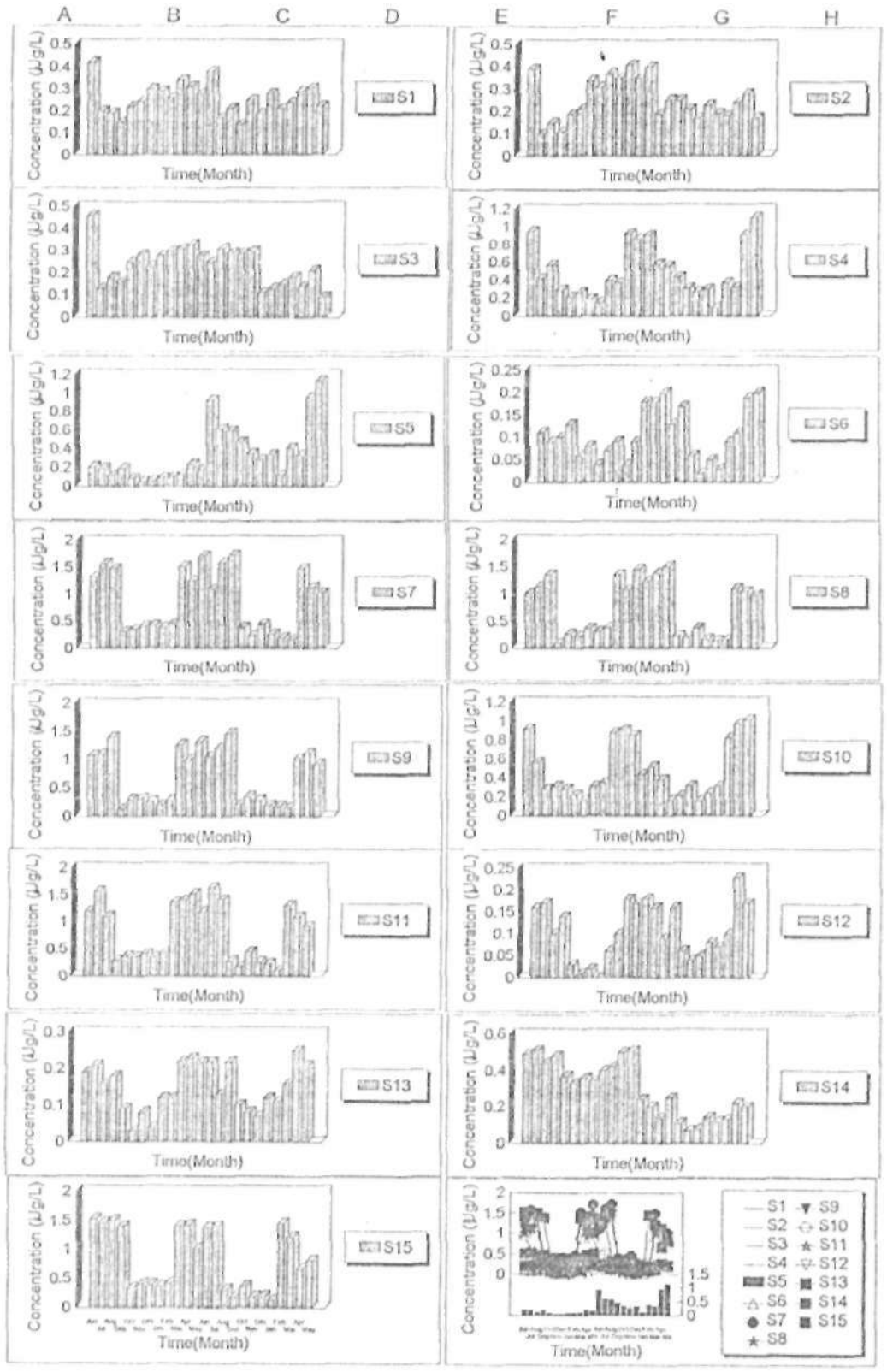


Fig.22 Monthly variation in concentration of zinc in water (µg/L) .

TABLE 21a VARIATION IN CONCENTRATION OF ZINC IN WATER.

Dry Season Mean	0.3673
Rainy Season Mean	0.5206
First Year General Mean	0.4606
Second Year General Mean	0.4273

ANALYSIS OF VARIANCE (ANOVA)

Procedure

Source of Variation	DF	Sum of Squares	Mean Square	F Value	Pr > F
REP.	5	0.02393583	0.00478717	0.04	0.9990
YEAR	1	0.09966694	0.09966694	0.86	0.3546
REP(YEAR)	5	0.03923806	0.00784761	0.07	0.9968
SEASON	1	2.11446694	2.11446694	18.24	0.0001
STATIONS	14	26.14754833	1.86768202	16.11	0.0001
SEASON BY STATIONS	14	1.94848722	0.13917766	1.20	0.2741
SEASON BY YEAR	2	0.01921361	0.01921361	0.17	0.6842
YEAR BY STATIONS	14	2.03143722	0.14510266	1.25	0.2375
SEASON BY YR. BY STS.	14	0.40120722	0.02865766	0.25	0.9978

alpha = 0.01.

TABLE 21b DUNCAN'S MULTIPLE RANGE TEST

DUNCAN'S GROUPING	MEAN	N	STATION
A	0.8737	24	7
A	0.8283	24	15
A	0.8100	24	11
A	0.7333	24	8
A	0.7054	24	9
B	0.4908	24	4
B	0.4833	24	10
C B	0.3417	24	5
C B D	0.2938	24	14
C D	0.2533	24	1
C D	0.2517	24	2
C D	0.2350	24	3
C D	0.1483	24	13
D	0.1054	24	12
D	0.1046	24	6

alpha = 0.05

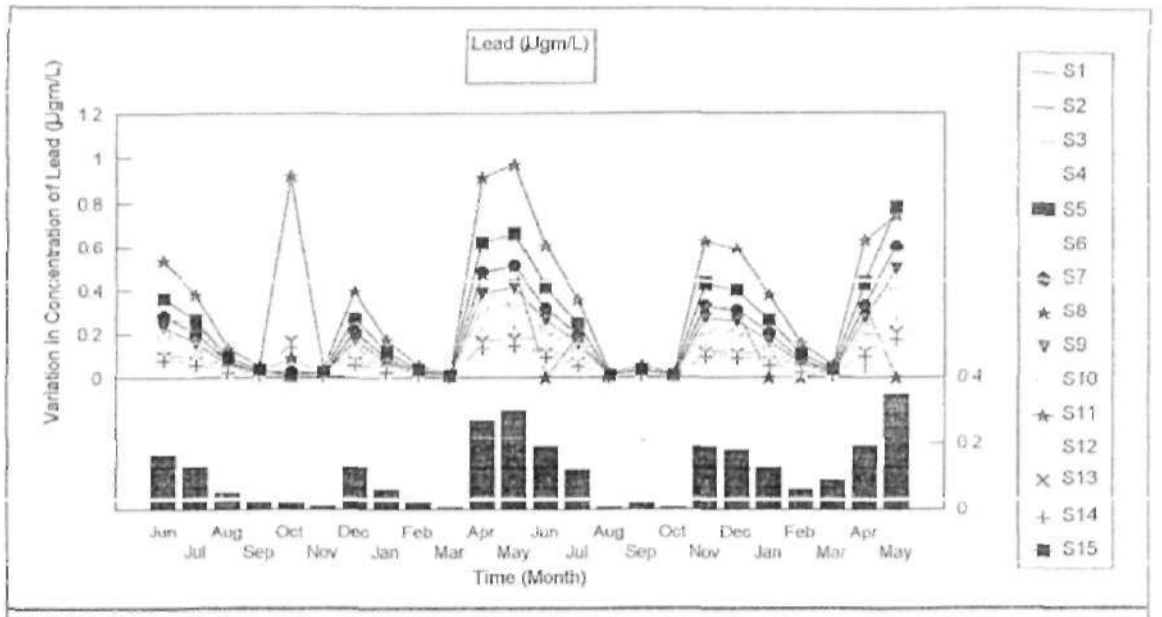


Fig. 22b. Monthly Variations in Concentrations of Lead, Arsenic and Zinc.

4.2.5.5 Manganese :

Fluctuation in concentrations of Mn fall within the range of 0.0 to 0.3 µg/L(Fig.23). The concentrations were generally low in May. The variation (Table 21a) with season, between stations, season by stations and season by year was highly significant ($P < 0.01$). Station 7 recorded the highest GSM of 0.4575. The lowest GSM was recorded at station 5, being 0.0954 µg/L. The analysis of interactions among parameters (correlation, table 1d) indicates highly significant positive correlation between Mn and hardness, conductivity, Ca, Mg, Na, Fe, Zn, As, Pb, Cu, K, Cd, Cl, BOD, and NO_3-N

($P < 0.01$). The correlation with temperature was negative and significant ($P < 0.05$).

4.2.5.6 Cadmium:

Cadmium concentrations were generally less than 0.05 µg/L and attained peaks in mid-rainy season (Fig. 24). The concentrations of cadmium were generally low in most of the stations, with the exception of stations 7, 8, 9, 10, 11 and 15 9. Station 11 (OWS) recorded the highest GSM of 0.14750 µg/L. Station 6 (RWS) had the lowest GSM of 0.02208 µg/L (Table 23b). Variations with year, stations and seasons were highly significant ($P< 0.01$). Increase in concentrations of Cd had significant positive effect on the increase in SS, hardness, Ca, Mg, Na, Fe, Zn, As, Pb, Cu, K, Mn, Do, Cl, PO_4-P, NO_3-N, BOD and electrical conductivity ($P < 0.01$).

4.2.5.7 Copper :

The variations in concentrations of Cu (Table 24a) were highly significant between months, year, seasons, stations and season by stations ($P < 0.01$). station 11

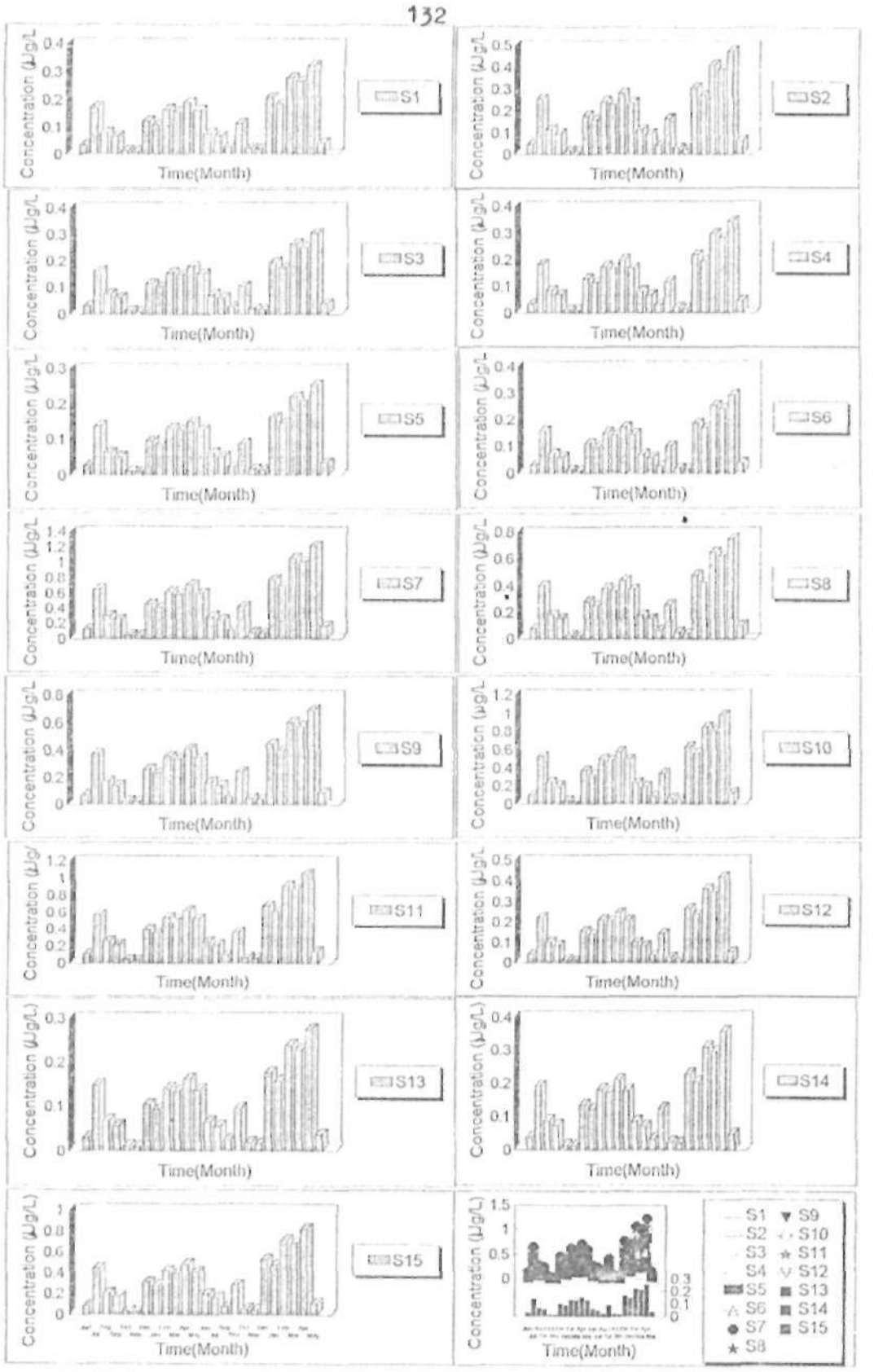


Fig.23 monthly variation in concentration of manganese in water (Ug/L) .

TABLE 22a VARIATION IN CONCENTRATION OF MANGANESE IN WATER.

Dry Season Mean	0.3009
Rainy Season Mean	0.1291
First Year General Mean	0.1890
Second Year General Mean	0.2411

ANALYSIS OF VARIANCE (ANOVA)

Procedure

Source of Variation	DF	Sum of Squares	Mean Square	F Value	Pr > F
REP.	5	1.05835139	0.21167028	12.95	0.0001
YEAR	1	0.24388028	0.24388028	14.92	0.0001
REP(YEAR)	5	0.68673139	0.13774628	8.43	0.0001
SEASON	1	2.65740250	2.65740250	162.55	0.0001
STATIONS	14	4.97015389	0.35501099	21.72	0.0001
SEASON BY STATIONS	14	0.79705167	0.05693226	3.48	0.0001
SEASON BY YEAR	2	0.98282250	0.98282250	60.13	0.0001
YEAR BY STATIONS	14	0.07145722	0.00510409	0.31	0.9923
SEASON BY YR. BY STS.	14	0.29364833	0.02097488	1.28	0.2166

alpha = 0.01.

TABLE 22b DUNCAN'S MULTIPLE RANGE TEST

DUNCAN'S GROUPING	MEAN	N	STATION
A	0.4575	24	7
B A	0.3983	24	11
B A	0.3704	24	10
D A	0.3104	24	15
D	0.2813	24	8
D	0.2621	24	9
E	0.1775	24	2
E	0.1587	24	12
E	0.1333	24	14
E	0.1292	24	4
E	0.1204	24	1
E	0.1154	24	3
E	0.1104	24	6
E	0.1050	24	13
E	0.0954	24	5

alpha = 0.05

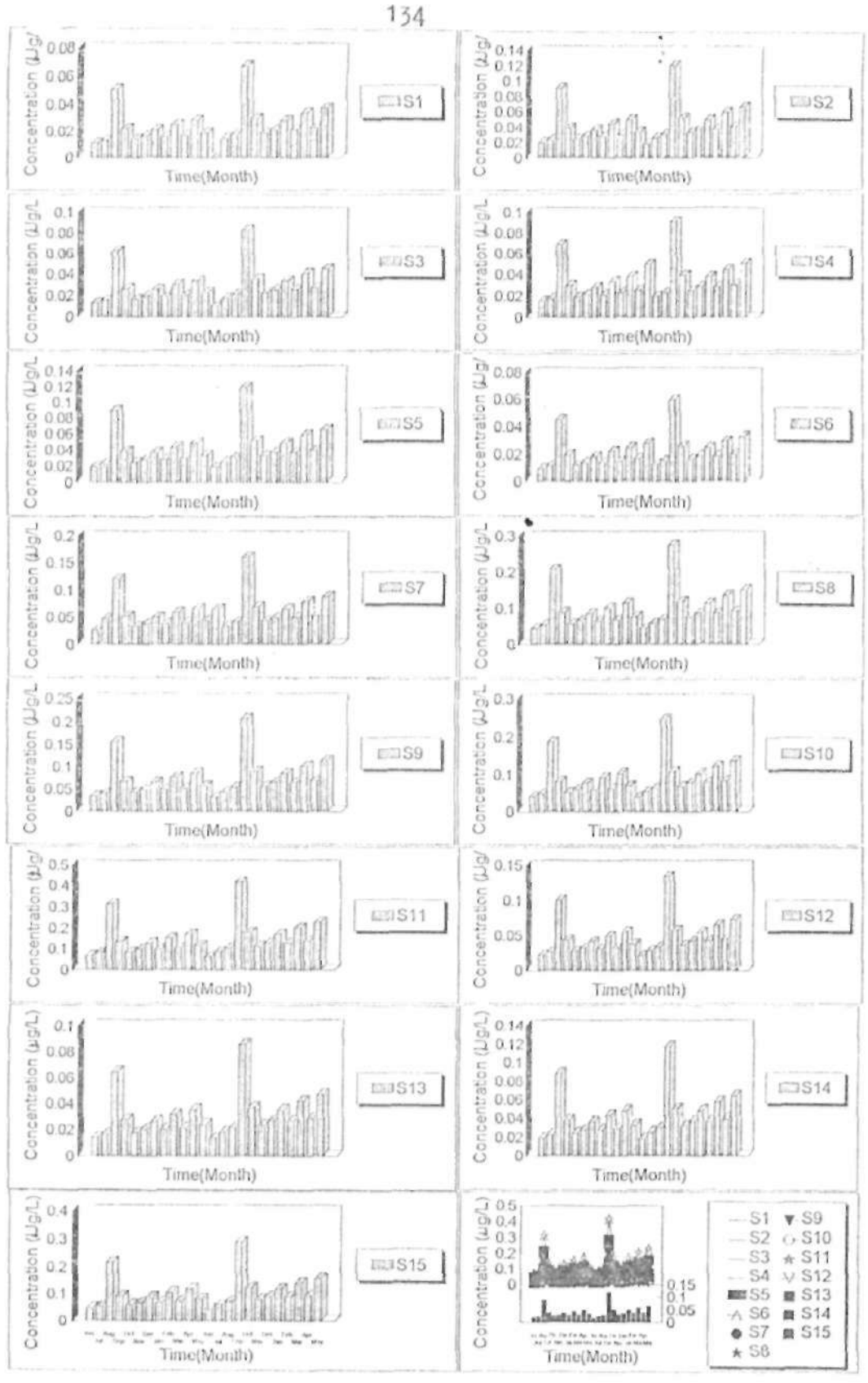


Fig.24 monthly variation in concentration of cadmium in water (µg/L) .

TABLE 23a VARIATION IN CONCENTRATION OF CADMIUM IN WATER.

Dry Season Mean	0.05483
Rainy Season Mean	0.06294
First Year General Mean	0.05161
Second Year General Mean	0.06617

ANALYSIS OF VARIANCE (ANOVA)

Procedure

Source of Variation	DF	Sum of Squares	Mean Square	F Value	Pr > F
REP.	5	1.08185889	0.01637178	19.16	0.0001
YEAR	1	0.01906778	0.01906778	22.31	0.0001
REP(YEAR)	5	0.11354889	0.02270978	26.57	0.0001
SEASON	1	0.00592111	0.00592111	6.93	0.0089
STATIONS	14	0.43678889	0.03119921	36.51	0.0001
SEASON BY STATIONS	14	0.00264556	0.00019997	0.22	0.9988
SEASON BY YEAR	2	0.00277778	0.00077778	3.25	0.0724
YEAR BY STATIONS	14	0.00554889	0.00039635	0.46	0.9506
SEASON BY YR. BY STS.	14	0.00077222	0.00005516	0.06	1.0000

alpha = 0.01.

TABLE 23b DUNCAN'S MULTIPLE RANGE TEST

DUNCAN'S GROUPING	MEAN	N	STATION
A	0.14750	24	11
B	0.10250	24	15
B	0.09833	24	8
C B	0.08792	24	10
C D	0.07375	24	9
E D	0.05917	24	7
E F	0.04708	24	12
E F G	0.04250	24	2
E F G	0.04250	24	5
E F G	0.04208	24	14
H F G	0.03375	24	4
H F G	0.03083	24	13
H F G	0.02958	24	3
H G	0.02375	24	1
H	0.02208	24	6

alpha = 0.05

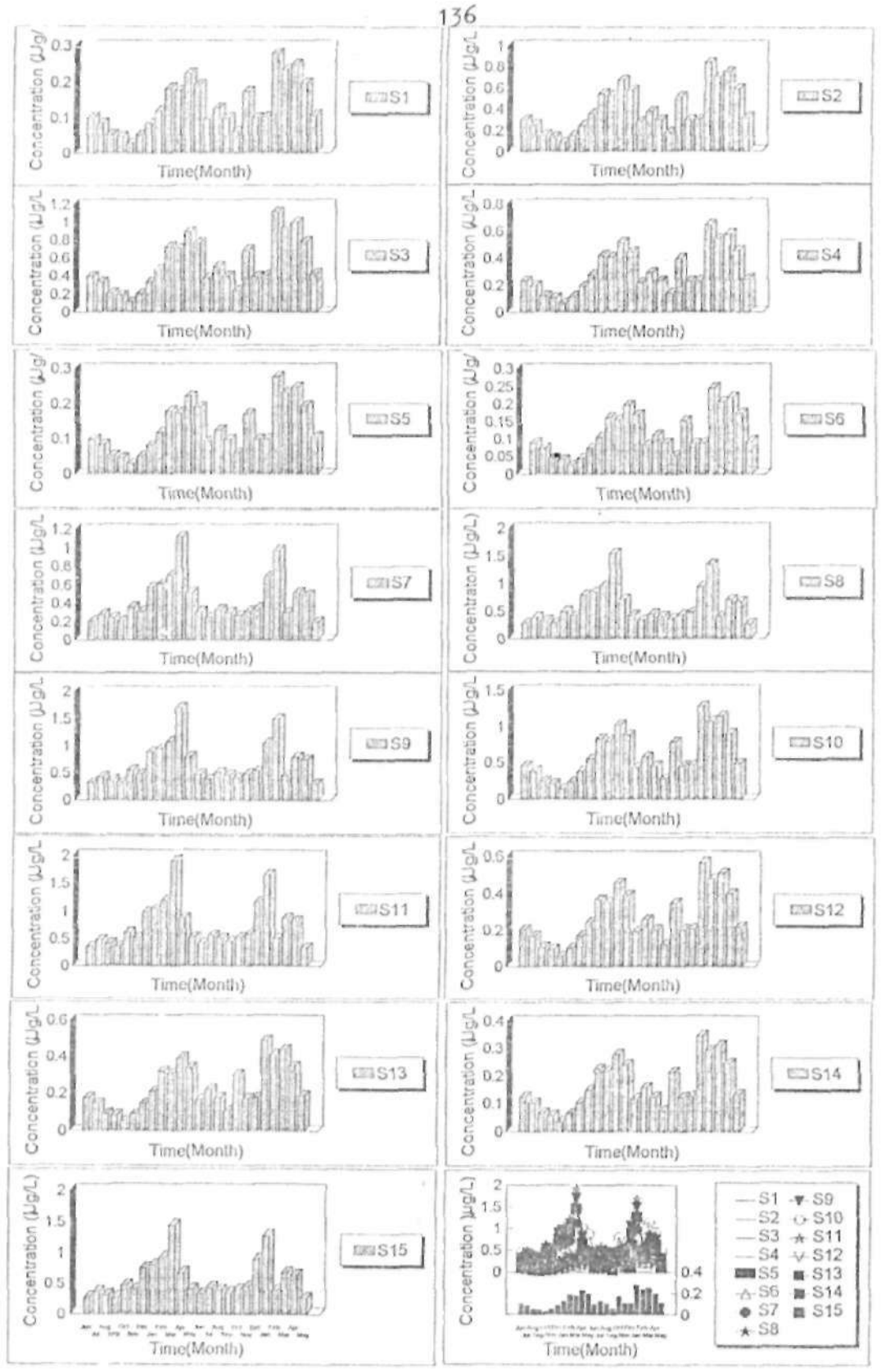


Fig.25 monthly variation in concentration of copper in water (µg/L) .

TABLE 24a VARIATION IN CONCENTRATION OF COPPER IN WATER.

Dry Season Mean	0.5178
Rainy Season Mean	0.2664
First Year General Mean	0.3718
Second Year General Mean	0.4124

ANALYSIS OF VARIANCE (ANOVA)

Procedure

Source of Variation	DF	Sum of Squares	Mean Square	F Value	Pr > F
REP.	5	1.31126289	0.26225378	8.05	0.0001
YEAR	1	0.14802778	0.14802778	4.55	0.0338
REP(YEAR)	5	0.90329889	0.18065978	5.55	0.0011
SEASON	1	5.68516000	5.68516000	174.57	0.0001
STATIONS	14	15.55097889	1.11364135	34.20	0.0001
SEASON BY STATIONS	14	2.42607333	0.17329095	5.32	0.0001
SEASON BY YEAR	2	0.00013444	0.00013444	0.00	0.9488
YEAR BY STATIONS	14	0.56412222	0.04029444	1.24	0.2473
SEASON BY YR. BY STS.	14	0.21146556	0.01510468	0.46	0.9906

alpha = 0.01.

TABLE 24b DUNCAN'S MULTIPLE RANGE TEST

DUNCAN'S GROUPING	MEAN	N	STATION
A	0.7417	24	11
B A	0.6671	24	9
B C	0.6038	24	10
B C	0.6008	24	8
B C	0.5667	24	15
D C	0.5250	24	3
D E	0.4358	24	7
F E	0.3950	24	2
F E	0.3042	24	4
F G	0.2675	24	12
H G	0.2321	24	13
H G I	0.1633	24	14
H J I	0.1321	24	1
H J I	0.1308	24	5
H J	0.1158	24	6

alpha = 0.05

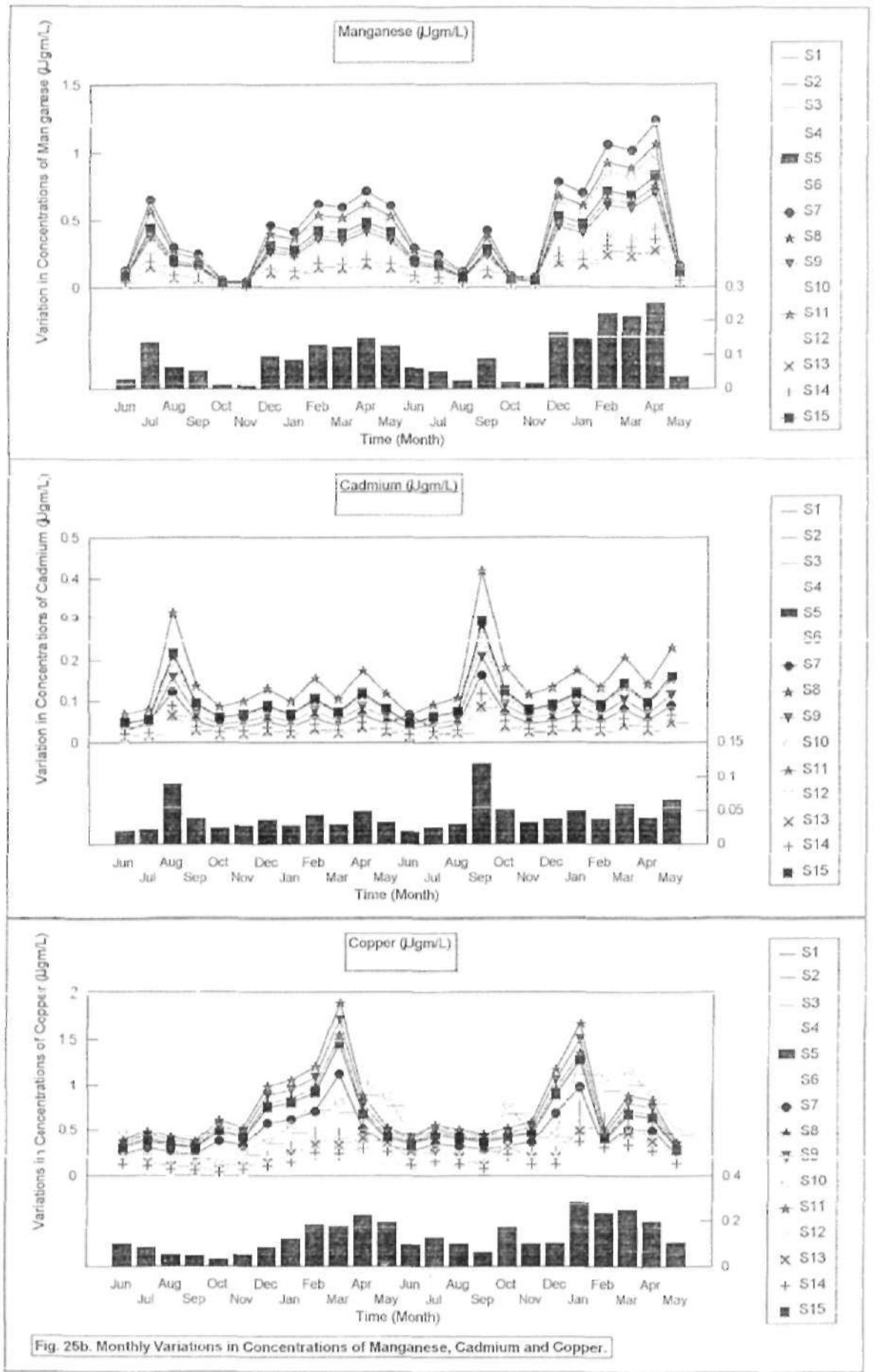


Fig. 25b. Monthly Variations in Concentrations of Manganese, Cadmium and Copper.

