ANALYSIS OF CONCENTRATIONS OF SOME METALS IN STREAM WATER OF THE UPPER KUBANNI DRAINAGE BASIN, SAMARU-ZARIA

BY

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DECLARATION

I, David Nyomo Jeb, hereby declare that this thesis is an original work written by me based on field investigations. It has not been presented elsewhere for a higher degree award, and all sources of information quoted are specifically acknowledged by use of references.

Sign ____________ Date 20 - 12 - 96

CERTIFICATION

This is to certify that the thesis "Analysis of Concentrations of Some Metal in streamwater of the Upper Kubanni Drainage Basin, Samaru, Zaria" submitted by David Nyomo Jeb, meets the requirements for the Award of the Master of Science Degree of the Ahmadu Bello University Zaria, is an original work based on field investigations that has been read and approved by:

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To my father, Mr. Jeb Nyinom for his love for education and inspiration.

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ABSTRACT

The analyses of streamwaters of the Upper Kubanni Drainage Basin Samaru, Zaria were carried out to determine the concentrations of six selected metals - Ca, Mg, Fe, Cu, Zn and Pb from June to October, 1994.

As a result of the huge wastes generated due to the rapid process of urbanisation, industrialisation, and agriculture, much concern has been placed recently on the metal pollution of streamwaters used as sources of public water supply. This is because of the severe impacts of the metals on health and the aquatic ecosystem. However, studies relating to the chemical quality of water in the Upper Kubanni basin have centred mainly on the A.B.U. reservoir, which is a source of domestic water supply to the A.B.U. community. Some of these studies have revealed the occurrences of chemicals such as Cl, F, I, No_3, So_4, Na, K, Ca, Mg, Fe, Zn, Pb and Cu, in the A.B.U. reservoir water in varying concentrations (Ogunrombi, 1979; Udoh et al, 1987). The concentration levels of Fe and Cu in the reservoir water have significantly increased from about 2.88mg/l and below detection in 1982 to about 4.82mg/l and 0.28mg/l in 1992 (Yusuf, 1992). Therefore, increasing metal pollution of the A.B.U. reservoir water and the non-evaluation of the chemical quality of streamwater from sub-basins tributaries that empty into the A.B.U reservoir present a major problem in identifying the sources and variations of metal pollutants into the reservoir.

The major aim of the study therefore, was to identify the presence and concentrations of the six selected metals in streamwaters of the Upper Kubanni basin; and the variations in their concentrations between, the months of study (temporal) and between the sub-basins (spatial); and, comparing the concentrations of the metals from sub-basin with the International Standards for Drinking Water and with the levels of the metals in the A.B.U reservoir water.

The methodology for data collection was the use of basin out-lets that empty into the A.B.U reservoir were chosen and monitored as sampling sites for water samples collection. These sub-basins were, the Samaru (urban), Institute for Agricultural Research-I.A.R. (rural/urban), and Kampagi Hill (rural). Water samples were collected in clean plastic bottles (500ml) with screw caps, while river stage was recorded during sample collection. Maps and air photos (1:50,000) were used to determine the areas and drainage densities of the basins, and the total percentage of rural or urban landuse areas of the basins. The concentrations of the metals were determined in the laboratory using the Atomic Absorption Spectrophotometer (A.A.S.) after digestion of the water samples by the Nitric acid Digestion Method.

The results of the laboratory analyses showed that the selected metals occur in the surface water resources of the basin in varying concentrations. Statistical analyses by means of one-way analysis of variance revealed that there were no significant temporal variations in metal concentrations between the months of study and significant spatial variations in mean total metal concentrations between the three sub-basins, due to differences in catchment characteristics such as land use and geological/geomorphological conditions.

Results of linear regression analyses showed that Fe in the Samaru and IAR sub-basins, Mg in the Samaru and Kampagi Hill sub-basins exhibited negative linear relationships with river stage. However the relationships between metal concentrations and river stage were not significant. Decrease in metal concentrations with river stage were observed to be due to dilutions of the metals in stream water during rising stages while increasing metal concentration with river stage were observed to be due to increasing wash off of the metals from the basin into the surface water resources. It was also observed that the non-significant relationship between metal concentrations and river stage indicated that a rise or fall in river

stage would not always signify a correspondent increase or decrease in metal concentrations in the basin.

Concentrations of Ca, Mg, Cu and Zn compared with the WHO standards were found to be above the recommended highest desirable levels for drinking water while Cu concentration which was below detection level in the ABU reservoir water prior to 1982 was found to occur in high concentrations (1.18mg/l, 0.59mg/l and 0.25mg/l in S, I.A.R and K.H. sub-basins respectively) above the W.H.O. standards. Ca and Mg showed highest concentrations throughout the period of study and in the three sub-basins. Different sources and activities are probable sources generating these metals in the basin.

Thus, it was concluded that there is increase in metal pollution of the streamwaters of the Upper Kubanni basin and consequently, the ABU reservoir water due to the concentrations of these metals in the stream water and the increases in human activities and changes in land use. The Samaru sub-basin was observed to be the major source of severe pollution hazard to the ABU reservoir. Thus, given the peculiar nature of and poor sanitary conditions especially in the Samaru township sub-basin, specific recommendations on pollution abatement and control were given to safeguard the quality of stream water in the Upper Kubanni basin. A critique of the study was made and recommendations for further studies were also given.

TABLE OF CONTENTS

CHAPTER THREE: STUDY AREA

CHAPTER FOUR: METHODOLOGY OF DATA COLLECTION AND ANALYSIS

CHAPTER FIVE: DATA PRESENTATION AND DISCUSSION OF RESULTS

LIST OF TABLES

Table **Title** **Page**

LIST OF FIGURES

CHAPTER ONE

GENERAL BACKGROUND TO THE STUDY

.1 INTRODUCTION

Water is one of the most abundant and important natural resources to man next to air. About 75% of the earth's surface is said to be covered with water. Although it is abundant in nature, the availability of freshwater for human use is limited and varies spatially and temporarily. Both natural conditions and human activities are affecting the quality of available water. Human activities have resulted in severe water pollution that caused different types of diseases, sudden deaths and disabilities. Water-borne diseases such as typhoid fever, cholera, gastro-enteritis, bilharziasis and guinea worm, for example, are good cases in point. Thus, river resources that are close to, or pass through large urban settlements have become unsafe as sources of water supply because of pollution.

Population explosion and the attendant growth of urbanisation, increased agricultural development and rapid industrialisation have led to further deterioration of water quality in many environments. However, the severe water pollution that has become a serious global concern is that which results from dumping of toxic chemical substances and compounds into surface water resources. The rate at which synthetic chemical products are being developed and used, and the indiscriminate discharges of the waste/bye-products into surface water bodies (rivers, lakes, estuaries or oceans) pose a serious threat to the total environment. Indeed, most sources of water supply for domestic use come mostly from these surface water resources that have become dumping trenches especially in developing countries.

Pollution of stream water with chemical compounds and metals from many different sources (especially industries) is becoming a matter of concern in Nigeria. This is due to the effects of these chemicals on the aquatic ecosystem and concomitant loss of economic gains (e.g. poor fishing) and danger to human health.

Stream water in the Upper Kubanni basin, Samaru-Zaria, is being heavily polluted with effluents (Smith, 1975). Sources through which these pollutants reach stream water in the basin are probably many. These pollutants may be metallic ions reaching the stream in the Upper Kubanni Basin which empty into the Ahmadu Bello University (A.B.U) Kubanni reservoir, that is used for water supply to A.B.U community and Samaru Township. It is therefore important to identify and monitor the nature of sources and concentrations of some metal pollutants and their variations in the stream water of the Upper Kubanni basin. This is because variations in the sources and types of metal pollutant concentrations in surface water and from different sources would have significant influence on treatment processes, the potability of water supply and long-term effects on animal life in the environment.

1.2 RESEARCH PROBLEM

Increasing incidences of water pollution is one of the major problems of potable water supply that water boards/corporations face today. Careless disposal of municipal and industrial wastes have resulted in a deteriorating water quality in many potential water resources supply environments. Because of increasing costs nowadays, most water authorities have had to pass on lower quality water supply to their consumers. Besides, the volumes required for domestic, industrial, and even agricultural purposes are becoming larger and meeting different consumers' needs by volume and desirable quality is becoming almost impossible (Borchard, and Walton, 1971). Water supply for domestic use containing chemical impurities especially heavy metals poses a serious danger to human health.

Field observations by Yusuf (1992) have shown that chemical pollution of surface water resources in the Upper Kubanni basin has become a matter of serious concern despite the absence of manufacturing industries. Casual walk through the Samaru Township shows evidence of an environment being littered with different kinds of synthetic chemical wastes from homes, commercial establishments, chemical laboratories and agricultural fields. These range from polyethylene bags and plastics, synthetic chemical wastes, soaps and detergents, several cosmetic waste products to chemical fertilisers, organic biocides, oils and petroleum products which eventually find their way into the stream and ground water resources of the basin.

Several specific water pollutants such as chloride, fluoride, iodide, nitrate, sulphate, sodium, magnesium, calcium, iron, copper, zinc potassium and lead have been found to occur in varying concentrations in the A.B.U reservoir water and treated water supply to ABU community (Ogunrombi, 1979; Udoh, et al, 1987; Yusuf, 1992). Iron, iodide and fluoride for example occur in concentrations that exceed the recommended maximum permissible limits in drinking water. Indeed, iron and copper have significantly increased in concentration from about 2.88mg/l and below detection in 1982 to about 4.82mg/l and 0.28m/l in 1992 respectively. (Yusuf, 1992).

However, the type of the present conventional /standard treatment processes for the removal of physical and pathogenic biological organisms in water employed at the A.B.U. water treatment plant have been observed by Okun (1977) to be ineffective in removing particularly heavy metals. Yet the A.B.U water authority continues to depend on this water resource for regular water supply to her community and parts of Samaru Township. Besides, an unprecedented on-set rainfall in March 1991 washed all sorts of solid and liquid wastes from the Samaru Township and upper reaches of the Kubanni watershed into the A.B.U reservoir. The treated water that was later supplied was not only markedly coloured, offensive in taste and smell but caused gastro-intestinal problems to many users particularly students of A.B.U. This led to a serious water crisis that prompted the eventual closure of the institution to avert any likely epidemic that would have resulted from the consumption of this poor quality water. It is possible that many pollutants including some metals and other chemical compounds would have passed into the water supply system unaffected by the treatment processes and consumed undetected.

It is of great concern to note that the A.B.U. water authority either pretends to be ignorant of the nature of pollution in the reservoir catchment or unaware of the presence of these specific water pollutants in both its reservoir or treated water supply. Apart from testing for free chlorine in treated water, little else is done to ascertain the (chemical) quality of water being distributed (Udoh et al, 1987).

While the presence of different types of pollutants in surface water (Physical, biological or chemical) has been noted in the A.B.U (Kubanni) reservoir water, little effort has been made to identify their specific sources in the basin. Most of the water quality studies carried out in the basin have centred mainly on sampling water quality parameters in the A.B.U reservoir.

None of the studies on chemical quality of water known to the author has been carried out on tributary streams or smaller sub-basins as potential sources of metal pollution. Assessment of water pollution in the A.B.U reservoir alone therefore does not provide any information on the sources of the pollutants. Therefore the research problem of this study is summarised by the following research questions: (i) what are the specific metal pollutants in stream water of the Upper Kubanni Drainage Basin? (ii) which sub-basins stream are the major sources of metals in stream water? (iii) are there any temporal or spatial variations in metal concentrations, (iv) what are the relationships between metal concentrations and river stage (v) what are the deviations of the concentration of the metals from 1982 levels and from the International Standards for Drinking water.

1.3 AIMS AND OBJECTIVES

The major aim of this research is to identify the presence and concentrations of Iron, Calcium, Magnesium, Copper, Zinc and Lead, (as metal pollutants) and their concentrations in the stream waters of the Upper Kubanni basin. This shall be achieved through the following objectives:

a. to determine and describe the concentration levels of the above-named six metal pollutants in the surface water resources stream water of the Upper Kubanni basin
b. establishing any temporal or spatial variations in the concentrations of the metals from different sub-basins in the Upper Kubanni basin, and;
c. establishing the extent to which the levels of concentrations of the metals can influence water pollution especially with reference to the A.B.U. reservoir.
d. establishing the deviations of the concentrations of these metals in the streams as compared with International Standards.
e. establishing any relationships that may exist between river stage and metal concentrations.

1.4 HYPOTHESES

The following hypotheses would be tested:

I. There are no significant temporal or spatial variations in metal concentrations between months of study and between sub-basins respectively
II. There are no significant linear relationships between river stage and metal concentrations.

1.5 JUSTIFICATION

Water reaching stream channels and reservoirs is a mixture of pollutant chemicals, biological matter, soil debris, etc. contributed from various sources within a basin. In the Upper Kubanni Basin, surface water originates from rainfall and enters the catchment reservoir through surface run off, urban run off, soil/ground water plus irrigation return flows. The quality of the water is dynamic and the changing characteristics require the water technologists to be adequately informed of the variations in the chemical quality of raw water reaching the water intake to ensure adequate and proper treatment especially for domestic uses.

The presence of metals in natural water resources can influence marine ecosystems and in some instances, have caused significant ecosystem degradation. They can also lead to possible mechanisms of depletion and possible extinction of a fishery or other aquatic organisms in a stream that is heavily polluted, (Royston, 1979; Nicola and Brye, 1975; Katz, 1975).

Epidemiological evidences relating trace metal content of municipal water supplies to chronic diseases (especially cardio-vascular diseases) abound. Particularly, are the long-term effects on health from the chronic ingestion of metals such as lead, cadmium, mercury, arsenic, zinc, copper, etc. These have a cumulative effect at relatively low-dose levels which could be teratogenic, mutagenic or carcinogenic (Biswas, 1980; Gower, 1978; Golterman, et al, 1987;). The accumulation and concentration of metals at hazard levels in the tissues of fish and other aquatic organisms used as food by man can cause serious diseases as they become enriched from one trophic level to another. The Minamata bay disease and the Itai-Itai disease near Tokyo, Japan are examples of mercury and cadmium enriched poisoning in fish consumed respectively (Nomiyama, 1975; Doi and Ui, 1975).

It is therefore important to examine the concentrations of some metals in stream water in the Upper Kubanni basin because the increased concentrations of Fe and Cu in the A.B.U. reservoir (Yusuf, 1992) is an indication of increasing pollution of stream water probably from both the Samaru township settlement and the upper reaches of the basin. Since the standard conventional treatment processes for water at the A.B.U. water treatment plant are not ebvffective in removing particularly toxic metals, the metals can pass into the water supply system relatively unchanged. Also the mere presence of heavy metals in stream water even in trace concentrations should be regarded as potential danger (Pojasek, 1977). Therefore, knowledge of the concentration levels, and variations in the different metal concentrations in stream water from various sources would provide a basis for effective water pollution control in the basin. Such knowledge, in turn, would help reduce water treatment costs and more importantly, exposures to health hazards and ecosystem degradation.

1.6 SCOPE AND LIMITATIONS

Initially, the experiment/study was designed to identify the presence of the selected chemical elements and heavy metals and determine the rainfall-rainfall variations in their concentrations, in both sediment and surface water from different sources in the Upper Kubanni basin. However, during the sample analyses, it became obvious that it was not possible to determine a wide range of chemical pollutants in both sediments and surface water because of the high cost of analyses. For example, to determine the concentration of one chemical parameter using the atomic absorption spectrophotometer cost N30.00 (thirty naira) per element in a sample (1994 student rate). Therefore, only the six metal pollutants described above were determined in surface water. Also, the study could not commence before and immediately at the onset of the rainy season due to logistic constraints. Thus, water samples were collected and analysed for the rainfall period of June to October 1994.

CHAPTER TWO

LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

2.1. THE WATER POLLUTION PROBLEM

Many chemical substances and compounds have been found in all types of natural water resources ranging from obviously polluted industrial rivers to rural watersheds and deep ground waters which were thought to be free from pollution (Organisation for Economic Co-operation and Development, OECD, 1982).