(OWS) contained the highest GSM of 0.7417 µg/L. Station 6 (RWS) recorded the lowest GSM of 0.1158 µg/L (Table 24b). The RSM was 0.264 µg/L, which was lower than that of the dry season being 0.5178 µg/L. The differences between FYGM and SYGM was less than 0.1 µg/L (Table 23a). The correlation (Table 1c) with hardness Ca, Mg, Na, Fe, Zn, As, Pb, K, Cd, Mn, DO, Cl, BOD, NO_3-N and electrical conductivity was positive and highly significant ($P < 0.01$). The increase in Cu concentration was accompanied by highly significant decrease in temperature ($P < 0.01$)

4.3.0 Biological Parameters

4.3.1 Phytoplankton:

The phytoplankton population had DSM of 15 organisms per litre (OPL) which turn out to be lower than the RSM of 19 OPL . The FYGM was 15 OPL and the SYGM recorded 20 OPL. Station 11 (OWS) recorded the highest GSM of 48 OPL. Stations 3, 12, 13 and 14 recorded zero (Table 25b). Analysis of variance (Table 25b) indicates highly significant difference between months of sampling, year, season, stations, season by stations, year by stations and season by stations ($P< 0.01$).

The number of phytoplankton recorded correlate positively with increase in the concentrations of Ca, Mg, Na, Zn, SS, hardness, PO_4-P, NO_3-N, BOD and electrical conductivity ($P< 0.01$). The detailed list of phytoplankton genera recovered is provided (Table 26c).

4.3.2 Zooplankton:

Stations 1, 2, 3, 4, 5, 12, 13 and 14 recorded zero zooplankton population per litre throughout the period of sampling (Table 26b). Zooplankton population in other

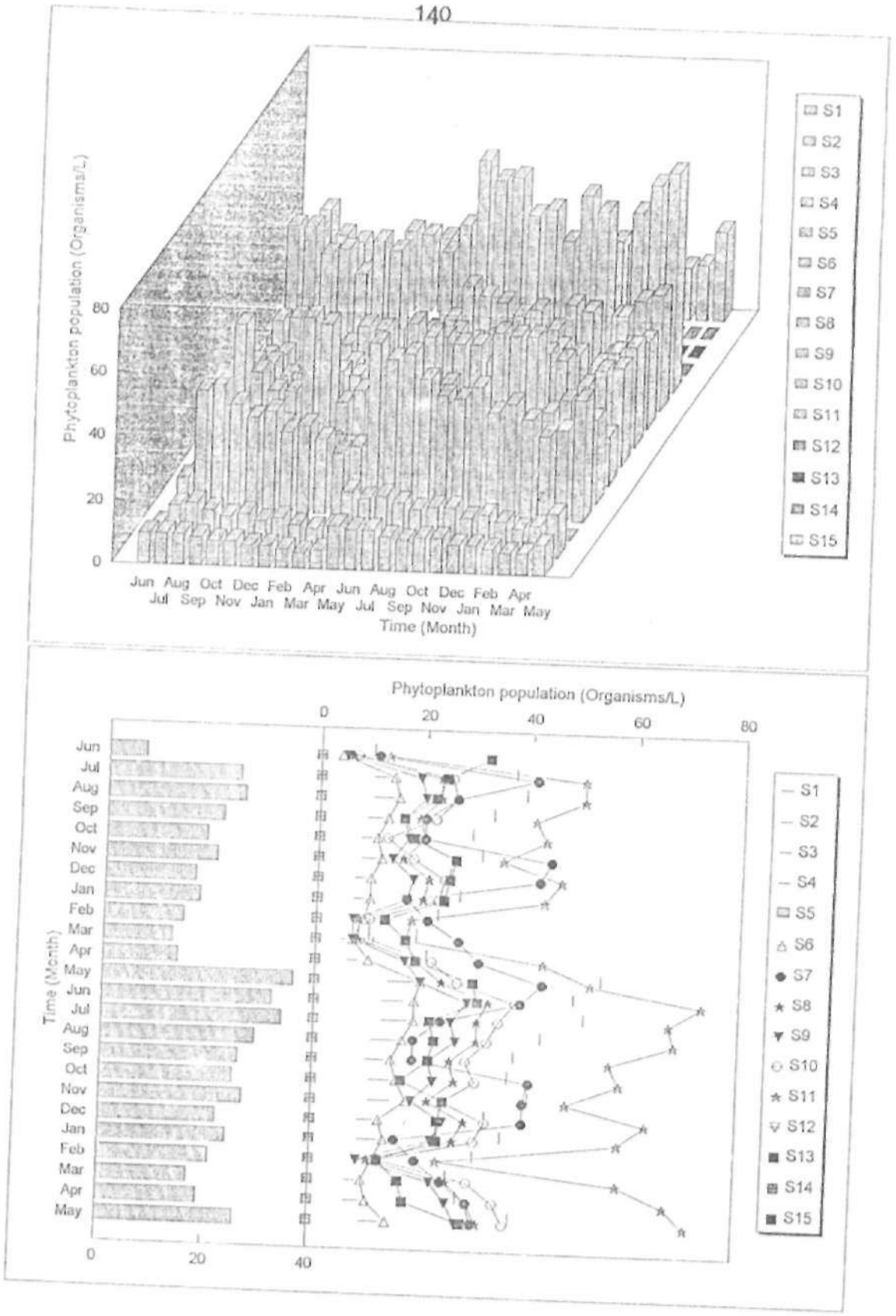


Fig.26. monthly variation in phytoplankton population (org./L).

TABLE 25a VARIATION IN PHYTOPLANKTON ABUDNDANCE IN WATER.

Dry Season Mean	15.289
Rainy Season Mean	18.794
First Year General Mean	14.583
Second Year General Mean	19.500

ANALYSIS OF VARIANCE (ANOVA)

Procedure

Source of Variation	DF	Sum of Squares	Mean Square	F Value	Pr > F
REP.	5	1214.42500	242.88500	7.89	0.0001
YEAR	1	2175.62500	2175.62500	70.65	0.0001
REP(YEAR)	5	758.29167	151.65833	4.92	0.0001
SEASON	1	1106.00278	1106.00278	35.92	0.0001
STATIONS	14	67155.33333	4796.80952	155.77	0.0001
SEASON BY STATIONS	14	1031.95556	73.71111	2.39	0.0036
SEASON BY YEAR	2	30.62500	30.62500	0.99	0.3195
YEAR BY STATIONS	14	3190.50000	227.89286	7.40	0.0001
SEASON BY YR. BY STS.	14	49.16667	3.51190	0.11	1.000

alpha = 0.01.

TABLE 25b DUNCAN'S MULTIPLE RANGE TEST

DUNCAN'S GROUPING	MEAN	N	STATION
A	48.417	24	11
B	33.292	24	4
C	28.625	24	7
D	25.292	24	10
E D	22.292	24	5
E D	22.167	24	8
E D	22.125	24	15
E	19.042	24	9
F	13.038	24	6
G F	12.167	24	2
G	9.125	24	1
H	0.000	24	12
H	0.000	24	13
H	0.000	24	14
H	0.000	24	3

alpha = 0.05

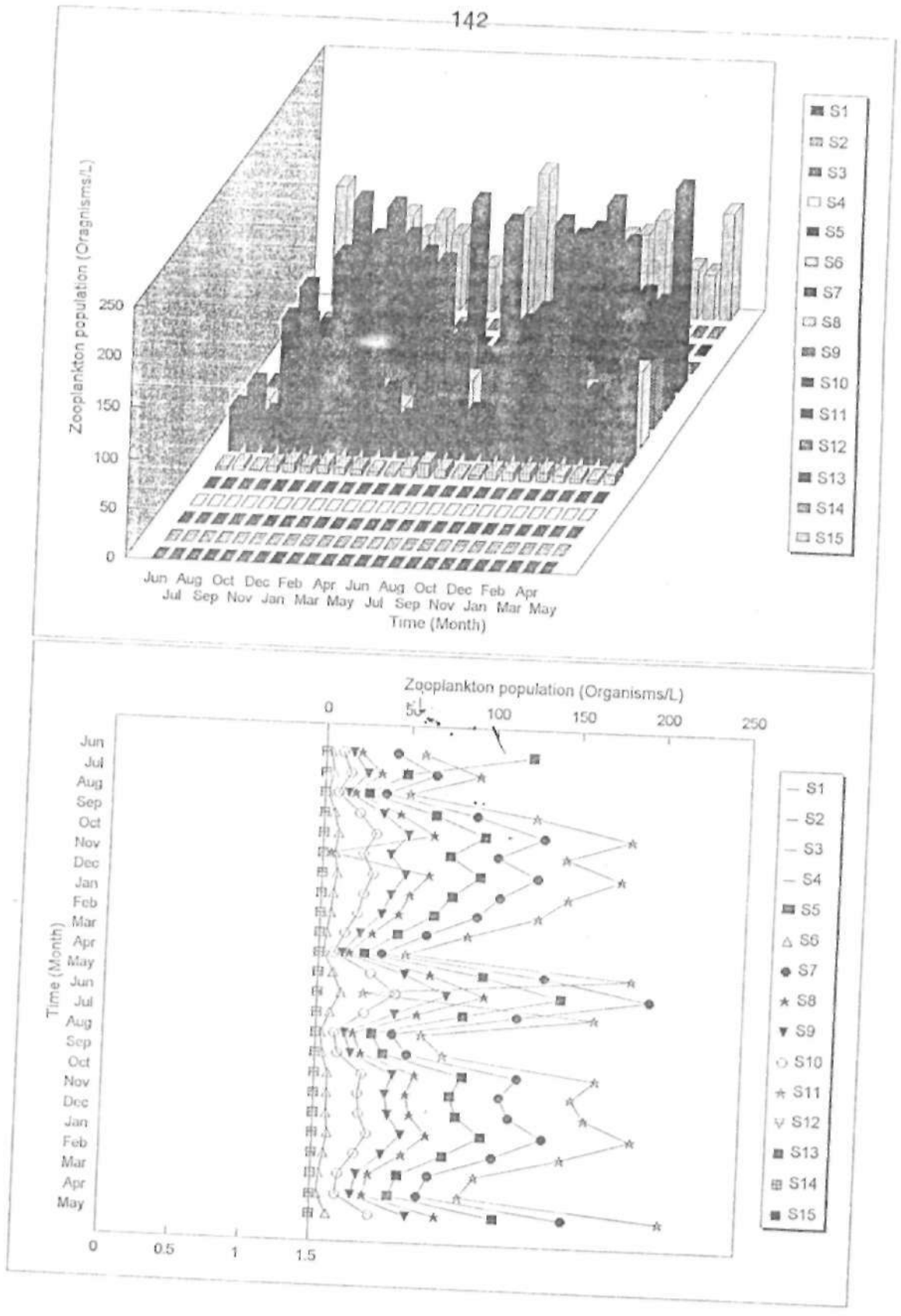


Fig.27. monthly variation in zooplankton population (org./L).

TABLE 26a VARIATION IN ZOOPLANKTON ABUNDANCE IN WATER.

Dry Season Mean	26.867
Rainy Season Mean	27.283
First Year General Mean	24.978
Second Year General Mean	29.172

ANALYSIS OF VARIANCE (ANOVA)

Procedure

Source of Variation	DF	Sum of Squares	Mean Square	F Value	Pr > F
REP.	5	12556.958	2511.3917	6.34	0.0001
YEAR	1	1583.4028	1583.4028	4.00	0.0465
REP(YEAR)	5	2397.9139	479.5828	1.21	0.3042
SEASON	1	15.6250	15.6250	0.04	0.8427
STATIONS	14	548657.7667	39189.8405	98.92	0.0001
SEASON BY STATIONS	14	2050.1667	146.4405	0.37	0.9823
SEASON BY YEAR	2	66.7361	66.7361	0.17	0.6818
YEAR BY STATIONS	14	3140.5556	224.3254	0.57	0.8903
SEASON BY YR. BY STS.	14	1044.8889	74.8492	0.19	0.9995

alpha = 0.01.

TABLE 26b DUNCAN'S MULTIPLE RANGE TEST TABLE

DUNCAN'S GROUPING	MEAN	N	STATION
A	122.583	24	11
B	95.992	24	7
C	73.875	24	15
D	47.667	24	8
E D	37.000	24	9
E D	22.625	24	10
E D	6.583	24	6
E	0.000	24	4
F	0.000	24	5
G F	0.000	24	2
G	0.000	24	1
H	0.000	24	12
H	0.000	24	13
H	0.000	24	14
H	0.000	24	3

alpha = 0.05

stations correlated positively with increase in SS, TS, hardness, Ca, Mg, Mn, DO, pH, electrical conductivity, macronutrients and BOD ($P < 0.01$). The correlation with COD was negative ($P < 0.05$). The zooplankton were copepods, rotifers and cladocerans.

Combined list of the total plankton is provided (Table 26c). Plates xxxi to xxxiii represent some of the zooplankton genera recorded and xxxiv to xlii represent some of the phytoplankton genera.

4.3.3 Eschericia coli MPN-index:

The MPN index for E. coli exhibited low DSM of 10/100ml. of water sample. The RSM was much higher being 13/100ml of the sampled water sources. There were close similarities between FYGM and SYGM. Analysis of variance (Table 27a) indicates highly significant difference between seasons, stations, season by stations and year by stations ($P < 0.01$). Stations 7, 8, 10, 11 and 15 had the highest *E. coli* MPN index of infinity. Station 3 recorded the lowest. The result infers that the *E. coli* indices for all the OWSs were extremely high (infinity). Stations 8 and 10 that were located in close proximity to toilets, gutters and along the major drains had infinite indices.

Correlation analysis (Table 1c), shows increase in SS, TS, hardness, Ca, Ma, Na, K, Fe, Mn, OD, DO, PO_4-P, NO_3-N, BOD, zooplankton, phytoplankton and *S. faecalis* to be accompanied by corresponding increase in *E. coli* index.

4.3.4 *Streptococcus faecalis* MPN-index:

Streptococcus faecalis count was drastically lower compared to that of *E. coli* index. It was virtually zero during the dry season, and the RSM was 1/100 ml of water

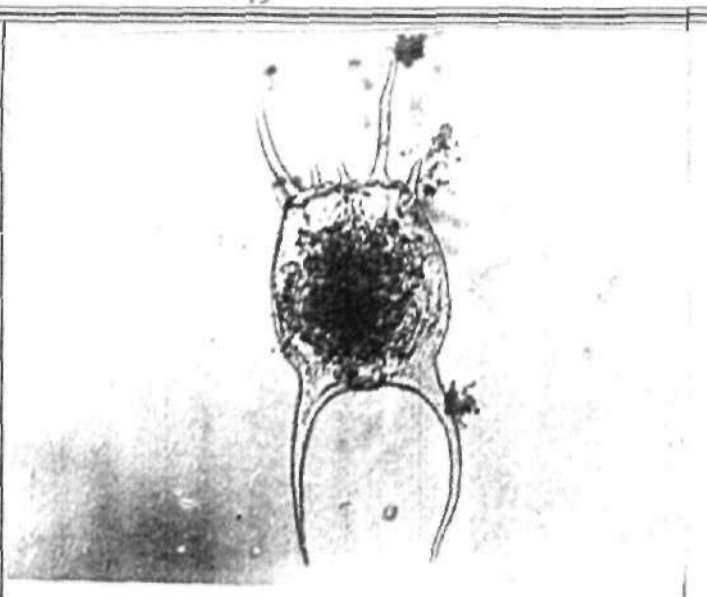


Plate xxv *Keratella sp.*

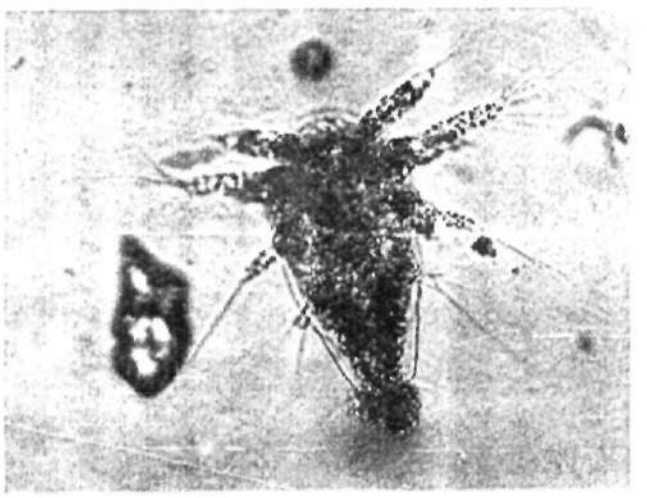


Plate xxvi Copepodan Nauplius



Plate xxvii *Cyclops sp.*

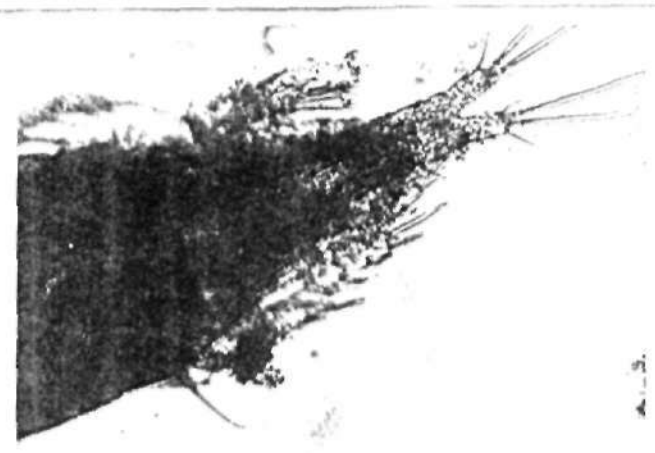


Plate xxviii *Cyclops sp.* (Posterior View)

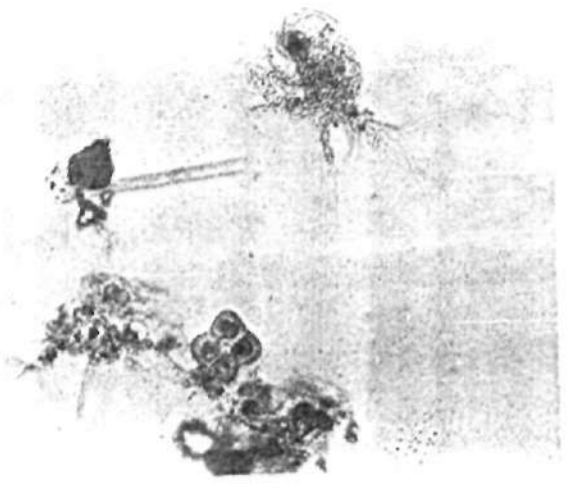


Plate xxix *Moina sp* in association with *Phytoconis sp.*

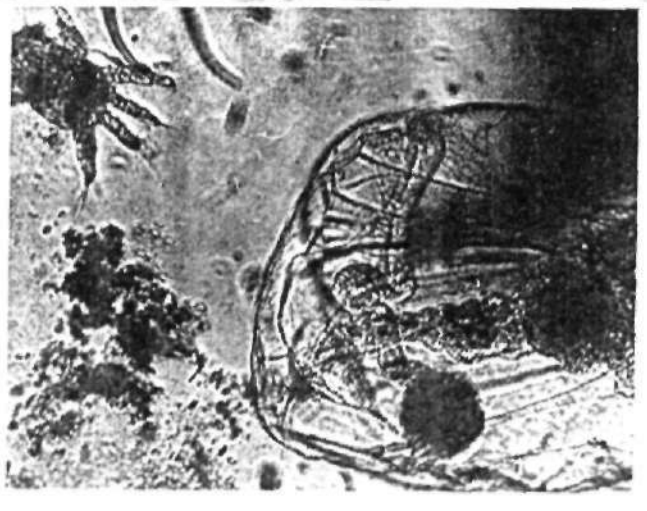


Plate xxx *Daphnia sp.* (anterior region) in association with Nauplius.

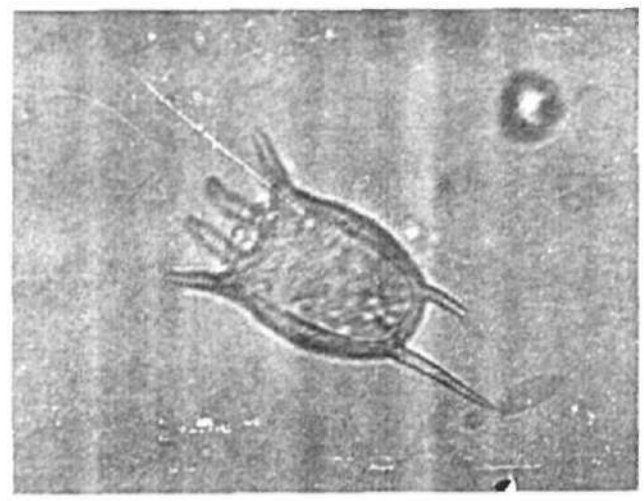


Plate xxxi *Keraiella sp.*

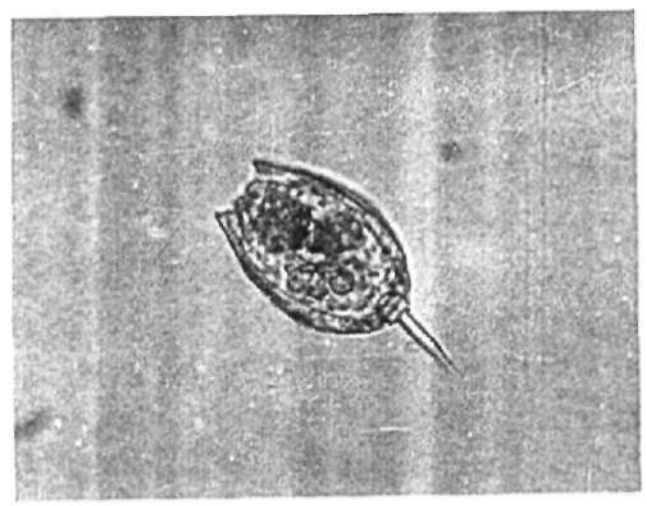


Plate xxxii *Kellikottia sp.*



Plate xxxiii Copepodan Nauplius. (dorsal view)

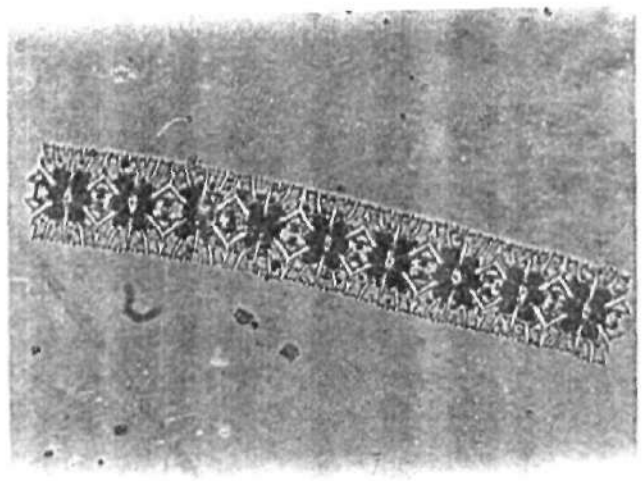


Plate xxxiv *Zygnema sp.*



Plate xxxv *Compsopogon sp .*

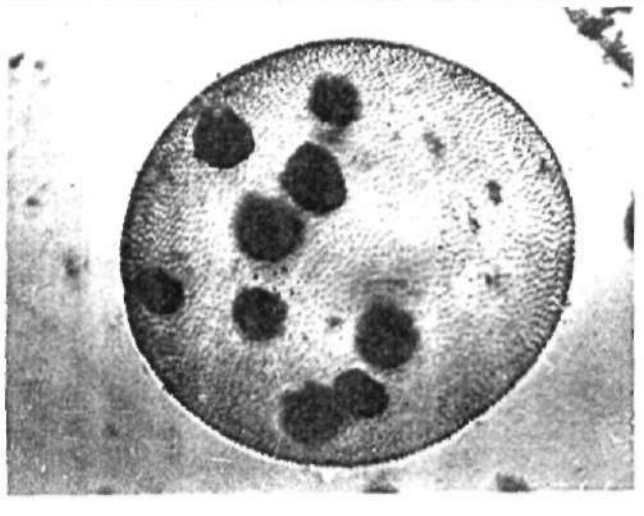


Plate xxxvi *Volvox sp.*

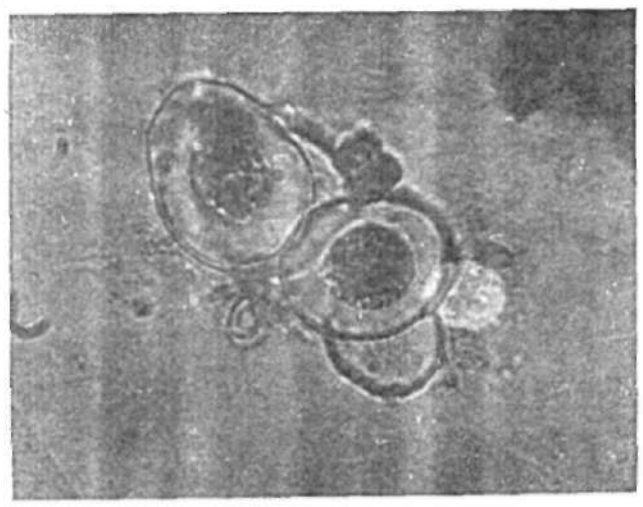


Plate xxxvii *Chlamydomonas sp.*



Plate xxxviii *Phacotus sp .*

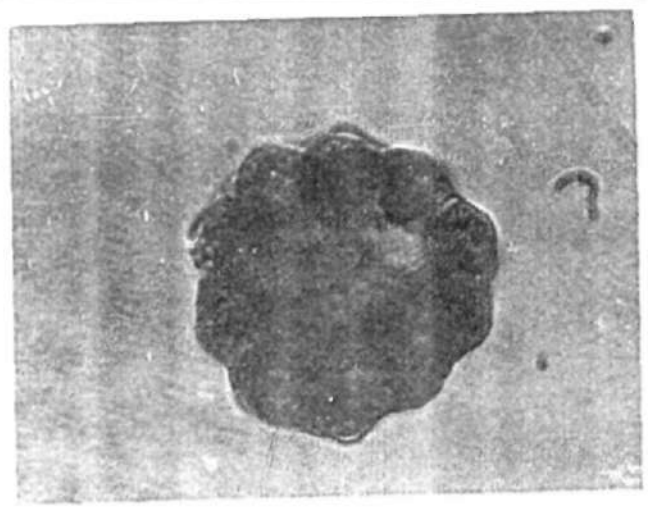


Plate xxxix *Coelastrum sp.*

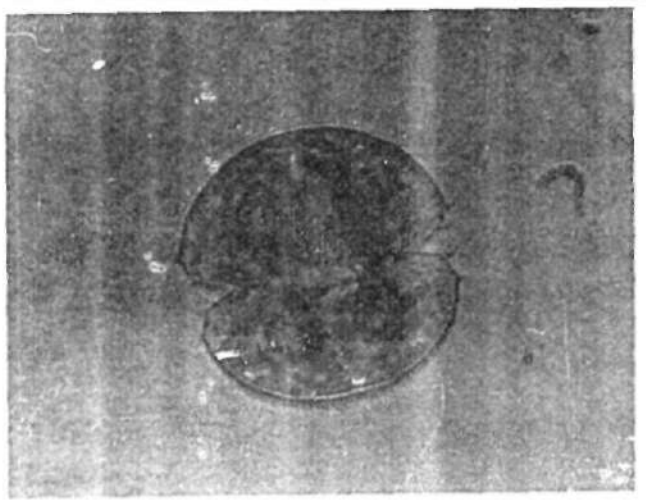


Plate xl *Staurastrum sp.*

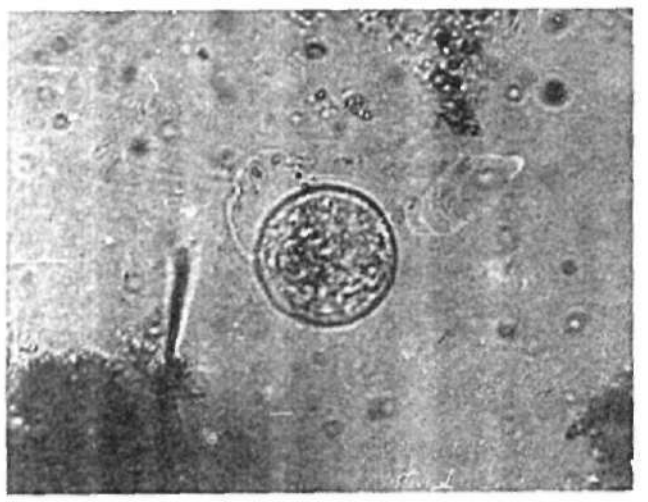


Plate xli *Chlorella sp .*

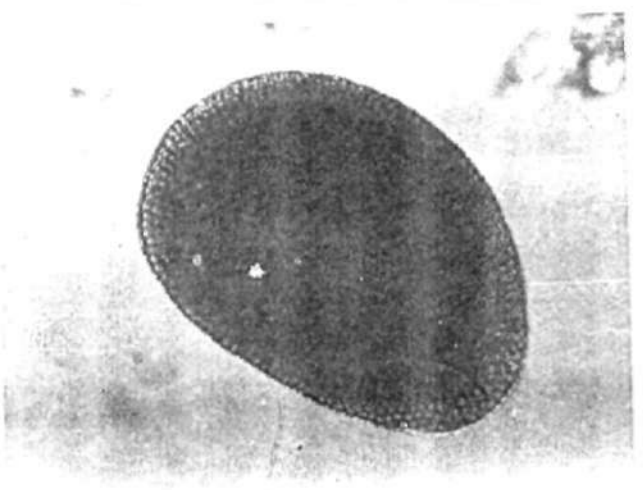


Plate xliii *Uroglenopsis sp.*

Table 26c The monthly variations in the plankton recorded during the 24 months of sampling.