In rural and urbanised watersheds, the quality of surface water resources is high because of plenty oxygen available to help in natural self-purification. Solute content in such water would not always and everywhere pose serious threat to health or environment except where the amount is in large quantities that it becomes detrimental to animal life (Fish, 1973; Okun, 1977; Tebbutt, 1977). However, nowadays, most surface water resources contain several non-biodegradable chemical substances and compounds such as heavy metals, organic biocides and other toxic chemicals, which are regarded as potential pollutants that are dangerous to animal and plant life. Thus, according to Fish (1973), defines water pollution as "any alteration of then natural chemical, physical, or biological quality of water by man, which results in an unacceptable depreciation of its quality or environmental value".

2.2 CAUSES OF WATER POLLUTION

The quality of the dissolved chemical/mineral matter in natural water resources has been described to be a function of the catchment characteristics such as the ambient precipitation, the geo-chemical property of the bedrock and its overlying soil, the nature of the weathering processes and the length of time for which the water has been in contact with them (Douglas, 1968; Berry and Horton, 1974; Ayoade, 1988).

Storm water runoff from urban areas often contains large amounts of contaminants derived from litter, garbage, car washing, vehicles' drippings and construction. The dissolved solute content in a river is frequently increased by drainage from mines or oil fields, by addition of industrial or municipal wastes or in irrigated regions by drainage from irrigated lands (Berry and Horton, 1974).

Fish (1973) has summarised the causes of surface water pollution to include:-

i. contamination of water by atmospheric droplets.

ii. disposal of domestic and industrial wastes and sewage into surface water.

iii. disposal of solid and liquid refuse on land, which later enters the drainage system by seepage and urban storm runoff.

iv. land development for urbanisation and construction works and increasing agricultural development.

Thus, a municipality obtaining its water supply from a source downstream of some users discharging untreated sewage and toxic substances in large quantities would find the water unsuitable or too costly to treat for use as a water supply (Gower, 1980).

2.3 STUDIES OF SOURCES OF WATER POLLUTION

Chemical pollutants in raw water are considered in connection with their sources. These pollutants come from two broad categories of sources:

(a) Point-sources, and,

(b) non-point or diffuse sources.

Point sources are characterised by specific localities from where pollution enters stream/rivers (e.g. point of discharge of industrial wastes into a river or point where municipal sewerage directly discharges its effluents into a river). The point of origin of these pollutants can easily be identified and controlled.

Non-point or diffuse sources consist of pollutants derived from a broader area and their origins are not easily determined. Also, there is little or no possibility for direct control. In some river basins, diffuse sources contribute a very large fraction of the total dissolved (solute) load carried. Examples of diffuse sources include sediments from erosion, acids from mines drainage, runoff from urban/industrial areas, runoff through agricultural surfaces and forests, leakage or spillage during transport or storage of materials (Fish, 1973; OECD, 1982).

However, Basta and Bower (1976) have pointed out that the dichotomy between point and non-point sources is not perfect. This is because, for example, although much urban effluent run off is diffuse in generation, the effluent enters stream/river courses at discrete points via urban sewer outlets.

2.4 EFFECTS OF WATER POLLUTION

The pollution of water resources from these different sources would have marked effects on the aquatic biota through addition of non-biodegradable material in solution and suspension, toxic substances, general environmental effects, effects on potability of water and impacts on health of users of such water.

The menace of heavy metal pollution as a result of dumping chemicals into rivers, lakes, etc has assumed a serious proportion in the world generally. Very limited areas of surface water bodies especially in industrialised regions remain unpolluted with hazardous chemical wastes such as DDT, alkylated lead, cobalt, benzo-a-pyrene, mercury, mirex, cadmium, arsenic, copper and a host of other synthetic chemicals to a level that aquatic life in them are becoming extinct (Gower, 1980; Environment Canada, 1989).

Although Golterman et al, (1987) contend that the availability of dissolved elements in the right concentrations (e.g. carbon, nitrogen, phosphorus, iron, magnesium, cobalt sulphur, etc) is required as nutrients to sustain aquatic ecosystem. Others such as calcium, fluorine, and iodine are desirable in drinking water and have positive effects (WHO, 1963). yet, many stream waters contain heavy metals, persistent organic biocides and toxic materials which when present in excesses are regarded as persistent pollutants.

In recent years, the pollution of surface water resources with these persistent toxic materials and non-biodegradable toxic chemicals has become a matter of serious concern. This is because heavy metals in water (in particular) present a far more intractable problem than physical or pathogenic impurities as they are hard to remove and can produce toxic sludge which are hard to dispose and cause severe health hazards (Golterman et al, 1987). In the Great Lakes of America, for example, about 360 different chemical compounds (many of which are persistently toxic) have been discharged into them (Envt. Canada, 1989).

Significantly high residues of DDT were observed to be concentrated in Lake Michigan (Great Lakes) and because of the serious deterioration of water quality, games species are no longer prevalent (Royston, 1979).

2.5 Studies of Variations in Water Quality

Water quality in many parts of the world has been observed to vary spatially and temporarily due to antecedent catchment characteristics. Feller, and Kimmins, (1979) have observed that the chemical quality of water in small streams near Haney in British Columbia vary from one stream to another and from season to season. They also observed decreasing concentrations of Na, Ca, K with decreasing discharge. This they attributed to soil and litter wash in the catchments, quick flows and differences in catchment characteristics.

Metal concentrations in the surface water and sediments of the Makwaye (A.B.U Farm) lake were observed to vary significantly from season to season and between the surface water and sediments (Balarabe and Oladimeji, 1991). They observed that metal concentrations and their variations were higher in the sediments than in surface water due to deposition and accumulation of the metals over a period of time and the nature of the sediments. They also observed that Na, K, Mg, Fe, and Pb showed initial fall in concentration in the rainy season followed by a subsequent rise during the tail end of the dry season. This they attributed to increasing lake volume in the rainy season that led to dilutions and higher concentrations in the dry season in response to fall in water level and re-suspension from the sediments as a result of mixing by wind.

Claridge (1970) observed that concentrations of several ions in water peaked during rising stages of a stream and then declined. He attributed the initial high concentrations in the rising stage to leaching of ions from leaves and litter from the rising stream. Livingstone (1963) considered that groundwater was more concentrated with chemical ions than overland flow. He further stated that decreases in chemical concentrations with increasing stream discharges imply significant contributions of overland flow to storm flows. Cleaves, et al, (1970) also reported that those chemicals whose concentrations increased with increasing discharge also exhibited high concentrations in surface organic layer suggesting significant contributions of this water to storm flow.

2.5.1 Nigerian Studies

Until recently, little attention has been paid to the environmental and health consequences of water resources pollution with metals in Nigeria. In urban and rural areas, there is virtually no control over domestic/municipal and industrial waste discharges. It is in fact, difficult to control uses of modern agricultural inputs such as various chemical fertilisers, insecticides, pesticides and herbicides. Thus, it is possible to view rivers passing through our towns and villages as open sewers.

Water quality studies in Nigeria have mainly been carried out on pathogenic organisms. This probably is due to the rampant outbreaks of water borne diseases and their death tolls in many parts of the country. The Nigerian Environment Study/Action Team, NEST, (1990) believes that there is increase in pollution of the country's water resources. The team identifies eight major groups of water pollutants to include (i) domestic sewage (ii) infectious disease agents (iii) plant nutrients (iv) pesticides and insecticides (v) industrial effluents, (vi) eroded sediments, (vii) solid wastes and (viii) petroleum products. Though the team observed that chemical pollutants would be contributed mainly by industries, it did not specify the type(s) of chemicals a particular industry will contribute or generate.

Nwosu (1983) reported that about 25.8million tonnes of faecal wastes were dumped in to the Lagos Lagoon in 1973. These wastes were mainly from municipalities. Sati (1990) also reported the indiscriminate dumping of large quantities of domestic and industrial wastes into the Kaduna river. He concluded that such wastes have led to severe water pollution and consequently lower environmental quality in Kaduna metropolis. Beecroft et al (1988) reported that the Kaduna river (particularly downstream of Kaduna South Water Works) is highly polluted with domestic and industrial wastes from the Kaduna South Industrial layout at Kakuri and Nassarawa. They reported high levels of chemical oxygen demand (COD), bio-chemical oxygen demand (BOD), which vary from source to source and increase in the dry season from their rainy season levels.

Yabagi (1989) has also observed that metal pollution of the Kaduna river water results from uncontrolled effluent waste discharges from industries in the Kaduna metropolis. Heavy metals such as iron, cobalt lead, cadmium, mercury and arsenic occur in the river water in very high concentrations above recommended standards for drinking water and also varied in concentration from one source (industry) to another. Ahmed and Tanko, (1994) have observed that the concentrations of calcium, magnesium, sodium, manganese, nitrate, chromium and lead vary spatially and seasonally in the river Hadejia region of Kano. They observed that the concentrations of lead, chromium and manganese in high amounts present a health hazard and that increasing chemical pollution of water in the area was due to increasing use of chemicals in irrigation and industrial discharges.

2.5.2 Upper Kubanni Basin Studies

Surface water in the Upper Kubanni Basin (especially in the Samaru Stream and ABU reservoir) have been reported to be heavily polluted with effluent wastes from Samaru township and ABU. It has been observed recently that tonnes of refuse along with all sorts of household wastes (toxic chemicals and probably heavy metals) are washed into storm runoff from the rapidly growing Samaru township (Smith, 1975; Bello, 1992). Thus significant changes occurring within the watershed would probably lead to marked changes in water quality (McDonald and Loeltz, 1978; Feller, and Kimmins, 1978; Bello and Jeb, 1996).
The concern about pollution of the surface water in the Upper Kubanni basin generally began during the surface water resources development (ABU reservoir) for the ABU Community in 1972. Hydro-geomorphological and water resources engineering investigations done on the transport of suspended solids (Bello, 1973) and organisms in raw water as indicators of pollution showed that the community's sources of water supply is being heavily polluted (Okuofo et al, 1979).

Smith (1975) observed that there already exists high conductivity and bio-chemical oxygen demand (BOD) levels while low oxygen levels were recorded in the rainy season entering the reservoir. Pathogenic organisms such as the sheath bacterium, Sphaerotilus natans (a sewage fungus) Euglena and Trachelomonus were also observed. He concluded that storm water from Samaru sub-basin contributes biological (organic) materials that can be considered as health hazards. However, heavy metal pollutants and their concentrations were not determined.

Ogunrombi (1979) analysed samples of the ABU reservoir water for some chemical pollutants and found that the concentrations of chemical elements such as calcium, sodium, magnesium and potassium were very low indeed. The concentration of iron however was 7.95mg/l, which was above WHO highest desirable level for drinking water. Thus, he concluded that the water in the Kubanni reservoir was suitable for both domestic use and irrigation purposes but advised that the water be adequately treated to reduce iron concentration.

However, Udoh et al's works (1987) show that both raw water and treated water samples collected from the Zaria dam, Kubanni (ABU) reservoir, the tap outside ABU water works and ten distribution tanks in various locations in Zaria contain a wide range of chemical and metallic pollutants including nitrogen, fluorine, chlorine iodide sulphate, sodium, potassium, calcium, iron and zinc in varying concentrations. Other heavy metals like arsenic, mercury, copper and manganese were below detection limit (Table 2.1). It was observed that the levels of iron, fluorine and iodide concentrations in both raw and treated water from the ABU reservoir were above the WHO permissible levels for drinking water (see Table 5.8).

The study however was not basin-wide and, therefore, could not give any knowledge on the surface/river water quality characteristics of the Upper Kubanni basin and the nature of the sources of the pollutants and variations in metal concentrations between sources of pollution.

Recently, Yusuf (1992) using water samples collected from the ABU reservoir found significant increases in the levels of Fe and Cu from their 1982 levels. Fe increased in concentration from 2.88mg/l to 4.82mg/l while Cu increased from below detection to 0.28mg/l. It is possible that other heavy metals might have increased in their level of concentrations considering the on-going changes and activities taking place within the entire Kubanni Basin.

Table 2.1 **CHEMICAL CONCENTRATIONS (Mg/l) FOR RAW AND TREATED WATER FROM A.B.U. WATER WORKS**

CHEMICAL	RAW WATER	TREATED WATER
Total Nitrogen (N)	-	-
Fluoride (F-)	6.5	2.0
Chloride (Cl-)	5.0	10.0
Iodide (I-)	0.1	0.2
Sulphate (SO_4)	85	140
Sodium (Na)	4.0	4.3
Potassium (K)	8.1	4.9
Calcium (Ca)	2.7	4.3
Magnesium (Mg)	2.7	2.0
Iron (Fe)	0.6	0.6
Zinc (Zn)	0.1	0.5
Lead (Pb)	0.3	B.D
Copper (Cu)	B.D	B.D
Manganese (Mn)	B.D	B.D
Arsenic (As)	B.D	B.D
Mercury (Hg)	B.D	B.D

Udoh et al (1987) B.D-Below Detection

From the few studies already carried out within the Kubanni Basin, two questions need be asked: (1) what are the source area(s) of the different chemical and heavy metallic pollutants in the water supply for the A.B.U and Samaru township Community? (2) If Yusuf's study showed increases in the concentration levels of some

pollutants in 1982 to above permissible levels in drinking water in 1992 which section/sub-basin is generating the pollutants in high concentrations?. This is the thrust of this study.

.6 Some Considerations For Water Quality Evaluation

Sampling and examination of water supply sources are generally undertaken to measure the degree of pollution and the suitability of the water for treatment and eventual use for domestic purposes (WHO, 1963).

To obtain a true picture of the nature of water pollution, it is first, necessary to ensure that the sample is actually representative of the source. Secondly, the appropriate analyses must be carried out using standard procedures so that results obtained by different analyses can be directly compared (Fish, 1973).

From a source of uniform quality, simple grab samples may be satisfactory to provide a spot check. However, were most raw waters are highly variable in quality, composite samples are collected at known intervals and bulked together in proportion to the appropriate flows to obtain an integrated composite sample. These samples can be collected manually or by automatic devices (Fish, 1973).

In the evaluation of present and future water resources, Nelson (1978) has pointed out that it is important to know the location of the pollutant, its arrival time at a critical point from the source and its quantity. This is because the source of a pollutant isolated from man both now and in the future may present little hazard when large quantities are present. Under conditions, small amounts of pollutants arriving at critical locations over a short period of time may involve severe hazard. Further more, WHO (1962) has suggested that in the choice of a source of drinking water and its maintenance in a satisfactory condition, sanitary and topographic aspects of the basin should be of primary concern. Ideally situated areas should be those that have experienced minimal human activities that may cause pollution. This condition hardly exists now in the Upper Kubanni basin following the rapid changes that have occurred and there is no certainty about the level of chemical pollution. It is therefore necessary that the levels of some metals in the stream water from some sub-basins in the Upper Kubanni basin and variation in their concentrations be known.

CHAPTER THREE

STUDY AREA

3.1 INTRODUCTION

This section describes the general physical background of the components of the Upper Kubanni basin that influence stream water quality.

3.2 LOCATION

The Upper Kubanni Basin, Samaru Zaria (Location 11° 11' N and 7° 38' E) Kaduna State is situated on the Central High plains of Hausa land in northern Nigeria. Upstream of the A.B.U. reservoir, the land area is about 54.25 km^2 and drained by two sets of third order streams (Fig. 3.2). Three sub-basins chosen for this study include an urban catchment the Samaru catchment (S), an urban-rural catchment IAR sub-basin (IAR), and a rural sub-basin, the Kampagi Hill (KH), [see Fig. 4.1]

3.3 GEOLOGY AND RELIEF

The Upper Kubanni Basin is underlain by crystalline rocks of the Pre-Cambrian age, which include gneisses and granites. The crystalline rocks are part of the Nigerian Basement Complex that underlie mostly the western and northern parts of Nigeria. The main components of the solid geology are Biotite Gneisses and Older Granites (Fig. 3.2). The biotite gneisses dominate most of the eastern part of the area outcropping mainly in stream valleys where they are deeply weathered. They are medium to coarse-grained and moderately-to-weakly foliated rocks principally composed of quartz, oligoclase biotite and occasionally porphyroblastic microline. The Older Granites are strongly to weakly porphyroblastic and are variably foliated sometimes seen in stream sections where they are difficult to distinguish from porphyroblastic gneisses. The granites contain quartz, turbid oligoclase and accessory appatite oxide, and zircon in addition to microline and biotite, which is often chloritised, (Wright and McCurry, 1970). The gneisses occur as elongated belts among the granite mass. Jointing and fracturing are heavily developed in the gneisses within structures.