	Vorax sp.	Conosplanon sp.	Dolestrum sp.	Zygnema sp.	Staurastrum sp.	Pinnotus sp.	Diadiaptora sp.	Phynotopsis sp.	Cyclotella sp.	Chlorella sp.	Chlamydomonas sp.	Spirogyra sp.	Promidium sp.	Euglena sp.	Closra sp.	Total(Phyto)	Keratella sp.	Copepodan nauph	Brachionus sp.	Cyclops sp.	Kellicottia sp.	Daphnia sp.	Diaphanosoma sp.	Bosmina sp.	Moina sp.	Total(Zoo)	Grand Tot
Jun	4	9	6	10	3	1	6	8	1	2	15	13	6	11	17	112	36	29	28	44	23	42	41	16	13	272	384
Jul	21	43	10	39	5	2	7	23	5	9	37	32	15	18	14	281	32	32	26	42	34	46	32	20	18	282	563
Aug	26	47	9	32	5	3	11	20	8	3	31	19	13	25	20	271	18	13	19	16	15	20	20	24	9	154	425
Sep	18	31	5	27	2	4	15	16	9	7	27	11	18	12	11	223	50	66	43	54	48	59	28	19	21	388	611
Oct	20	23	11	20	3	7	12	17	6	3	23	19	15	9	17	208	68	92	47	76	55	121	32	20	50	551	759
Nov	24	21	13	22	7	10	18	21	9	8	21	17	19	11	15	236	36	56	34	68	52	80	34	18	19	397	633
Dec	24	20	14	22	11	10	27	25	10	3	26	21	14	13	4	244	92	0	57	80	64	112	30	4	0	547	791
Jan	21	23	9	20	13	9	19	14	11	5	24	18	12	10	8	216	14	131	40	148	45	33	16	0	25	452	668
Feb	9	11	7	11	7	10	12	11	9	8	10	17	11	9	6	139	6	67	55	94	45	57	22	0	31	397	535
Mar	13	13	6	9	12	8	14	10	5	7	8	10	11	7	12	137	0	55	60	47	31	28	12	0	37	270	407
Apr	29	17	5	17	15	6	28	13	7	8	5	14	22	10	14	210	0	13	42	50	22	6	10	0	16	159	369
May	35	21	14	23	20	15	24	18	15	27	21	25	20	18	21	339	48	13	51	197	37	210	6	0	9	571	910
Jun	29	30	17	28	23	19	31	24	22	29	26	22	24	22	27	373	51	0	67	225	0	238	6	12	0	599	972
Jul	28	37	21	30	17	12	15	19	14	23	29	27	25	23	20	340	25	12	44	192	11	202	4	18	0	508	848
Aug	25	40	12	23	21	17	13	14	16	13	35	23	21	25	19	317	0	0	10	90	4	67	8	14	0	193	510
Sep	22	38	14	25	18	16	13	10	17	15	28	15	18	12	16	277	21	13	35	80	0	53	0	18	8	234	511
Oct	27	31	17	30	15	11	19	15	24	13	22	19	26	18	14	301	40	34	57	162	15	169	5	20	10	512	813
Nov	30	34	21	25	18	9	17	21	18	10	25	16	21	15	11	291	57	59	63	104	8	104	30	22	23	470	761
Dec	28	22	24	15	26	11	25	13	15	18	32	27	16	14	17	303	66	50	58	106	21	128	34	10	21	494	797
Jan	25	20	16	10	19	16	19	23	14	15	27	16	22	19	14	275	71	93	80	114	29	122	32	4	40	581	856
Feb	13	11	15	12	21	9	10	14	6	10	13	7	14	11	5	171	76	62	75	87	53	58	26	2	16	455	626
Mar	16	9	18	16	24	15	13	20	11	16	21	24	19	17	9	248	20	45	38	67	49	52	8	0	19	298	546
Apr	27	38	15	43	11	8	5	16	21	10	27	30	12	11	7	281	0	58	52	45	35	60	8	0	12	270	551
May	32	21	21	30	13	21	19	27	19	12	18	34	22	19	15	331	96	103	82	111	63	138	5	0	39	637	968

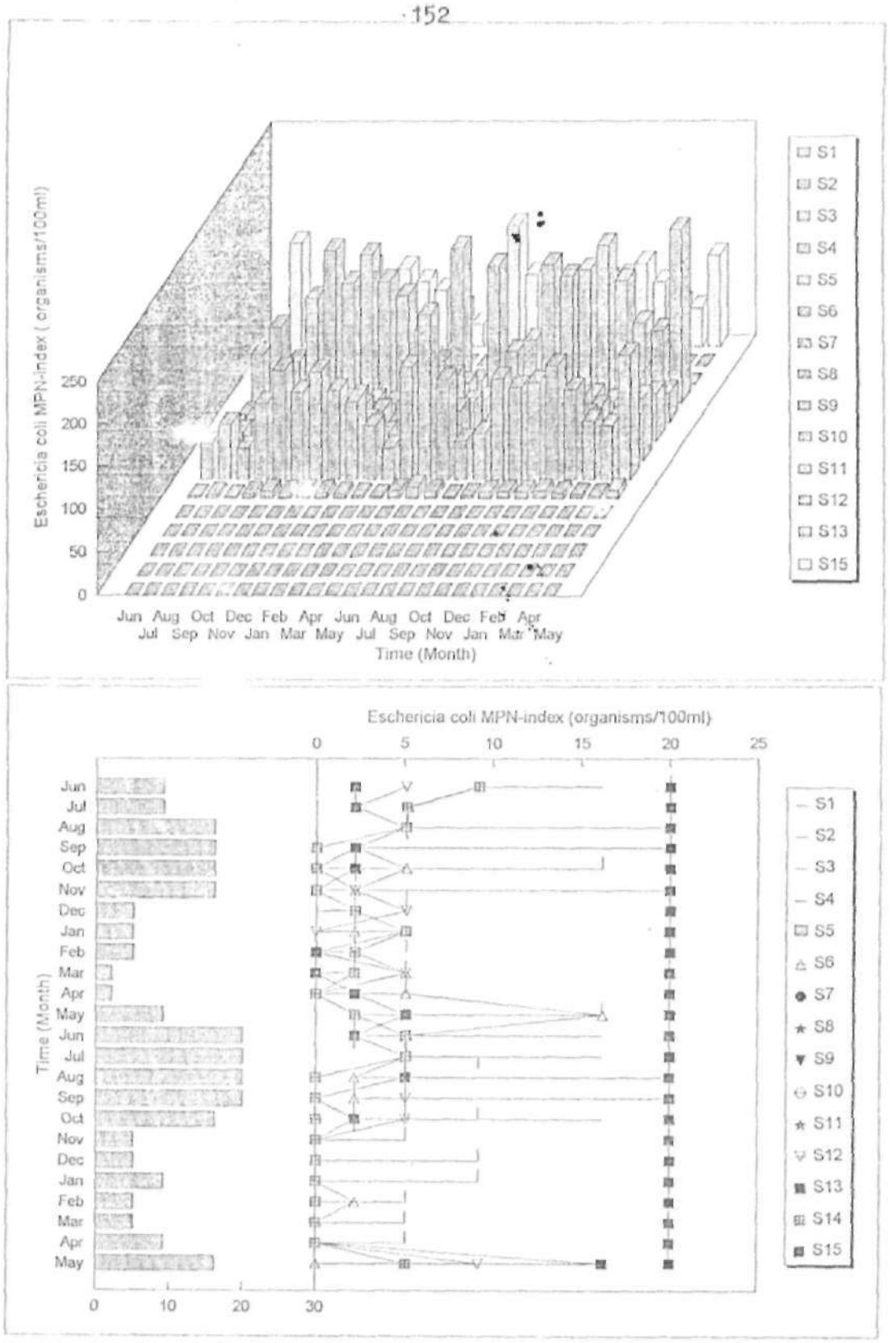


Fig.28 monthly variation in E.coli MPN-index (org./100ml).

TABLE 27a VARIATION IN E.coli MPN-INDEX IN WATER.

Dry Season Mean	9.619
Rainy Season Mean	13.001
First Year General Mean	11.435
Second Year General Mean	11.184

ANALYSIS OF VARIANCE (ANOVA)

Procedure

Source of Variation	DF	Sum of Squares	Mean Square	F Value	Pr > F
REP.	5	77.95781	15.59156	2.80	0.0173
YEAR	1	5.65003	5.65003	1.02	0.3145
REP(YEAR)	5	24.14047	4.82809	0.87	0.5030
SEASON	1	1029.21025	1029.21025	184.95	0.0001
STATIONS	14	22435.78556	1602.55611	287.98	0.0001
SEASON BY STATIONS	14	1407.13025	100.51519	18.06	0.0001
SEASON BY YEAR	2	11.13025	11.13025	2.00	0.1584
YEAR BY STATIONS	14	169.73122	12.12366	2.18	0.0087
SEASON BY YR. BY STS.	14	109.84767	7.84626	1.41	0.1471

alpha = 0.01.

TABLE 27b DUNCAN'S MULTIPLE RANGE TEST

DUNCAN'S GROUPING	MEAN	N	STATION
A	20.000	24	9
A	20.000	24	10
A	20.000	24	11
A	20.000	24	8
A	20.000	24	7
A	20.000	24	15
C B	12.608	24	4
C	11.817	24	2
D	10.921	24	5
D	3.371	24	6
D	2.542	24	12
D	2.463	24	13
D	2.025	24	1
D	2.025	24	14
D	1.875	24	3

alpha = 0.05

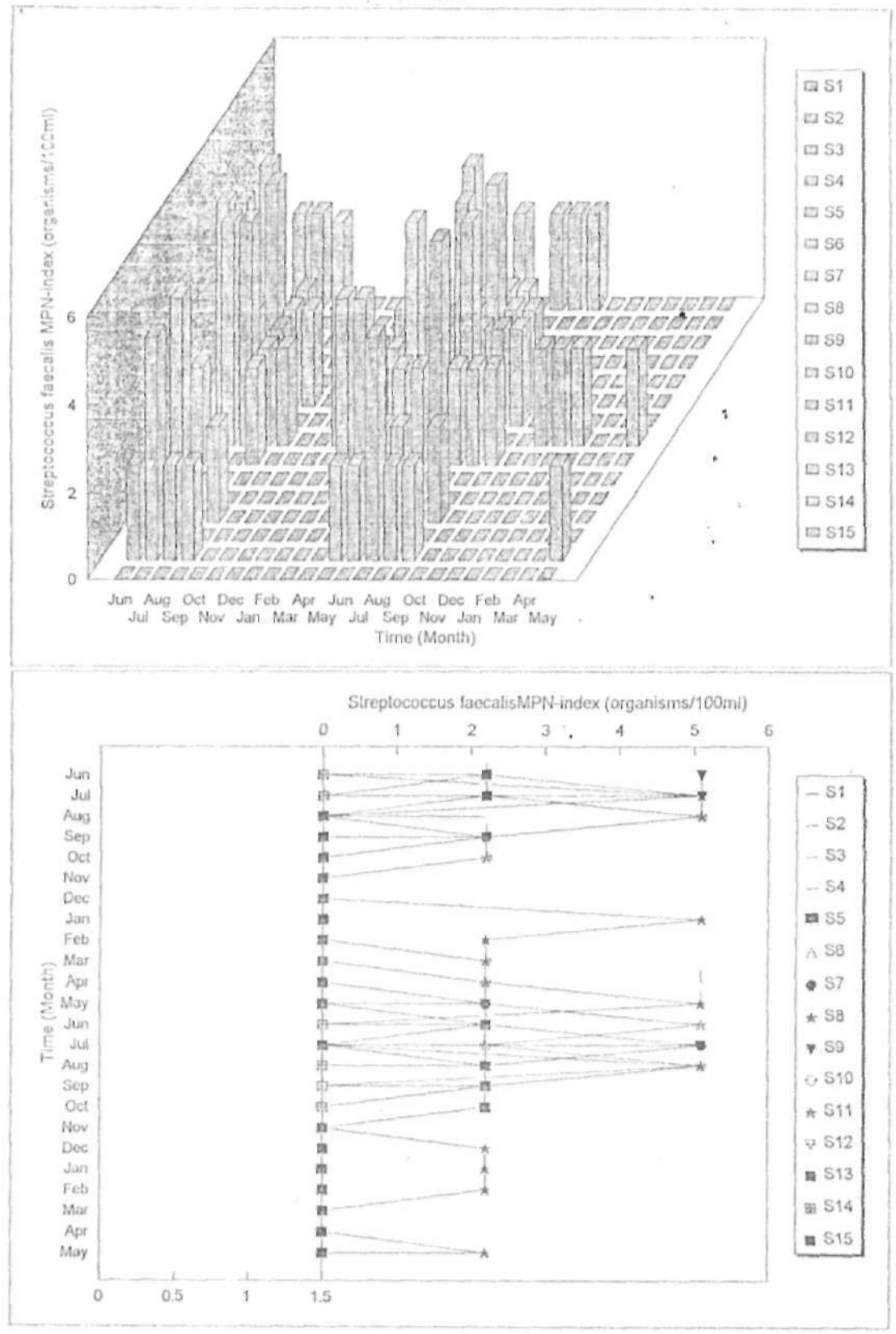


Fig.29. monthly variation in St.faecalis MPN-index (org./100ml).

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TABLE 28a VARIATION IN Streptococcus faecalis MPN-INDEX.

Dry Season Mean	0.167
Rainy Season Mean	1.052
First Year General Mean	0.682
Second Year General Mean	0.537

ANALYSIS OF VARIANCE (ANOVA)

Procedure

Source of Variation	DF	Sum of Squares	Mean Square	F Value	Pr > F
REP.	5	13.7688889	2.7537778	2.89	0.0146
YEAR	1	1.9067778	1.9067778	2.00	0.1583
REP(YEAR)	5	6.2082222	1.2416444	1.30	0.2627
SEASON	1	70.5787778	70.5787778	74.06	0.0001
STATIONS	14	141.9362222	10.1383016	10.64	0.0001
SEASON BY STATIONS	14	75.7328889	5.409421	5.68	0.0001
SEASON BY YEAR	2	0.1521111	0.152111	0.16	0.6898
YEAR BY STATIONS	14	22.0598899	1.5757063	1.65	0.0649
SEASON BY YR. BY STS.	14	6.4745556	0.4624683	0.49	0.9402

alpha = 0.01.

TABLE 28b DUNCAN'S MULTIPLE RANGE TEST

DUNCAN'S GROUPING		MEAN	N	STATION
	A	1.888	24	8
B	A	1.340	24	10
B		1.187	24	9
B	C	1.158	24	2
B	C	1.096	24	4
B	C	1.067	24	11
B	C	0.854	24	7
D	C	0.550	24	15
D	F	0.000	24	5
D	F	0.000	24	6
D		0.000	24	1
D		0.000	24	12
D		0.000	24	13
D		0.000	24	14
D		0.000	24	3

alpha = 0.05

sample. There were similarities between the FYGM and SYGM (Table 28). Station 8 recorded the highest GSM of 2/100 ml. Stations 2, 4, 7, 9, 10, 11 and 15 ranked second highest with MPN index of 1/100 ml. Other stations recorded zero throughout the period of sampling (Table 28b). Analysis of variance (Table 28a) reveals highly significant difference between stations, seasons and season by stations ($P < 0.01$). Correlation analysis (Table 1c) indicated increase in the density of *Streptococcus faecalis* to be accompanied by increase in the concentrations of Na, Mg, COD, Macronutrients, hardness, Fe, conductivity, zooplankton and phytoplankton densities, *E. coli* index and OD ($P < 0.01$). Significant negative correlation was recorded with pH of the water .

CHAPTER FIVE

5.0 DISCUSSION:

5.0.1 Physico-chemical Parameters:

5.1.1 Temperature:

Insignificant variation in water temperature recoeded with respect to the sources of variation could be attributed to the ability of the water to withstand changes in temperature despite fluctuations in temperatures of the environment due to its high specific heat capacity. It was however observed that there was slightly significant difference in temperature with season at 5% level of significance. Such difference may be due to the effect of the North-east trade winds (harmattan). Similar observations were reported by Anyam (1980), Hassan (1983), Oladimeji and Wade (1984), Saad and Abbas (1985), Awanda (1987), Kemdirim (1987), Balarabe (1989) and Hassan (1989).

The ability of the open water sources (lakes) to maintain relatively constant temperature in comparison with the restricted sources (wells) may be attributable to the constant mixing of the water body due to flow, turbulence and large surface-air interphase. relative constancy in temperature of open water sources was similarly reported by Hassan (1989) and attributed reason to high specific heat and dilution due to precipitation and increased turbulence.

5.1.2 Optical Density :

The optical density of the water bodies, being the measure of light penetration per unit volume of the water, was observed to be high during the rainy season as compared to dry season, with highest GSM in station 15 (an open water source).

Such increase in OD during the period of rains may be attributed to increased concentrations of dissolved and suspended materials from both autochthonous source and the catchment area. The OD was observed to show significant positive correlation with the amounts of suspended solids, water hardness, electrical conductivity, chemical oxygen demand and macro-nutrients at 1% level of significance. In water quality assessment (water quality examination of Sebeel water), Hammad and Dirar (1982), recorded OD range of 0.005 to 0.015, which turned out to be low and attributed such low OD to location of water sources in areas of low pollution load.

5.1.3 Suspended and Total Solids:

The recorded peak in amount of SS in early rains was attributed to the increased input of SS from the surface run-off. The late dry season increase in SS was due to the reduction in volume of water per unit amount of SS. Station 1 had the highest GSM owing to the fact that the water source was unprotected. In addition to its autocthonous contribution of SS due to possible eutrophication and direct introduction of debris could have accounted for the recorded highest GSM. According to Cairncross and Richard (1983), open hand-dug wells were more liable to pollution due to rubbish thrown down the well and spilt water among others especially if the wells were not protected by fitted covers.

Generally, the amount of TS was observed to be higher during the rainy season as compared to dry season. Location of the water sources, nature of soil, seepage from the surface and event during the period of rains could be responsible for the elevated level of TS observed. Cairncross and Richard (op cit),implicated the location of well too close to pit latrine, soakaway, or refuse dump, which

influence extends to about 10 metres in a typical soil; seepage of water from the surface into the well through the top few meters of the well lining if not sufficiently water tight near the surface; and straight down washing of surface water into the well especially where the ground water surface has sunk, to account for high enrichment of water sources with solids. These factors were also observed with respect to the physical characteristics of the most of the water sources sampled. The amount of TS correlated with positively with SS, COD, BOD, and electrical conductivity. These parameters also recorded high during the rainy season, suggesting a link between these parameters and the recorded increase in TS.

5.1.4 Water Hardness .

The recorded high Ca and Mg contents of the water may have contributed to the high hardness of the water. The concentrations of these ions (Ca and Mg) were observed to have increased during the period of rains (Ca and Mg) and late dry season (Ca). Highly significant positive correlation was observed between water hardness and Ca as well as hardness with Mg, indicating link between hardness and the ions. In studying the effects of effluent on a stream in Kaduna, Hassan (1989) recorded similar results and attributed high level of Ca and Mg ions in the water to have caused high level of hardness of the water throughout the year. Jop and Wajton (1981) associated low hardness to low levels of Ca and Mg ions. Nikoladze et al (1989) linked water hardness to high levels of Ca and Mg ions in water.

5.1.5 Reactivity of Water:

The relatively stable pH of the water recorded could be due to the effective buffering capacity of the water. The geology of the area reveals massive presence of igneous rock, which provides good source of $CaCO_3$. The $CaCO_3$ may have provided sufficient amount of bicarbonate ions resulting in effective buffering of the water and the fairy stable pH recorded. According to Richardson (1989), the concentration of hydrogen ions (pH) in a buffer system remains constant due to the effect of the buffer system, which often consists of dissolved CO_2 and HCO_3.

The recorded narrow range of fluctuations in pH from weakly acidic to weakly alkaline (6.2 to 7.8) is usual of most fresh waters characterised by high level of hardness. Hynes (1963) observed hard waters were more alkaline with stable pH and do not change readily. Similar circumneutral pH was reported by Kemdirim (1987) in limnological and trace element studies in some water bodies in Nigeria, and attributed such slight fluctuation within the low levels of acidity and alkalinity to the nature of the bedrock. Increased CO_2 production as a result of vegetative decay, additional alocthonous and autocthonous organic matter could possibly be the key factors contributing to the recorded slight lowering of pH in stations 1, 2, 8, 9 and 10 that were observed. Fall in pH due to low O_2 content, high decomposition of organic matter and high BOD associated with the stations was recorded. In studying the quality of well water in two districts of Conakry (Republic of Guinea), Gelinas et al (1996), reported measured values of pH as being weakly acidic and associated reason to location of the wells in highly populated centres, hence subject to variety of anthropogenic input of pH lowering pollutants.

5.1.6 Electrical Conductivity .

Electrical conductivity of the water was recorded to be generally high during the late dry season. This may be attributed to the reduction in volume of water during the period of drought. The increased concentrations of ions during the rainy season seemed to coincide with increased volume of water during the same period, hence, the ratio of ions to unit volume of water (conductivity) remained fairly low during the period of rains (with the exception of early rains). However, with increased loss of water to the atmosphere and the reduction in volume of water due to submerging water table, and the possible desorption of ions from sediment due to low pH , conductivity was high during the dry season. Similar observation was made by Comin et al (1983) in limnological study of Gallocanta lake, Spain. They attribute high balance of evaporation leading to the reduction in water volume and increased salt concentration. According to Green (1960), Biswas (1966) and Imevbore (1970), low conductivity of water bodies during the rains could be due to dilution effect. Also, the recorded increase in conductivity during the dry season with respect to the wells appeared to be under the influence of submerging water table and the close proximity of the sources to liquid point source of pollution (gutters and pit latrines). According to Richardson (1989), tube wells and boreholes are subject to being polluted by seepage and leachate if left unprotected by concrete slabs, at least 2 metres across, and open hand dug wells are more liable to pollution by ground water due to being located close to pit latrine, soakaway, or refuse dump, which influence may extend to about 10 metres in typical soil. It was observed that some of the sources of water are located within close proximity to gutters and latrines that remain wet throughout the seasons. Gelinas et al (1996) assessed the quality of some well water in Conakry and associated high levels of conductivity to their close proximity (less than 50 metres) from the ocean in Bonfi. This tends to suggest that

a distance of less than the 50 metres may have influenced the conductivity of the water sources. Most of the sources sampled in this research fall short of 10 metres from either gutter, toilet, drainage or other point source of contamination.

5.1.7 Macronutrients:

The concentrations of NO_3-N were high during the rainy season and showed positive correlation with PO_4-P. Station 10 recorded the highest GSM of 1.9 mg/L, followed by the OWSs. Relatively low concentrations were recorded, which fall below the allowable concentration limits in drinking water of 45 mg/L of WHO (1971). The recorded higher concentrations during the rainy season may be due to enrichment by surface run-off from cultivated land, anthropogenic input and desorption from sediment. Comin et al (1983) reported that increased concentrations of nitrate were frequently found in shallow farms and rural community wells, often due to inadequate protection from barn yard drainage or from septic tanks. Increased concentrations of nitrates were also recorded in streams due to farmland drainage in areas of intense application of fertilizers, and attributed such increase to input from cultivated land Comin et al (op cit). Increased nitrate concentrations during the period of flood was reported by Hassan (1989). Gelinas et al (1996) recorded high levels of nitrate with a maximum of 51.8 mg/L in wells located in urban areas, and linked nitrate origin to inadequate disposal of human excreta and domestic sewage, particularly coupled with high soil permeability and depth of the wells.

According to Gelinas et al (op cit), the leaching effect of rain becomes more pronounced where the ground is more permeable and the wells are shallow. They also observed that after long period of dryness (about 6 months), high quantities of

nitrogen were accumulated in the superficial layers of the ground. At the beginning of rainy season (5 months of heavy rains), a high proportion of the nitrogen was leached and reached the aquifer as soluble nitrate form of nitrogen. Schnabel et al (1993) and Ghedin et al (1993) reported similar findings. The recorded general low levels of NO_3-N may be due to sorption phenomenon, resulting in reduced concentration in water and its increased concentration in sediment. Rippey and Rippey (1986) reported fall in concentration of NO_3-N due to uptake by plants and sorption to sediment. Station 10 recorded second most acidic (pH 6.4) and registered the highest GSM for NO_3-N. Such reduced alkalinity may be responsible for desorption of NO_3-N from sediment to the water , coupled with the agricultural and anthropogenic input. Stewart et al (1982) reported that sediment water interphase was an engine room for aquatic nitrogen cycle through nitrification.

The recorded PO-P trend in the water appeared similar to that of NO_3-N, except that the GSM was highest in station 7 (Bomo Lake). Input from cultivated land, aided by the run-off during the period of rains could be responsible for this. Winger (1981) reported rainfall as an important source of biogenic components flowing into surface water as they contain nitrogen and phosphorus. These macro nutrients in the aquatic system were reported to have arising from rainfall and input from land use in cropping (Jamison and Fox,1994). Bradley (1978) attributed nutrient enrichment to surface input mainly from cultivated land, and desorption from bottom sediments.

5.1.8 Oxygen :

The recorded negative but significant correlation between DO and temperature ($P < 0.05$), seems to indicate that the variation in water temperature was minimal

enough to cause significant change in DO content of the water. Rather, the oxygen content of the water appeared to be more significantly affected by OD and oxygen demand by chemical substances. According to Maitland (1978), the amount of oxygen in a water body depends upon the extent of contact between water and atmosphere, and the amount produced by phytoplankton photosynthesis as well as the amount consumed. Twelve out of the fifteen water bodies sampled were RWSs, with restricted contact with the atmosphere, low phytoplankton density, high conductivity, COD and BOD. The collective inter play of these parameters appeared to have exerted much influence on the DO content rather than temperature fluctuation. Slightly lower DSM (December to February) was however recorded, which could be attributed to lowered temperature of the water due to the North-East trade wind (harmattan). Such fluctuations were recorded most in the OWSs.

The concentration of oxygen in the OWSs were periodically high. Station 6 (RWS). however, recorded the highest GSM . Increased amount of macronutrients, which probably stimulated the growth and abundance of phytoplankton and other aquatic plants, leading to increased photosynthetic activities and evolution of oxygen as well as high turbulence and sufficient air-water interphase may have been responsible for the recorded high DO in the OWSs. Biswass (1966), Adeniji (1973), Hassan (1989),and Balarabe (1989) reported similar increase in DO in OWSs (Lake Volta in Ghana, Kainji Lake, Romi stream and Makwaye Lake in Nigeria , respectively), and attributed such increase in DO to increased phytoplankton activities, which coincided with the period of phytoplankton abundance.

5.1.9 Chloride ion :

Chloride ion concentrations were high during the rainy season. This could be due to enrichment by rains particularly with respect to the lakes (OWSs). Gorham (1961) measured the influence of atmospheric precipitation on the supply of ions to natural waters in English Lake District, and associated the enrichment with chloride ion to rains, with a range of 0.1 mg/L in Minnesotta and 8.9 mg/L in New found land. Gibbs (1970) reported that the chloride ion concentration of Rio Tefe (a tributary of the Amazon), was sourced mainly from the rains.

Some of the RWSs also recorded high concentrations of chloride ions. The proximity of these stations liquid point sources and their location in the major drains suggest anthropogenic input to be largely responsible for the enrichment, especially as urine contains variable amounts of chloride ions. In quality investigation of well water in Guinea, Gelinas et al (1996), reported chloride level in traditional wells with minimum concentration of 22.5 mg/L and maximum concentration of 284 mg/L. Reason for the recorded high level was attributed to ground water contamination.

5.1.10 Metals :

The concentrations of alkaline earth metals (K, Ca, Na, Mg) were elevated with the onset of rain. however, the collective seasonal means indicate that the DSMs were higher for K, Ca, and Na. The only exception was Mg, which had higher RSM. This indicates that the early enrichment of the water bodies by these metals was not as remarkable in elevating their total concentrations as did the reduction in water volume experienced during the dry season. The recorded high DSM regarding the exchangeable ions could be attributed to reduction in volume of water with increased evaporation and submergence of the water table during the dry season

(October to April).

The sediment samples were not studied. It is however known that sediments could influence the kinetics of these metals through sorption desorption mechanism. Variation in reactivity of the water (pH) for instance, could drastically influence the retention time of metals in water. Borg (1983) reported decrease in pH to have favoured the retention time of some metals in freshwater body in Sweden.

The apparent reason for the observed kinetics of the exchangeable ions appeared to be linked with the nature of the water source and its proximity to alocthonous influence: The three most high ranking GSMs indicate that 50 % (6 stations) of the water samples from OWSs had high GSMs. Over 40 % (5 stations) had close proximities to gutters and toilets. In contrast, all the stations that recorded the lowest GSMs were RWSs and distant from gutters and toilets. Kindler (1992), reported that sewage is a dominant factor contributing to the contamination of ground water

Similar pattern was recorded with respect to the heavy metals: all stations distant from gutters and toilets (stations 5, 6, 13, and 14) had the lowest GSMs. The OWSs (stations 7, 11 and 15) recorded high GSMs : Station 11 had high GSMs for Cu, Pb, Zn, and Fe. Station 7 had high GSM for Cu, and Station 15 had high GSM for Pb. The OWSs were subject to enrichment from the catchment area especially during the period of rains when leaching and surface run-off could have served as source of metal pollution. Base line research by many authors have reported elevated levels of trace metals in freshwater system, especially rivers and lakes (Ashraf and Jaffar, 1990; Ashraf et al, 1991, 1992; Jaffar et al, 1988; Jaleel et al, 1991, 1996) , arising mainly from unregulated agricultural and industrial sewage and effluent.

In studying ground water as source of contamination for water supply in Pakistan, Rahman (1996), reported Lead (Pb) in high concentrations from samples of ground water collected throughout the city of Karachi, Pakistan with maximum amount detected being above any standard set for water intended for domestic use. It appears that the heavy metals are anthropogenically sourced. The widespread use of metals and their components, leaching of metals from domestic refuse and solid waste dumps, animal and human excrement could have been contributed to the enrichment of the water sources with these metals.

5.2.0 Biological Parameters:

5.2.1 Phytoplankton:

The recorded higher RSM for phytoplankton coincided with the NO_3-N and PO_4-P trends, which were both observed to be higher during the rainy season. The role of these macronutrients in stimulating growth and abundance appear to have influenced in conjunction with other factors the observed phytoplankton rhythm in the water sources. Kemdirim (1987) reported that among the factors controlling phytoplankton abundance, considerable attention has been given to nutrients especially nitrate-nitrogen and phosphate-phosphorus. Increase in concentrations of PO_4-P and NO_3-N with corresponding increase in phytoplankton growth and subsequent algal bloom was reported by Palmer (1980). The favourable condition created by the availability of the macronutrients and the needed micronutrients such as Mn could have been the reason for the observed relatively high phytoplankton density especially in the OWSs.

5.2.2 Zooplankton:

There were no zooplankton recorded throughout the sampling period in stations 1, 2, 3, 4, 5, 12, 13, and 14. They are all RWSs and happen to be distant from the OWSs. Zooplankton species were recorded in all the lakes (OWSs) and some wells which are located in close proximities to the lakes. Increase in zooplankton population appeared to be favoured by increased concentrations of Ca, DO, increase in pH, BOD, and TS. It was however observed that the zooplankton species were affected negatively by increase in COD.

Zooplankton abundance appeared to be related to changes in water chemistry, most especially as the maxima for chemical parameters recorded in early rains coincided with zooplankton peaks. Zooplankton peak with the on-set of rain fall followed by gradual decline was reported by Adeniji (1973). Comin et al (1983) reported seasonal abundance of zooplankton in relation to changes in chemical quality of water and its phytoplankton. Hassan (1989) reported decline in zooplankton density as dry season progressed, with positive correlation between zooplankton and DO, BOD and NO_3-N

5.2.3 Bacteriological Indices:

All the OWSs had high GSMs for *Eschericia coli* MPN-index . Stations 8, 9 and 10 located close to pit latrines, gutters and along the major drains leading to station 11 (Shika Dam) as well as station 4 located only a few metres from an extended gutter that remains wet throughout the seasons recorded high MPN-indices. The location of these stations near point sources of faecal contamination could be responsible for the recorded high indicator counts. Gelinas et al (1996) sampled water from open wells in Conakry and reported widespread well water contamination for nitrate

and faecal bacteria . Reason for this was linked with insufficient well maintenance, high permeability of the soil and shallow water table of the area sampled. Lewis et al (1981) reported that pit latrine sanitation and shallow underground water exploitation for drinking purposes conflict one another because of the facilitated migration of contaminants, both bacteriological and chemicals, through the soil. The role of sediment in this respect is unclear. Several studies however, highlighted the importance of sediments as potential reservoirs for microorganisms in the aquatic environment (Hendricks,1971; Grimes, 1975; Erkenbrecher, 1981). The prolonged survival of coliform and possibly other faecal bacteria in sediments and the likelihood of their being desorbed by dilution and thus becoming resuspended has been stressed by Geldreich (1970) and Grimes (1975). The high counts recorded during the rainy season may however be attributed to wet weather events.

Ferguson et al (1996) studied the relationship between indicator pathogens and water quality in an estuarine system and associated rainfall and sewage overflows with significant increases in the counts. They (ibid), also reported significant increase in faecal coliform in sediments after rainfall. The presence of total organic matter was associated with significant increases in the density of both faecal coliform and faecal streptococci Gerba and McLeod (1976). Hammad and Dirar (1982) enumerated some factors controlling microbial population in homes and at public watering stands (Sebeel)in Sudan among temperature, dust storms, frequent use by humans and possible regrowth of bacteria as well as coliform of non faecal origin to be responsible for high coliform counts.

A possibility for the recorded high MPN count for the indicators in the OWSs and some of the stations could be due to the unprotected nature of the sources from direct contamination by fetching materials and spilt water. In the OWSs, human and

animal excrement deposited close to the water shed could be introduced directly into the water sources, particularly during the rainy season. This could also have accounted for the recorded high MPN count during the rainy season. Regarding the RWSs, the sanitation practices of the dwellers, involving the use of water for cleansing faeces, provided the possibility of used water to be in contact with soles of feet wears (shoes and slippers) and be transported from toilets to the well vicinity to become a source of contaminating the fetching ropes and containers and ultimately the water sources.

Almost similar pattern was observed with respect to *Streptococcus faecalis* MPM-index, except that the all values recorded were extremely lower than that of *Escherichia coli* and *Streptococcus faecalis* appeared to be exclusively related to proximity to pit latrines.

4.3.5 RELATIVE ABUNDANCE:

The abundance and diversity of micro-organisms has been used to provide an integrated picture of conditions in a natural body of water which may be used as a guide to the sustainability of the water body for domestic use and for general amenity purpose (Evison and James, 1978). According to Palmer (1980), reduction in phytoplankton genera in a given water body could serve as an evidence of rapid eutrophication. The results obtained in this work indicate that Phytoplankton constitute 38.69 % and zooplankton 61.30 % of the planktonic organisms recorded. *Chlorophyceae, Euglenophyceae, Myxophyceae, Bacillariophyceae, Desmidiaceae* and *Rhodophyceae* constitute the phytoplankton families recorded. the family *Chlorophyceae* consists of 7 genera, followed by *Euglenophyceae* with 4 genera. The other families consist of 1 genus each. The Zooplankton groups were made up of Cladocera with 4 genera (*Daphnia. sp, Diaphanosoma. sp, Moina sp* and *Bosmina. sp);* the Rotifera *(Brachionus. sp, Keratella. sp* and *Kellikortia. sp)* and Copepoda *(Cyclops. sp* and *Copepodan Nauplius.).* See (Fig.30).

Most of the phytoplankton species persisted throughout the year with high relative abundance during the mid-rainy season and late dry season. The OWSs contributed to the wide-spread abundance and diversity of the phytoplankton as well as most of the zooplankton groups. Table 29a,b provides detailed list of genera per station. This indicates that the OWSs were most adopted for the changes in the physico-chemical parameters. The reduction in water quality as a result of corresponding changes in physico-chemical parameters appeared to have negative effects on the abundance and diversity of the biota in the RWSs.Station3 is newly dug well and S12, S13 and S14 have been recently concretised, hence recorded no planktonic abundance

Table 29 The distribution of Plankton per station for the period of sampling.

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	Total
Vovox sp.	0	0	0	65	27	18	26	70	82	96	162	0	0	0	0	546
Comsopogon sp.	0	0	0	131	59	22	118	59	57	63	101	0	0	0	0	610
Coelastrum sp.	12	19	0	26	23	16	40	32	17	21	51	0	0	0	63	2966
Zygnema sp.	11	56	0	88	21	31	42	86	35	46	68	0	0	0	55	2849
Staurastrum sp.	17	24	0	43	65	19	38	17	7	39	50	0	0	0	0	319
Phacotus sp.	4	7	0	26	42	30	43	6	4	0	37	0	0	0	50	2349
Cladophora sp.	25	38	0	42	48	22	30	24	38	30	46	0	0	0	49	2450
Phyotconis sp.	32	20	0	96	53	31	22	16	22	28	40	0	0	0	52	2596
Cyclotella sp.	24	16	0	68	46	0	0	11	59	17	66	0	0	0	0	307
Chlorella sp.	0	44	0	40	14	22	14	13	20	35	68	0	0	0	5	485
Chlamydomonas sp.	22	30	0	54	39	25	56	67	43	82	98	0	0	0	36	2063
Spirogyra sp.	31	28	0	36	60	28	53	39	42	37	70	0	0	0	52	2650
Phormidium sp.	0	0	0	3	19	25	91	66	0	68	102	0	0	0	42	2180
Euglena sp.	41	10	0	52	20	27	14	28	31	35	57	0	0	0	44	2207
Chara sp.	0	0	0	29	0	0	100	0	0	0	146	0	0	0	58	2769
Total(Phyto)	219	292	0	799	535	316	687	534	457	597	1162	0	0	0	506	18754
Keratella sp.	0	0	0	0	0	28	168	90	138	52	341	0	0	0	106	923
*Copepodan Nauplius**	0	0	0	0	0	16	224	181	126	98	302	0	0	0	149	1096
Brachionus sp.	0	0	0	0	0	6	332	202	148	31	328	0	0	0	114	1163
Cyclops sp.	0	0	0	0	0	26	456	263	185	153	693	0	0	0	523	2299
Kellikottia sp.	0	0	0	0	0	12	294	0	91	8	235	0	0	0	119	759
Daphnia sp.	0	0	0	0	0	0	540	277	130	170	651	0	0	0	437	2205
Diaphanasoma sp.	0	0	0	0	0	31	127	0	50	0	192	0	0	0	49	449
Bosmina sp.	0	0	0	0	0	10	66	27	11	18	47	0	0	0	62	241
Moina sp.	0	0	0	0	0	27	92	58	9	13	153	0	0	0	84	436
Total(Zoo)	0	0	0	0	0	158	2299	1098	838	543	2942	0	0	0	1643	9571
Grand Total	219	292	0	799	535	474	2986	1632	1345	1140	4104	0	0	0	2149	28325

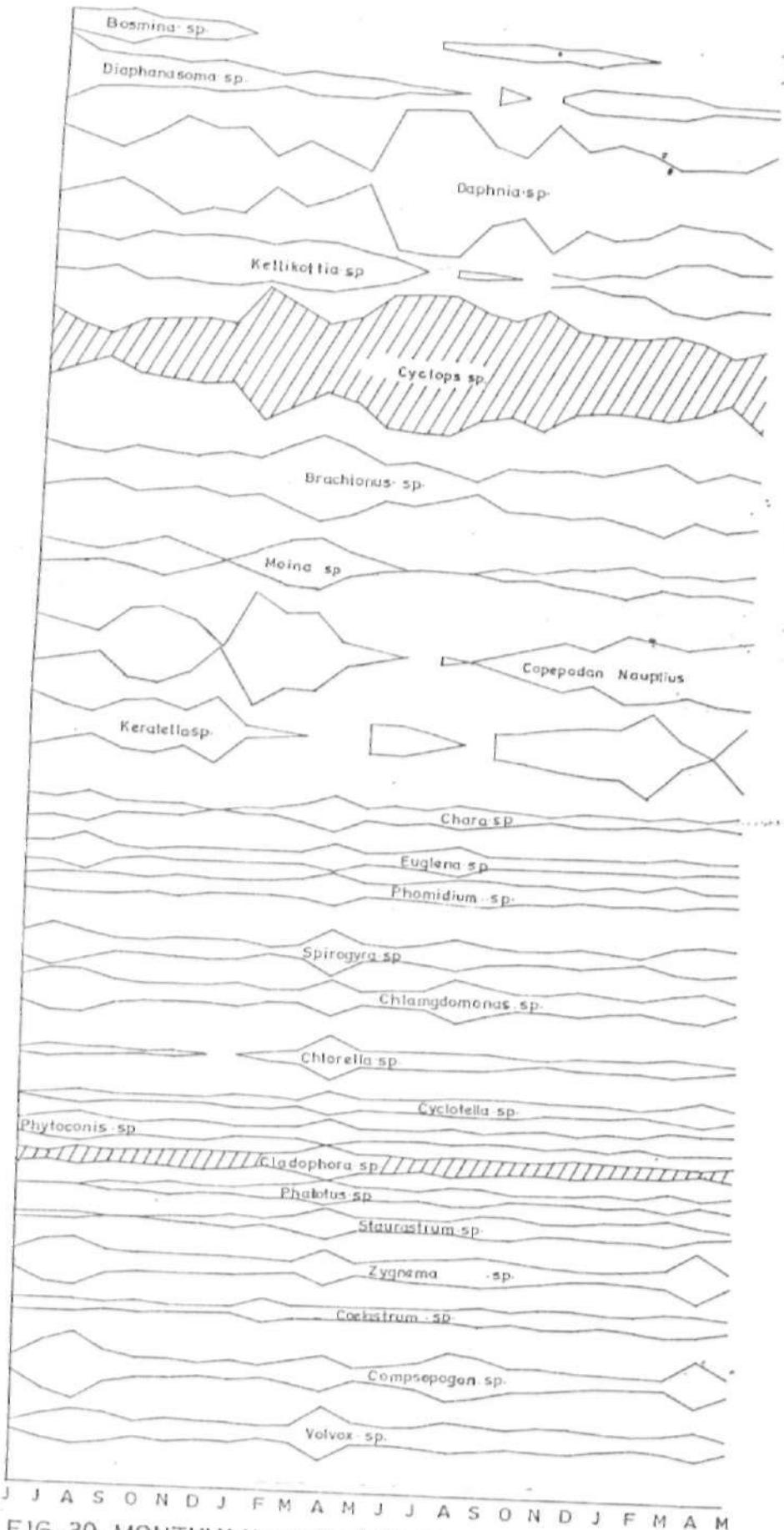


FIG. 30 MONTHLY VARIATION IN RELATIVE ABUNDANCE OF PHYTOPLANKTON AND ZOOPLANKTON GENERA IN ALL THE STATIONS

Table 30. Monthly Distribution of Plankton Genera Recorded.

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Vovox sp.	4	21	26	18	20	24	24	21	9	13	29	35	29	28	25	22	27	30	28	25	13	16	27	32
Comsopogon	9	43	47	31	23	21	20	23	11	13	17	21	30	37	40	38	31	34	22	20	11	9	38	21
Coelastrum s	6	10	3	1	6	8	1	2	15	13	6	11	17	112	36	29	28	44	23	42	41	16	13	272
Zygnema sp.	10	39	5	2	7	23	5	9	37	32	15	18	14	281	32	32	26	42	34	46	32	20	18	282
Staurastrum s	3	5	5	3	11	20	8	3	31	19	13	25	20	271	18	13	19	16	15	20	20	24	9	154
Phacotus sp.	1	2	3	4	15	16	9	7	27	11	18	12	11	223	50	66	43	54	48	59	28	19	21	388
Cladophora s	6	7	11	15	12	17	6	4	23	19	15	9	17	208	68	92	47	76	55	121	32	20	50	561
Phyotconis sp.	8	23	20	16	17	21	9	8	21	17	19	11	15	236	36	56	34	68	52	80	34	18	19	397
Cyclotella sp.	1	5	8	9	6	9	10	3	26	21	14	13	4	244	92	0	57	80	64	112	30	4	0	547
Chlorella sp.	2	9	3	7	4	8	3	5	24	18	12	10	8	216	14	131	40	148	45	33	16	0	25	452
Chlamydomo	15	37	31	27	23	21	26	24	10	17	11	9	6	139	6	67	55	94	45	57	22	0	31	397
Spirogyra sp.	13	32	19	11	19	17	21	18	17	10	11	7	12	137	0	55	60	47	31	28	12	0	37	270
Phormidium s	6	15	13	18	15	19	14	12	11	11	22	10	14	210	0	13	42	50	22	6	10	0	16	159
Euglena sp.	11	18	25	12	9	11	13	10	9	7	10	18	21	339	48	13	51	197	37	210	6	0	9	571
Chara sp.	17	14	20	11	17	15	4	8	6	12	14	21	27	373	51	0	67	225	0	238	6	12	0	599
Total(Phyto)	112	281	271	223	208	236	244	216	139	137	210	339	373	340	25	12	44	192	11	202	4	18	0	508
Keratella sp.	36	32	18	50	68	36	92	14	6	0	0	48	51	25	0	0	10	90	4	67	8	14	0	193
Copepodan N	29	32	13	66	92	56	0	131	67	55	13	13	0	12	0	13	35	80	0	53	0	18	8	234
Brachionus s	28	26	19	43	47	34	57	40	55	60	42	51	67	44	10	35	57	162	15	169	5	20	10	512
Cyclops sp.	44	42	16	54	76	68	80	148	94	47	50	197	225	192	90	80	162	104	8	104	30	22	23	470
Kellikottia sp.	23	34	15	48	55	52	64	45	45	31	22	37	0	11	4	0	15	8	21	128	34	10	21	494
Daphnia sp.	42	46	20	59	121	80	112	33	57	28	6	210	238	202	67	53	169	104	128	122	32	4	40	581
Diaphanason	41	32	20	28	32	34	30	16	22	12	10	6	6	4	8	0	5	30	34	32	26	2	16	455
Bosmina sp.	16	20	24	19	20	18	4	0	0	0	0	0	12	18	14	18	20	22	10	4	2	0	19	298
Moina sp.	13	18	9	21	50	19	0	25	31	37	16	9	0	0	0	8	10	23	21	40	16	19	12	270
Total(Zoo)	272	282	154	388	561	397	547	452	397	270	159	571	599	508	193	234	512	470	494	581	455	298	270	637

4.3.6 GENERAL QUALITY ASSESSEMENT:

4.3.6.1 The Biological Index of Pollution (BIP):

Changes in water quality exert a selective action on the flora and fauna which constitute the living population of a water body, and the effects produced in them can be used to establish biological indices of water quality (Palmer, 1980). While chemical and physical measurements tend to measure the cause of change in water quality, biological tests deal primarily with effects of such changes, and one of the methods of assessing the degree of purity or contamination of water has been that of measurement of Biological Index of Pollution (BIP). The method is developed for applicatiobn over a wide range of waters.

The calculation of BIP enables comparison between chlorophyll bearing aquatic organisms (phytoplankton) and the consumers (zooplankton), and the product of the above enables placement of water according to its appropriate quality zone (WQZ).

The use of aquatic biota to detect toxic pollution in water is an option that has recently become attractive to some researchers. The Biological Index of Pollution (BIP), was first proposed by Horasawa (1942) and again by Palmer (1980).

4.3.6.1.1 Sampling and Enumeration Procedures:

Water samples were collected from the 15 stations comprising three open water sources (lakes) and twelve hand-dug wells on a monthly basis. Ten litres of the simples from wells were concentrated to 50mls by filtering through 70 meshes per cm plankton net. Collections from the lakes was by means of dragging the plankton net

over a 3 meter distance. The water was also concentrated to 50ml.

The collections were examined and the organisms were counted under the microscope by means of the survey count of WHO (1963) and APHA (1980), (using a sedwick-rafter counting cell)

4.3.6.1.2 Biological Index of Pollution (Bip) Computaton:

The underlying principle of the method is that changes in the quality of water exert selective impacts on the existing flora and fauna in the water. Therefore, the effect produced in them could be used to estimate water quality. By using the relative abundance of the most affected biota (zooplankton) and the least affected (phytoplankton) it could be possible to establish a biological index of the quality of the water. In the method, a comparison of the chlorophyll- bearing aquatic organisms (phytoplankton) and the consumers in the system (zooplankton) is carried out.

The BIP was calculated as:

$$\frac{B}{A+B} \times 100$$

Where,

A = No of Phytoplankton genera identified

B = No of Zooplankton genera identified.

The product of the above enables placement of water according to its appropriate quality zone (WQZ). This method was proposed by Horasawa in 1942 and adopted by Palmer (1980). This interaction enables quality classification of the water into one of four zones.

Accordingly,

0.6 = represents clean water (Oligosaprobic)

12.0 = water with moderate decomposition (beta-saprobic)

30.9 = water with active decomposition (alpha-saprobic)

55.1 = water that is septic (poly-saprobic).

4.3.6.1.3 Results and Discussions:

Figure 31a shows the monthly variations in the BIP'S of the water sources. The sources were either beta saprobic (with moderate decomposition of organics), or alphasaprobic (with extensive organic decomposition). There was a gradual shift in the observed BIP's from beta to alpha-saprobism as the dry season advanced. This shift, representing a reduction in the quality of the water sources is probably due to the fact that the effect of dilution (due to rainfall), reduced progressively as the dry season progressed. The inflow into lakes and infiltration into wells reduced or ceased completely. Also migration of pollutants, especially with respect to the wells located close to liquid point sources (gutters and pit-latrines) prevailed throughout the period of sampling and may have accounted for the observed gradual shift from beta to alphasaprobic quality of the water sources. According to Lewis et al (1981), pit latrine sanitation and shallow underground water sanitation for drinking purpose were in conflict with each other due to the facilatated migration of contaminnats, both bacteriological and chemical through the soil. The unprotected nature of the water sources further subjects them to both alocthonous and autocthonous influence of decaying organics.

Figure 31b shows the BIP's of the different sampling stations. It may be observed that the quality of the water in lakes was less than the quality of the well waters. The lakes were polysaprobic with an average BIP of 73 while the average BIP of the wells is 17.5 making

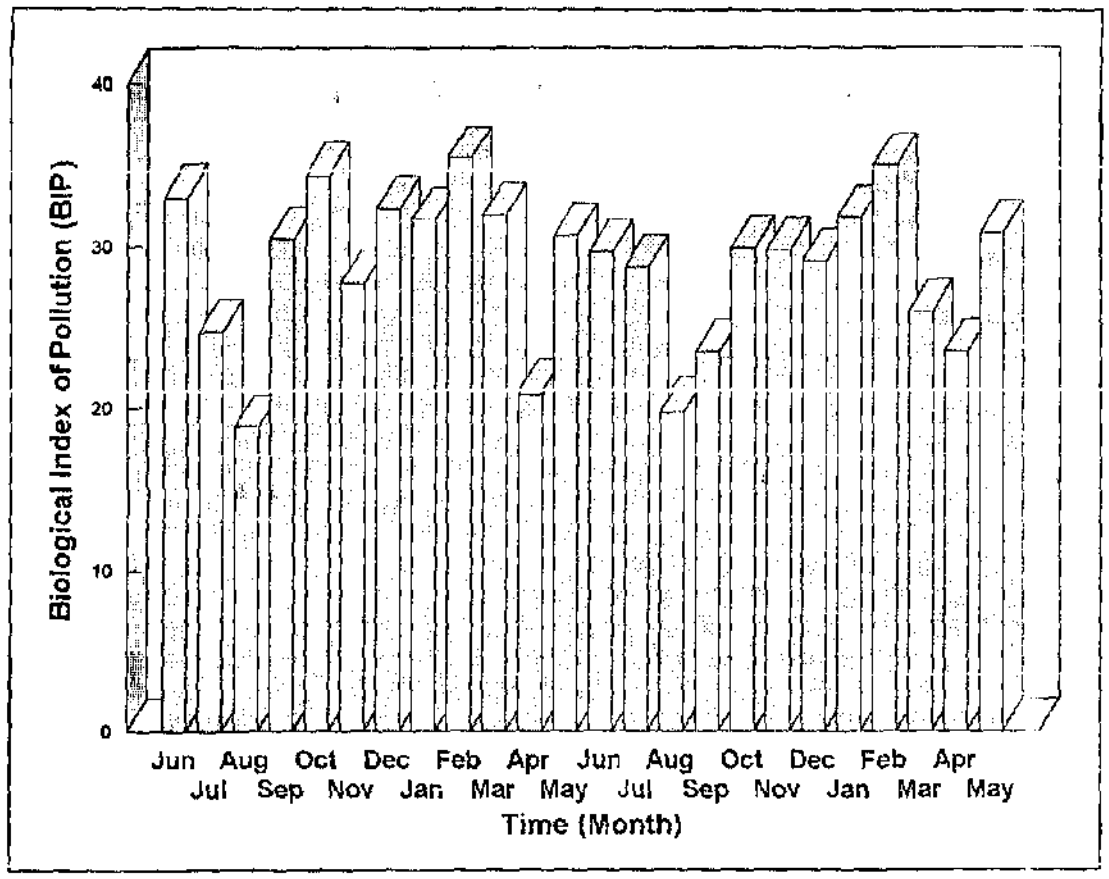


Fig. 31a. The general BIP for the 24 months.

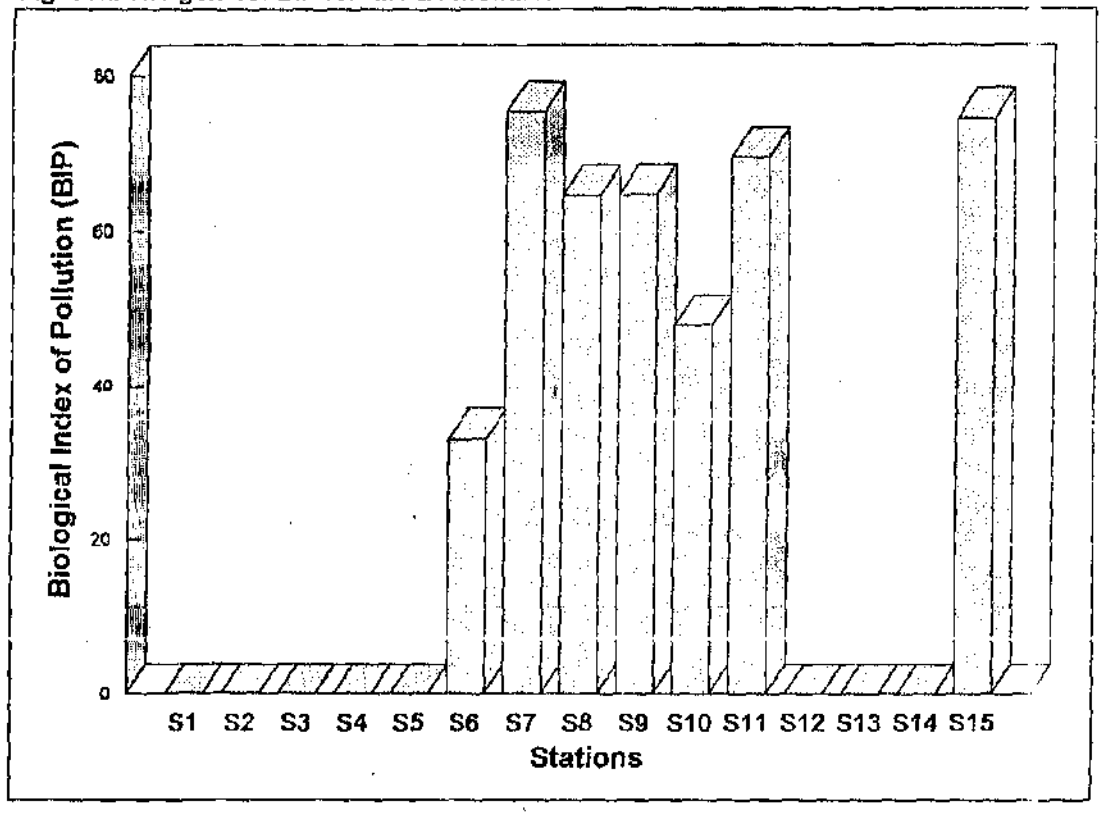


Fig. 31b. The biological Index of Pollution (BIP) for all the Stations.

them beta saprobic (Table 31). In some cases, either zoo or phytoplankton were not found in the sample collected for examination. As a result of this, key variables used in the calculation of BIP were missing; resulting in difficulties in the application of the index. In situations were either phytoplankton or zooplankton are absent from water, it may be difficult to apply the BIP.