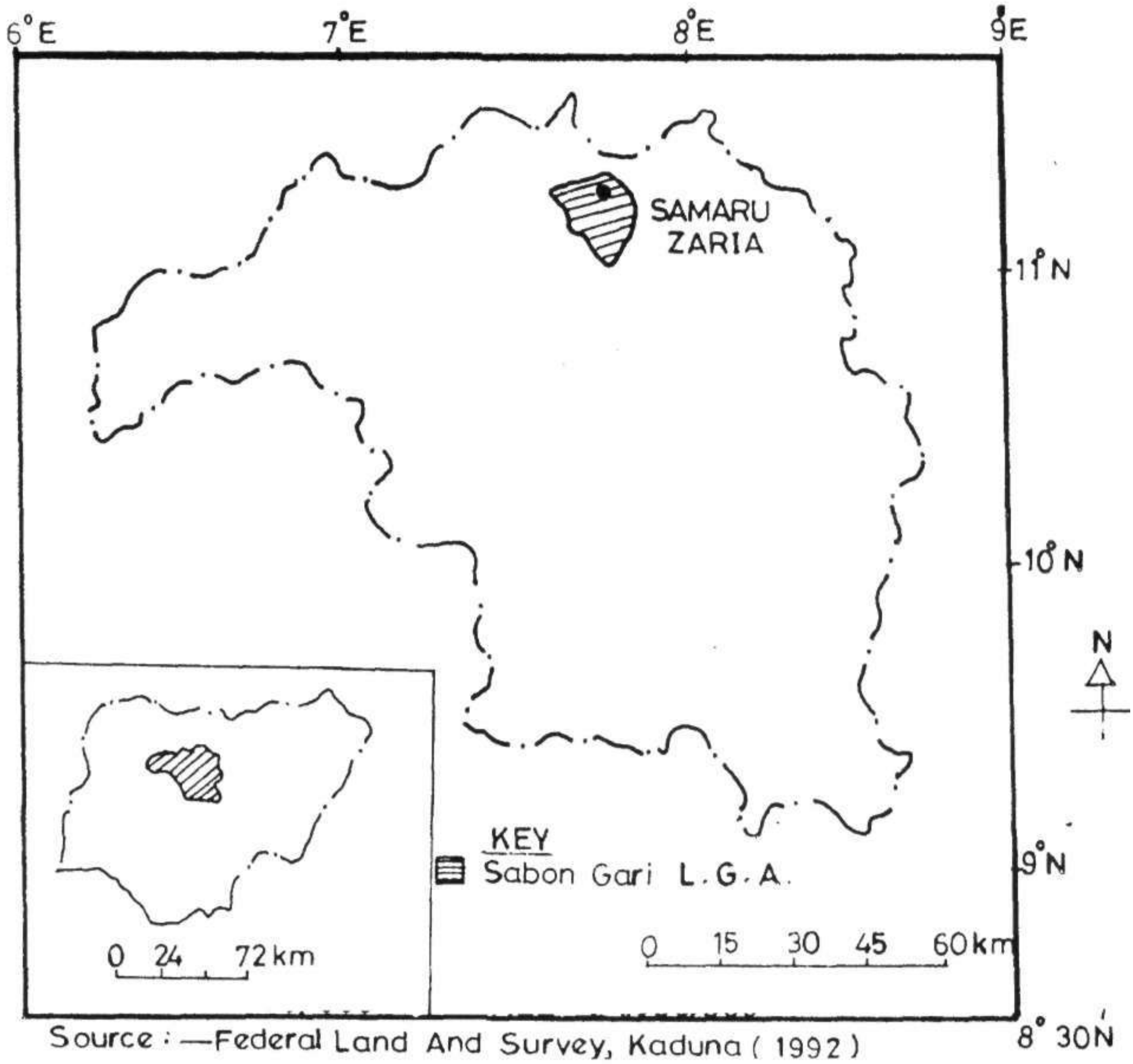

FIGURE 3.1: LOCATION OF STUDY AREA

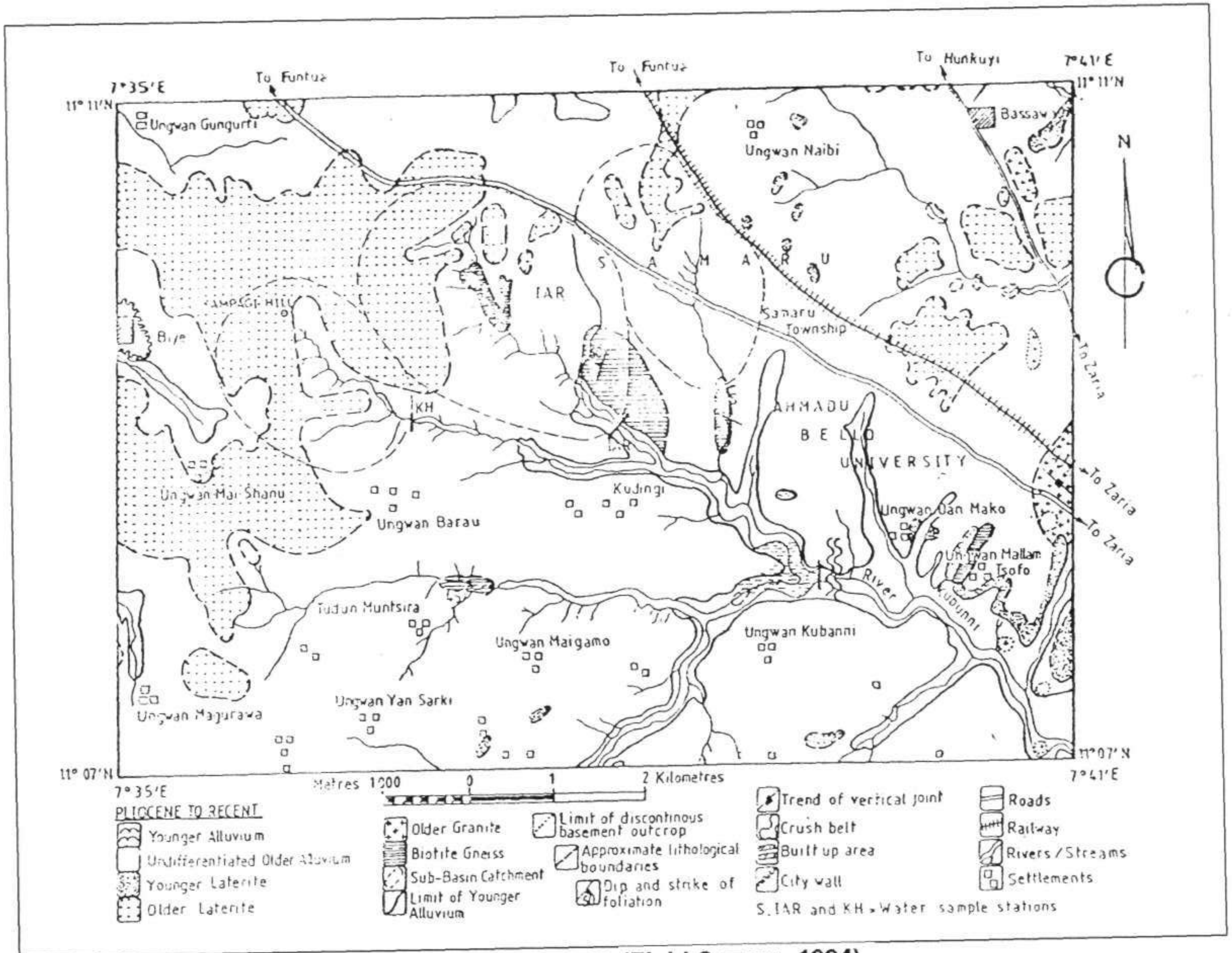

FIGURE 3.2: UPPER KUBANNI BASIN - GEOLOGY (Field Survey, 1994).

Insitu weathering in the upper part of the Basement Complex has produced an extensive mobilised weathered cover, which is overlain by aeoline drift and laterite. Collectively, they have been described by Wright and McCurry, (1970) as Superficial Deposits. These include (i) Older Laterite remnants about six metres thick, red brown, cellular and relatively free of impurity; (ii) Younger Laterite sheets barely more than 2 metres, generally browner, less cellular and less free of impurity, (iii) Older Alluvium which covers much of the land between river valleys and in-fills old drainage channels. It consists mainly of accumulations of fine grey/brown sands, clays, red sands and gravel reach thickness of 5-12 metres, (iv) Younger Alluvium developing in present-day river valleys consists of grey-brown sands, silts and clays over 9 metres thick in many places.

The Upper Kubanni Basin is part of the vast undulating plain scenery of the Hausa land at a height of about 1,830m. The topography reflects the nature of the underlying geology. The plains are in many places surmounted by broad lateritic iron-capped mesa-like divides and sometimes on steep valley-side slopes where accelerated stripping exposes the lateritic formations, (Thorp, 1970).

3.4 CLIMATE

The hinterland location far away from the maritime, places the Upper Kubanni Basin within the tropical continental type climate with distinct wet and dry seasons that are preceded by short hot dry and cool dusty spells respectively, (classified as a Tropical Savannah, Aw Climate). (Kowal and Knabe, 1970). The two seasons are under the influences of two air masses, the dry tropical continental air mass (cTs), which originates from the Sahara desert and the moist and cool equatorial maritime air mass (mTs), which originates from the Atlantic Ocean.

The seasonal pattern of the climate is attributed to the movement of the ITD over the area, which forms a boundary for the normal weather system, and structure associated with the moist mTs and the dry cTs and so controls the pattern of the rains (Hore, 1970).

On the average, the rains start in early to mid May or June when the ITD prevails over the study area. Thus, the rainfalls occur mainly during the months of June and September with a single peak in August. Rain days vary from 80 to 100. The average rainfall is about 1100mm occurring mostly in the afternoons sometimes persisting into the nights.

During the months of October/November to April, there is virtually no rainfall. Relative humidity is generally less than 30%. Surface winds tend to be strongly northeasterly and very cold to cool in the mornings.

Air mean temperatures vary very little throughout the year averaging 21-26^{oc} in most months. Higher temperatures averaging between 27-31^{oc} however occur in March as a result of the rising insulation, which encourages high evaporation and transpiration most especially on bare surface areas.

3.5 DRAINAGE AND HYDROLOGY

The Upper Kubanni Basin is drained by two northern most tributaries of river Kubanni (Fig. 3.2). The entire river system is seasonal in flow and during the rainy season stream flow occurs following rainfall events. The Kampagi tributary (KH) dries up fast and even during rainfall events, its flow duration is short. The streams in the IAR basin experience high flow duration, especially the Samaru stream that is in flow throughout the year, because it is sustained by urban run off and sewage.

The streams in this basin are characterised by a number of unbroken first-order tributaries with high stream frequencies. The stream are usually characterised by intense gullying and head water erosion (Thorp, 1970). The drainage pattern of the basin is dentritic and most of the tributaries are fairly short, and their total number being small. Therefore, the discharge of water from the upper sections of the basin into the ABU reservoir takes a very short travel-time.

Within the Samaru sub-basin, many sections of the drainage channels are used as sites for refuse dumps, while many sections of the drainage system in the IAR/KH sub-basins are used for rainy season farming and dry season irrigation. Thus, surface run off in the basin usually contains all sorts of wastes from homes, shops, and farmlands.

3.6 SOILS AND VEGETATION

The major soil type in this basin is the Tropical Ferruginous. Along the wide gentle sloping valley bottomlands are the dark vertisols ("Fadama" soils - Hausa) and these are soils classified as hydromorphic. These fadama soils are particularly found along the middle to lower reaches of the river systems (Klinkenberg, 1970).

The Zaria region falls within the Guinea Savannah vegetation. The climax climatic vegetation of the area was thought to be tropical deciduous. However, because nearly all the vegetation within the basin had been degraded due to intense cultivation, fuel wood felling and urbanisation processes, true climax climatic vegetation is absent except for few scattered tree stands here and there, interspersed with tall grasses about 1-15m and 2-5m respectively that remain, (Jackson, 1970). Common trees found include shear butter *(Butteres permium parkia)*, tamarind *(Tamarindus heodedotti)*, locust bean *(Parkia clappertonia)*, isoberilina *(Isoberilina doka*; *I-dalziecti*), silk cotton and deleb palm. The grass types include *Andropogonaea spp* such as *Hypharrhenia* spp, *Andropon spp,* others are *Schizachirium semiberbe,* and *Monocymbium ceresiiforme*(Jackson, 1970). The type of soil and vegetation in an area influences the water quality of that area due to the interaction of water with vegetal and soil particles (Ayoade, 1988).

3.7 LANDUSE CHARACTERISTICS

Within the basin, major landuse types easily recognised include residential, agricultural and commercial. The land use types vary considerably in the study area.

The Samaru Basin is essentially residential, commercial and educational. It is characteristically urbanised, densely populated with closely packed residential houses, (Kabir, 1993). Samaru town is the main commercial centre in the basin and commercial activities here include wholesale and retail trading in electronic wares, foot wares, clothing, building materials, patent medicine, foodstuffs, and etc, Others include road side mechanical repairs, welding (soldering), battery charging, vulcanising, hair/barbing saloons and so on. Thus, the sanitary condition of the immediate environment is very poor. Large heaps of refuse dumps, heavily polluted gutters and ditches/ponds, human and animal wastes and garbage are littered along almost every street and between houses.

The Kampagi Basin and part of IAR basin to the west across the stream are used purely as rural farmlands/grazing land by Hausa-Fulani hamlet communities dispersed widely in the area. The rest of IAR basin is residential quarters (Areas E, F and G) for A.B.U staff. However, the Institute for Agricultural Research complex is located here on the Eastern valley side slope. Here, back yard farming and associated tracts of farmlands, demonstration plots of the institute are also obvious.

Generally, land use within the Upper Kubanni Basin has changed significantly since the establishment of A.B.U in 1962. Urban expansion and developments have encroached into marginal lands to the north and Northwest of the basin. Field observations show that A.B.U residential areas and services have expanded towards the headwaters of the rural tributary in the study area. The Samaru town on the other hand has expanded across the railway line (Hayin Dogo) and towards the lateritic mesa near the students' hostel of the College of Agriculture(Bello, 1992).

Table 3.1: **THE PHYSICAL CHARACTERISTICS OF THE BASIN**

		DARINAGE DENSITY(Km/Km^2)	LAND USE (% TOTAL AREA)	
BASIN	AREA(Km^2)		URBAN	RURAL
S	4.4	3.4/4.4 = 0.80	65.07	34.93
IAR	6.15	12/6.15 = 1.95	15.57	84.43
KH	3.5	4.6/3.5 = 1.31	0.00	100

(Field Survey, 1996)

The nature and character of land use in a basin influences the quality of water in that basin Kabir (1993), for example has observed that rapid urbanisation of the Samaru township is causing serious pollution of stream water due to rapid wash-off of domestic sewage and refuse from the township into the Samaru stream.

CHAPTER FOUR

METHODOLOGY OF DATA COLLECTION AND ANALYSIS

4.1 INTRODUCTION

Data for this study were obtained from experimental fieldwork and comprised daily rainfall total and surface water samples from outlets of three sub-basins. The water samples collected were analysed in the laboratory to determine the occurrence and level of concentrations of some metals. The statistical analysis used in the study to determine the spatial and temporal variations in metal concentrations between the three sub-basins and any relationship between runoff characteristics and the metal concentrations are also explained.