For most parts of the year, the quality of the water from the different sources was poor (Figure 32). In the rainy season there was enrichment of the water sources through inflows and infiltration of dissolved matter macronutrients and metals. The measured total hardness, COD , optical densities etc. were higher during the rainy reason. Also water sources which had proximity to point sources of pollution like pit latrines and polluted drains (gutters) recorded higher BIP's during the rains.

Table 33 shows some results obtained with respect to the physico-chemical parameters and their comparison with the calculated corresponding BIP's as measured for the sampling stations.

It was possible to classify the quality situation of the sources into betsaprobic and alphasaprobic. Some of the water sources, especially in the rainy reason, gradually shifted in quality from betasaprobism to alphasaprobism. The BIP method gave a satisfactory indication of the quality status of each water source especially when the results obtained were compared with the result of physico-chemical and bacteriological analysis of the water sources. However, unless the water source contains both phytoplankton and zooplankton which are key variables in the BIP computation, the index may prove difficult of apply.

Table 31 The Calculated Values for Biological Index of Pollution (BIP).

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15		Mean B
Jun.	0.00	0.00	0.00	0.00	0.00	42.80	97.20	77.70	76.10	58.80	81.60	0.00	0.00	0.00	79.20	495.40	33.00
Jul.	0.00	0.00	0.00	0.00	0.00	26.30	61.30	58.90	86.80	37.50	64.50	0.00	0.00	0.00	66.60	371.90	24.70
Aug.	0.00	0.00	0.00	0.00	0.00	11.70	58.00	43.90	41.10	23.50	50.00	0.00	0.00	0.00	54.10	282.30	18.80
Sep.	0.00	0.00	0.00	0.00	0.00	31.50	1.80	70.30	68.60	48.80	75.30	0.00	0.00	0.00	80.40	456.70	30.40
Oct.	0.00	0.00	0.00	0.00	0.00	42.80	86.60	76.40	74.60	70.40	80.80	0.00	0.00	0.00	84.00	515.60	34.30
Nov.	0.00	0.00	0.00	0.00	0.00	36.80	70.00	23.80	74.00	57.10	80.30	0.00	0.00	0.00	74.20	416.20	27.70
Dec.	0.00	0.00	0.00	0.00	0.00	47.30	76.90	75.00	73.10	55.50	79.20	0.00	0.00	0.00	78.80	485.80	32.30
Jan.	0.00	0.00	0.00	0.00	0.00	41.10	86.00	72.20	70.60	52.00	77.10	0.00	0.00	0.00	76.20	475.20	31.60
Feb.	0.00	0.00	0.00	0.00	0.00	40.00	81.40	85.10	83.70	68.70	87.60	0.00	0.00	0.00	83.70	530.20	35.30
Mar.	0.00	0.00	0.00	0.00	0.00	36.30	70.00	79.40	77.40	60.00	83.60	0.00	0.00	0.00	73.00	479.70	31.90
Apr.	0.00	0.00	0.00	0.00	0.00	23.30	54.40	48.60	45.10	29.00	54.20	0.00	0.00	0.00	58.60	312.90	20.80
May.	0.00	0.00	0.00	0.00	0.00	31.00	75.50	73.30	71.80	53.40	77.90	0.00	0.00	0.00	76.30	459.20	30.60
Jun.	0.00	0.00	0.00	0.00	0.00	42.40	83.30	74.80	72.30	62.10	27.00	0.00	0.00	0.00	82.10	444.00	29.60
Jul.	0.00	0.00	0.00	0.00	0.00	29.60	83.00	65.50	63.80	44.40	70.80	0.00	0.00	0.00	72.80	429.20	28.60
Aug.	0.00	0.00	0.00	0.00	0.00	15.00	70.30	41.50	38.60	25.00	47.60	0.00	0.00	0.00	58.90	292.90	19.70
Sep.	0.00	0.00	0.00	0.00	0.00	21.00	73.90	50.90	48.80	32.90	57.20	0.00	0.00	0.00	64.50	347.20	23.40
Oct.	0.00	0.00	0.00	0.00	0.00	33.30	74.30	68.60	66.60	47.40	73.90	0.00	0.00	0.00	83.60	447.70	29.80
Nov.	0.00	0.00	0.00	0.00	0.00	30.70	73.10	71.00	68.80	50.90	75.80	0.00	0.00	0.00	76.10	446.40	29.70
Dec.	0.00	0.00	0.00	0.00	0.00	38.00	74.10	66.20	63.10	45.00	71.60	0.00	0.00	0.00	77.70	436.30	29.00
Jan.	0.00	0.00	0.00	0.00	0.00	39.10	89.40	71.20	69.30	50.70	76.30	0.00	0.00	0.00	80.40	476.40	31.70
Feb.	0.00	0.00	0.00	0.00	0.00	36.80	84.10	82.80	82.00	65.70	85.80	0.00	0.00	0.00	85.50	522.70	34.80
Mar.	0.00	0.00	0.00	0.00	0.00	33.30	73.40	56.60	54.00	34.70	62.30	0.00	0.00	0.00	75.00	389.30	25.90
Apr.	0.00	0.00	0.00	0.00	0.00	26.60	67.70	50.80	48.00	30.00	56.40	0.00	0.00	0.00	71.20	351.30	23.40
May.	0.00	0.00	0.00	0.00	0.00	40.00	82.60	59.80	67.00	48.00	74.20	0.00	0.00	0.00	78.80	461.00	30.70
Total	0.00	0.00	0.00	0.00	0.00	33.10	75.40	64.70	64.80	48.00	69.60	0.00	0.00	0.00	74.60		Mean B

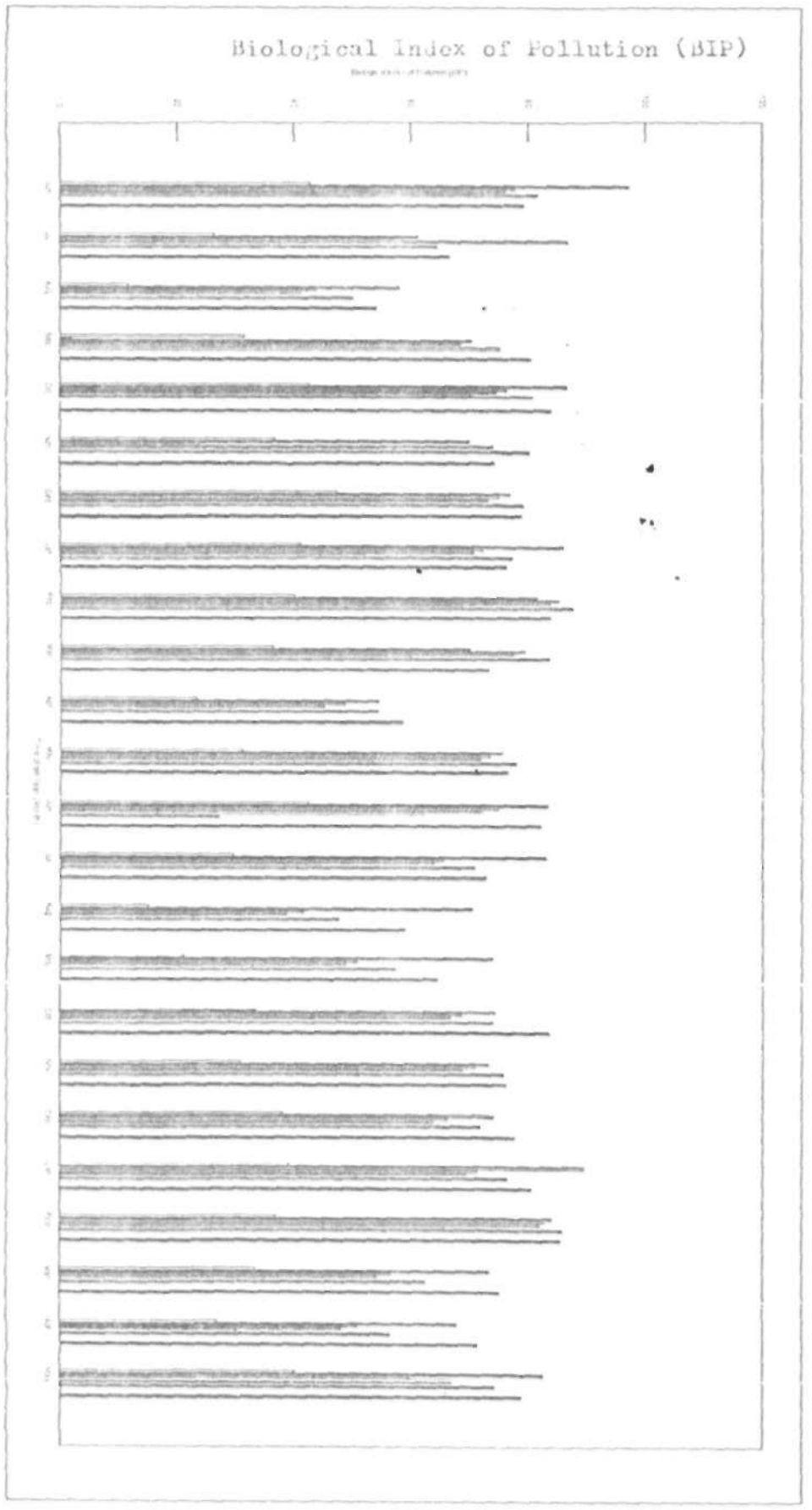

Biological Index of Pollution (BIP)

Table 33 Comparison of BIP with Physico-chemical parameters

Prameters	Unit	RSM	DSM	OWS mean	RWS mean
Optical density		1.0882 x 10	0.8111 x 10	1..383 x 10	0.963 x10
Suspended Solids	mg/L	111.62	102.34	180.083	88.708
Total Solids	mg/"	389.5	376.89	644.316	328.572
Hardness	mg/"	151.1	132.3	186.29	130.725
NO_3-N	mg/"	3.32	2.8	4.586	2.684
PO_4P	mg/"	74.71	49.5	121.152	47.354
COD	mg/"	20.951	20.226	16.839	21.526
BOD	mg/"	3.554	3.617	5.279	3.162
Coliform count	per 100 ml	13.001	9.619	20	9.293
Streptococcus count	per 100 ml	1.052	0.167	0.823	0.555
BIP		27.805	27.033	73.2	17.55

RSM = Rainy Season Mean

DSM = Dry Season Mean

OWS = Open Water Sources

RWS = Restricted Water Source

Table 32 COMPARISON OF DRINKING STANDARDS AND THE OBSERVED

Criteria	Min. Al Conc.	Max. Al.Conc.	Limit
Parametres affecting potability	WHO (MAL)	(WHO)	
Total Solids	500mg/L	1500mg/L (WHO)	
Iron (Fe)	0.3-10mg/L		DWL = 0.03mg/L
Manganese (Mn)	0.1-0.5mg/L	5.0 mg/L (WHO)	0.05mg/L-0.10mg/L
Copper (Cu)	1-1.5 "	1.5 mg/L "	1.0mg/L (Max.AL)
Zinc (Zn)	5-15 "	1.5 mg/L "	< 5mg/L (MAL)
Calcium (Ca)	75-200 "		
Magnesium (Mg)	50-150 "		30mg/L(DWL AWQS) if SO_4 = 250mg/L
Chloride (Cl)		200-600 mg/L	200 mg/L
PH range		7.0-8.5	6.5-9.0
Hardness		100-500 (HDL-MPL)	100mg/L $CaCO_3$ (Derived Working Level)
Parameters having definite effects upon health	(WHO)		
Nitrate	10 mg/L		10mg/L (DWL)
Sodium (Na)			20-27mg/L (DWL)depending on physiological state
Parameters that are definite toxins			
Lead (Pb)		(Max.AL)	
Arsenic (As)		0.05mg/L	
Cadmium (Cd)		0.01mg/L	
		(Min.AL)	Minimum limit of pollution
Parameters that are indicators of pollution			
Chemical oxygen Demand (COD)		10 mg/L	
Biological oxygen Demand (BOD)		6 mg/L	
Parameters affecting the acceptability of water			
DO			Min. 5mg/L allwable limit
Temp.			10-15°C
PO_4-P			0.2mg/L(Suggested Max. Limit AWQS)

Table 34 The observed average values for the physico-chemical Parameters

TS	Fe	Mn	Cu	Zn	Ca	Mg	Cl	pH	Hardness	NO_3-N
388	3	0.22	0.39	0.44	3.9	3.6	80.8	7.07	142	3.06
Na	Pb	As	Cd	COD *	BOD	DO	Tem	PO_4-P*	*E. coli**	*S. faecalis.**
129	0	0.12	0.59	20.1	3.6	4.73	26.6	62.1	11.5/100ml	0.5/100ml

* Signifies the parameters that fall below the minimum standards set for water indended for human consumption and other domestic uses.

The *Escherichia coli* MPN-Index , *Streptococcus faecalis* , COD, NO_3-N and PO_4-P were above the recommended limits set for water quality intended for human consumption. Temperature, pH, SS, TS and metal concentrations were found to be within the acceptable limits of water quality.

CHAPTER SIX

6.0. SUMMARY:

The biological and physico-chemical characteristics, distribution, abundance and seasonal variation of phytoplankton and zooplankton groups were studied for a period of twenty four months (June 1993 to May 1995) in three selected rural communities in Zaria (Shika-Dam, Bomo and Tudun- Sarki).

Water samples were collected monthly from fifteen (15) different water sources (three OWSs and twelve RWSs) methods of Lind (1979), APHA (1980), WHO (1963,1971), DHSS (1983), Smith (1977) was used. Water temperature, electrical conductivity and pH were measured on the spot using mercury thermometer, portable conductivity and PH metres respectively. Optical density of the water was measured by spectrophotometry (Lee, 1978,. Hammad and Dirar, 1996). Dissolved and suspended solids by methods of Lind (1979), WHO (1963 and 1971), APHA (1980). Water hardness, chloride ion by titration method of Lind (1979) and APHA (1980), DO by modified Winkler's method (Lind, 1979 ; APHA, 1980), BOD (APHA, 1980, COD (Golterman, (1970). No_3-N, $P0_4$-P concentrations are determined by spectrophotometry using Deniges and Phenol-disulphonic acid respectively (APHA, 1980).

Alkaline earth metals (K,Ca,Na and Mg) were determined by Flamephotometry (WHO, 1963; APHA, 1980). Heavy metals (Pb,Zn, Cd, Fe, Mn, and Cu) were determined by Atomic Absorption Spectrophotometry (APHA, 1980). Faecal coliform and faecal streptococcus MPN-indices were determined by multiple tube method(WHO, 1963, 1971; Smith, 1977, DHSS, 1983 and APHA (1985).

Measured Parameters were analysed using ANOVA (SPSS), Duncan's Multiple Range Test (SAS), and Rank Correlation Analysis (SPSS/Pc+4.0) using two-tailed test at 0.01 (1%) and 0.05 (5%) levels of significance as appropriate. Graphic representations were obtained using lotus 1-2-3 release 5 for windows.

Water temperature recorded was within the optimum range, from 18.0 C with higher RSM of 28.1 C and lower DSM of 25.1 C reflecting slightly significant difference between seasons($P< 0.05$). The OWSs maintained fairly uniform range of temperature with variations of less than 2 C. Reason for the recorded little fluctuation in water temperature was attributed to high specific heat of the water and turbulence.

The optical density (OD) of the water sampled was higher during the rainy season with significantly higher differences between seasons and stations ($P< 0.01$). The increased OD during the rainy season was attributed to increased autochthonous and allocthonous input of dissolved and suspended matter, especially as OD had highly significant positive correlation with amount of SS, conductivity, hardness, COD and micronutrient.

The amount of suspended solids (SS) maintained peaks during the early rains and late dry season. The early mains increase was due to allocthonous input from surface run- off into the OWSs owing to lack of protection of the services. The late dry season peak was attributed to the reduction in volume of water per unit of SS. The amount of total solids (TS) ranged from 90 mg/L to 1504 mg/L. The average concentration (AC) of TS was 387.74 mg/L, which falls below the HDL set by the WHO, hence regarded acceptable in terms of water quality for domestic use. The amount of TS was higher during the rainy season with highly significant variation between stations ($P< O.01$ seepage from the surface water during the

period of rains coupled with the high porosity of the soil were attributed to the high RSM. There was highly significant positive correlation between TS and electrical conductivity (P< 0.01).

Water hardness was observed to be high during the rainy season long with increased concentrations of Ca and Mg ions, with highly significant variations between season ad stations (P< 0.01). Water hardness ranged from 52 mg/L. CaCO3 to 289 mg/L. CaCO3. The AC was 141.7 mg/L. CaC03. The correlation between hardness and Ca, mg, and conductivity was positive and significant (P< 0.01).

Relative stable pH values were recorded throughout the 24 months sampling period. The water pH ranged from weakly acidic to weakly alkaline. The recorded range of 6.0 to 8.3, with GM pH value of 7.07 that falls within the highest desirable limit of water quality. The geological structure of the area characterised by the presence of igneous rock, which provides sufficient source of HCO3 thereby creating effective buffering system was responsible for the observed circum-neutral pH.

The electrical conductivity of the water was generally higher during the late dry season and early rained. This was attributed to the reduction in volume of water through evaporation and the submergence of the water table during the period of drought (November to April), and possible desorption of ions from sediment due to low pH and close proximity of the water sources to point sources of ion enrichment (gutters and toilets). There was highly significant correlation between conductivity and increase in most of the chemical parameters (P< 0.01).

The concentrations of Macronutrients were higher during the rainy season with significant difference between seasons (P< 0.01). The observed higher RSM

was due to enrichment by surface run-off from agricultural land, anthropogenic impact, desorption from sediment and ground-water contamination. No3-N and PO4-P exhibited positive correlation with each other (P< 0.01). The AC of nitrate was 3.06 mg/L, which was extremely low to cause any water quality concern.

The amount of DO in water was slightly influenced negatively by increase in water temperature (P< 0.05). There was positive correlation between amount of DO and pH and macronutrients (P< 0.01). The correlation between DO and OD was highly significant and negative (P< 0.01). The AC was 4.7 mg/L. With the exception of stations,1,2,4,9,10,12,13 and 14, which were all RWSs the GSMs for all the stations were higher than 4.0 mg/L. The amount of DO, especially in the OWSs, was adequate to sustain the biota.

Chloride ion concentration was higher during the rainy season. In the OWS this was due to enrichment by rains. Station 10 (RWS) measured the highest GSM of 196.38 mg/L. Its proximity to point-source of chloride enrichment(Toilet and Gutter) was attributed to such through ground-water contamination. The difference in Cl concentration was highly significant between seasons and stations (P< 0.01). chloride ion ranged from 22 mg/L to 280 mg/L with AC of 80 mg/L. The quality standard for the HDL Cl is 200 mg/L. With the exception of stations 10 and , such limit was not exceeded.

The general means (GM) for the BOD was 3.6 mg/L, which falls far below the WHO quality standard of 10 mg/L. Hence BOD level was generally within the acceptable quality limits.

The COD ranged from 1.3 mg/L to 58.5 mg/L with AC of 20.1 mg/L, which was more than three folds above the minimum limits of pollution set by the international standard for Drinking-water (WHO, 1971).

The concentration of alkaline earth metals were elevated with the o set of rains. However, the collective seasonal means indicate that the DSM, were igher (except for mg), suggesting that the early enrichment by rains was ot as remarkable in elevating their total concentrations as did the reduction in vol me of water, increased evaporation and submergence of the water table during t ie dry season. Enrichment was further enhanced by the proximity of sour es to allocthonous point sources. The difference between stations and seasons, s well as the positive correlation of these methods with conductivity of the wate were highly significant ($P< 0.01$).

With the exception of Cu and Mn, all the heavy metals had maxima i rainy season. Cu and Mn had maxima in dry season, stations distinct from point s urces had the lowest GSMs, while stations located in close proximity to point sourc s had higher GSMs reasons attributed to enrichment fro the catchment area dur g the rainy season through surface run-off, leaching and anthropogenic imparts.

The phytoplankton species recorded higher RSM which coincided w th the macronutrients maxima. The phytoplankton were more abundant in the OW s with four of the RWSs recording zero. Reasons for higher abundance was attrib ted to the higher concentration of macronutrients, Mg, Mn, BOD and condu tivity. Significant positive correlation between phytoplankton groups and macronu ients, BOD, Mg, Mn and conductivity was recorded ($P< 0.01$). The difference be ween stations, months, and seasons was significant ($P< 0.01$).

Zooplankton species were recorded in all the OWSs and four other s ations closely located to the OWSs.

Abundance was found to be related to maxima recorded in Ca, DO, p H, and TS ($P< 0.05$). ZooPlankton population correlated positively with increase in S S, TS,

Ca, Mg, Mn, DO,pH, hardness macronutrients, conductivity and BOD ($P< 0.01$). Eight (8) RWSs recorded zero.

The OWSs and two other stations (8 and 10) had E. Coli MPN-indices at infinity. Seasonal means revealed higher RSM. Reasons for higher E. coli index was attributed to contamination from surface run-off during the rains, shallow water table, proximity to pit latrines, and gutters and drainage, resulting in ground water contamination (GWC). Spilt and unprotected nature of the OWSs were also contributory.

Streptococcus faecalis indices were drastically low. The DSM was zero and the RSM was 1/100 ml. of water sample. The highest GSM was 2/100ml. In station eight five (5) other stations located near liquid point sources and all the OWSs had MPN-indices of 1/100ml water sample. Other stations recorded zero with highly significant difference between stations and seasons ($P< 0.01$). Presence of St. faecalis was linked with close proximity of stations 2,4,8,9 and 10 to pit latrines and gutters. The OWSs were subjected to directs contamination. The bacteriological WHO norm (WHO 1986) for acceptable drinking water is zero MPN index per 100 ml of water sample. Hence month of the sources were regarded unsafe.

6.1 CONCLUSION

1. Despite the intensive application of artificial and organic fertilizers in the catchment area and contributions from point sources, the level of nitrate in the water falls below the minimum permissible limit

2. The microbial quantity, especially of the OWSs, and sources located near point sources raised some points of concern particularly in the rainy season when the water sources became extensively contaminated. Such contamination, coupled with the corresponding high temperature of the water stand as potential indicator for pathogenic transmission.

3. The mean level of hardness(in S7 to S15) were higher than the desirable limits set regarding water intended for domestic use (WHO/971). The geological structure of the area and run-off were contributory to this. The use of the water for washing may be impaired, however, it use for drinking purpose remains acceptable.

4. Run-off from the catchment area during the rains was largely responsible for the alkaline earth metals enrichment of the water sources, further enhanced by liquid point-sources. Enrichment during the rainy season was however not as remarkable in elevating the total concentration of these metals as did the reduction in volume of water, increased evaporation and submergence of the water table during the dry season, which generally presented no danger to the water quality.

5. Elevated levels of Pb, Zn, Cd, As, and Fe in the water during the rainy season appeared to have been influenced by run-off, leaching and GWC; while proximity to liquid point sources seemed to have elevated Ca and Mn levels. The values detained for the inorganic elements do not show extensive contamination, with concentrations being below the international standard norms for safe drinking water.

6. High macro-nutrients enrichment during the rainy season appeared to have influenced corresponding abundance in phytoplankton groups during the same period. The OWSs that were most enriched recorded the highest GSMs for phytoplankton.

7. Abundance of the zooplankton species especially in the OWSs tallied with increased concentrations of DO, Ca, high PH, TS and electrical conductivity. Proximity of other stations (S6 S8, S9 and S10) to the OWSs appeared to have influence on their physio-chemical quality, hence the zooplankton characteristics too.

8. Stations I and II recorded mean BOD level above 6 mg/ L hence regarded of lesser quality than minimum allowable standard. Most of the stations with the exception of S6, S12, S13 and S15 were below standard quality specification with COD value more than 10 mg/L .

9. Quality of water from all the sampled sources based on the quality standard (WHO, 1963,1971) in other parameters; including amount of TS, Cl, PH, fall within the acceptable limits.

10. The BIP index may succesfully be use in establishing the pollution or quality status of water sources provided the source contains both Zooplankton and phytoplankton alike. Its attribute for routine applications rests primarily on its ease of application, low cost , adaptability and simplicity.

6.2 AREAS OF FURTHER STUDIES:-

1. Water quantity in the rural areas water sources was significantly affected by rainfall and proximity to liquid point sources (Pit latrines, gutter and drainage) following wet weather events amount of indicator bacteria in the water was significantly increased with rainfall. The exact significance of these quality indices remain unsolved. Hence the need for further studies on the contaminant migration pathway.

2. Similar studies have highlighted the importance of sediments as potential reservoirs of micro-organism and mental species in the aquatic environment . The physio chemical as well as biological relationship between sentiments and water quality needs to be studied, particularly the aspects of sentiment-water sorption-desorption phenomena, so as to establish comprehensive autochthonous hydro-dynamics of the quality indices.

3. Agricultural practices in the rural communities create situation for intensive application of artificial fertilizers which provide source of nitrate. Further, aerobic soil condition and the presence of nitrifying bacteria in the soil, convert ammonia sourced from organic matter to nitrate. In this study, extensive nitrate contamination has been recorded in the water sources.

Despite the fact that the AC of nitrates was too law as to cause any health concern, the RWSs being less phytoplankton populated may end up accumulating nitrate to the levels that would pose as health risk. Hence the need to study nitrate turn-over pathway of the ground-water, particularly as unsewered sanitation

offers the only affordable technical solution for waste disposed in the area.

6.3 RECOMMENDATIONS:-

Recommendations are aimed at preventing the following:

a. Ground water pollution through contaminant migration from liquid point sources to the communities' water sources.

b. Seepage and infiltration from the surface soil unto the water sources.

c. Contamination of water sources through vessels and rope use in drawing water.

d. Introduction of solids in to the sources.

e. Contamination by surface water run-off load.

f. Contamination through spilt water.

1. Ground water contamination (GWC) can result from location of water source too close to pit latrine, gutters, drainage, refuse dumps, or farm land. The influence of these point sources can extend to distance of about 10 metre in typical soil organic and inorganic contaminants as well as faecal bacteria contamination of the water sources through GWC may result. To prevent this, it is recommended that the minimum distance between water source and point source of pollution to be 10 metres.

2. The porous nature of the soil allows for seepage of water through the top few metres of the well lining, most especially as the well living is not sufficiently water tight near the surface. To prevent this, it is recommended that a concrete slab of at least 2 metres be laid surrounding the well head.

3. Rope of vessels carelessly used for drawing water provide effective link between contaminated well site and the water. To prevent this, it is recommended that the abandoned technique (the, early 1960s) of attaching rollers to the head well be re-introduced. By this technique, the vessel and rope are prevented from contacting contaminated soil and subsequent contamination of the water is thus avoided.

4. Spilt and surface run-off contaminating well water can be prevented by the construction of head well. This method was equally reported by Richardson (1989) as being effective in controlling Guinea Worm (Drancunculus medinensis) contamination of shallow wells in West Africa where drancontiasis was endemic.

5. For effective control of both seepage. GWC contamination from run-off and other sources, concretizing the well lining and complete sealing of the wells and installation of hard pump is recommended. This may however be far from being affordable to the communities and maintenance of the pump will present another major problem.

6. The major sources of water for domestic use for the rural communities both by availability and preference are the hand-dug well, which comprise over

90% of the water sources in the hight of which, recommendations are largely centred on them. The OWSs being more productive and largely inhabited by greater life diversity, may be capable of accumulating the pollutants through bio-accumulation and their diverse hydro-ameliorative. It is recommended that the habitual free squatting method of faeces disposal near the OWSs be avoided.

Also clean environment within the anthropogenic set up reduces the run-off load during the rainy season, particularly as open water bodies are the ultimate recipients of the run-off from human settlements. This may lead to reduction in TS, SS & OD in the OWSs.

The goal of the International Drinking water and Sanitation Decade (1981-1990) is to improve public health by a reduction in water and excreta related diseases. The decade had witnessed considerable progress, at least in terms of number of water supply and sanitation units provided. Unfortunately the anticipated health benefits had not been automatically followed by improved service provision. Reasons for this, according to Ward (1989) centred on the public lack of understanding of the relationship between excreta, contaminated water and disease. It is in the light of the above that public education to re-direct the attitude of the rural dwellers towards the understanding of the health risks associated with pollution of water sources is recommended.

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APPENDIX 1

Montly variation in water temperature (C)

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
Jun	25	30.1	29	30	29	28.7	32.5	27	26.5	26.7	26.7	27	26.8	27	30
Jul	25.9	29.5	29.8	30.2	30.6	30	31.2	31.4	30.6	31.3	25.2	30.3	30.1	28.9	29.2
Aug	26	21.7	30.1	30.8	30.3	30.2	31.4	32.3	30.2	30.2	24	30	30	30	30
Sep	25.8	22.4	29.7	30.5	30.5	31	29.8	29.8	30	30.3	22.5	29.3	29.5	30	30.1
Oct	26.7	22.6	20.3	28	30.1	30.3	29.1	30.1	31.2	31	21.4	30	30.2	30.4	30
Nov	22.3	22.4	21	26.8	28	28	28.2	24.4	27.8	28.2	20.1	22	22.3	24	21.7
Dec	24.2	22.4	21.4	24	24.5	24.7	20	22.1	22	21.9	18.5	21.8	21.8	23.7	21.3
Jan	23.7	23.9	21.4	26.4	27.9	26.3	19.1	22.3	24.6	22.7	18	21.3	20.3	23.4	21.1
Feb	23	24.1	22	25	28	27.1	19.3	22	21.9	22	18.6	21	21	24.1	21.1
Mar	23.5	27	22.1	25	28	27.6	21	23.4	21.9	22	21	21	21	24.3	21.2
Apr	26.6	27.5	22.1	27.6	27.7	27.6	25	27.2	23	22.3	24	27.5	21	25.5	24.9
May	27	26.2	27.2	28	27.5	27.9	27.2	28	27	27.3	27	28.1	27.2	26.8	31.2
Jun	28	26.1	28.1	26.5	28.1	28.6	30	30	28	27.6	28.2	30	27.2	27	30.8
Jul	25.7	26.1	25.1	26.3	29	28.8	31.2	30.8	29.3	30.9	26.2	30.1	27.5	28	28.3
Aug	26.3	27	24.6	26	30.1	30	30	30.6	30	30	25	30	29.8	28.4	29
Sep	26.2	23.8	25.3	26.2	30	30	28	29.2	30	30	24.7	28.3	30	29.1	28.8
Oct	25.3	24.7	24	27.2	30.1	30	26.2	28.1	29.2	30.2	22.6	22.1	27	30	29.8
Nov	23.7	24	23.5	23.3	29.1	29.1	24	22.8	29.1	29.1	25	22	25.1	23.6	27.6
Dec	22.4	23.6	21	23.5	28.3	28.3	21.3	22.3	23	23.2	26.3	22	21.8	24	25.9
Jan	23.4	23.4	22.3	26.3	21	25	21	22.4	22.8	22	27.2	22.4	21	23.8	27.7
Feb	23	24	21.7	26	27.9	22.8	23	22.9	23	22.1	29	23.1	21	24.2	27.8
Mar	25.1	24	22	26.1	27.7	24.7	24.5	23.2	22.6	22.8	28.3	25	23.1	25	28
Apr	25.3	24.7	23.6	25.7	26.8	25	25.3	25.7	22	23.2	28.1	25.4	24	25.3	28
May	27.6	28.2	24.2	26	26.4	25.4	27.6	26.9	23.4	24.1	27	25.3	26.1	25.7	27.9

APPENDIX 2

Montly vanation in optical density of the water (x 10-2).

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
Jun	2.9339	1.0863	0.8568	2.4328	0.6069	0.688	0.51	1.3622	1.0166	5.9245	1.4331	2.5179	2.9717	3.1513	1.8309
Jul	0.8082	1.1502	0.9072	0.6702	0.6426	0.7285	0.54	1.4187	1.0587	1.6321	1.5174	0.6936	0.8187	0.8681	1.9386
Aug	0.7546	1.0437	0.8232	0.6257	0.5831	0.661	0.49	1.3245	0.9885	1.5238	1.3769	0.6476	0.7643	0.8105	1.7591
Sep	0.894	1.3206	1.0416	0.7414	0.7378	0.8364	0.62	1.5693	1.1711	1.8054	1.7422	0.7673	0.9056	0.9603	2.2258
Oct	0.5767	1.8105	1.428	0.4782	1.0115	1.1467	0.85	1.0122	0.7554	1.1645	2.3885	0.4949	0.5841	0.6194	3.0515
Nov	0.6453	1.9809	1.5624	0.5351	1.1067	1.2546	0.93	1.1327	0.8453	1.3031	2.6133	0.5538	0.6537	0.6932	3.3387
Dec	0.4566	1.5123	1.1928	0.3786	0.8449	0.9578	0.71	0.8014	0.598	0.9219	1.9951	0.3918	0.4624	0.4904	2.5489
Jan	0.2935	1.1076	0.8736	0.2434	0.6188	0.7015	0.52	0.5152	0.3845	0.5927	1.4612	0.2519	0.2973	0.3153	1.8668
Feb	1.0772	1.0863	0.8568	0.8932	0.6069	0.688	0.51	0.5001	0.3732	2.1752	1.4331	0.9245	1.0911	1.157	1.8309
Mar	1.1745	1.1502	0.9072	0.9739	0.6426	0.7285	0.54	0.5453	0.407	2.3718	1.5174	1.008	1.1897	1.2616	1.9386
Apr	1.0123	1.0437	0.8232	0.8394	0.5831	0.661	0.49	0.47	0.3508	2.0442	1.3769	0.8688	1.0254	1.0874	1.7591
May	1.434	1.3206	1.0416	1.1891	0.7378	0.8364	0.62	0.6658	0.4969	2.8958	1.7422	1.2307	1.4525	1.5403	2.2258
Jun	4.3126	1.8105	1.428	3.576	1.0115	1.1467	0.85	2.0023	1.4943	8.7085	2.3885	3.7011	4.3681	4.6322	3.0515
Jul	1.2265	1.9809	1.5624	1.0171	1.1067	1.2546	0.93	2.1529	1.6067	2.4768	2.6133	1.0526	1.2424	1.3175	3.3387
Aug	0.9906	1.5123	1.1928	0.8214	0.8449	0.9578	0.71	1.7387	1.2976	2.0003	1.9951	0.8501	1.0033	1.064	2.5489
Sep	0.7868	1.1076	0.8736	0.6524	0.6188	0.7015	0.52	1.381	1.0306	1.5888	1.4612	0.6752	0.7969	0.8451	1.8668
Oct	0.2849	1.0863	0.8568	0.2363	0.6069	0.688	0.51	0.5001	0.3732	0.5754	1.4331	0.2445	0.2886	0.3061	1.8309
Nov	0.2163	0.9159	0.7224	0.1794	0.5117	0.5801	0.43	0.3796	0.2833	0.4368	1.2083	0.1856	0.2191	0.2323	1.5437
Dec	0.1734	0.8094	0.6384	0.1438	0.4522	0.5126	0.38	0.3043	0.2271	0.3501	1.0678	0.1488	0.1756	0.1862	1.3642
Jan	0.0618	0.5325	0.42	0.0513	0.2975	0.3373	0.25	0.1085	0.081	0.1249	0.7025	0.0531	0.0626	0.0664	0.8975
Feb	1.0772	1.0863	0.8568	0.8932	0.6069	0.688	0.51	0.5001	0.3732	2.1752	1.4331	0.9245	1.0911	1.157	1.8309
Mar	0.8177	0.9159	0.7224	0.678	0.5117	0.5801	0.43	0.3796	0.2833	1.6512	1.2083	0.7018	0.8282	0.8783	1.5437
Apr	0.6555	0.8094	0.6384	0.5435	0.4522	0.5126	0.38	0.3043	0.2271	1.3237	1.0678	0.5626	0.6639	0.7041	1.3642
May	0.2338	0.5325	0.42	0.1938	0.2975	0.3373	0.25	0.1085	0.081	0.4721	0.7025	0.2006	0.2368	0.2511	0.8975

APPENDIX 3

Montly variation in amount of suspended solids in water (mg/L)

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
Jun	246	98	80	92	53	45	202	99	85	134	199	41	38	43	281
Jul	252	101	81	97	51	48	209	101	99	134	199	39	42	45	293
Aug	238	96	77	63	48	43	222	132	140	153	202	31	37	40	304
Sep	214	95	71	66	44	40	219	147	149	166	232	28	34	37	313
Oct	219	92	62	62	43	39	225	154	157	178	248	25	32	36	271
Nov	280	103	65	93	52	42	201	160	157	93	391	27	39	41	253
Dec	301	121	63	95	55	53	191	112	98	93	211	43	45	49	247
Jan	228	130	68	106	55	51	173	99	87	67	216	51	46	49	241
Feb	251	159	70	129	62	57	150	56	52	51	147	48	51	54	190
Mar	297	171	73	135	65	57	124	51	48	46	150	49	53	55	152
Apr	300	175	76	147	69	59	121	46	41	52	132	54	53	56	137
May	321	178	80	152	74	62	90	42	41	85	129	56	57	59	148
Jun	319	182	83	91	78	66	87	83	57	99	102	61	60	63	163
Jul	330	101	76	84	62	58	100	95	63	82	198	53	51	54	169
Aug	345	91	74	80	59	54	132	98	77	91	192	51	47	51	202
Sep	215	88	68	67	53	49	138	103	100	111	224	46	43	46	215
Oct	211	83	59	69	40	41	135	79	75	124	161	39	34	35	244
Nov	201	107	61	97	45	39	170	48	60	120	181	36	37	36	163
Dec	132	131	66	96	52	40	201	43	51	96	157	34	37	37	171
Jan	210	138	69	101	67	46	213	40	45	81	93	43	41	44	165
Feb	232	163	73	132	68	45	112	40	45	87	81	40	39	42	160
Mar	283	175	74	148	71	44	104	37	40	92	80	38	37	40	115
Apr	269	180	78	153	73	49	99	33	41	94	131	44	42	45	201
May	301	191	77	161	77	51	173	31	37	98	167	47	45	48	154

APPENDIX 4

Montly variation of total solids in the water (mg/L).

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
Jun	734	377	308	354	204	134	603	296	254	400	515	158	146	165	1081
Jul	969	302	312	290	152	143	624	388	381	515	785	150	162	173	1127
Aug	711	287	296	242	185	165	854	508	538	588	603	119	110	119	908
Sep	823	365	273	254	169	154	842	439	445	496	892	108	131	142	1204
Oct	842	354	238	288	165	116	672	460	469	531	740	96	123	138	1042
Nov	1077	396	250	358	200	125	600	478	469	278	1504	104	150	158	973
Dec	1158	465	242	365	212	158	570	334	377	358	811	165	173	188	950
Jan	877	500	203	316	212	196	665	381	335	258	831	196	177	188	927
Feb	965	611	209	385	238	219	577	215	200	196	565	185	196	208	731
Mar	1142	658	281	519	250	219	477	196	185	137	448	146	158	212	585
Apr	1154	673	292	565	265	227	485	177	158	200	508	208	204	167	409
May	1234	658	308	585	285	238	346	162	158	254	385	167	219	227	569
Jun	1227	700	319	350	300	254	335	319	219	381	392	235	179	188	487
Jul	1269	388	292	323	238	223	385	284	188	245	591	204	196	208	650
Aug	1327	350	285	308	227	161	394	293	230	272	738	196	181	196	777
Sep	827	338	262	258	204	188	531	396	299	331	669	137	165	177	827
Oct	811	319	227	265	154	122	403	304	288	477	619	150	131	135	938
Nov	773	411	182	290	173	150	654	185	231	461	696	138	142	138	627
Dec	508	504	254	369	200	154	773	165	196	369	604	102	110	110	511
Jan	808	531	265	388	258	177	819	154	173	312	358	165	122	131	635
Feb	892	627	281	508	262	173	431	154	173	260	242	119	116	125	478
Mar	845	673	285	569	273	169	400	142	154	354	308	146	110	119	343
Apr	803	629	300	588	281	188	381	127	158	361	504	169	162	173	773
May	1158	735	296	619	296	196	516	93	110	377	642	181	173	185	592

APPENDIX 5

Montly variation in hardness of the water(mg/L CaCO3).

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
Jun	101	129	113	122	108	112	273	244	258	254	260	243	234	254	251
Jul	96	114	81	90	78	83	281	241	248	251	257	221	237	262	254
Aug	92	106	76	85	73	78	192	191	198	194	200	124	100	143	132
Sep	87	69	71	84	68	73	185	148	139	145	157	108	102	145	134
Oct	63	67	69	83	66	71	180	128	126	132	144	95	89	132	121
Nov	72	64	67	81	62	69	130	117	112	118	130	102	96	139	128
Dec	63	66	61	75	56	63	127	113	108	114	126	99	93	136	125
Jan	74	69	72	86	67	74	113	185	180	176	198	110	89	132	121
Feb	98	73	96	110	91	98	148	197	192	195	210	131	122	147	139
Mar	101	97	102	116	99	104	152	203	198	201	216	215	224	249	241
Apr	122	138	133	142	130	132	170	235	230	233	248	220	229	254	246
May	99	176	128	137	125	127	246	238	233	239	251	240	216	241	248
Jun	113	130	121	130	118	120	289	241	245	251	254	242	221	246	253
Jul	100	101	90	99	87	89	289	119	123	129	132	249	228	253	260
Aug	89	99	78	92	75	77	273	118	132	138	134	132	108	151	140
Sep	85	76	63	77	60	65	181	115	129	135	131	112	106	149	138
Oct	65	72	61	75	58	63	175	119	110	116	128	103	112	140	129
Nov	60	73	57	71	52	59	172	116	107	103	125	96	105	133	122
Dec	61	72	60	74	55	62	123	105	103	106	121	94	103	128	120
Jan	79	69	64	78	59	66	117	126	121	117	139	122	116	156	148
Feb	111	78	79	88	76	81	113	228	223	229	241	179	158	183	190
Mar	130	84	82	91	79	81	132	233	228	234	246	204	183	218	215
Apr	134	91	99	108	96	98	158	237	241	247	250	201	195	238	227
May	97	120	130	144	127	129	277	235	246	252	248	230	224	234	241

APPENDIX 6

Montly variation in water reactivity (pH)

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
Jun	6.1	6.6	7.1	7.3	7.4	7.6	7.3	6.8	6.4	6	7.5	7.3	7.1	7.2	8.2
Jul	6	6.5	6.8	7.1	7.5	8	7.2	6.7	6.7	6.6	7.3	6.9	7	7.2	8
Aug	6.2	6.5	6.8	6.9	7.7	7.9	7.6	7.1	6.5	6.5	7.3	7.1	7	7.5	7.9
Sep	6.3	6.7	7	6.9	7.6	7.8	7.3	7	6.9	6.5	7.6	7.1	6.9	7.8	7.5
Oct	6.1	6.5	7.1	6.9	7.7	7.8	7.6	7.1	7	6.3	7.4	7	7.1	7.2	7.6
Nov	6.1	6.3	7	7.2	7.5	8	7.4	6.9	6.8	6.5	7.5	7.1	7.3	7.6	7.6
Dec	6.2	6.4	7.2	7.4	7.7	7.8	7.4	6.8	6.9	6	7.5	6.8	7.2	7.5	7.7
Jan	6	6.4	7.2	7	7.4	7.9	7.3	6.9	6.5	6.3	7.3	6.8	7.2	7.6	7.5
Feb	6.3	6.4	7.2	7	7.9	8	7.8	7.1	6.7	6.4	7.1	6.9	7	7.2	8
Mar	6.4	6.4	7.3	6.8	7.7	8.2	7.6	7	6.7	6.4	7.2	7	7	7.4	7.8
Apr	6.2	6.7	7.2	6.9	7.7	7.8	7.3	6.8	6.8	6.3	7.1	6.9	7	7.7	7.5
May	6.3	6.8	7.1	6.9	7.5	8	7.4	6.9	6.6	6.2	7.4	7.2	7	7.3	7.6
Jun	6.6	6.5	7	6.9	7.2	7.3	7.2	6.9	7	6.2	7.3	7.5	7.1	7.5	7.4
Jul	6.6	6.4	6.8	7	7.3	7.8	7	6.8	7	6.2	7.3	7.5	7.3	7.6	7.2
Aug	6.5	6.4	7	7.2	7.1	7.3	7	6.8	6.8	6.7	7.3	7.3	7.1	7.4	7.3
Sep	6.7	6.4	6.8	7.5	7.4	7.9	7.1	7	6.7	6.3	7.2	7	6.9	7.3	7.5
Oct	6.2	6.6	6.9	7.3	7.3	7.4	7.2	7	6.9	6.6	7	7.1	7	7.4	7.8
Nov	6.2	6.5	6.8	7	7.5	8	7.2	6.7	6.9	6.7	7.2	6.9	7	7.1	7.8
Dec	6.2	6.7	7.1	7.1	7.3	7.4	7.2	6.8	6.5	6.7	7.2	6.4	7	7.3	7.7
Jan	6.1	6.5	7.2	7.4	7.8	8.3	7.5	6.7	6.7	6.5	7.2	7	7.2	7.2	7.9
Feb	6.3	6.5	7	7.2	7.5	7.6	7.4	7	6.9	7	7.3	7	7.1	7.5	7.6
Mar	6	6.5	7	7.5	7.5	8	7.2	6.6	6.4	6.8	7.2	6.8	7	7.4	7.5
Apr	6.2	6.8	7.1	7.9	7.2	7.3	7.1	6.6	6.7	6.5	7.6	6.9	7	7.5	7.3
May	6.1	6.8	7.3	7.2	7.3	7.8	7	6.8	6.7	6.2	7.4	7	7.3	7.2	7.5

APPENDIX 7

Monthly variation in electrical conductivity of the water (Um/cm3).

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
Jun	62	63	45	84	41	33	59	78	94	105	81	48	40	55	81
Jul	21	21	15	28	14	11	45	57	69	35	44	33	29	39	57
Aug	19	19	14	25	12	10	48	51	61	32	41	36	31	41	61
Sep	26	27	19	36	17	14	42	72	87	45	104	56	48	65	96
Oct	21	22	16	29	14	11	53	59	71	37	57	28	24	33	48
Nov	24	24	17	32	16	13	50	65	79	40	102	47	41	54	81
Dec	17	17	13	23	11	9	51	47	57	29	117	56	48	65	96
Jan	25	26	18	34	17	13	56	69	84	43	120	58	50	67	99
Feb	55	56	41	75	36	30	61	152	183	94	138	87	56	75	111
Mar	116	118	85	157	76	62	67	146	177	197	137	87	58	71	111
Apr	78	79	57	105	51	41	103	98	118	132	88	80	51	69	102
May	72	74	53	98	48	39	91	91	101	123	51	54	35	50	69
Jun	60	62	45	82	40	32	56	86	98	103	49	43	28	37	55
Jul	24	25	18	33	16	13	45	66	80	41	75	30	26	35	51
Aug	19	19	14	26	13	10	47	52	63	32	41	25	22	29	43
Sep	17	17	13	23	11	9	48	47	57	29	41	23	20	27	40
Oct	16	16	11	21	10	8	50	43	52	27	43	22	19	25	37
Nov	19	19	14	25	12	10	48	51	61	31	44	24	21	29	41
Dec	22	22	16	30	14	12	51	60	73	37	49	33	28	40	57
Jan	27	27	20	36	18	14	55	73	88	45	60	38	32	43	64
Feb	31	32	23	42	20	17	68	85	103	53	72	41	35	47	69
Mar	73	74	54	99	48	40	64	92	111	124	81	57	38	50	73
Apr	71	73	53	97	47	38	112	90	109	121	75	56	35	41	72
May	62	63	45	84	41	33	88	78	94	105	62	51	36	49	72

APPENDIX 8

Monthly variation in concentration of nitrate-nitrogen of the water (mg/L)

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
Jun	3	2.7	1.6	3.3	2.3	4.8	4.9	3.5	3.6	6.3	5.3	1.9	1.3	1.5	3.6
Jul	2.5	2.5	1.4	3.5	2.7	4.8	5.2	3.9	4.1	6.9	5.7	1.7	1.8	2.1	3.8
Aug	2.8	2.6	1.5	3.4	3	5.2	5.1	3.9	4.7	6.8	5	1.8	1.9	2	4.1
Sep	2.5	2.6	1.5	3.8	3.1	5.5	6	4.5	4.2	7.7	5.1	1.9	1.9	2.1	4.1
Oct	2.4	1.8	1.6	3.8	3	5.6	5.7	4.8	4.3	8.1	5	1.8	1.5	1.7	4
Nov	2.4	1.9	1.3	2.3	3.3	4.9	4.3	4.2	3.3	6	6.3	1.6	1.5	1.8	3.6
Dec	1.8	1.8	1.4	2.4	2.8	4.6	4.3	3.8	3.1	5.8	5.8	1.8	1.4	1.6	3.4
Jan	2.5	1.5	1.3	2.3	2.1	4.2	4.1	3.9	3.1	5.6	5.1	1.7	1.2	1.4	3.4
Feb	2.9	1.5	1	2.3	2.1	2.8	4	4	3.2	5.3	5.1	1.5	1	1.3	3.5
Mar	2.8	1.4	1	2.2	1.9	2.5	4.1	3.8	3	5.5	5.1	1.4	1	1.2	3.4
Apr	2.7	1.6	1.1	2.1	1.9	2.1	4.7	3.5	2.8	5.1	4.9	1.4	1.1	1.3	4
May	3.2	2.3	1.2	2.6	2	2.2	5.6	3.7	3.2	5.8	4.9	1.6	1.2	1.5	4.1
Jun	2.9	2.1	1.3	3.2	1.8	3.5	5.3	3.9	3.6	6.7	5	1.8	1.6	1.8	4
Jul	2.9	2.1	1.8	3.2	2.5	3.9	5.8	3.9	3.6	6.5	4.8	1.7	1.4	1.6	4.5
Aug	2.5	2.2	1.9	3.6	2.4	4	5.2	4.1	3.8	6.2	5.5	2	1.5	1.3	4.7
Sep	2.3	2.1	1.8	3.7	2.4	3.9	5.9	1.5	3.6	4.8	5.4	2.1	1.6	1.9	4.6
Oct	2.6	2	1.5	3.1	2.1	4.2	5.5	3.9	3.5	6.5	5.6	1.8	1.6	2	4.1
Nov	2.9	1.7	1.6	2.2	2.2	3.1	5.5	3.7	3	5.4	5.4	1.9	1.3	1.6	3.8
Dec	3	1.7	1.4	2.1	1.7	3.1	4.6	3.7	2.9	5.3	4.1	1.6	1.4	1.7	3.5
Jan	3	1.4	1.2	2.3	1.6	2.6	4.4	3.4	2.9	5.4	4	1.6	1.3	1.5	3.5
Feb	3.3	1.2	1	2.4	1.3	2.4	4.4	3.3	2.8	5.2	4.3	1.4	1	1.3	3.9
Mar	3.5	1.2	1	2.2	1.2	2.5	4.4	3.5	2.8	5	4.1	1.7	1	1.5	4
Apr	3.8	1.2	1.1	2.1	1.1	2.5	4.4	3.1	2.6	5	4.2	1.5	1.1	1.6	4.2
May	3.7	1.3	1.2	2.3	1.2	2.3	4.5	3	2.7	4.8	4.2	1.4	1.2	1.3	2.6

APPENDIX 9

Montly variation in phosphate-phosphorus in water (mg/L)

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
Jun	56	37	32	60	42	80	175	67	57	53	192	45	35	33	280
Jul	58	38	35	60	45	83	260	65	53	51	166	31	36	35	310
Aug	58	41	38	63	49	98	261	60	61	56	162	47	39	37	240
Sep	60	43	38	67	49	98	280	62	64	60	167	48	41	39	201
Oct	61	46	40	68	43	101	272	63	64	61	175	49	44	40	173
Nov	55	50	36	67	32	62	166	61	63	60	153	51	24	25	39
Dec	47	48	30	53	30	75	134	57	49	46	140	43	46	43	25
Jan	49	45	27	51	30	71	109	57	50	44	37	43	43	41	27
Feb	47	45	29	48	28	66	102	55	46	41	29	41	43	40	38
Mar	47	43	30	50	25	61	91	54	48	43	30	40	41	40	36
Apr	43	41	28	51	25	53	107	54	48	44	48	41	39	40	29
May	51	38	29	49	24	53	160	51	45	42	98	41	36	39	52
Jun	53	32	27	48	28	132	160	53	47	41	123	41	30	33	29
Jul	55	52	35	51	45	140	192	59	58	43	140	43	50	41	157
Aug	57	49	32	63	42	153	190	67	60	55	122	46	47	41	228
Sep	58	45	31	67	40	153	209	80	60	61	108	48	43	39	230
Oct	58	41	31	58	39	135	131	74	52	52	76	30	39	35	92
Nov	53	40	30	42	55	121	107	51	43	40	77	32	38	35	97
Dec	51	38	26	43	34	99	99	51	40	38	65	31	36	34	58
Jan	47	34	25	43	31	94	98	49	40	35	48	29	32	30	55
Feb	46	35	24	45	32	76	95	45	39	37	42	30	33	30	58
Mar	44	33	22	43	31	72	92	41	38	37	47	34	31	30	75
Apr	43	30	23	43	29	72	92	40	33	32	38	34	28	30	110
May	48	30	21	40	27	53	105	38	34	35	38	35	28	31	76

APPENDIX 10

Montly variation in biochemical oxygen demand of the water (mg/L)

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
Jun	7.1	4.3	1.4	6.1	3.6	4	2.8	3.9	3.7	3.3	3.8	0.1	0.7	1.7	2.6
Jul	6.7	3.8	1.7	5.9	3.4	3.8	3.1	3.7	3.5	2.8	4.2	0.2	0.9	1.6	2.9
Aug	6.9	3.5	1.3	5.7	3.2	3.6	3.2	3.5	3.3	2.7	4.3	0.2	0.7	1.5	3
Sep	6.5	3.7	1.4	6	3.5	3.9	0.81	3.8	3.6	2.9	0.6	0.3	0.8	1.6	1.3
Oct	6.1	3.8	1.6	6.2	3.8	4.2	3.5	4.1	3.9	3	4.7	0.4	0.9	1.7	3.2
Nov	5.8	4	1.2	5.8	3.3	3.7	3.8	3.5	3.4	2.8	5.1	0.4	1.1	1.6	3.6
Dec	5.7	3.8	1.1	5.5	3	3.4	4.2	3.3	3.1	2.6	5.7	0.5	0.8	1.5	3.9
Jan	5.8	3.8	1.3	5.7	3.2	3.6	4.4	3.4	3.3	2.7	6	0.4	0.7	1.5	4.1
Feb	6.7	4.2	1	5.4	3	3.3	4.8	3.4	3.2	2.7	6.5	0.6	0.6	1.4	4.5
Mar	8	4.5	0.9	6.1	3.7	4	5.1	4	3.8	3	6.9	0.4	0.8	1.5	4.8
Apr	8.1	4.8	0.8	6.1	3.8	4	5	4.2	4	3	6.8	0.3	0.5	1.5	4.7
May	8.4	5.1	1	5.8	3.6	4.1	5	3.9	3.7	2.9	6.7	0.5	0.7	1.6	4.5
Jun	6	5.6	1.5	6	3.7	3.9	6.1	4.1	3.9	3	8.2	0.7	1.1	1.8	5.7
Jul	5.7	3.9	1.4	5.8	3.4	3.7	5.8	3.7	3.5	2.8	7.8	1	1.2	1.8	5.5
Aug	5.7	4	1.5	5.8	3.3	3.7	5.3	3.6	3.4	2.8	7.1	1.2	1.3	1.9	5
Sep	4.8	3.8	1.3	6.2	3.5	4.1	5.2	3.9	3.7	2.9	7	1.4	1.3	1.9	4.9
Oct	4.9	3.8	1.1	6	3.7	4	4.9	3.9	3.8	3	6.6	1.7	1.4	2	4.6
Nov	4.7	3.5	1	5.5	3.1	3.3	5.3	3.6	3.5	2.8	7.2	1.7	1.3	1.9	4.9
Dec	4.7	4	1.2	5.7	3	3.3	5.8	3.5	3.2	2.7	7.8	0.8	0.9	1.6	5.4
Jan	4.5	4.1	1.1	5	3	3.1	5.8	3.7	3.3	2.7	7.5	0.9	1	1.6	5.1
Feb	5.2	4.3	0.9	5.4	3.6	3.8	6.3	4	3.8	3	8.5	1	0.9	1.7	5.9
Mar	5.6	4.7	0.8	5.7	3.3	3.5	6.5	3.8	3.5	3	8.8	0.7	0.7	1.6	6.1
Apr	6.3	4.5	0.9	6.1	3.6	4	6.9	3.9	3.7	2.9	9.3	0.7	0.8	1.6	6.5
May	7	5.1	0.7	5.9	3.9	4.1	6.3	4.1	4	3.1	8.5	0.6	0.6	1.6	5.9

APPENDIX 11

Montly variation in chemical oxygen demand of the water (mg/L)

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
Jun	58.8	42	24	23.9	14.3	8.8	28.3	25.2	28.1	22.7	25.4	10.5	10.2	24.2	9.2
Jul	46.2	33.4	22.4	21.7	14.1	8.6	24	25.7	28.4	20.9	25.7	10.3	10	23.1	8.6
Aug	50.3	31.8	22	21.2	13	8.2	24	26	30.7	32.7	25.4	9.9	9.6	23.5	8.6
Sep	41.2	30.3	24	20.1	12.8	7.9	18.9	24.1	32.1	23.5	23.9	9.9	9.3	22.4	8.9
Oct	38.9	40.8	23	20	11.1	8	18.5	22.4	34	24	26	9.7	9.4	22.1	9.1
Nov	39.1	41	28	21.3	11.3	8.1	17	22.9	33.9	29.3	25.8	9.8	9.6	23.3	9.1
Dec	40.1	39.6	26.4	24.2	12.7	8.1	16.8	20.9	29.3	28.1	25.5	9.6	9.6	25	8.2
Jan	40	36.8	27.6	24	13.2	7.8	17	18.2	27.8	25.2	23.1	9.5	9.2	22.7	8.5
Feb	32.8	34.3	22	24	13.7	7.5	17.6	18	19.8	35	20.6	9.2	8.9	21.5	7.6
Mar	34	32.1	27.6	26.5	14.3	7.9	19.1	17.6	17	39.8	20.8	9.6	9.3	20.2	7.9
Apr	34	30.4	26	27	14.8	8	21.4	15	17	39.4	19.5	9.7	10	19.9	6.8
May	35.3	31.3	20.3	27	13.8	8.3	22	15.3	16.2	39	17.8	9.9	9.7	19.3	8
Jun	40	46.1	22.4	25	13.8	8.5	20.7	19.7	16	39	24.9	10.2	9.6	19.7	8
Jul	40.3	39.2	26.6	24.7	12.9	8.2	22	20	17.1	23.3	23.7	9.9	9.4	21.3	8.2
Aug	43.5	37.7	22.3	22.8	12.5	8.1	21.4	24.4	17.9	21.6	24.3	9.9	9.2	21.9	7.7
Sep	37.8	30.6	24.5	22.6	12	8	21.7	22.3	27.8	20.9	24.7	9.7	8.8	21.9	7.6
Oct	35	41.2	23.4	22.5	11.8	8	20.6	21.8	18.2	22.5	25.4	9.7	8.5	30.2	8
Nov	33.7	40.2	28.2	21.9	12.2	7.6	1.3	20.1	17.5	28.2	23.2	9.3	8.5	30.6	9.1
Dec	32.6	40.1	26.5	23.6	12.9	7.8	19.8	17.4	17.6	28.6	21.9	9.5	7.9	30.7	9.1
Jan	31	39.2	27.8	23.7	12.9	7.7	19.1	17.9	17.5	32.1	20.4	9.3	8	31	7.9
Feb	30	35.7	22.5	24	12.8	7.7	20.4	16.5	16.3	32.1	20.4	9.3	8	29.1	8.2
Mar	30	32.1	27.4	24.5	12.7	7.6	21	15.8	15.8	39.8	18.7	9.4	8.6	21	8.1
Apr	32.4	35	26.7	26.3	13	7.4	20.5	13.8	15.5	40.3	18.2	9.2	8.1	19.8	6.6
May	31.3	44.3	20.5	27.1	13.8	7.1	19.8	13.3	14	40.3	18.2	8.9	8.1	19.1	7

APPENDIX 12

Montly variation in concentration of oxygen in water (mg/L).