4.2 STUDY APPROACH

The study approach adopted is the drainage basin experiment, which uses catchments outlets as point sources (Helmer, 1978; Moss, 1979). Figure 3.3 illustrates the location of the three sub-basins selected and the instrumentation. Apart from financial limitations and advanced research equipment, the advantage of existing instrumented catchment in the study area, nearness and easy accessibility to the basins guided the selection of the sub-basins. In fact, one of them (i.e. the Samaru sub-basin) had already been instrumented for monitoring urban run off. However, the water level recorder at the `S' outlet point is no longer operational (Bello, 1991). Also, the IAR sub-basin has an existing simple meteorological station. Besides, the sub-basins are all tributaries of the Upper Kubanni stream draining three characteristically distinct catchments (Section 3.4). For example, sub-basin `KH' is purely a rural catchment used for grazing and rain fed subsistence agriculture. In contrast, the "S" sub-basin is wholly urbanised while the IAR sub-basin is partly urban and partly rural. Thus, the differences in the three sub- basins' land uses provide the opportunities to determine the types and sources of water pollution entering the water resources supply of the ABU reservoir developed on the Kubanni river immediately downstream (fig. 4.1).

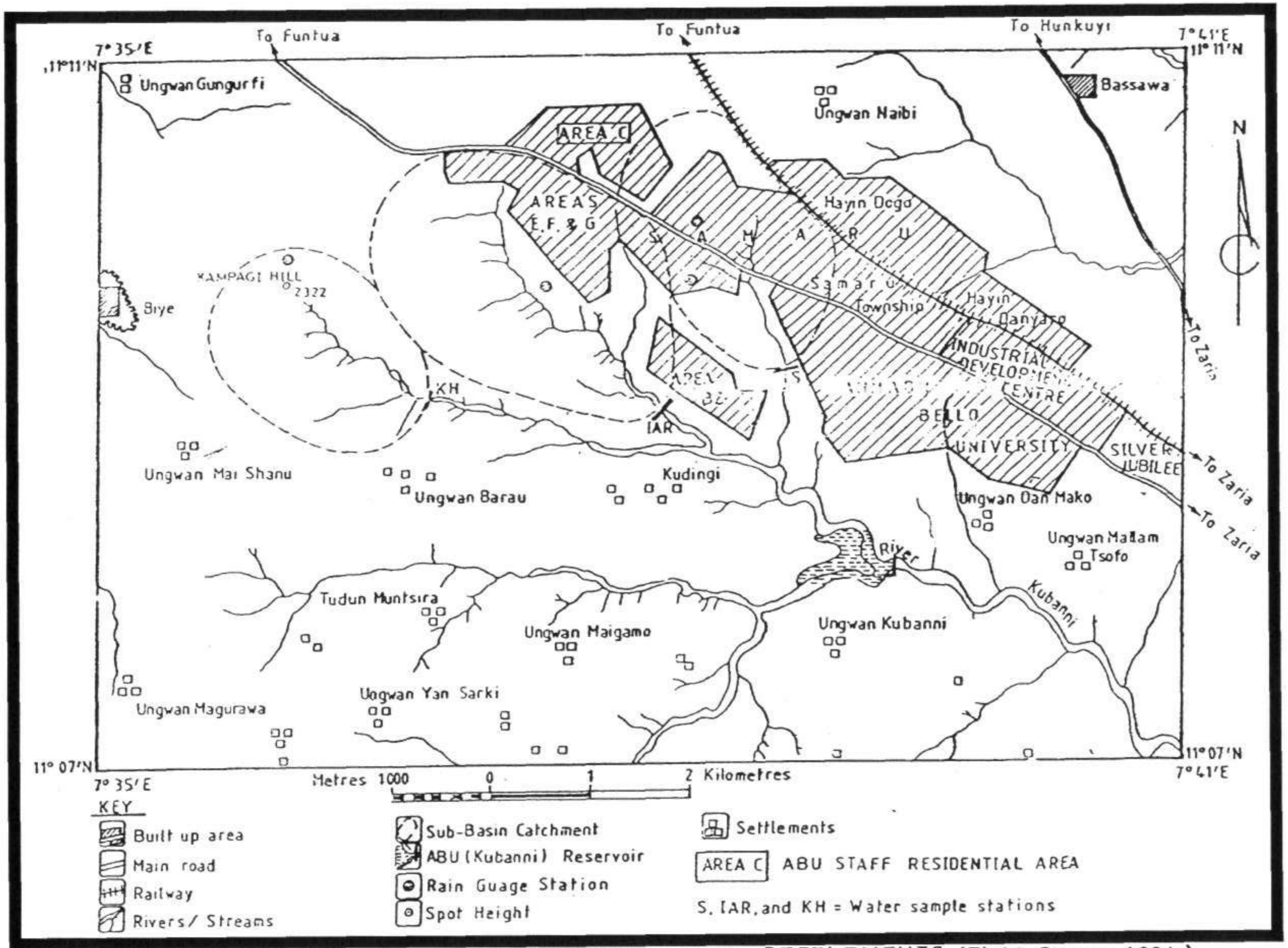

FIGURE 4.1 UPPER KUBANNI BASIN - SETTLEMENTS (Field Survey, 1994)

Thus, the outlet points of each of the three sub-basins were monitored as water sampling points during rainfall run-off events. However, this "whole catchment" approach has its limitations. For example, Bello et al (1978) have demonstrated that only a small area of particular sites is the source of about 70% of what is being measured at the catchment outlet. Although water monitoring organisations always use catchment outlets as point-sources in their experimental design, for water quality studies, the cost, purpose of study and fieldwork logistics are major considerations that guide the use of catchment outlets approach as point sources.

4.3 SAMPLING DESIGN AND DATA COLLECTION PROCEDURE

Three categories of data were collected for the study these were (i) the basins' physical/environmental characteristics (i.e. area of basins, drainage density and urban/rural land use), (ii) rainfall, and (iii) river stage and water samples.

3.3.1 Physical Characteristics of the Basins

For this set of data, topographical maps and air photographs (1:50,00) were carefully studied in the laboratory. From these topographical maps and air photographs, the size of each basin, their drainage characteristics and variation in land uses between sub-basins were measured and recorded (table 3.1).

4.3.2 Rainfall Data Collection

From the Standard Manual type rain gauges installed in the basin (127mm "Winsor Model" - W 5010 - WMO), average daily rainfall - data were observed using simple arithmetic mean. Other methods of obtaining average daily rainfall depths are isohyets and Thiessen polygons. Each has its merits and limitations depending on the nature of the terrain of the area and rain gauge network (Wiesmer, 1967). Because of the small local relief and the small size of the entire Upper Kubanni basin, the arithmetic mean has been used like other previous workers (Iguisi, 1996). The average daily rainfall data are given in Appendix A.

4.3.3 Rainfall Run off and Water Samples

Water samples were obtained during rainfall run off resulting from selected rainfall events. Various methods for obtaining water samples for water quality determination have been advocated (Imeson, 1974; Gregory and Walling, 1979; and Lam, 1979). The methods range from manual, using U.S. DH - 48 suspended water/ sediment sampler mounted on a wading rod, US. DH - 59 mounted on a cable drawn by a vehicle on a bridge, to automatic pumping suspended water/sediment samplers. In this study, the U.S. DH - 48 suspended water/sediment sampler mounted on a four feet wading rod was used. Care was taken to obtain the sample using the depth-integrated method (i.e. by lowering the sampler at a velocity as much as practicably similar to that of the stream flow). This is so as to obtain a representative sample of water-sediment/solute mixture passing the gauging station at that point in time. The water level was determined on the staff gauge and recorded (see data on Appendices B and C).

Thus water samples were obtained both on the rising peak and falling stages during the rainfall producing storm runoff events through the months of June to October 1994 rainy season. All the samples obtained were stored in clean plastic bottles (500ml) with screw caps in a refrigerator (after adding 5ml of concentrated Nitric acid, (HNO_3) as preservative) before they were taken to the laboratory for analyses.

4.4 LABORATORY ANALYSIS

Six water quality parameters were purposefully selected for this study. They include two alkaline-earth metals, i.e. Calcium (Ca) and Magnesium (Mg); and four heavy metals - Iron (Fe), Zinc (Zn) Copper (Cu) and Lead (Pb). These metallic elements were selected because of their potential health hazards, impacts on water resources development and water supply utilities. Out of 131 water samples collected, 51 samples (both grab and composites samples) were analysed. Grab samples here refer to when single water samples collected were used for analysis while composites samples refer to when two or more water samples collected were "compounded", mixed thoroughly and a representative sample (500ml) was taken and used for analysis. The water samples were analysed to (i) identify and (ii) determine the concentrations of each metal in the water sample based on the standard methods for the examination of water and waste water prescribed by the American Public Health Association, APHA, et al, (1985). The analytical procedures were as follows:

4.4.1 Preliminary Filtration Analysis

To identify the presence of specific metallic elements, the water samples obtained during the rainstorm run off events were first filtered through an ungrided 0.45*um* pore diameter membrane filter. Other filtering mediums include the Gooch Crucible, Whatman filter paper and glass fibres. With each medium, errors can occur in the determination of concentration, especially concentrations of suspended sediment (Loughran and Malone 1976; Douglas, 1971). The medium used in this study, however, was chosen to avoid contamination as a result of further weathering of solutes due to storage time and handling using decanting or over drying methods.

The assembled filtering unit was pre-conditioned by rinsing with 50ml de-ionised water and then with 100ml of the sample and was discarded but the volume use was recorded. This is necessary to guard against contamination of the sample. Then the remaining sample was filtered and the filtrate acidified to pH ≤ 2 with concentrated nitric acid, (HNO_3) and is ready for further analysis.

4.4.2 Determination of Pollutants by Digestion of Acidified Sample Filtrate.

50ml of the acidified sample filtrate was mixed and pipetted into a 100ml-glass beaker. 5ml of concentrated nitric acid, (HNO_3) was added and the solution digested on a hot plate (i.e. slowly boiled and evaporated) to a volume of 20ml before precipitation or salting out occurred. 5ml of HNO_3 was again added and covered with a watch glass and then heated to obtain a gentler refluxing action. The solution was continuously heated and 2ml of concentrated nitric acid, added as necessary until digestion was complete as shown by a light - coloured clear solution. At no point was the sample allowed to dry completely during digestion. Another 2ml of HNO_3 was added and warmed slightly to dissolve any remaining residue. The walls of the beaker and watch glass were washed down with de-ionised water. Then the digested filtrate was transferred to a 100ml volumetric flask with two 5ml portions of the filtered water after adding the rinsings from the walls of the beaker and watch glass to the volumetric flask. The solution was marked, allowed to cool, and mixed thoroughly.

Other digestion methods that could be used include the Nitric acid-Sulphuric acid Digestion, Nitric acid Perchloric acid Digestion, and Nitric acid-Perchloric acid - Hydrofluoric acid

Digestion. (APHA, et al, 1985). However, the Nitric acid Digestion method described above was chosen because it is quicker, cheaper and simple to perform with the reagents available. Apart from the non-emission of poisonous gases during digestion, it is the method recommended for the analysis of the selected metals under investigation in this type of study (APHA, et al, 1985).

Portions of the digested solutions of each water sample so prepared as described above were taken for the identification and their respective concentration levels measured on a Varian Techtron Atomic Absorption Spectrophotometer, AAS (Pye Unicam SP192 model) using an air acetylene flame and the appropriate metallic element lamp. Thus, the concentrations of each metal obtained was expressed in mg/l.

4.5 STATISTICAL ANALYSES

The data obtained from the field investigations and laboratory analyses were used to statistically determine the hypotheses stated in Section 1.5, that is to determine (i) the temporal variations and spatial variations in the concentration levels of the metals between the months of study and between the three sub-basins using the one-way analysis of variance and (ii) the relationship between river stage and metal concentration, using the Least Square Regression Analysis.

4.5.1 Analysis of Variance (ANOVA)

Two measures of variations were tested (i) variation of each metal between the months of study (temporal variation) and (ii) the total variation of all the metals between the three sub-basins (spatial variation); using the One-way ANOVA.

The One-way ANOVA is used to test the measure of the total variation in metal concentration between the months of study and between the three sub-basins. It is tested by the total sum of squares which is given as:

$$SST = \sum_{i=1}^{k} \sum_{j=1}^{n} (Xij - Xg)^2 \qquad 4.1$$

where:

SST = total sum of squares

Xij = jth observation of the ith sample (i: 1.2 ... k and j= 1,2 ...k)

Xg = grand mean

Denoting by Xi, the mean of the ith sample, the basis of the one-way ANOVA can be re-written as;

$$SST = n\sum_{i=1}^{k} (Xi - X)^2 + \sum_{i=1}^{k} \sum_{j=1}^{n} (Xij - X)^2 \qquad 4.2$$

where

Xi = mean of the ith sample

X = grand mean

n = number of samples

k = number of categories (classes) and

$n\sum_{i=1}^{k}(Xi - X)^2 =$ treatment sum of squares SS(Tr)

$\sum_{i=1}^{k} \sum_{j=1}^{n} (Xij - X)^2 =$ Error sum of square (SSE) that is "experimental error"

Freund, (1973).

The One-way ANOVA is performed/using the ANOVA table below.

Table 4.1 : **ONE-WAY ANOVA TABLE**

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	F
Treatment	k-1	SS(Tr)	$MS(Tr)=\frac{SS(Tr)}{k-1}$	$\frac{MS(Tr)}{MSE}$
Error	k (n-1)	SSE	$MSE=\frac{SSE}{K(n-1)}$	
Total	(kn-1)	SST		

Freund (1973)

4.5.2 Regression Analysis

The regression analysis was performed to determine the linear relationships between the concentrations of the metals and river stage in the three sub-basins. In this case, the river stage was considered as the independent variable (X) while metal concentration as the dependent variable (y). The linear regression analysis was performed using the least square regression technique given by the formula:

$$Y = a + bx \quad \text{(i.e. the regression of x on y).} \qquad 4.3$$

where:

$$a = \frac{\sum Y - b\sum X}{\sum X^2 - \frac{(\sum X)^2}{n}} \qquad 4.4$$

$$b = \frac{\sum XY - \frac{\sum XY}{n}}{\sum X - \frac{(\sum Y)^2}{n}} \qquad 4.5$$

$\sum X$ = the sum of the values of the independent variable for the ith observation.

$\sum Y$ = the sum of the values of the dependent variable for the ith observation

a, b = the estimates of the unknown parameters of the system

Clark and Hosking (1986).

The Pearson's (r) was use to test for any significant relationships between the concentrations of the metals and river stages in the three sub-basins. The test-statistic is derived from the formula:

$$r = \frac{\sum XY - \frac{\sum X \sum Y}{n}}{\sqrt{\left(\sum X2 - \frac{(\sum X)^2}{n}\right)\left(\sum Y2 - \frac{(\sum Y)^2}{n}\right)}} \qquad 4.6$$

Clark and Hosking (1986)

However, the correlation (r), on the basis of sample data may show strong positive or negative relation purely by chance when there was actually no relationship between the two variables. To investigate whether or not the values of r where attributed purely to chance, the null hypothesis of no correlation was postulated and tested using the t - statistic.

$$t = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}} \qquad - 4.7$$

Clark and Hosking, (1986) which

has the t-distribution with n-2 degrees of freedom and 0.05 (95%) confidence limit. A condition of no significant relationship is accepted if the calculated t-value is less than the table value at the 0.05 confidence limit. The detailed tested data in the study are presented and discussed in Chapter 5.

CHAPTER FIVE

DATA PRESENTATION AND DISCUSSION OF RESULTS

5.1 INTRODUCTION

This chapter presents the data obtained from laboratory analysis of water samples collected and the results of the statistical analyses of the data (Section 5.2). Section 5.3 discus the results of the investigation.

5.2 Data Presentation

Following the laboratory analyses of the water samples collected from the three sub-basins (Section 4.4), the concentration levels of the selected metals were determined at different river stage conditions. Appendix C illustrates the variations in the stage characteristics and occurrences of the selected metallic pollutants and the nature of variations in the levels of concentrations.

5.2.1 Monthly Metal Concentrations

Table 5.1 presents the mean monthly metal concentrations for the three sub-basins.