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
Jun	2.7	4.1	5.4	4.3	7.2	8.1	5.2	6.7	3.2	2.8	6	3.6	2.9	4	5.8
Jul	2.4	3.3	5.1	4	7.2	7.3	6.1	5.7	3	2.5	5.8	3.4	2.5	3.2	6.3
Aug	2.4	3.6	4.7	3.8	6.3	8	6	5.4	2.8	2.2	5.5	3.8	2.6	3.6	6.5
Sep	2.1	3.4	4.3	3.6	6	8.1	6.7	5.2	3.1	2.1	6	4	3.8	2.7	6
Oct	2	3.7	3.9	3.6	6.1	7.3	8.4	4.8	3.6	2.4	6.3	3.7	3.7	2.5	7.1
Nov	1.9	3.7	7.8	3.7	6.1	7.5	8.3	4.6	3.7	3.1	7.1	3.1	4.1	4	7
Dec	2	3.9	5.8	4.6	6.8	7.9	8.9	4.6	4.3	3	8	2.8	3.1	3.7	8.2
Jan	2	4	5.2	4.3	5.4	7.7	8.7	5.1	4.6	3.3	8	3.7	3.9	3.8	8.2
Feb	1.8	4	4.1	4.1	5.5	6.9	6.9	5.3	4.6	3.7	7.7	3.4	4.2	3.4	6.9
Mar	1.8	3.8	3.8	4.1	5.7	7	6.2	5.5	4.1	3.4	7.2	3.1	3.9	4.2	6.8
Apr	1.3	3.7	3.9	4.2	6.1	7	6	6	4	3.1	6.9	2.1	3.1	3.1	6.9
May	1.5	3.9	4.9	4.4	7	7.4	4.9	5.3	3.5	2.9	6.9	3	4.1	3.4	5.8
Jun	1.9	4.5	5.2	4.1	7.3	7.1	6.3	6.7	3	2.5	6.1	2.8	3.7	3.8	5.3
Jul	2.8	4	4.2	3.8	6.9	6.9	7.1	6.2	2.8	2	6.4	4.2	3.8	3.8	5.5
Aug	2.6	3.6	4	3.6	7.2	6.2	7	6.2	2.5	2.4	7.2	3.4	2.6	3.6	6.1
Sep	2.8	3.6	4	3.6	6.1	6.5	7.7	5.4	2.2	2.3	7.2	4.3	2	3.2	6
Oct	2	3.2	3.8	3.4	6.2	6.6	8.1	5.1	3.1	2.8	7.7	3.7	3.1	3	7.1
Nov	2.2	3.3	3.5	3.5	6	6.4	8.3	4.8	3.3	3	6.2	4.3	3.1	3.2	7.5
Dec	2.4	4.5	4.7	4	6.9	8.8	8.8	4.5	4.7	3.2	8.6	3.9	3.3	2.3	8.3
Jan	2.3	4.1	3.9	3.9	8.7	7.2	8.9	4.4	4.4	3.7	8.6	4	3.2	3.2	8.3
Feb	1.9	3.8	3.6	3.4	6.1	6.9	7.1	4	4.4	3.7	7.3	2.9	4.4	3.2	7.7
Mar	1.3	0.3	8.3	4.3	2.6	8.6	8.7	0.5	1.4	1.3	5.6	9.2	8.3	8.2	9.6
Apr	1.2	3.6	3.4	3.3	6.3	6.3	6.8	5.8	4.1	3	6.4	2.6	2.9	3.1	5.7
May	1.2	4.8	4.7	4.2	7	5.7	5.5	6.1	3.8	2.3	6.1	2.8	3.1	2.8	5.2

APPENDIX 13

Montly variation in concentration of chloride ion in water (mg/L).

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
Jun	219	162	77	81	52	55	120	62	101	127	113	43	41	50	127
Jul	211	175	91	80	52	53	131	69	135	132	109	41	38	48	130
Aug	213	190	80	83	47	43	128	70	137	148	120	39	35	37	125
Sep	201	190	76	85	40	41	130	69	141	151	136	40	39	35	131
Oct	107	161	53	82	40	37	120	68	128	163	128	35	33	32	107
Nov	101	97	52	78	39	35	108	59	111	257	140	33	35	29	120
Dec	111	92	48	70	36	35	97	47	108	249	98	34	37	30	122
Jan	111	77	50	65	38	33	92	42	102	244	72	33	35	28	101
Feb	117	70	52	65	37	36	57	42	87	247	66	32	30	31	96
Mar	119	70	48	62	34	38	54	40	84	252	68	31	31	32	92
Apr	107	58	45	59	35	41	49	37	81	247	52	34	29	36	77
May	211	52	47	43	40	40	59	40	79	266	49	31	27	35	71
Jun	200	54	43	41	43	42	48	52	82	248	51	30	30	37	62
Jul	193	60	60	44	41	46	50	55	85	237	70	29	32	41	65
Aug	179	101	59	57	49	50	69	57	103	240	75	34	37	45	63
Sep	162	107	64	61	52	55	72	61	112	129	74	45	34	50	61
Oct	159	121	65	64	48	53	79	64	136	106	101	41	40	48	97
Nov	170	119	71	70	45	40	83	60	141	104	92	36	38	39	101
Dec	162	106	62	63	43	41	101	58	129	193	134	40	41	39	98
Jan	141	84	59	58	43	40	126	55	102	187	120	38	37	35	113
Feb	127	76	48	52	39	37	141	49	100	190	122	35	33	32	104
Mar	130	80	43	52	35	33	139	44	96	188	138	34	31	29	138
Apr	107	73	43	49	36	34	111	40	88	207	124	32	29	28	107
May	99	61	40	44	38	32	116	41	71	201	102	30	28	26	100

APPENDIX 14

Montly variation in concentration of potassium in water (Ug/L).

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
Jun	3.17	2.7991	8.4838	4.2541	9.9917	8.5083	4.41	11.181	9.5013	5.622	12.26	2.9631	3.3751	2.4817	4.3615
Jul	2.01	1.7748	4.3862	2.6974	5.1658	4.3988	2.28	5.7806	4.9123	3.5647	6.3384	1.532	1.7449	1.283	2.2549
Aug	1.96	1.7307	3.9052	2.6303	4.5994	3.9165	2.03	5.1468	4.3736	3.4761	5.6434	1.364	1.5536	1.1424	2.0077
Sep	1.38	1.2185	4.0976	1.852	4.8259	4.1095	2.13	5.4003	4.5891	2.4474	5.9214	1.4312	1.6301	1.1986	2.1066
Oct	1.3	1.1479	4.4054	1.7446	5.1885	4.4181	2.29	5.806	4.9338	2.3056	6.3662	1.5387	1.7526	1.2887	2.2648
Nov	2	1.766	4.1553	2.684	4.8939	4.1673	2.16	5.4764	4.6537	3.547	6.0048	1.4513	1.6531	1.2155	2.1362
Dec	2.05	1.8102	5.9637	2.7511	7.0237	5.9809	3.1	7.8596	6.679	3.6357	8.618	2.0829	2.3725	1.7445	3.0659
Jan	3.51	3.0993	7.5411	4.7104	8.8815	7.5629	3.92	9.9386	8.4456	6.225	10.898	2.6339	3.0001	2.2059	3.8769
Feb	3.79	3.3466	9.3495	5.0862	11.011	9.3765	4.86	12.322	10.471	6.7216	13.511	3.2655	3.7195	2.7349	4.8065
Mar	3.02	2.6667	8.6569	4.0528	10.196	8.6819	4.5	11.409	9.6953	5.356	12.51	3.0236	3.444	2.5323	4.4505
Apr	2.75	2.4283	8.5223	3.6905	10.037	8.5469	4.43	11.232	9.5444	4.8771	12.315	2.9766	3.3904	2.4929	4.3813
May	2.38	2.1015	8.2722	3.194	9.7425	8.2961	4.3	10.902	9.2644	4.2209	11.954	2.8892	3.2909	2.4198	4.2527
Jun	3.11	2.7461	8.1567	4.1736	9.6066	8.1803	4.24	10.75	9.1351	5.5156	11.787	2.8489	3.245	2.386	4.1934
Jul	1.28	1.1302	4.0976	1.7178	4.8259	4.1095	2.13	5.4003	4.5891	2.2701	5.9214	1.4312	1.6301	1.1986	2.1066
Aug	1.31	1.1567	3.4435	1.758	4.0556	3.4535	1.79	4.5383	3.8566	2.3233	4.9762	1.2027	1.3699	1.0073	1.7703
Sep	1.02	0.9007	3.9629	1.3686	4.6673	3.9744	2.06	5.2228	4.4383	1.809	5.7268	1.3841	1.5766	1.1592	2.0373
Oct	1.34	1.1832	4.0591	1.7983	4.7806	4.0709	2.11	5.3496	4.546	2.3765	5.8658	1.4177	1.6148	1.1874	2.0868
Nov	1.91	1.6865	3.809	2.5632	4.4861	3.8201	1.98	5.02	4.2659	3.3874	5.5044	1.3304	1.5153	1.1142	1.9582
Dec	2.07	1.8278	4.5401	2.7779	5.3471	4.5532	2.36	5.9834	5.0846	3.6711	6.5608	1.5857	1.8062	1.3281	2.334
Jan	3.81	3.3642	7.5411	5.113	8.8815	7.5629	3.92	9.9386	8.4456	6.757	10.898	2.6339	2.86	2.2059	3.8769
Feb	4.36	3.8499	9.638	5.8511	11.351	9.6659	5.01	12.702	10.794	7.7325	13.928	3.3663	3.8343	2.8193	4.9549
Mar	3.98	3.5143	8.2337	5.3412	9.6972	8.2575	4.28	10.851	9.2213	7.0585	11.898	2.8758	3.2756	2.4085	4.2329
Apr	3.17	2.7991	7.6758	4.2541	9.0401	7.698	3.99	10.116	8.5965	5.622	11.092	2.6809	3.0537	2.2453	3.9461
May	2.85	2.5166	7.9451	3.8247	9.3573	7.9681	4.13	10.471	8.8981	5.0545	11.481	2.775	3.1608	2.3241	4.0846

APPENDIX 15

Montly variation in concentration of calcium in water (Ug/L).

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
Jun	2.4	2.7	3.1	3.5	2.5	2.1	7.3	4.9	3.4	2.5	8.1	2.1	1.9	2	7.5
Jul	2.6	2.8	2.6	3.6	2.6	2.5	7.2	4.7	3.2	2.7	7.9	1.8	2	2.1	7.7
Aug	2.9	3	3.3	3.8	2.8	3.2	6.5	4.6	3.1	3	7.8	2.5	2.2	2.3	6.8
Sep	3.2	2.8	3.1	4.1	2.6	2.5	5.2	3.7	2.2	3.3	6.9	2.3	2	2.1	6.1
Oct	3.5	3.1	2.9	4	3.3	3.8	4.9	2.9	1.4	3.6	6.3	2.6	2.1	2.4	5.7
Nov	3.5	3	3.3	4.4	3.5	3.7	4.7	2.9	1.2	3.8	6.1	2.4	2.3	3	5.4
Dec	3.8	3.5	3.6	4.8	3.8	4.1	4.3	2.3	0.8	3.9	5.5	3	2.7	2.8	5
Jan	4	4.2	3.9	5	4.5	4.8	4.4	2.6	1.1	4.1	5.8	3.7	3.4	3.5	5.2
Feb	4	4.5	4	5.3	4.8	5.1	4	2.3	0.8	4.1	5.5	4	3.7	3.8	5
Mar	4.3	4.4	4.1	5.7	4.7	5	6.1	2	0.7	4.4	5.1	3.9	3.6	3.4	5.1
Apr	4.5	4.6	4.3	5.9	4.9	5.2	6.4	2.2	0.9	4.6	5.4	4	3.8	3.9	5.3
May	4.7	4.4	4.1	5.7	4.2	4.1	6.7	2.6	1.1	4.8	5.8	3.9	3.6	3.7	5.5
Jun	2.8	2.5	2.9	3.8	2.3	2.7	6.5	3.5	2	2.9	6.7	2	1.7	1.8	5.8
Jul	2.4	2.6	2.3	3.1	2.4	2.8	6.8	3.7	2.2	2.9	6.9	2.1	1.8	1.9	6
Aug	3	2.8	2.5	3.5	2.1	3	6.1	3.8	2.3	3.1	7	2.3	2	2.2	6.1
Sep	3.2	2.7	3	3.6	2.6	2.5	6.3	4	2.5	3	7.2	2.3	2	2.1	6
Oct	3.5	3	3.2	4.3	2.8	3.2	5.9	3.6	2.1	3.6	6.8	2.5	2.2	2.3	5.3
Nov	3.8	3.3	3.6	4.6	3.5	3	5	3.2	1.8	3.9	6.5	2.8	2.5	2.6	4.9
Dec	4.4	3.7	3.5	5	4	4.3	4.6	3.5	1.8	4.8	6.5	3.2	2.9	3	4.2
Jan	4.6	4	3.2	5.3	4.3	4.6	4.4	3.2	1.7	4.4	6.4	3.5	3.2	3.3	4.1
Feb	4.3	4.1	4.1	5.6	4.1	4.4	6.9	3.9	2.4	4.3	7.1	3.8	3.5	4	6.6
Mar	4.1	4.3	4.2	5.4	4.8	4.9	6.4	4.6	3.1	3.6	7.8	3.7	3.3	3.6	6.7
Apr	4.5	4.7	4	6	4.5	5.3	7	3.9	2.4	4.1	7.1	4.2	3.9	4	6.8
May	3.6	4.2	3.8	5.1	4.1	4.9	6.8	2.7	1.2	3.7	5.9	3.8	3.5	3.6	6.2

APPENDIX 16

Montly variation in concentration of sodium in water (Ug/L).

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
Jun	57	128	64	142	57	59	66	188	237	202	71	56	50	44	63
Jul	53	112	39	137	43	52	61	175	241	198	68	58	52	46	61
Aug	52	107	34	129	46	51	60	192	246	221	62	55	48	42	61
Sep	47	111	56	199	41	48	55	210	208	279	57	51	45	35	54
Oct	64	248	33	213	63	66	72	222	219	318	76	63	57	47	66
Nov	68	255	128	241	65	71	76	251	240	325	78	65	59	51	68
Dec	73	231	77	248	72	76	81	263	252	329	79	64	66	52	71
Jan	76	279	140	260	71	79	84	277	230	343	78	66	61	50	73
Feb	81	286	84	281	79	81	89	292	275	351	84	63	66	54	71
Mar	80	285	124	290	82	86	91	298	300	294	93	72	74	60	79
Apr	83	289	86	283	74	83	91	327	322	358	99	75	75	63	82
May	89	292	146	320	89	90	97	194	341	361	95	78	80	66	85
Jun	65	161	88	161	62	68	73	201	217	282	71	81	76	65	84
Jul	58	148	74	156	53	59	66	217	196	296	65	71	61	55	74
Aug	53	131	45	142	56	54	61	219	201	299	64	66	60	47	69
Sep	46	127	64	133	43	47	54	234	225	299	57	55	49	39	58
Oct	59	210	38	211	62	60	67	238	240	271	81	47	41	31	50
Nov	61	216	108	218	58	61	69	243	251	282	81	61	58	47	63
Dec	63	222	65	225	64	59	71	258	262	296	87	60	63	49	68
Jan	65	231	116	231	61	67	72	263	271	299	82	65	61	53	72
Feb	63	243	70	352	60	66	71	278	285	303	90	68	70	56	75
Mar	67	261	131	263	58	69	75	293	291	319	93	71	73	59	78
Apr	73	266	78	263	70	76	81	316	330	341	98	70	72	58	77
May	76	279	140	271	69	71	83	321	351	367	101	81	75	61	84

APPENDIX 17

Montly variation in concentration of magnesium in water (Ug/L).

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
Jun	3.5	3.4	4.1	4.2	4.3	2.7	6	3.4	4.5	3.6	6.2	1.6	1.3	1.7	5.8
Jul	3.1	3.8	3.3	4.6	4.1	3.1	6.7	3.6	4.7	4.4	6.4	2	1.7	1.9	5.9
Aug	3.3	3.5	3	4.3	3.8	2.8	5.1	2.3	3.4	3.7	5.1	1.7	1.4	1.6	5.1
Sep	3.1	3.3	3.8	3.9	3.4	2.4	4.8	1.9	3	3.3	4.7	1.3	1	1.3	4.4
Oct	3.2	3.5	3.2	4.3	3.6	2.8	4.5	2.1	3.2	3.7	4.9	1.7	1.4	1.6	4
Nov	3.3	3.7	3.1	4.5	4.6	3	4.3	1.9	3	3.9	4.7	1.9	1.6	2.2	3.9
Dec	3.2	3.6	3.6	4.4	4.5	2.9	3.9	1.8	2.7	3.8	4.4	1.8	1.5	1.9	4
Jan	3.8	3.8	3.8	4.6	4.7	3.1	4	1.3	2.4	4	4.1	2	1.7	2.1	3.8
Feb	3.5	3.9	4	4.7	4.5	3.2	4	1.4	2.5	4.1	4.2	1.4	1.8	1.8	3.6
Mar	3.6	3.9	4.1	4.7	4.8	3.2	4.3	2.6	3.1	4.5	5	2.1	1.8	2	4.5
Apr	3.8	4.3	4.3	5.1	5.2	3.6	4.8	2.6	3.7	4.9	5.4	2.5	2.2	3.4	4.8
May	4.8	4.5	4.4	5.3	5.4	3.8	5	2.9	4	5.1	5.7	2.7	2.4	3.6	4.8
Jun	4.2	4.8	4.1	5.6	5.1	4.1	4.7	3.1	4.2	5.4	5.9	3	2.7	3.9	5.1
Jul	4.5	4.9	4.2	5.7	5.2	4.2	5.3	2.8	3.9	5.5	5.6	3.1	2.8	4	5
Aug	4.3	4.6	4	5.4	4.9	3.9	4.8	2.1	3.2	4.8	4.9	2.8	2.5	3.7	5.2
Sep	4.1	4.4	3.1	5.2	4.7	3.7	4.4	1.9	3	4.6	4.7	2.6	2.3	2.8	4.6
Oct	3.9	2.9	3.3	3.7	3.8	2.2	4.6	2	3.1	3.1	4.8	1.1	0.8	2	4.4
Nov	3.7	3.1	3.3	3.9	4	2	4.5	1.9	3	2.9	4.7	1	1.3	1.9	3.9
Dec	4.1	3	3.8	3.9	3.7	2.4	4.2	1.7	2.8	3.3	4.5	1.5	1	1.5	4.1
Jan	4.3	3.9	4	4.7	4.8	3.2	4.3	1.7	2.8	4.1	4.5	2.1	1.8	2	4.3
Feb	4.6	4.2	4.1	5	5.1	3.5	4.1	1.2	2.3	4.4	4	2.4	2.1	2.3	3.8
Mar	4.4	4	4.6	4.8	4.9	3.3	5.2	3.1	4.2	4.6	5.9	2.2	1.9	2.3	4.9
Apr	4.7	4.3	4.8	5.1	5.2	3.6	5.9	3	4.1	4.9	5.8	2.5	2.2	4	5.3
May	4.9	4	4.7	4.8	4.3	3.3	5.7	3.2	4.3	4.6	6	2.2	1.9	2.1	5.5

APPENDIX 18

Montly variation in concentration of iron in water (Ug/L).

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
Jun	2.9	2.1	2.8	2.3	2.5	2.1	5.3	3.5	4.5	4.2	7.3	3.3	3.5	3.1	10.1
Jul	2.3	2.1	2.5	2.2	1.8	1.9	6	4.2	5.2	4.9	8.9	2.9	2.7	2.2	11
Aug	1.8	2	1.9	2	1.9	1.7	5.7	3.9	4.9	4.2	7.5	2.3	2.4	1.9	8.6
Sep	2.2	2.1	2.3	1.9	2.1	2	5.1	3.3	4.3	3.6	7.1	2	1.9	1.7	6.2
Oct	1.8	2.3	2.1	2.1	2.3	2.1	3.9	2.1	3.1	2.4	5.3	2.3	2.1	2	5
Nov	2.1	2.5	2.5	2.3	2.4	2.3	3.2	1.4	2.4	1.7	3	2.5	2.2	2.4	4.7
Dec	2.3	2.7	2.6	1.9	2.1	2.4	2.7	0.9	1.9	1.2	3	2.8	2.4	2.7	3.9
Jan	2.5	2.4	2.9	2.6	2.4	2	4.1	2.3	3.3	2.6	2.8	3.2	3	2.9	3.1
Feb	2.2	2.6	2.9	2.3	2.3	2.5	5.6	3.8	4.8	4.5	3.3	3.5	3.8	3.1	3.8
Mar	2.8	3	3.2	2.5	2.1	2.3	5.9	4.1	5.1	4.8	4	3.9	4.4	3.6	4.4
Apr	3.1	2.9	3	2.9	2.8	2.1	4.4	2.8	3.6	3.3	4.5	4.8	5.1	4.7	5.2
May	3	3.8	3.1	2.7	2.7	2.6	3.2	1.4	2.4	1.7	6.7	3.6	3.9	5.3	8.7
Jun	3.2	3.4	3.3	3	2.4	2.9	4.9	3.1	4.1	3.4	6.9	2.8	3	3.7	9.8
Jul	1.9	2.6	1.8	3.2	2.5	1.8	1.9	3	1.5	1.8	7.4	2.1	2.4	3.1	10.2
Aug	1.3	2	1.8	2.9	2.4	1.1	1.3	4.2	0.9	1.6	4.8	1.6	1.9	2.5	5.1
Sep	1.1	1.5	2.3	2.3	1.6	1.6	1.1	3	4.5	4.8	4.8	2.1	2.3	1.7	4
Oct	2.3	1.5	2.4	1.5	1.5	1.8	2.3	3.6	4.8	5.2	5.1	2.3	2.5	2	4
Nov	2.4	1.1	2.6	1.3	1.7	2	2.4	4.8	5.4	4.4	3.5	2.6	2.4	2.3	3.7
Dec	2.6	1.4	2.8	1.7	1.9	2.1	2.6	0	3	1.2	3.1	2.6	2.9	2.5	3.7
Jan	1.8	1.6	2.4	1.8	1.5	1.4	1.8	2.4	1.8	0.4	3.7	3.9	4.3	3.9	3.8
Feb	1.4	2.2	2.1	3.3	2.8	2.1	1.4	3	4.5	4.8	3.9	4.4	4.8	4.1	4.6
Mar	2.3	1.9	2.9	3.3	2.5	2	2.3	4.8	5.4	6	4.2	4.7	5	4.5	5.4
Apr	2.6	2.1	3.3	2.4	2.7	1.8	2.6	3.6	4.8	5.2	4.2	5.3	4.8	5.6	9.2
May	2.4	2.4	3.2	2.2	2.5	2.5	2.4	3.1	2	4.3	7	5.2	4.3	4.9	7.1

APPENDIX 19

Montly variation in concentration of lead in water (Ug/L).

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
Jun	0.12	0.13	0.1	0.2	0.16	0.12	0.28	0.27	0.23	0.19	0.532	0.0869	0.0944	0.0792	0.364
Jul	0.086	0.094	0.07	0.14	0.12	0.09	0.2	0.25	0.16	0.13	0.38	0.0621	0.0675	0.0566	0.26
Aug	0.03	0.033	0.025	0.05	0.04	0.03	0.07	0.068	0.058	0.046	0.133	0.0217	0.0236	0.0198	0.091
Sep	0.012	0.014	0.011	0.02	0.02	0.01	0.03	0.029	0.025	0.02	0.057	0.0093	0.0101	0.0085	0.039
Oct	0.013	0.014	0.01	0.02	0.017	0.01	0.03	0.09	0.008	0.007	0.92	0.1503	0.1633	0.1369	0.013
Nov	0.008	0.009	0.007	0.014	0.01	0.09	0.02	0.019	0.016	0.013	0.038	0.0062	0.0067	0.0057	0.026
Dec	0.09	0.1	0.074	0.144	0.12	0.09	0.21	0.204	0.172	0.139	0.399	0.0652	0.0708	0.0594	0.273
Jan	0.04	0.04	0.03	0.06	0.05	0.04	0.09	0.087	0.074	0.06	0.171	0.0279	0.0304	0.0255	0.117
Feb	0.013	0.014	0.01	0.02	0.02	0.01	0.03	0.029	0.025	0.021	0.057	0.0093	0.0101	0.0085	0.039
Mar	0.004	0.004	0.004	0.007	0.006	0.04	0.01	0.009	0.008	0.006	0.019	0.0031	0.0034	0.0028	0.013
Apr	0.21	0.226	0.17	0.33	0.27	0.21	0.48	0.47	0.39	0.318	0.912	0.149	0.1619	0.1357	0.624
May	0.219	0.24	0.18	0.35	0.3	0.24	0.51	0.51	0.418	0.339	0.969	0.1583	0.172	0.1442	0.663
Jun	0.138	0.15	0.112	0.22	0.19	0.14	0.32	0.2438	0.262	0.212	0.608	0.0993	0.1079	0.0905	0.416
Jul	0.08	0.089	0.067	0.13	0.11	0.08	0.19	0.19	0.16	0.125	0.361	0.059	0.0641	0.0537	0.247
Aug	0.004	0.005	0.004	0.006	0.006	0.004	0.01	0.009	0.009	0.006	0.019	0.0031	0.0034	0.0028	0.013
Sep	0.013	0.014	0.01	0.02	0.017	0.013	0.03	0.029	0.025	0.023	0.057	0.0093	0.0101	0.0085	0.039
Oct	0.004	0.04	0.004	0.006	0.006	0.004	0.01	0.009	0.008	0.007	0.019	0.0031	0.0034	0.0028	0.013
Nov	0.14	0.155	0.12	0.23	0.19	0.145	0.33	0.321	0.27	0.219	0.627	0.1024	0.1113	0.0933	0.429
Dec	0.133	0.146	0.11	0.21	0.18	0.14	0.31	0.302	0.254	0.206	0.589	0.0962	0.1045	0.0877	0.403
Jan	0.5478	0.5988	0.07	0.14	0.116	0.09	0.2	0.9555	0.163	0.123	0.38	0.0621	0.0675	0.0566	0.26
Feb	0.03	0.038	0.028	0.16	0.05	0.04	0.08	0.2925	0.066	0.053	0.152	0.0248	0.027	0.0226	0.104
Mar	0.012	0.014	0.01	0.12	0.08	0.01	0.03	0.029	0.025	0.02	0.057	0.0093	0.0101	0.0085	0.039
Apr	0.14	0.016	0.19	0.23	0.19	0.15	0.33	0.32	0.27	0.219	0.627	0.1024	0.1113	0.0933	0.429
May	0.26	0.28	0.21	0.41	0.35	0.26	0.6	0.195	0.491	0.41	0.74	0.1862	0.2024	0.1697	0.78

APPENDIX 20

Montly variation in concentration of arsenic in water (Ug/L x10-1)

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
Jun	0.15	0.18	0.22	0.2	0.18	0.12	0.34	0.35	0.3	0.28	0.34	0.05	0.01	0.06	0.24
Jul	0.17	0.2	0.21	0.15	0.11	0.14	0.36	0.35	0.3	0.29	0.4	0.07	0.08	0.08	0.29
Aug	0.04	0.09	0.08	0.06	0.04	0.01	0.17	0.08	0.03	0.08	0.13	0	0	0.01	0.21
Sep	0.06	0.04	0.03	0.01	0	0.03	0.06	0.02	0	0.03	0.15	0.05	0	0	0.23
Oct	0.04	0.04	0.03	0.01	0	0.01	0.03	0.02	0	0.03	0.1	0.02	0	0	0.18
Nov	0.05	0.03	0.02	0	0	0.02	0.08	0.02	0	0.02	0.12	0	0	0.01	0.2
Dec	0.09	0.14	0.13	0.11	0.03	0.06	0.34	0.1	0.08	0.13	0.3	0.05	0.01	0.03	0.26
Jan	0.06	0.11	0.1	0.08	0	0.03	0.31	0.07	0.05	0.1	0.26	0.02	0	0	0.3
Feb	0.12	0.17	0.16	0.14	0.06	0.09	0.37	0.13	0.11	0.16	0.29	0.08	0.04	0.09	0.28
Mar	0.04	0.04	0.03	0.01	0	0.01	0.13	0.02	0	0.03	0.09	0.02	0	0	0.17
Apr	0.06	0.03	0.02	0	0	0.03	0.1	0.02	0	0.02	0.11	0	0	0.03	0.19
May	0.14	0.19	0.18	0.16	0.08	0.11	0.31	0.32	0.3	0.27	0.34	0.02	0.03	0.03	0.28
Jun	0.13	0.21	0.17	0.15	0.07	0.1	0.32	0.31	0.29	0.31	0.32	0.03	0	0.04	0.3
Jul	0.18	0.17	0.22	0.2	0.12	0.15	0.38	0.35	0.3	0.31	0.37	0.09	0.05	0.07	0.25
Aug	0.06	0.11	0.1	0.08	0	0.03	0.31	0.07	0.02	0.19	0.08	0.02	0	0	0.2
Sep	0.03	0.08	0.07	0.05	0.03	0	0.28	0.1	0.05	0.07	0.05	0.13	0.05	0.01	0.13
Oct	0.06	0.11	0.1	0.08	0	0.03	0.31	0.05	0	0.1	0.26	0.02	0.03	0	0.34
Nov	0.03	0.04	0.03	0.01	0	0	0.2	0.05	0.03	0.03	0.17	0	0	0	0.25
Dec	0.04	0.09	0.08	0.06	0.04	0.01	0.29	0.1	0.08	0.08	0.3	0	0	0.01	0.27
Jan	0.09	0.14	0.13	0.11	0.03	0.06	0.34	0.08	0.06	0.13	0.31	0.05	0.01	0.06	0.31
Feb	0.07	0.12	0.11	0.09	0.01	0.04	0.32	0.05	0.03	0.11	0.29	0.03	0	0.01	0.3
Mar	0.04	0.09	0.08	0.06	0.04	0.01	0.29	0.013	0.01	0.08	0.21	0	0.01	0	0.29
Apr	0.12	0.31	0.1	0.28	0.09	0.13	0.5	0.19	0.14	0.13	0.13	0.09	0.18	0.13	0.3
May	0.15	0.2	0.19	0.17	0.09	0.12	0.33	0.32	0.27	0.19	0.36	0.04	0	0.05	0.24

APPENDIX 21

Montly variation in concentration of zinc in water (Ug/L).

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
Jun	0.42	0.39	0.46	0.95	0.21	0.11	1.33	1.01	1.08	0.92	1.19	0.16	0.19	0.49	1.52
Jul	0.2	0.1	0.13	0.42	0.19	0.09	1.57	1.14	1.1	0.56	1.57	0.17	0.21	0.51	1.46
Aug	0.19	0.15	0.18	0.57	0.12	0.1	1.48	1.36	1.4	0.28	1.11	0.1	0.16	0.44	1.5
Sep	0.15	0.11	0.16	0.29	0.19	0.13	0.31	0.1	0.13	0.31	0.28	0.14	0.18	0.48	1.39
Oct	0.22	0.19	0.25	0.21	0.09	0.06	0.35	0.27	0.3	0.28	0.37	0.03	0.09	0.37	0.33
Nov	0.24	0.21	0.28	0.26	0.05	0.08	0.4	0.23	0.31	0.22	0.35	0.01	0.03	0.33	0.4
Dec	0.3	0.34	0.23	0.19	0.06	0.04	0.42	0.36	0.27	0.17	0.4	0.02	0.08	0.36	0.38
Jan	0.29	0.31	0.28	0.15	0.09	0.07	0.39	0.31	0.21	0.31	0.35	0	0.04	0.34	0.36
Feb	0.26	0.37	0.3	0.4	0.1	0.09	0.46	0.38	0.29	0.35	0.43	0.06	0.12	0.4	0.41
Mar	0.34	0.35	0.31	0.37	0.13	0.04	1.52	1.36	1.27	0.88	1.37	0.1	0.12	0.42	1.4
Apr	0.31	0.41	0.33	0.93	0.24	0.09	1.25	1.08	1.01	0.91	1.41	0.18	0.22	0.5	1.42
May	0.28	0.35	0.28	0.87	0.18	0.18	1.71	1.46	1.33	0.85	1.53	0.17	0.23	0.51	1.01
Jun	0.38	0.4	0.25	0.91	0.93	0.18	1.11	1.24	1.06	0.44	1.19	0.18	0.22	0.24	1.38
Jul	0.17	0.19	0.31	0.58	0.62	0.2	1.59	1.39	1.22	0.52	1.63	0.16	0.22	0.2	1.39
Aug	0.21	0.25	0.29	0.55	0.59	0.13	1.72	1.51	1.47	0.38	1.42	0.09	0.13	0.14	0.31
Sep	0.14	0.25	0.29	0.43	0.47	0.17	0.39	0.23	0.21	0.17	0.28	0.16	0.22	0.25	0.2
Oct	0.25	0.21	0.3	0.31	0.35	0.06	0.24	0.2	0.35	0.21	0.17	0.06	0.1	0.11	0.36
Nov	0.19	0.17	0.11	0.27	0.29	0.02	0.45	0.37	0.29	0.31	0.45	0.04	0.08	0.07	0.19
Dec	0.28	0.23	0.13	0.3	0.34	0.05	0.27	0.17	0.2	0.16	0.27	0.05	0.07	0.08	0.2
Jan	0.21	0.19	0.15	0.1	0.12	0.03	0.2	0.14	0.19	0.24	0.23	0.08	0.12	0.14	0.13
Feb	0.24	0.18	0.18	0.37	0.41	0.09	0.17	0.15	0.17	0.31	0.1	0.07	0.11	0.12	1.45
Mar	0.29	0.24	0.14	0.32	0.34	0.11	1.49	1.11	1.03	0.82	1.31	0.1	0.16	0.13	1.21
Apr	0.3	0.28	0.21	0.92	0.96	0.19	1.13	1.05	1.12	0.98	1.1	0.23	0.25	0.22	0.67
May	0.22	0.17	0.09	1.11	1.13	0.2	1.02	0.98	0.92	1.02	0.93	0.17	0.21	0.2	0.81

APPENDIX 22

Montly variation in concentration of manganese in water (Ug/L)

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
Jun	0.0331	0.0489	0.0316	0.0355	0.0263	0.0303	0.1258	0.0777	0.0723	0.1019	0.1092	0.0436	0.0284	0.0368	0.0851
Jul	0.1719	0.254	0.1638	0.184	0.1363	0.1574	0.6528	0.4033	0.375	0.529	0.5664	0.2261	0.1475	0.1912	0.4416
Aug	0.0788	0.1164	0.0751	0.0843	0.0625	0.0722	0.2992	0.1848	0.1719	0.2425	0.2596	0.1036	0.0676	0.0876	0.2024
Sep	0.0654	0.0966	0.0623	0.07	0.0518	0.0599	0.2482	0.1533	0.1426	0.2011	0.2154	0.086	0.0561	0.0727	0.1679
Oct	0.0125	0.0185	0.0119	0.0134	0.0099	0.0115	0.0476	0.0294	0.0273	0.0386	0.0413	0.0165	0.0108	0.0139	0.0322
Nov	0.0107	0.0159	0.0102	0.0115	0.0085	0.0098	0.0408	0.0252	0.0234	0.0331	0.0354	0.0141	0.0092	0.012	0.0276
Dec	0.1209	0.1786	0.1152	0.1294	0.0959	0.1107	0.459	0.2836	0.2636	0.372	0.3983	0.159	0.1037	0.1344	0.3105
Jan	0.1083	0.1601	0.1032	0.116	0.0859	0.0992	0.4114	0.2541	0.2363	0.3334	0.357	0.1425	0.093	0.1205	0.2783
Feb	0.1638	0.2421	0.1561	0.1754	0.1299	0.1501	0.6222	0.3844	0.3574	0.5042	0.5399	0.2155	0.1406	0.1822	0.4209
Mar	0.1567	0.2315	0.1493	0.1677	0.1243	0.1435	0.595	0.3676	0.3418	0.4822	0.5163	0.2061	0.1345	0.1743	0.4025
Apr	0.1889	0.2791	0.18	0.2022	0.1498	0.173	0.7174	0.4432	0.4121	0.5814	0.6225	0.2485	0.1621	0.2101	0.4853
May	0.1602	0.2368	0.1527	0.1716	0.1271	0.1468	0.6086	0.376	0.3496	0.4932	0.5281	0.2108	0.1375	0.1783	0.4117
Jun	0.077	0.1138	0.0734	0.0824	0.0611	0.0705	0.2924	0.1806	0.1679	0.237	0.2537	0.1013	0.0661	0.0856	0.1978
Jul	0.0645	0.0952	0.0614	0.069	0.0511	0.059	0.2448	0.1512	0.1406	0.1984	0.2124	0.0848	0.0553	0.0717	0.1656
Aug	0.0295	0.0437	0.0282	0.0316	0.0234	0.0271	0.1122	0.0693	0.0644	0.0909	0.0974	0.0389	0.0254	0.0329	0.0759
Sep	0.1111	0.1642	0.1059	0.1189	0.0881	0.1018	0.4219	0.2607	0.2424	0.3419	0.3661	0.1461	0.0954	0.1236	0.2854
Oct	0.0213	0.0315	0.0203	0.0228	0.0169	0.0195	0.0809	0.05	0.0465	0.0656	0.0702	0.028	0.0183	0.0237	0.0547
Nov	0.0183	0.027	0.0174	0.0196	0.0145	0.0167	0.0694	0.0428	0.0398	0.0562	0.0602	0.024	0.0157	0.0203	0.0469
Dec	0.2055	0.3036	0.1958	0.22	0.1629	0.1882	0.7803	0.482	0.4482	0.6323	0.677	0.2703	0.1764	0.2286	0.5279
Jan	0.1842	0.2721	0.1755	0.1972	0.146	0.1687	0.6994	0.4321	0.4017	0.5668	0.6068	0.2422	0.1581	0.2049	0.4731
Feb	0.2785	0.4115	0.2654	0.2982	0.2209	0.2551	1.0577	0.6534	0.6075	0.8572	0.9177	0.3664	0.2391	0.3098	0.7155
Mar	0.2663	0.3935	0.2538	0.2852	0.2112	0.244	1.0115	0.6249	0.581	0.8197	0.8776	0.3503	0.2286	0.2963	0.6843
Apr	0.3211	0.4745	0.306	0.3438	0.2547	0.2941	1.2196	0.7534	0.7005	0.9883	1.0582	0.4224	0.2756	0.3572	0.825
May	0.043	0.0635	0.0409	0.046	0.0341	0.0394	0.1632	0.1008	0.0937	0.1323	0.1416	0.0565	0.0369	0.0478	0.1104

APPENDIX 23

Montly variation in concentration of cadmium in water (Ug/L).

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
Jun	0.011	0.0196	0.0134	0.0149	0.0194	0.0097	0.026	0.0448	0.0337	0.0406	0.0677	0.0217	0.0139	0.019	0.0467
Jul	0.013	0.0232	0.0159	0.0176	0.0229	0.0115	0.0479	0.053	0.0399	0.048	0.08	0.0257	0.0164	0.0224	0.0552
Aug	0.051	0.091	0.0622	0.0689	0.0898	0.045	0.1204	0.2079	0.1564	0.1881	0.314	0.1007	0.0645	0.088	0.2165
Sep	0.022	0.0392	0.0268	0.0297	0.0387	0.0194	0.0519	0.0897	0.0675	0.0811	0.1354	0.0435	0.0278	0.038	0.0934
Oct	0.014	0.025	0.0171	0.0189	0.0247	0.0124	0.0331	0.0571	0.0429	0.0516	0.0862	0.0277	0.0177	0.0242	0.0594
Nov	0.016	0.0285	0.0195	0.0216	0.0282	0.0141	0.0378	0.0652	0.0491	0.059	0.0985	0.0316	0.0202	0.0276	0.0679
Dec	0.021	0.0375	0.0256	0.0284	0.037	0.0185	0.0496	0.0856	0.0644	0.0774	0.1293	0.0415	0.0266	0.0362	0.0892
Jan	0.016	0.0285	0.0195	0.0216	0.0282	0.0141	0.0378	0.0652	0.0491	0.059	0.0985	0.0316	0.0202	0.0276	0.0679
Feb	0.025	0.0446	0.0305	0.0338	0.044	0.0221	0.059	0.1019	0.0766	0.0922	0.1539	0.0494	0.0316	0.0431	0.1061
Mar	0.017	0.0303	0.0207	0.023	0.0299	0.015	0.0401	0.0693	0.0521	0.0627	0.1047	0.0336	0.0215	0.0293	0.0722
Apr	0.028	0.05	0.0342	0.0378	0.0493	0.0247	0.0661	0.1141	0.0858	0.1033	0.1724	0.0553	0.0354	0.0483	0.1189
May	0.019	0.0339	0.0232	0.0257	0.0335	0.0168	0.0449	0.0774	0.0583	0.0701	0.117	0.0375	0.024	0.0328	0.0807
Jun	0	0.019	0.011	0.05	0.0188	0.028	0.0661	0.0434	0.0327	0.0393	0.0656	0.021	0.0135	0.0184	0.0452
Jul	0.0146	0.0261	0.0178	0.0198	0.0258	0.0129	0.0345	0.0596	0.0449	0.054	0.0901	0.0289	0.0185	0.0253	0.0621
Aug	0.0173	0.0308	0.0211	0.0233	0.0304	0.0153	0.0408	0.0705	0.053	0.0638	0.1064	0.0342	0.0219	0.0298	0.0734
Sep	0.0678	0.121	0.0828	0.0916	0.1194	0.0599	0.1601	0.2765	0.208	0.2501	0.4176	0.134	0.0858	0.1171	0.288
Oct	0.0293	0.0522	0.0357	0.0395	0.0515	0.0258	0.0691	0.1193	0.0897	0.1079	0.1801	0.0578	0.037	0.0505	0.1242
Nov	0.0186	0.0332	0.0227	0.0251	0.0328	0.0164	0.044	0.0759	0.0571	0.0687	0.1146	0.0368	0.0236	0.0321	0.0791
Dec	0.0213	0.038	0.026	0.0287	0.0375	0.0188	0.0502	0.0867	0.0652	0.0785	0.131	0.042	0.0269	0.0367	0.0904
Jan	0.0279	0.0498	0.0341	0.0377	0.0492	0.0247	0.0659	0.1138	0.0856	0.103	0.172	0.0552	0.0353	0.0482	0.1186
Feb	0.0213	0.038	0.026	0.0287	0.0375	0.0188	0.0502	0.0867	0.0652	0.0785	0.131	0.042	0.0269	0.0367	0.0904
Mar	0.0333	0.0593	0.0406	0.0449	0.0585	0.0294	0.0785	0.1355	0.1019	0.1226	0.2047	0.0657	0.0421	0.0574	0.1412
Apr	0.0226	0.0403	0.0276	0.0305	0.0398	0.02	0.0534	0.0922	0.0693	0.0834	0.1392	0.0447	0.0286	0.039	0.096
May	0.0372	0.0664	0.0454	0.0503	0.0656	0.0329	0.0879	0.1518	0.1142	0.1373	0.2293	0.0736	0.0471	0.0643	0.1581

APPENDIX 24

Montly variation in concentration of copper in water (Ug/L).

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
Jun	0.1	0.299	0.3979	0.23	0.099	0.088	0.21	0.291	0.324	0.4577	0.36	0.2031	0.1755	0.1237	0.273
Jul	0.083	0.2482	0.3303	0.1909	0.0822	0.073	0.28	0.389	0.432	0.3799	0.48	0.1686	0.1457	0.1027	0.364
Aug	0.052	0.1555	0.2069	0.1196	0.0515	0.0458	0.24	0.33	0.3672	0.238	0.408	0.1056	0.0913	0.0643	0.312
Sep	0.046	0.1375	0.183	0.1058	0.0455	0.0405	0.21	0.289	0.3213	0.2105	0.357	0.0934	0.0807	0.0569	0.273
Oct	0.029	0.0867	0.1154	0.0667	0.0287	0.0255	0.36	0.496	0.5508	0.1327	0.612	0.0589	0.0509	0.0359	0.468
Nov	0.051	0.1525	0.2029	0.1173	0.0505	0.0449	0.31	0.427	0.4743	0.2334	0.527	0.1036	0.0895	0.0631	0.403
Dec	0.083	0.2482	0.3303	0.1909	0.0822	0.073	0.58	0.799	0.8874	0.3799	0.986	0.1686	0.1457	0.1027	0.754
Jan	0.12	0.3588	0.4775	0.276	0.1188	0.1056	0.62	0.854	0.9486	0.5492	1.054	0.2437	0.2106	0.1485	0.806
Feb	0.182	0.5442	0.7242	0.4186	0.1802	0.1602	0.71	0.978	1.0863	0.833	1.207	0.3696	0.3194	0.2252	0.923
Mar	0.176	0.5262	0.7003	0.4048	0.1742	0.1549	1.12	1.542	1.7136	0.8056	1.904	0.3574	0.3089	0.2178	1.456
Apr	0.224	0.6698	0.8913	0.5152	0.2218	0.1971	0.52	0.716	0.7956	1.0252	0.884	0.4549	0.3931	0.2772	0.676
May	0.193	0.5771	0.7679	0.4439	0.1911	0.1698	0.31	0.427	0.4743	0.8834	0.527	0.392	0.3387	0.2388	0.403
Jun	0.095	0.2841	0.378	0.2185	0.0941	0.0836	0.25	0.344	0.3825	0.4348	0.425	0.1929	0.1667	0.1176	0.325
Jul	0.127	0.3797	0.5053	0.2921	0.1257	0.1118	0.33	0.454	0.5049	0.5813	0.561	0.2579	0.2229	0.1571	0.429
Aug	0.1	0.299	0.3979	0.23	0.099	0.088	0.3	0.413	0.459	0.4577	0.51	0.2031	0.1755	0.1237	0.39
Sep	0.061	0.1824	0.2427	0.1403	0.0604	0.0537	0.27	0.372	0.4131	0.2792	0.459	0.1239	0.107	0.0755	0.351
Oct	0.172	0.5143	0.6844	0.3956	0.1703	0.1514	0.31	0.427	0.4743	0.7872	0.527	0.3493	0.3018	0.2128	0.403
Nov	0.099	0.296	0.3939	0.2277	0.098	0.0871	0.35	0.482	0.5355	0.4531	0.595	0.2011	0.1737	0.1225	0.455
Dec	0.101	0.302	0.4019	0.2323	0.1	0.0889	0.69	0.95	1.0557	0.4623	1.173	0.2051	0.1772	0.125	0.897
Jan	0.28	0.8372	1.1141	0.644	0.2772	0.2464	0.98	1.35	1.4994	1.2816	1.666	0.5687	0.4914	0.3465	1.274
Feb	0.236	0.7056	0.939	0.5428	0.2336	0.2077	0.3	0.413	0.459	1.0802	0.51	0.4793	0.4142	0.292	0.39
Mar	0.251	0.7505	0.9987	0.5773	0.2485	0.2209	0.52	0.716	0.7956	1.1468	0.884	0.5098	0.4405	0.3106	0.676
Apr	0.198	0.592	0.7878	0.4554	0.196	0.1742	0.49	0.675	0.7497	0.9062	0.833	0.4021	0.3475	0.245	0.637
May	0.107	0.3199	0.4258	0.2461	0.1059	0.0942	0.2	0.275	0.306	0.4897	0.34	0.2173	0.1878	0.1324	0.26

APPENDIX 25

Montly variation in phytoplankton population of the water (org/L).

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
Jun	10	7	0	10	7	4	11	6	5	7	13	0	0	0	32
Jul	10	13	0	37	25	14	41	23	19	25	50	0	0	0	24
Aug	10	14	0	39	26	15	26	23	20	26	50	0	0	0	22
Sep	9	12	0	33	22	13	20	19	16	22	41	0	0	0	16
Oct	8	10	0	29	19	11	20	20	17	13	43	0	0	0	18
Nov	8	11	0	31	21	12	44	16	14	18	35	0	0	0	26
Dec	7	9	0	25	17	10	42	21	18	24	46	0	0	0	25
Jan	7	10	0	27	18	10	17	20	17	23	43	0	0	0	24
Feb	6	8	0	23	15	9	21	8	7	10	18	0	0	0	13
Mar	5	7	0	19	13	7	27	8	7	10	17	0	0	0	17
Apr	6	8	0	21	14	10	31	19	17	22	43	0	0	0	19
May	14	19	0	54	36	20	43	24	20	27	52	0	0	0	30
Jun	13	17	0	49	32	19	39	33	29	38	73	0	0	0	31
Jul	13	18	0	51	34	19	24	31	26	35	67	0	0	0	22
Aug	11	16	0	43	29	17	19	31	27	33	68	0	0	0	23
Sep	10	14	0	38	26	15	19	26	22	29	56	0	0	0	22
Oct	11	15	0	37	25	16	41	27	23	31	58	0	0	0	17
Nov	11	15	0	41	27	18	40	22	19	25	48	0	0	0	25
Dec	9	12	0	33	22	13	40	29	25	33	63	0	0	0	24
Jan	9	13	0	36	24	14	16	27	23	31	58	0	0	0	24
Feb	8	11	0	31	21	12	20	11	9	13	24	0	0	0	13
Mar	7	9	0	26	17	10	25	26	23	30	58	0	0	0	17
Apr	7	10	0	28	19	11	30	30	26	35	67	0	0	0	18
May	10	14	0	38	26	15	31	32	28	37	71	0	0	0	29

APPENDIX 26

Montly variation in zooplankton population of the water (org/L).

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
Jun	0	0	0	0	0	3	42	21	16	10	58	0	0	0	122
Jul	0	0	0	0	0	5	65	33	25	15	91	0	0	0	48
Aug	0	0	0	0	0	2	36	18	14	8	50	0	0	0	26
Sep	0	0	0	0	0	6	90	45	35	21	125	0	0	0	66
Oct	0	0	0	0	0	9	130	65	50	31	181	0	0	0	95
Nov	0	0	0	0	0	7	103	5	40	24	143	0	0	0	75
Dec	0	0	0	0	0	9	127	63	49	30	176	0	0	0	93
Jan	0	0	0	0	0	7	105	52	41	25	145	0	0	0	77
Feb	0	0	0	0	0	6	92	46	36	22	128	0	0	0	67
Mar	0	0	0	0	0	4	63	31	24	15	87	0	0	0	48
Apr	0	0	0	0	0	3	37	18	14	9	51	0	0	0	27
May	0	0	0	0	0	9	133	66	51	31	184	0	0	0	97
Jun	0	0	0	0	0	14	195	98	76	46	27	0	0	0	143
Jul	0	0	0	0	0	8	118	59	46	28	163	0	0	0	86
Aug	0	0	0	0	0	3	45	22	17	11	62	0	0	0	33
Sep	0	0	0	0	0	4	54	27	21	13	75	0	0	0	40
Oct	0	0	0	0	0	8	119	59	46	28	165	0	0	0	87
Nov	0	0	0	0	0	8	109	54	42	26	151	0	0	0	80
Dec	0	0	0	0	0	8	115	57	44	27	159	0	0	0	84
Jan	0	0	0	0	0	9	135	67	52	32	187	0	0	0	99
Feb	0	0	0	0	0	7	106	53	41	25	146	0	0	0	77
Mar	0	0	0	0	0	5	69	34	27	16	96	0	0	0	51
Apr	0	0	0	0	0	4	63	31	24	15	87	0	0	0	46
May	0	0	0	0	0	10	148	74	57	35	205	0	0	0	108

APPENDIX 27

Montly variation in E. coli MPN-indexf of the water (org/100ml). *20 =infinity

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
Jun	9.2	16.2	2.2	20	9.2	9.2	20	20	20	20	20	5.1	2.2	9.2	20
Jul	16.2	16.2	5.1	20	9.2	5.2	20	20	20	20	20	2.2	2.2	5.1	20
Aug	5.1	20	5.1	20	16.2	5.1	20	20	20	20	20	5.1	5.1	5.1	20
Sep	2.2	20	2.2	20	16.2	2.2	20	20	20	20	20	2.2	2.2	0	20
Oct	0	16.2	2.2	16.2	16.2	5.1	20	20	20	20	20	0	2.2	0	20
Nov	0	20	5.1	20	16.2	2.2	20	20	20	20	20	2.2	0	0	20
Dec	0	2.2	0	5.1	5.1	2.2	20	20	20	20	20	5.1	2.2	2.2	20
Jan	0	5.1	0	2.2	5.1	2.2	20	20	20	20	20	0	5.1	5.1	20
Feb	0	2.2	0	5.1	5.1	2.2	20	20	20	20	20	0	0	2.2	20
Mar	0	2.2	0	5.1	2.2	5.1	20	20	20	20	20	5.1	0	2.2	20
Apr	0	5.1	0	5.1	2.2	5.1	20	20	20	20	20	0	2.2	0	20
May	2.2	16.2	2.2	16.2	9.2	16.2	20	20	20	20	20	2.2	5.1	2.2	20
Jun	2.2	16.2	2.2	20	20	5.2	20	20	20	20	20	2.2	2.2	5.1	20
Jul	5.1	16.2	9.2	20	20	5.1	20	20	20	20	20	5.1	5.1	5.1	20
Aug	2.2	20	5.1	20	20	2.2	20	20	20	20	20	5.1	5.1	0	20
Sep	2.2	20	2.2	20	20	2.2	20	20	20	20	20	5.1	0	0	20
Oct	2.2	16.2	2.2	9.2	16.2	2.2	20	20	20	20	20	5.1	2.2	0	20
Nov	0	5.1	0	5.1	5.1	0	20	20	20	20	20	0	0	0	20
Dec	0	9.2	0	9.2	5.1	0	20	20	20	20	20	0	0	0	20
Jan	0	9.2	0	9.2	9.2	0	20	20	20	20	20	0	0	0	20
Feb	0	5.1	0	5.1	5.1	2.2	20	20	20	20	20	0	0	0	20
Mar	0	5.1	0	5.1	5.1	0	20	20	20	20	20	0	0	0	20
Apr	0	5.1	0	5.1	9.2	0	20	20	20	20	20	0	0	0	20
May	0	16.2	0	20	16.2	0	20	20	20	20	20	9.2	16.2	5.1	20

APPENDIX 28

Montly variation in St. faecalis MPN-indexf of the water (org/100ml).

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
Jun	0	2.2	0	2.2	0	0	2.2	0	5.1	2.2	2.2	0	0	0	2.2
Jul	0	5.1	0	5.1	0	0	0	5.1	5.1	2.2	5.1	0	0	0	2.2
Aug	0	2.2	0	0	0	0	0	5.1		5.1	0	0	0	0	0
Sep	0	2.2	0	2.2	0	0	2.2	2.2	2.2	2.2	2.2	0	0	0	0
Oct	0	0	0	0	0	0	0	2.2	0	2.2	0	0	0	0	0
Nov	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jan	0	0	0	0	0	0	0	5.1	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	2.2	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0	2.2	0	2.2	0	0	0	0	0
Apr	0	0	0	5.1	0	0	0	2.2	0	2.2	2.2	0	0	0	0
May	0	2.2	0	5.1	0	0	2.2	5.1	2.2		2.2	0	0	0	0
Jun	0	2.2	0	2.2	0	0	2.2	0	2.2	2.2	5.1	0	0	0	2.2
Jul	0	5.1	0	2.2	0	0	5.1	0	5.1	2.2	2.2	0	0	0	0
Aug	0	2.2	0	0	0	0	2.2	5.1	2.2	5.1	2.2	0	0	0	2.2
Sep	0	2.2	0	2.2	0	0	2.2	0	2.2	2.2	2.2	0	0	0	2.2
Oct	0	0	0	0	0	0	2.2	0	2.2	2.2	0	0	0	0	2.2
Nov	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0	2.2	0	0	0	0	0	0	0
Jan	0	0	0	0	0	0	0	2.2	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	2.2	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	0	2.2	0	0	0	0	0	2.2	0	0	0	0	0	0	0