TABLE 5.1 : MEAN MONTHLY METAL CONCENTRATIONS OF SELECTED METALLIC POLLUTANTS (MG/L) IN THE THREE SUB-BASINS

Month	Sub-basin	Fe	Ca	Mg	Cu	Zn	Pb
J	S	0.05	211.9	68.4	1.03	0.08	0.002
U	IAR	0.07	114.9	37.73	0.25	0.52	0.002
N	KH	0.04	112.7	93.33	0.15	0.22	0.005
J	S	0.08	306.3	57.2	1.23	0.45	0.002
U	IAR	0.05	171.7	63.6	0.62	0.53	0.004
L	KH	0.02	121.5	50.5	0.25	0.38	0.005
A	S	0.05	246.4	70.7	1.21	0.12	0.003
U	IAR	0.07	151.5	28.28	0.86	0.82	0.004
G	KH	0.05	235.2	119.98	0.15	0.87	0.004
S	S	0.11	249.1	151.8	1.17	0.45	0.002
E	IAR	0.12	141.4	33.7	0.54	0.35	0.003
P	KH	0.04	154.3	103.3	0.48	0.26	0.002
O	S	0.04	303.0	80.8	1.25	0.52	0.004
C	IAR	0.03	162.0	76.2	0.69	0.65	0.004
T	KH	0.03	133.6	76.3	0.22	0.32	0.001

"S" = Samaru (Urban) sub-basin (Field Survey, 1994)
"IAR" = Inst. for Agric. Res. (rural/urban) sub-basin
"KH" = Kampagi Hill (rural) sub-basin

In the Samaru sub-basin, Fe mean monthly concentrations ranged between 0.4mg/l and 0.11mg/l in October and September respectively; Ca was between 211.9mg/l in June and 306mg/l in July; and Mg ranged between 68.4mg/l in June and 151.8mg/l in September. The mean monthly concentration of Cu ranged between 1.03mg/l in June and 1.25mg/l in October; Zn was between 0.08mg/l in June and 0.52mg/l in October; and Pb ranged 0.002mg/l in the months of June, July and September and 0.004mg/l in October.
Although in the IAR sub-basin the mean monthly concentration level variations were almost similar to the `S' sub-basin, concentration levels were nearly always lower than in the former sub-basin. For example, Fe ranged between 0.3mg/l in October and 0.12mg/l in September; Ca concentration was between 114.9mg/l in June and 171.7mg/l in July. The concentration of Ca gradually decrease, from July to September but rose to a secondary peak in October. Mg concentrations ranged between 28.28mg/l in August and 76.2mg/l in October. Again, in the heavy metallic pollutant group, concentrations levels of Cu and Zn in the IAR sub-basin followed the similar variation pattern in the `S' sub-basin. Cu concentration rose from 0.25mg/l in June to 0.69mg/l in October. Similarly, Zn concentration levels decreased from a high of 0.82mg/l in August to 0.52mg/l in September but rose to a secondary peak of 0.65mg/l in October. Pb was between 0.002mg/l in June and 0.004mg/l in July, August and October.

In the "KH" sub-basin, which is mainly rural,, the Fe level of concentration was low. The range was between 0.02mg/l in July and 0.05mg/l in August. Ca concentration too was relatively low compared with that in the other two sub-basins except for the high mean monthly concentration in August (235.2mg/l) and September (154.3mg/l). Mg concentration ranged between 50.5mg/l in July and 119.98mg/l in August. Zn concentration increased sharply from a low of 0.23mg/l in June to 0.87mg/l in August and decreased sharply also to 0.26mg/l and 0.32mg/l in September and October respectively. Observed Pb concentrations in this basin ranged from a high of 0.005mg/l in June and decreased to 0.001mg/l at the end of the study period. The concentrations of these six metals exhibited the same characteristics as observed by Bello and Jeb, (1996).

5.2.2 Mean Total Metal Concentration

The mean total concentrations of the metals measured in the three sub-basins during the study period are presented in table 5.2

Table 5.2 **MEAN TOTAL METAL CONCENTRATIONS (IN Mg/l) IN THE THREE SUB-BASINS**

METAL	'S'	'IAR'	"KH"
Fe	0.07	0.07	0.04
Ca	263.34	148.30	151.46
Mg	85.78	47.90	88.68
Cu	1.18	0.59	0.25
Zn	0.32	0.57	0.41
Pb	0.002	0.003	0.003

(Field Survey, 1994)

Fe concentrations were 0.07mg/l each for the 'S" and "IAR" sub-basins and 0.04mg/l for the KH sub-basin. Ca concentrations from the urbanised sub-basin 'S' was the highest with 263.34mg/l and 148.30mg/l from the IAR sub-basin as the least concentration. Mg concentrations were lowest in the IAR sub-basin (48.1mg/l) and highest in the KH sub-basin (88.68mg/l). Cu concentrations were lowest in KH sub-basin (0.25mg/l) and highest in 'S' sub-basin. Zn concentration were lowest in the S basin (0.32mg/l) but highest in the IAR sub-basin (0.57mg/). Pb concentrations were generally very low. In the 'S' sub-basin, Pb was 0.002mg/l being the lowest and 0.003mg/l being the highest in the IAR and KH sub-basins.

5.3 RESULTS OF STATISTICAL ANALYSES

The data on Table 5.1 were used to compute the temporal variations in metal concentration within the three sub-basins while data on Table 5.2 were used to determine the total mean spatial variation in metal concentration between the three sub-basins. Also data in Appendix C were used to determine the for any relationships between river stage and metal concentrations in the three sub-basins. The results are thus presented below.

5.3.1 Temporal Variations In Metal Concentrations

Table 5.3 is the summary of the results of the One-way ANOVA performed for the temporal variations in metal concentrations between the month of study in three sub-basins.

Table 5.3 **RESULTS OF THE ONE WAY ANOVA FOR THE TEMPORAL VARIATIONS IN METAL CONCENTRATIONS**

Basin	Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F
SAMARU	Treatment (SSB)	5	281050.74	56210.5	109.82
	Blocks (SSW)	24	12284.11	511.84	
	Total	29	293335.85		
IAR	Treatment (SSB)	5	105688.71	17797.48	117.15
	Blocks (SSW)	24	12565.76	151.92	
	Total	29	11825.47		
KAMPAGI	Treatment (SSB)	5	105688.47	21137.74	40.37
	Blocks (SSW)	24	12565.76	523.57	
	Total	29	11825.47		

The Table shows that the calculated F - values for the within monthly (temporal) metal variations for individual metals between the months were 109.82, 117.15 and 40.37 for S, IAR and KH sub-basins respectively. The Table F - values at 0.05 (95%) confidence level and at 5 and 4 degrees of freedom for the three sub-basins was 2.62. Since the calculated F-values for the three sub-basins were less than the Table F-values at the 0.05 confidence level. They indicate that there were significant variations in metal concentrations between the months of study. These therefore, show that between the months of study, each individual metal exhibited significant variation in concentrations from one month to another.

5.3.2 Spatial Variations in Metal Concentrations

Table 5.4 presents the summary of the results of the one-way ANOVA performed for the mean total variation(i.e. spatial variation) in metal concentrations between the three sub-basins.

Table 5.4 **RESULT ONE-WAY ANOVA FOR SPATIAL VARIATION IN METAL CONCENTRATION**

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
SSB	5	87610.82	17522.17	
SSW	12	9822.52	818.54	21.41
TOTAL	17	97433.44		

The above table shows that the calculated F-value for the total mean (spatial) variation in metal concentrations between the three sub-basins is 21.41 while the given table F-value at F = 0.05(95%) confidence levels and at 5 and 12 degrees of freedom are 11 and 5.06 respectively. Since the calculated F- value of 21.41 is highly greater than the Table F-value of 11 at the 0.05 confidence level, and 5.06 at the 0.01 confidence level, we accept that there is a highly significant variation in metal concentrations between the three sub-basins. Thus, we conclude that the concentration of one metal between one basin and another vary very significantly.

5.3.3 Results of Regression Analysis

Data on appendix 3 were used for the computations for the regression techniques discussed in chapter four. River stage was considered as the independent variable (X) while metal concentration was considered as the dependent variable (Y). Applying the equations in section 4.5.2 for the least square regression analysis, the results of the least square regression analysis are summarised by the figures below (i.e. fig 5.1-5.6) and table 5.5 is the summary of the results of the regression analysis.

Table 5.5 SUMMARY OF RESULTS OFREGRESSION ANALYSES.

Basin	Variable Regressed	Regression Coeff. (r)	Coef. Of Determination (r^2)	Regression Equation (Y=a+bX)	Calculated t - Value	Degrees of Freedom	F = 0.05
S	Stage Vs Fe	-0.2211	0.0489	Y=0.768-0.0191X	-0.8780		
A	" " Ca	0.3647	0.1330	Y=221.92+59.62X	1.5166	17-2=15	
M	" " Mg	-0.3509	0.1231	Y=117.77-43.94X	-1.4513		1.753
A	" " Cu	0.2782	0.0773	Y=1.1094+0.1136X	1.1165		
R	" " Zn	0.0828	0.069	Y=0.2106+0.0799X	0.3218		
U	" " Pb	0.0873	0.1131	Y=0.0022+0.0002X	0.3393		
I	Stage Vs Fe	-0.2238	0.0500	Y=0.0963-0.0538X	-0.8893		
	" " Ca	0.1522	0.0232	Y=137.81+25.16X	0.5964		
A	" " Mg	0.3776	0.1426	Y=36.53+44.77X	1.5793		
	" " Cu	0.2300	0.0529	Y=0.4008+0.5187X	0.9153		1.753
	" " Zn	0.3150	0.0992	Y=0.4830+0.2763X	1.3696	17-2=15	
R	" " Pb	0.0543	0.0029	Y=0.0033+0.0026X	0.2106		
K	Stage Vs Fe	0.3910	0.1529	0.0204+0.0453X	1.6453		
A	" " Ca	0.1318	0.6174	Y=143.76+55.47X	0.5150		
M	" " Mg	-0.2889	0.0835	Y=110.79-58.45X	1.1687		
P	" " Cu	0.3059	0.0936	Y=0.0743+0.6353X	1.2444		
A	" " Zn	0.1258	0.0158	Y=0.3767+0.3767X	0.4911	17-2=15	1.753
G	" " Pb	0.2987	0.0892	Y=0.0023+0.0037X	1.2120		
I							

The results of the least square regression analyses showed that in the Samaru sub-basin, all the metals exhibited a positive linear relationship with river stage except magnesium and Fe which exhibited a negative linear relationship with river stage (Figures 5.1-5.6). However, the regression analysis result (Table 5.5) showed that the calculated t-values for the metals were within the range of the table-t-value of $\pm$ 1.753 at the 0.05(95%) confidence limit and 15 degrees of freedom. Hence, it was concluded that there were no significant relationship between rive stage and metal concentrations in the Samaru sub-basin.

In the IAR sub-basin, all the metals (except Fe) exhibited a positive linear relationship with river stage (fig). However, results of the regression analysis showed that the calculated t-values for the metal were within the range of the table t-value of $\pm$ 1.753 at the 0.05(95%) confidence limit at 15 degrees of freedom. Thus it was concluded that there were no significant relationships between river stage and metal concentrations in the IAR sub-basin.

In the KH sub-basin, results of the linear regression showed that magnesium exhibited a negative linear relationship with river stage while the other five metals exhibited a positive linear relationship in concentrations with river stage. However, result of the regression analysis showed that the calculated t-values of the metals were within the range of the table t-value of $\pm$ 1.753 at the 0.05(95%) confidence limit at 15 degrees of freedom. Thus, it was concluded that there were no significant relationship between river stage and metal concentrations in the KH sub-basin.

5.4 DISCUSSION OF RESULTS

In this section, the results described in Sections 5.2 and 5.3 are discussed. Specifically explanations are given for the occurrences and ranges of concentrations of the six metals in the three sub-basins. Variations in metal concentrations between sub-basins (temporal and spatial) and major sources of the metals in the study area are identified and explained along with their likely implications on the health of the people using the Kubanni reservoir water resources.

5.4.1 Occurrence and Ranges in Metal Concentrations

All the selected six metallic pollutants were found to occur in each of the sub-basins in the Upper Kubanni catchment in varying concentration levels. Ca exhibited the highest mean concentration levels in the three sub-basins followed by Mg. while the four heavy metals, Fe, Cu, Zn and Pb were very low (table 5.2). The high concentrations of Ca and Mg are attributed to their presence in the geologic bedrock as alkaline- earth metals, ionic behaviour and solubility and their higher mobility in comparison to the other four heavy metals (Forstner and Witman, 1979; Golterman et al, 1987). Fe, Cu, Zn and Pb are trace metal and do not occur as ore deposits in the basin (except Fe as ferricrete) thus their very low concentrations.

The ranges in the monthly concentrations of the metals in the three sub-basins were not very wide except for Ca. Table 5.2 however shows that the highest concentrations of Fe were in the S and IAR sub-basins. Ca and Cu were highest in the 'S' sub-basin; Mg in the KH sub-basin; Zn in the IAR sub-basin; and Pb in the IAR and KH sub-basins.

5.4.2 Temporal and Spatial Variations in Metal Concentration

The significant temporal variations in metal concentrations between the months of study and spatial variations between the three sub-basins showed that the concentrations of the six selected metals vary between one month and another and between one basin and another. The temporal variations in metal concentrations in the three sub-basins could be said to be due to variations in the nature of stream flow and rainfall run off. Thus the concentrations of the metals varied from one rainfall run off to another. The spatial variations in metal concentrations on the other hand, were due to differences in catchment characteristics between the three sub-basins, such as geology/geomorphology and land use.

5.4.3 Relationship Between Metal Concentration and River Stage

In sub-basins 'S' and KH, Mg exhibited a negative linear relationship with river stage while the other five metals exhibited a positive linear relationship in concentration with river stage. Similarly, Fe in the "S" and IAR sub-basins exhibited a negative linear relationship in concentration with river stage while the other five metal concentrations showed a positive linear relationship with river stage. These imply that Mg in sub-basins 'S' and KH and Fe in "S" and IAR sub-basins decrease in concentrations with increasing river stage while the other metals in these sub-basins increase in concentrations with increasing river stage. Also, the results of the correlation analyses showed that the relationship between the concentrations were not significant (section 5.3.2 and table 5.5). This confirms the non-significant linear relationships between the two variables shown in figures 5.1-5.6. Non-significant relationships between the metal concentrations and river stages implies that increasing or decreasing river stage does not lead to either marked increases or decreases in the concentrations of the metals. Studies carried out in North South West Australia showed that Mg dilutes with increase in discharge. (Loughran, 1976). Thus the study shows that contributions of some solutes of chemical origin is dependent to many interactive complex chemical processes taking place in the sub-basins which in turn are due mainly to differences in land use, geology and vegetation cover (Lam, 1979; Ayoade, 1988).

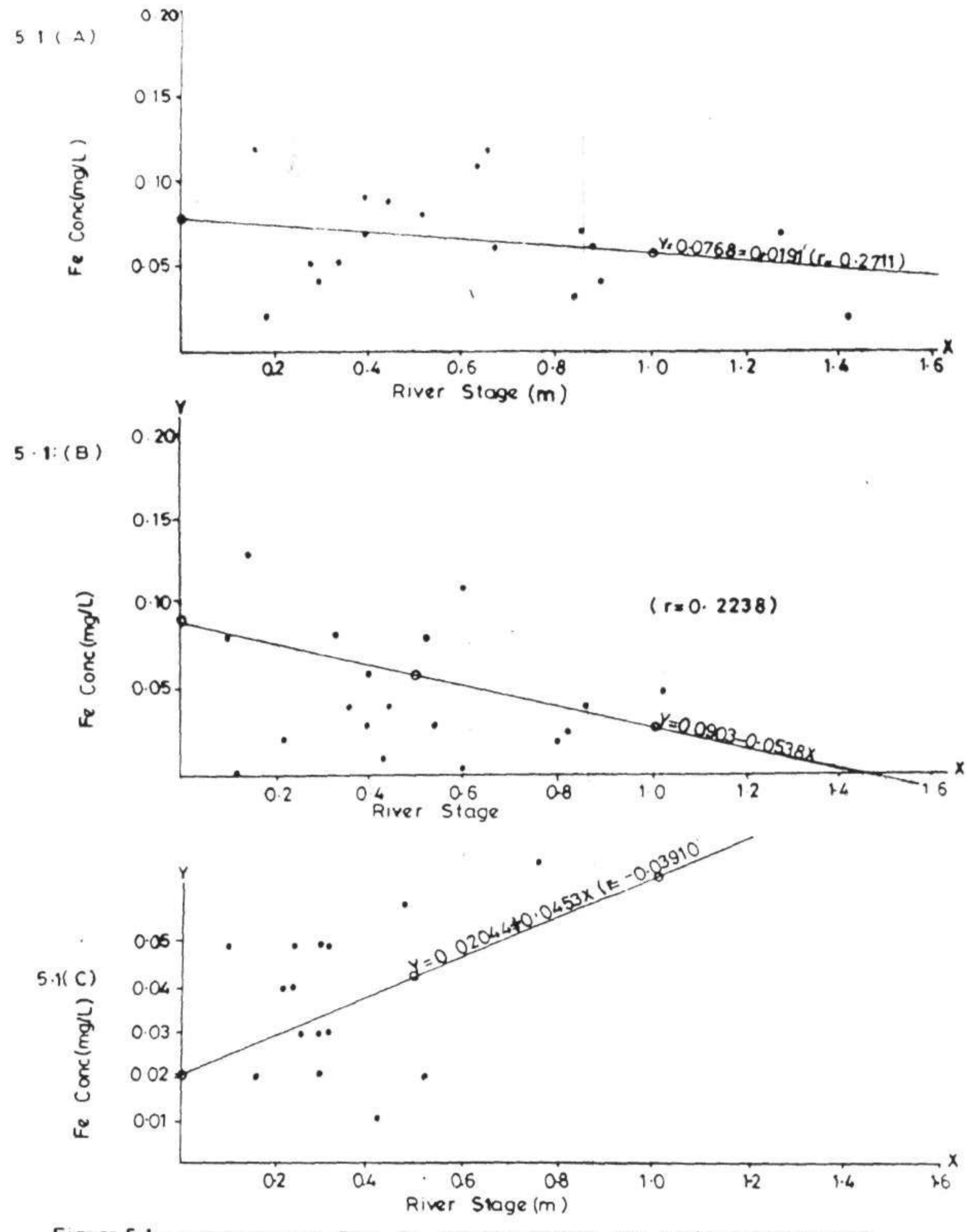

Figure 5.1. SCATTERGRAMS FOR Fe CONCENTRATION ON RIVER STAGE IN THE THREE SUB-BASINS

A= Samaru Sub basin B= IAR Sub-basin and C=Kampagi Hill Sub-basin

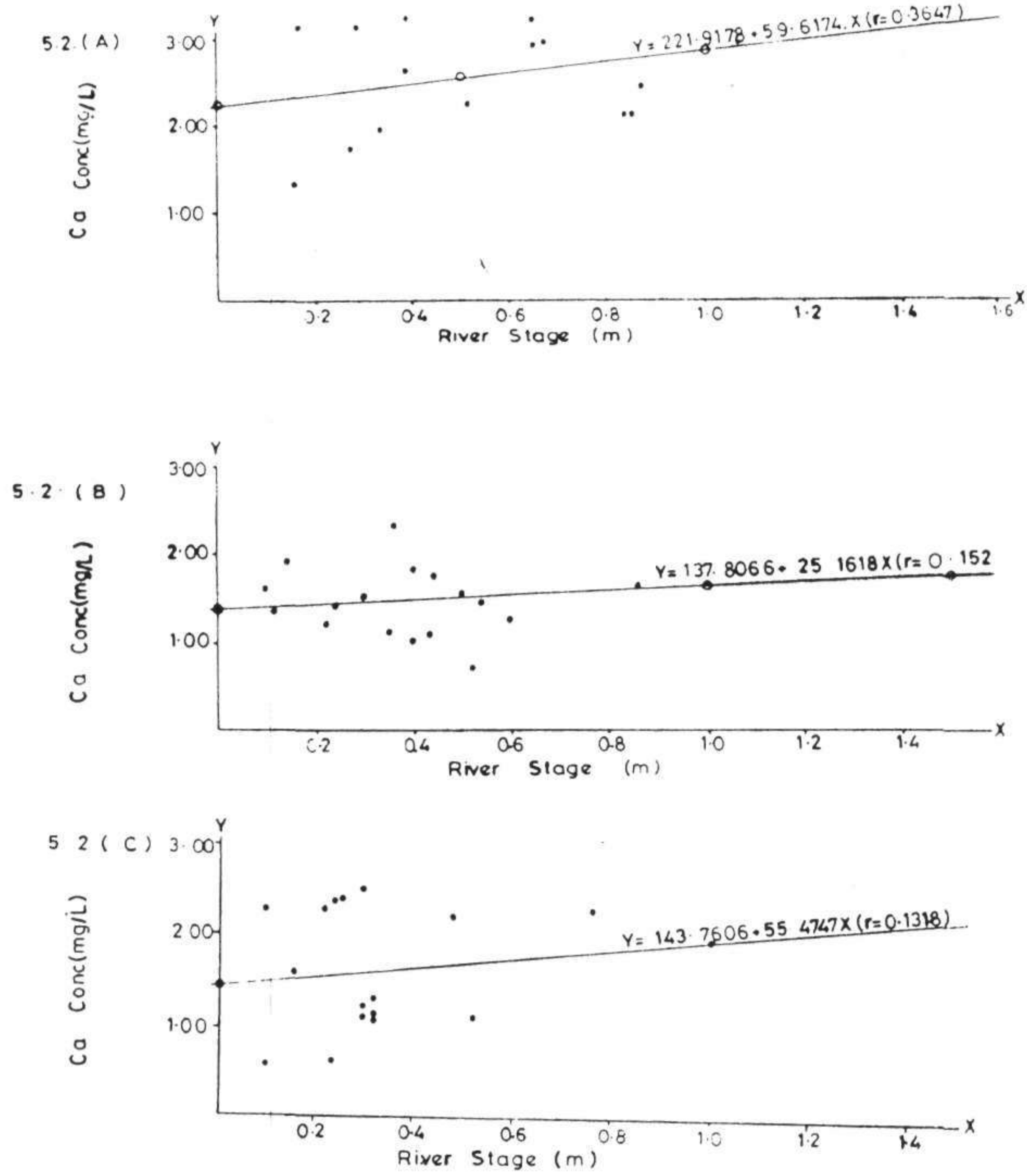

FIGURE 5.2: SCATTERGRMS FOR Ca CONCENTRATION ON RIVER STAGE IN THE THREE SUB BASINS.

A - Samaru Sub-basin B - IAR Sub-basin and C = K H Sub-basin

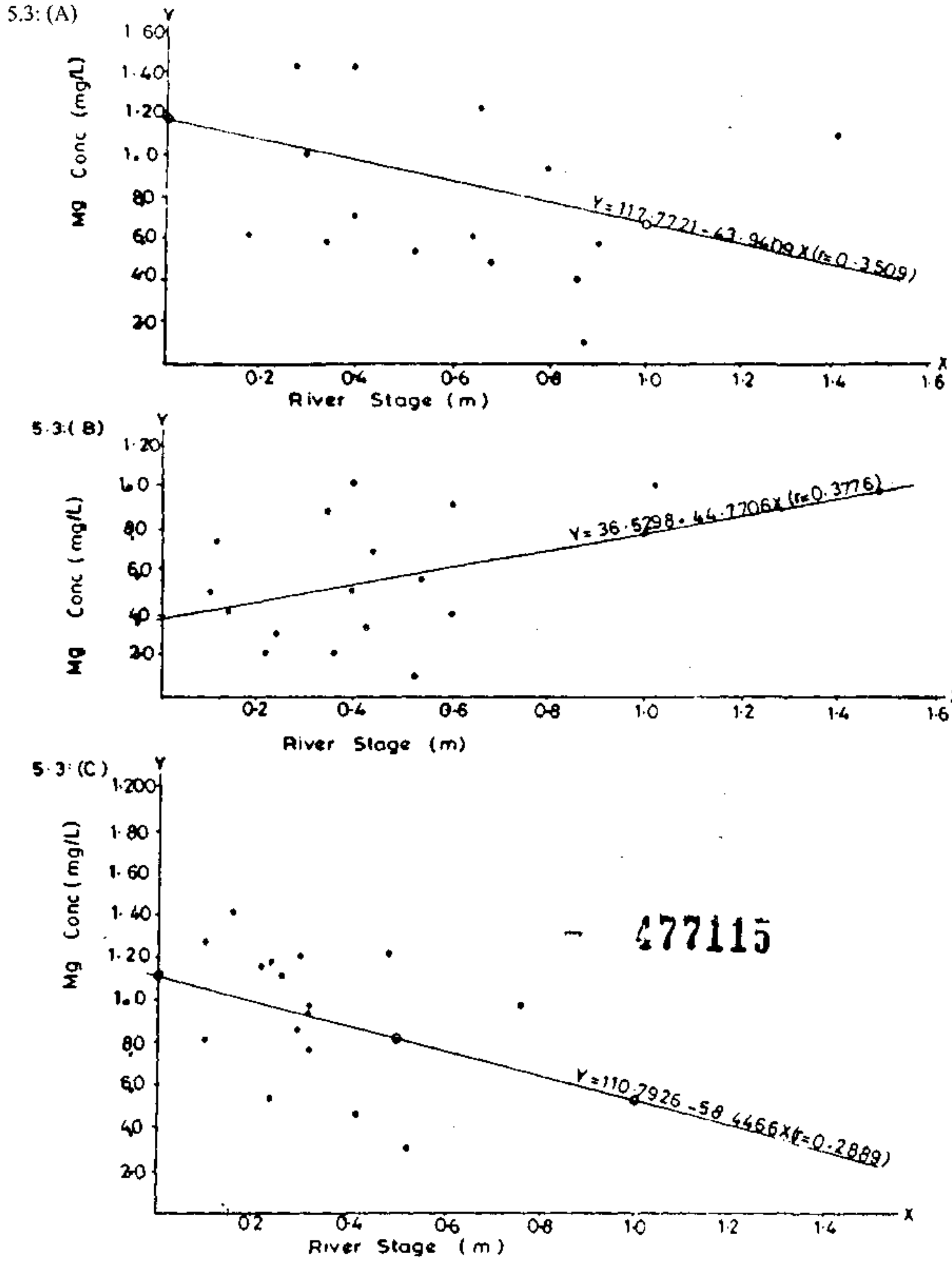

Figure 5.3: **SCATTERGRAMS FOR Mg CONCENTRATION ON RIVER STAGE IN THE THREE SUB-BASINS**

A- Samaru Sub-basin B - IAR Sub-basin and C= K H Sub basin

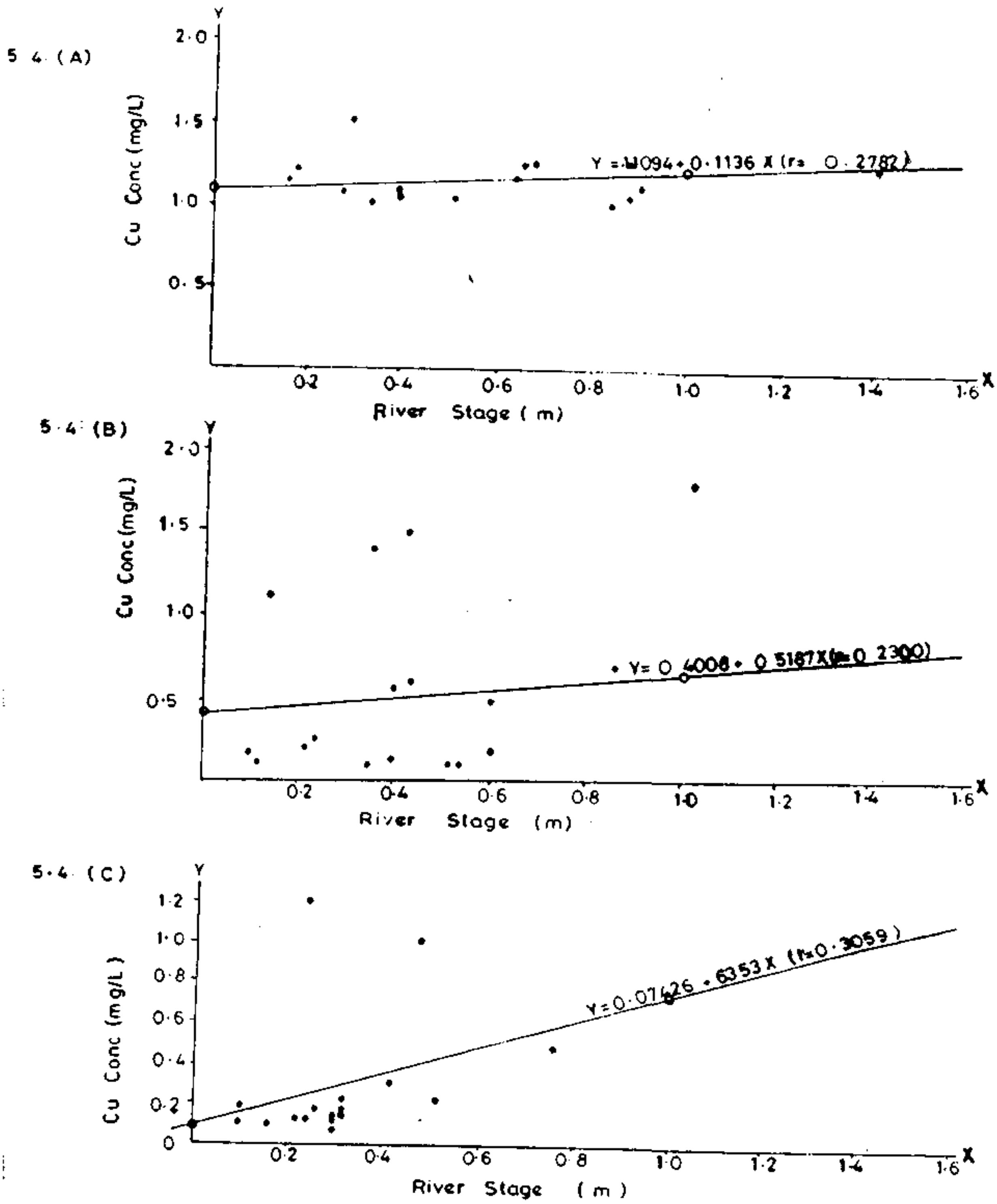

Figure 5.4: SCATTERGRAMS FOR Cu CONCENTRATION ON RIVER STAGE IN THE THREE SUB BASINS

A = Samaru Sub-basin B = IAR Sub basin and C = K.H Sub-basin

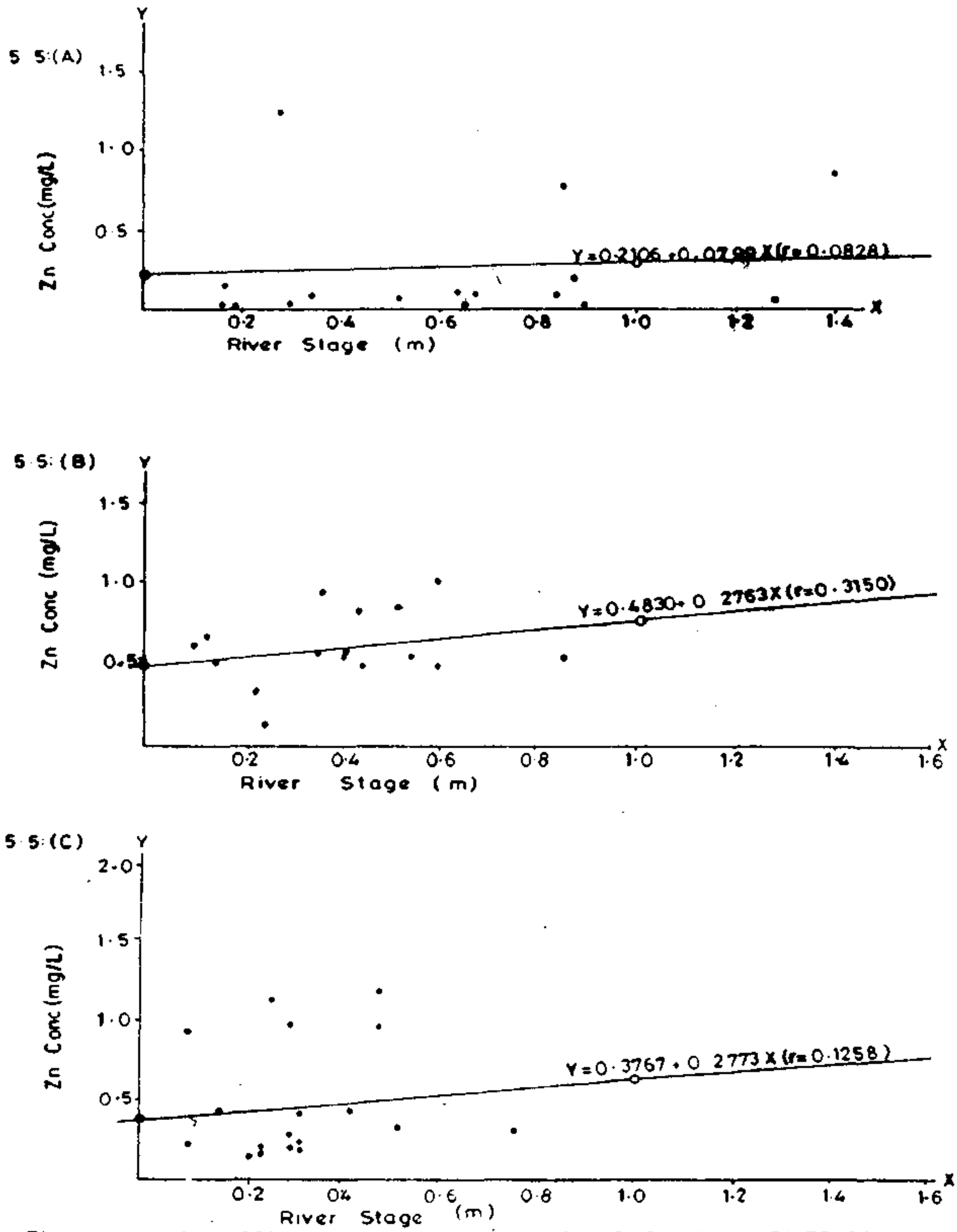

Figure 5.5 : **SCATTERGRAMS FOR Zn CONCENTRATIONS ON RIVER STAGE IN THE THREE SUB BASINS**

A - Samaru Sub-basin B - IAR Sub-basin and C = K. H. Sub-basin

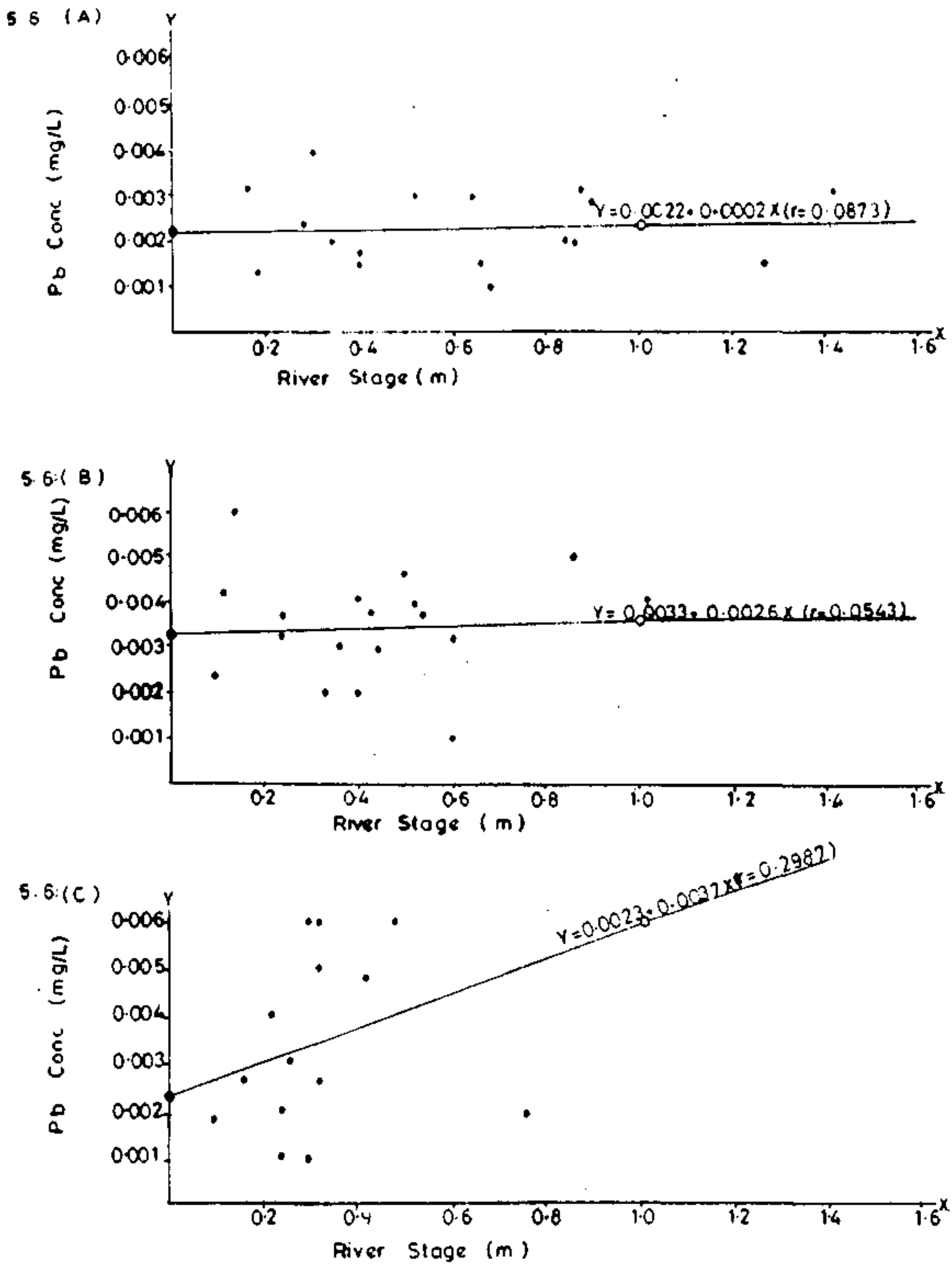

Figure 5.6 SCATTERGRAMS FOR Pb CONCENTRATION ON RIVER STAGE IN THE THREE SUB-BASINS

A= Samaru Sub-basin B= IAR Sub-basin and C= K H Sub-basin

In addition, those metals, which exhibited increasing concentrations with increasing stage, suggest that they are contributed from surface sources, which are probably the result of direct discharge into the sub-basin, by man. This is because increasing surface run off from urbanised catchment leads to increase in the river stage. Consequently, an increase in metal concentration with increase in river stage would be observed as a result of wash off of surface matter containing these metals from the basin. Claridge (1970) and Cleaves et al, (1970) have observed that several ions in a basin would peak during rising stages of a stream and then decline due to leaching from surface organic layer. Those metals (e.g. Fe and Mg) which exhibited decreasing concentrations with increasing stage signify that they are mainly contributed by the conditions in the geological/geomorphological/pedological processes. Therefore, decreases in chemical concentrations with increasing stages or rainfall discharges imply significant contributions of quick flow leading to significant dilutions.

5.5 LIKELY SOURCES OF SELECTED METALS IN THE UPPER KUBANNI BASIN

The occurrence of Fe in the surface water in the three sub-basins can be linked to its widespread occurrence as ferricretes both of primary and secondary sources (lateritic alluvial deposits). Besides human activities in the sub-basins especially "S" and "KH" which exhibited high concentrations, are probably responsible for the significant quantities observed in the study. Human activities such as widespread cultivation and increasing exposure of the land surface due to overgrazing or careless vegetation clearing, and consequently erosion and leaching of the metals from the component geology. From urban effluent discharges containing wash-off of paints (particularly those containing titanium dioxide), iron filings from the various metal workshops and construction sites in especially Samaru township could contribute to quantities of Fe.

The concentrations of Ca were the highest in the three sub-basins. Higher concentration of the metal as already explained in Section 5.4.1 is due to its abundance in the component geologic bedrock of the area (alkaline-earth metal), high solubility and mobility. Its occurrences in this environment could also be linked to its widespread use as a component of Calcium Ammonium Nitrate, CAN, (a brand of chemical fertiliser used in the basin). Especially high concentrations of the metal in the 'S' and IAR sub-basins are linked to effluent wastes of pharmaceutical substances, leather manufacture especially "beam house processes"(located in the sub-basin 'S'), glues and gelatine wastes which contain high concentrations of Ca. (OECD, 1982).

Mg like Ca is an alkaline-earth metal, which occurred, in high concentrations next to Ca. Its presence in the study area could be due to leaching and wash-off of clay minerals (especially the alumino-magnesian silicates found in the alluvial and hydromorphic soils along river courses). Higher concentrations especially in the Samaru town sub-basin could be due to wash off of effluent wastes of pharmaceuticals, plastics and synthetics originating from the township.

Cu concentrations in the three sub-basins could be from effluent discharges containing pesticides, fungicides and animal wastes (especially in the purely rural/agricultural KH sub-basin). Higher concentrations of the metals from the 'S' sub-basin was observed to be due to the effluent waste discharges from soldering (welding) and mechanical workshops, wash-off of organic paints and synthetic dyes into the surface water of the urbanised basin.

The concentrations of Zn particularly in the S and IAR sub-basins probably come from effluent discharges containing various cosmetic wastes from homes and hair saloons, soldering wastes from mechanical workshops, storm water discharges from road drainage, petroleum products and rubber (foams in particular). Besides, rusting zinc-roof tops especially from the Samaru township sub-basin is a major contributing source. Zn in the Kampagi sub-basin was probably due to animal wastes and fungal treatments given to some crops in the field. Indeed, some fungicides contain Zn as active components e.g. Zineb and Ziram, (Martin, 1968).

The occurrence of Pb especially in the Samaru sub-basin again is probably due to contributions through effluent discharges containing in organic paints and storm water (road drainage) which are sites of disposal of used battery cells from residents in Samaru and IAR sub-basins and especially battery chargers road-side shops in Samaru township. These battery wastes contain lead. Pb could also occur in the area due to deposition of lead oxides from exhaust of automobile vehicles, which have grown in hundreds in the last few years in the township.

Suprisingly, it was observed that Pb concentration in the KH sub-basin (free from the human impacts mentioned above) was higher than in Samaru basin. This might probably be due to the fact that at the onset of the rainstorms in April and May, water samples were not collected for analysis from which large amounts of the metal would have been washed off without being observed. Table 5.6 illustrates in summary the observed/probable sources of the metals in the Upper Kubanni basin.

Table 5.6 **LIKELY SOURCES OF THE METALS IN THE UPPER KUBANNI BASIN**

METAL	SOURCES
Iron (Fe)	Geology, paints containing titanium dioxide
Calcium (Ca)	Geology, fertilisers, leather manufacture (Beam house), pharmaceuticals
Magnesium (Mg)	Geology, pharmaceuticals, plastics and synthetics (cellulose acetate)
Copper (Cu)	Pesticides and fungicides, electronic (printer circuit), animal excreta, soldering, various inorganic paints, synthetic dying.
Zinc (Zn)	Cosmetics, inorganic paints, soldering, rubber(foam), storm water (road drainage).
Lead (Pb)	Various in organic paints, storm-water (road drainage) battery storage, car exhaust deposits.

(O.E.C.D. 1982)

5.6 EFFECTS OF STREAMWATER QUALITY ON THE ABU RESERVOIR WATER

Water reaching a reservoir is mainly contributed from various sources. The origins, in some cases are often not from the immediate vicinity of the reservoir. Therefore the chemical quality of water in that reservoir will invariably depend, to a large extent, on the chemical quality and condition of the source areas. Since the source areas of the water obtainable in the A.B.U reservoir are mainly from surface run off from its catchment in the Upper Kubanni, definitely, the water from the reservoir will reflect significantly contributions from the three sub-basin under study which are part of the Upper Kubanni catchment.

A comparison of the concentrations of the metals in stream water from the three sub-basins with that of the A.B.U reservoir water (Table 5.7) show that only Fe in the Kampagi sub-basin and Pb in the three sub basins were below the concentrations of Fe and Pb in the A.B.U reservoir. While Fe in the 'S' and IAR sub-basins and Ca, Mg, Cu and Zn in the three sub-basins were higher than in the A.B.U reservoir water. Ca, Mg and Cu were very much higher in concentrations in the stream water than in the reservoir water while Cu which was below detection in the reservoir water prior to 1987 now has concentrations of between 0.5mg/l and 1.18mg/l in KH and 'S' sub-basins respectively. It would be expected that the pollutant would now be found in the reservoir.

Table 5.7 **COMPARATIVE LEVELS OF METAL CONCENTRATIONS BETWEEN THE THREE SUB-BASINS AND A.B.U RESERVOIR IN Mg/L**

	S	IAR	KH	A.BU RESERVOIR*
Fe	0.07	0.07	0.04	0.06
Ca	263.34	148.30	151.46	2.7
Mg	85.78	48.10	88.68	2.7
Cu	1.18	0.59	0.25	B.D
Zn	0.32	0.57	0.40	0.1
Pb	0.002	0.003	0.004	0.3

*Source: Udoh, et al (1987) B.D- Below Detection

Although the concentration levels of the metals in A.B.U reservoir water were those presented by Udoh et al (1987), it reveals that the concentrations of the metals from the three sub-basins in very high concentrations (especially of Ca, Mg, Cu, and Zn) could mean their increasing concentrations in the reservoir water over the years. More so, if we consider that the distance from the upper reaches of the Upper Kubanni basin to the A.B.U reservoir is short (hence short travel time interval of rainfall run off to the reservoir), and that the reservoir serves as a mix and a store for the complex reactions that take place between water, sediments, aquatic biota in the reservoir and the water atmosphere air interphase, then large amounts of these metals contributed into the reservoir could build up due to bio-transformations and accumulation. In addition, these metals (especially Fe, Cu, Zn and Pb) are not removed by natural self-purification processes that organic pollutants undergo during transport and storage but rather, are transformed from one form to another and hence build up in the aquatic ecosystem (Golterman at al, 1987) and so become health hazard.

5.7 Impacts of Metal Concentrations on Water Quality and Health

The chemical quality of surface water limits the use to which the water can be put to. A comparison of the concentrations of the metals from the three sub-basins (Table 5.2) with the International Standards for drinking water set by the World Health Organisation WHO, (1972) is presented on table 5.8.

Table 5.8 **International Standards For Drinking Water**

Substance	Highest Desirable Level (mg/l)	Maximum Permissible Level (Mg/l
Ca	75	200
Cu	0.05	1.50
Fe	0.1	1.0
Mg	30.0	150
Zn	5.0	15.0
Pb	01	10

Source: World Health Organisation (1972).

From Tables 5.7 and 5.8, the concentration levels of Fe, Zn and Pb from the three sub-basins were below the WHO tolerable limits. However Ca, Mg and Cu concentrations were found to be above the WHO highest desirable levels. Only the concentrations levels of Ca in the 'S' and IAR sub-basins of 263.34mg/l and 151.46mg/l respectively exceed the WHO maximum permissible levels for potable water.

However, whether these metals exceed the WHO highest desirable level/maximum permissible levels or not, their presence in the levels of concentrations observed in this study should begin to cause concern (Smith, 1972; Odun, 1977).

For instance WHO (1972) observed that concentrations of Ca and Mg in such high concentrations can lead to excessive scale formation on plumbing, hardness and unpalatable tastes. The presence of Mg in association with sulphate can cause gastro-intestinal problems. Fe causes unpalatable tastes, discoloration and growth of iron bacteria Cu causes astringent tastes, discoloration of pipes, fittings and utensils. Concentrations above the WHO maximum permissible levels can lead to gastro-enteritis with nausea and intestinal irritation. Zn can also cause astringent taste, opalescence and sand-like deposits and is poisonous as organic zinc. The concentrations of Pb in water above recommended standards can lead to severe chronic toxicity because it accumulates in bones and tissues. Chronic adverse effects of Pb poisoning can lead to damage of the haematopoietic system, central and peripheral nervous system and the emphysema and proteinura of kidneys (Tebbutt, 1983; OECD, 1982).

Thus, presence of and at high concentration levels of these metals in the stream water in the Upper Kubanni basin can have marked effects on the water quality of the ABU reservoir water. This will consequently result to increasing treatment cost as the water works has to supply water of sufficiently good quality to meet the potable water needs of the growing community.

CHAPTER SIX

SUMMARY AND CONCLUSION

6.1 AN OVERVIEW OF THE STUDY

The analysis of metals in stream waters of the Upper Kubanni Drainage Basin, Samaru, Zaria was carried out to determine the concentrations of Fe, Ca, Mg, Cu, Zn and Pb from June to October, 1994. This was due to the growing concern on increasing metal pollution of the A.B.U reservoir water, the impacts of the metals on health and the aquatic environment, and also, the non-evaluation of chemical quality of stream water from different sub-basins emptying into the A.B.U. reservoir, which is used as a source of domestic water supply to the A.B.U. community.

Thus, the major aim of the study was to identify the presence and concentration levels of the six selected metals in stream water, from three different sub-basins, that empty into the A.B.U. reservoir; the spatial and temporal variations in metal concentrations; and, compare the concentrations of the metals with the International standards for Drinking Water.

Three small sub-basins' out lets-Samaru (Urban), I.A.R. (Rural/Urban), and Kampagi Hill (Rural) were used as point sources for water samples collection. The water samples were collected in clean plastic bottles (500ml) and were analysed in the laboratory using the Atomic Absorption Spectrophotometer to determine the concentrations of the metals. Results of the laboratory analysis were used to statistically determine the spatial and temporal variations in metal concentrations by use of the One-way ANOVA; and the linear relationships between river stage and metal concentrations by the correlation/least square regression analyses.

6.2 Summary of Findings

The results of the laboratory analyses showed that the six selected metals - Ca, Mg, Fe, Cu, Zn and Pb in stream water from the three (point-source) sub-basins in the Upper Kubanni Basin Samaru, Zaria occurred in varying concentrations despite the absence of heavy industries in the area. The study revealed that the concentrations of the metals vary throughout the period of study between the months of study and between sub-basins due to differences in catchment characteristics such as land use, geology/geomorphological conditions. Increasing metal concentrations with increasing river stage were attributed to metal contributions from wash off of surface matter into storm run off from the upper reaches of the Kubanni basin.

The concentrations of Ca, Mg, Cu and Zn were above the WHO highest desirable limits for drinking water and are higher than their levels in A.B.U reservoir water in 1987. Cu which was below detection level in 1987 now shows a mean concentration of 1.18mgl 0.59mg/l and 0.25mg/l in the 'S' IAR and KH sub-basins respectively and probably reaching the ABU dam. All these indicate that there is increasing metal pollution of the surface water resources in the Upper Kubanni basin which consequently might lead to significant increase in the concentrations of these metals in the ABU reservoir water. Also, the concentrations of Ca and Mg were observed to be higher than the other four heavy metals due to their relative abundance as alkaline earth metals in the bedrock. The occurrence of these metals in varying concentrations therefore will influence the chemical quality of water reaching the A.B.U reservoir and if the water is not adequately treated, it will be passed on to its consumers with serious health hazards.

6.3 CRITIQUE OF THE STUDY

Although the results of the study showed that the selected metals occurred in the stream waters of the Upper Kubanni Basin and the concentrations of the metals significantly varied between months of study and between sub-basins, it is important to make a critical appraisal of the study generally, with a view to highlighting some of the limitations to the study. These critical appraisals of the study are as follows:

1. data collection did not commence at the beginning of the rainy season but from the months of June to October, 1994. The period of data collection did not also include the dry season months, and as such, the significant temporal variations in metal concentrations observed might not really have been so.

2. Only six metals were selected for analysis even though there are many other persistent toxic metals like cadmium (Cd), arsenic (As), cobalt (Co), chromium (Cr), and mercury (Hg), which are known to be non-biodegradable and have long-term effects on health.

3. Most of the water samples used for the metal analysis were collected during or after rainfall events, not with standing low flows of stream water, which have significant influence, especially on variations of metal concentrations.

4. Metal analysis was not carried out for the A.B.U. reservoir water, and so, comparisons could not be made between the concentrations of metals in stream waters of the sub-basins and the A.B.U. reservoir water.

5. River stage was measured instead of the basins' areas or stream discharge, which are known to influence stream water quality.

However, these critiques would serve as guides for future studies.

6.4 RECOMMENDATIONS

Many organisations and governments especially in developed countries where severe chemical pollution from several industrial processes have caused deaths, deformations and serious ecosystem degradation, have made several recommendations to safeguard aquatic ecosystems and public health. These range from planning, policy formulation and enforcement, to management of water resources watersheds.

It has been observed that encroachment of urbanisation into previously undeveloped rural supply watersheds generate large amounts of urban run off and industrial effluents which become a problem in treated water supplied to it. While water treatment processes that remove most of the pollutants introduced by run off are available, the construction and operation of the treatment facilities are expensive. It is more economical in many cases to maintain the quality of the water through source protection measures (Kuhner et al, 1977; Ring, 1977; and OECD, 1982).

The above however are general recommendations. But the peculiar nature of pollutant generation and nonchalant attitude of residents in the basin to sanitary environmental ethics and in view of the importance of water in our national development require that we make specific recommendations to tackle our peculiar problem. The following are specific recommendations for peculiar pollution abatement and control in the Upper Kubani basin.

1. Establishment of any future industry should be sited outside the catchments of the ABU reservoir (i.e. the Upper Kubanni basin)
2. Proper land use planning and control of land development should be adopted. In this case, there is need for the ABU authority to check/limit agricultural activities in IAR and KH sub-basins and along the valley bottom lands during the dry season. It is not unlikely that high amounts of solute and solid loads are being generated and contributed to the water in the dam. The use of organic biocides in the IAR sub-basin should also be checked..
3. The local government authority should provide waste management disposal systems that would take care of huge wastes and refuse dumps that litter Samaru township and parts of ABU.
4. Efforts should be made by government and individuals to improve the living standards of the people thereby improving the sanitary quality of the environment.
5. There is need for mass education on the impacts of indiscriminate waste discharge on water quality, health and the environment.
6. There is need for long-term planning in potable water supply and re-orientation of policies in priority areas to discourage increased use of low quality waters from "easy-to-get- at" rivers near urban/industrial areas to meet increasing demand. Plans and decisions should be made primarily in the light of health and social requirements and not only from the restricted engineering and economic viewpoints, or on a short-term basis as previously might have been the case.
7. There should be proper monitoring of effluents, receiving waters, potable water as an integral part of water management in the basin to enable verification of whether or not imposed standards, and regulations are met.
8. A regular schedule for sampling tributary streams should be established on the basis of the potential pollution effects of stream water from the upper reaches of the Kubanni basin on the ABU reservoir water Frequency of sampling should take into consideration the types of hazards, seasonal flows, low flows, storms and any

other factor which could change during the year and after the data has been collected.

The above recommendations are integral aspects of planning, policy formulation and enforcement, and management of water supply watersheds, which if carried out would help ensure better surface water quality in the Upper Kubanni basin.

6.5 SUGGESTIONS FOR FURTHER STUDY

In view of the findings of this study, the observations made coupled with increasing land use changes in the basin, few suggestions for further studies are made here.

i. An analysis of a wide range of potentially toxic metals with known long-term persistence in the aquatic environment and bio accumulation such as Cd, As, Cr, Co, Hg, haloforms, organo-chlorines and biocides of both stream waters of the basin and the A.B.U. reservoir water should be carried out.

ii. A regular measurement of the concentrations of metals in stream water of the basin.

iii. Determination of specific sources of origins of the metals in stream water and the variations in the concentrations of the metals between the different sources.

iv. Evaluation of the variations in discharge of the metals from different sub-basins' outlets to the A.B.U. reservoir.

6.6 CONCLUSION

This study has shown that there is an increase in metal pollution of the surface water resource from the Upper Kubanni basin into the ABU reservoir due to increasing human activities and changing land uses in the basin. Rapid population growth and urbanisation and increasing use of synthetic chemical products in homes, commercial establishments and agriculture are generating waste pollutant effluents of dangerous chemical origins into the surface water resources. Therefore, there is obvious occurrences and increases of heavy metals and toxic substances in the basin's stream water resources which were absent in the ABU reservoir prior to 1992.

The Samaru sub-basin presents a more severe source of hazard to the ABU reservoir because of the high concentrations of Ca, Mg, Cu and the total amounts of metals generated and measured during the study period. This is more so because the flow of the Samaru stream is perennial which contributes pollutants throughout the year unlike IAR and KH streams which are highly ephemeral. It is therefore important that the ABU authority and Sabon-Gari Local Government Area should begin to take appropriate measures to protect the animal life by improving the quality of the surface water resources in the area.

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APPENDIX A' **AVERAGE DAILY RAINFALL (mm) IN THE UPPER KUBANNI BASIN 1994**

DATE	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
1			1.20		24.30		0.40	
2			41.40				3.60	
3			5.90	1.40		3.00		26.50
4							2.50	66.80
5						1.80	1.30	
6		2.40				24.60	3.10	1.00
7				1.70		28.80		
8					19.40	6.90	5.60	
9					42.20	6.00	8.80	
10						1.40	2.50	0.60
11				9.90		44.00	1.50	
12						0.60	12.40	
13		2.50				8.40	35.10	4.60
14		11.50				8.60	21.90	
15				1.70	19.40		13.20	16.40
16			3.40	11.70		34.00		
17			12.00		1.60			
18		8.40		13.60	5.60			1.60
19				19.40	2.20		3.80	10.40
20							2.00	
21				2.40	31.40		27.20	
22		0.40			6.60			
23								
24		3.70						0.20
25			1.60	13.90	0.80			
26			0.90					
27		1.10	41.20	35.20	1.60		1.00	
28							12.80	
29					68.40			
30					2.20			
31								
MONTHLY TOTALS		30.00	107.60	110.90	225.70	168.10	158.70	128.11

APPENDIX B **SELECTED RAINFALL (mm) AND RIVER STAGE (m) DATA FOR THE THREE SUB-BASINS**

S/No.	DATE	RAINFALL (mm)	STAGE (mm)			No. OF SAMPLES		
			S	IAR	KH	S	IAR	KH
1	11-6-94	9.9	0.34	0.4	0.32	1	2	1
2	19-6-94	19.4	0.52	0.35	0.32	2	1	1
3	27-6-94	41.2	0.84	0.6	0.3	3	2	2
4	9-7-94	42.2	1.28	0.86	0.52	5	4	3
5	21-7-94	31.4	0.68	0.44	0.42	2	2	2
6	29-7-94	68.4	0.64	0.4	0.32	3	2	2
7	6-8-94	24.6	0.88	0.52	0.3	3	2	1
8	7-8-94	28.8	0.9	0.43	0.26	3	2	2
9	8-8-94	6.9	0.3	0.36	0.23	2	2	1
10	11-8-94	44	0.86	0.6	0.48	3	2	2
11	16-8-94	34	0.28	0.14	0.1	1	1	1
12	8-9-94	5.6	0.16	0.24	0.1	1	1	1
13	21-9-94	35.1	0.66	0.22	0.24	2	1	1
14	28-9-94	27.2	0.4	0.1	0.24	2	1	1
15	4-10-94	66.8	1.42	1.02	0.76	4	3	2
16	15-10-94	16.4	0.18	0.12	0.1	1	1	1
17	19-10-94	10.4	0.4	0.54	0.3	2	2	1

N.D- Not Detectable

APPENDIX C. METAL CONCENTRATIONS(Mg/L) AND DRIVER STAGE(M) FOR SELECTED RAINSTORMS

	SAMARU (S)							INSTITUTE OF AGRIC. RESEARCH (IAR)							KAMPAGI HILL (KH)						
	METAL CONCENTRATION (MgL)							METAL CONCENTRATION (Mg/L							METAL CONCENTRATION (Mg/L						
Date	Fe	Ca	Mg	Cu	Zn	Pb	Stage (m)	Fe	Ca	Mg	Cu	Zn	Pb	Stage (m)	Fe	Ca	Mg	Cu	Zn	Pb	Stage (m)
11 JUNE	0.05	196.00	58.80	1.02	0.09	0.002	0.34	0.03	104.10	102.40	0.14	0.52	0.002	0.40	0.03	100.60	98.60	0.14	0.18	0.00	0.32
19 JUNE	0.08	228.60	54.00	1.05	0.07	0.003	0.52	0.08	116.00	88.60	0.12	0.56	0.002	0.35	0.05	114.20	94.30	0.18	0.23	0.01	0.32
27 JUNE	0.03	211.00	92.40	1.01	0.08	0.002	0.84	0.11	124.50	90.20	0.48	0.48	0.001	0.60	0.03	123.20	87.10	0.12	0.26	0.01	0.30
9 JULY	0.07	303.00	60.80	1.25	0.06	0.002	1.28	0.04	162.20	71.20	0.71	0.54	0.005	0.86	0.02	111.10	30.00	0.22	0.32	0.00	0.52
21 JULY	0.06	294.60	48.20	1.27	0.09	0.001	0.68	0.04	174.30	68.90	0.60	0.48	0.003	0.44	0.10	120.40	45.20	0.30	0.43	0.00	0.42
29 JULY	0.11	321.30	62.60	1.18	0.10	0.003	0.64	0.06	178.60	50.70	0.56	0.56	0.004	0.40	0.02	133.10	76.30	0.23	0.41	0.01	0.32
6 AUG	0.06	242.60	10.10	1.05	0.19	0.003	0.88	0.08	70.70	10.10	0.12	0.84	0.004	0.52	0.05	251.50	121.20	0.14	0.97	0.01	0.30
7 AUG	0.04	292.20	59.60	1.12	0.02	0.003	0.90	0.10	11.70	30.30	1.50	0.82	0.004	0.43	0.03	242.40	112.10	0.18	1.12	0.00	0.26
8 AUG	0.04	313.10	101.00	1.52	0.03	0.004	0.30	0.04	232.80	20.20	1.40	0.94	0.003	0.36	0.04	231.80	116.30	0.12	0.14	0.00	0.22
11 AUG	0.07	212.40	40.40	1.26	0.77	0.002	0.86	N.D	151.00	40.40	0.19	1.00	0.003	0.60	0.06	220.20	123.20	1.10	1.18	0.01	0.48
16 AUG	0.05	171.70	142.40	1.09	1.24	0.002	0.28	0.13	191.90	40.40	1.10	0.50	0.006	0.14	0.05	230.10	127.10	0.19	0.93	0.00	0.10
8 SEP	0.12	131.30	192.90	1.15	0.30	0.003	0.16	0.25	141.50	30.30	0.25	0.13	0.004	0.24	0.02	161.60	141.40	0.11	0.42	0.00	0.16
0021 SEP	0.12	292.90	121.20	1.25	0.02	0.002	0.66	0.02	121.10	20.30	0.20	0.32	0.003	0.22	0.04	240.60	118.00	0.12	0.20	0.00	0.24
28 SEP	0.09	323.20	141.40	1.10	0.03	0.002	0.40	0.08	161.60	50.50	1.18	0.60	0.002	0.10	0.05	60.60	50.50	1.20	0.15	0.00	0.24
4 OCT	0.02	333.20	11.20	1.48	0.85	0.003	1.42	0.45	212.10	101.00	1.80	0.76	0.004	1.02	0.07	231.30	98.10	0.48	0.55	0.00	0.76
15 OCT	0.02	313.20	60.50	1.23	0.20	0.001	0.18	N.D	131.30	74.00	0.16	0.65	0.004	0.12	N.D	58.40	80.30	0.11	0.22	N.D	0.10
19 OCT	0.07	262.60	70.70	1.05	0.30	0.002	0.40	0.03	142.60	56.30	0.11	0.54	0.004	0.54	0.02	111.10	50.50	0.07	0.19	0.00	0.30

N.D- Not Detectable