DISSOLVED SEDIMENT DELIVERY BY THE SAMARU STREAM INTO THE AHMADU BELLO UNIVERSITY RESERVIOR, ZARIA, NIGERIA

BY

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AUGUST, 2015

DECLARATION

I, Shehu Jonah hereby declare that this thesis has been written by me with the effort of my supervisor and that it is the product of my research work. It has not been presented in any previous application for a higher degree. All materials, ideas, quotations and views from other sources are indicated and the sources of the information used in the review or in support of the arguments are duly acknowledged in the references.

…… .....

Jonah SHEHU Date

CERTIFICATION

This dissertation entitled "**DISSOLVED SEDIMENT DELIVERY BY THE SAMARU STREAM INTO THE AHMADU BELLO UNIVERSITY RESERVIOR, ZARIA, NIGERIA**", by Shehu Jonah meets the regulations governing the award of the degree of Master of Science of Ahmadu Bello University, Zaria and is approved for its contribution to the body of knowledge.

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DEDICATION

I am dedicating this project to my parents Mal. Shehu Tula Yiri and Mallama Halima Shehu Tula who supported me all through the course of this research.

ACKNOWLDEMENT

I will begin by thanking and expressing my profound gratitude to my Creator, Most Merciful, Most Beneficent and Most Compassionate for giving me the strength and energy to undertake and complete this research work successfully.

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ABSTRACT

This study assessed the dissolved sediment delivery by the Samaru stream into the Kubanni reservoir by monitoring the stream for seven months. The study assessed the dissolved sediment concentration, stream discharges using the USDH 48 sampler to collect sediment sample, an estimate of the dissolved sediment yield and the dissolved mineral component of the sediment by the use of an XRF analysis.The AV method was employed for the discharge measurement of the Stream which gave a mean value of 0.2528m^3/s and an annual total discharge value of 4,850,232m^3/yr. The lowest discharge of 0.057m^3/s was recorded in April and the highest discharge of 4.133m^3/s was recorded in August. Regressing rainfall on discharges shows that there is a strong direct relationship between the two at 0.05 significant levels. The relationship is strong because both r (0.913) and r^2 (0.834) values are significantly high. Dissolved sediment concentration (Cd_1) values obtained vary from a minimum value of 20mg/l to a maximum value of 120mg/l with a mean value of 58.87mg/l and total sum of 4180mg/l.The rating equation relationship shows that there is a weakbut direct relationship between Cd_1 and Q at 0.05 significant level because both values of r (0.122) and r^2 (0.015) are low. Derived dissolved sediment discharge (Qd) obtained vary from a minimum value of 1.14mg/s to a maximum value of 325.44mg/s with a, mean value of 44.52mg/s and a total value of 3162mg/s. Relating Qd with Cd_1 shows that there is direct relationship between the two with the values of r (0.545) and r^2 (0.296) and also, Qd and Q were related and the rating curve gives a very strong relationship with a straight line starting from the origin and both values of r (0.866) and r^2 (0.749) are high. A totalvalue of 174,000 kg/yr was produced as the dissolved sediment yield of the stream with a Channel Sediment Yield (CSY) of 174 tons/yr.

The XRF analysis identified a total of 17 mineral compounds and elements with varying degree of concentrations ranging from as low as 0.001mg/l for Re_2O_7andV_2O_5 to 8.88mg/l for CaO in the compounds and as low as 0.0 for Re to 9.50mg/l for Ca in the elements. 11 of the compounds and elements identified are of heavy metals with nickel (Ni) as the most toxic with a mean concentration value of 0.08mg/l while the WHO (2011) and NSDQW recommended standards for drinking and domestic use are 0.02mg/l and 0.07mg/l respectively and the limits to discharges into a stream is below 1mg/l which is therefore, relatively above the recommended standard for drinking and domestic use but below the standard for discharges into the stream. Other elements identified to be above the recommended standard are Iron (Fe) with a mean value of 1.25mg/l and the permissible limits for drinking and domestic use as 0.3mg/l. Also, aluminum (Al) has concentration value of 0.38mg/l while its permissible limit for drinking purpose is 0.2mg/l. Comparing the result of the XRF analysis with WHO (2011) and NSDQW(2007) recommended standards, it was observed that most of the heavy metals identified arebelow the permissible limits for drinking purpose, domestic use and discharges into a stream which implies that the Samaru stream is not very polluted and finally, an F-ratio test (ANOVA) between the compounds of heavy metals and the compounds of non-heavy metalswas conducted and the result gives a significance value of 0.036 to imply that there is a significant difference between the two at 0.05 level of significance. This indicates that there is a difference in the effects of the factors that contributes in dissolve sediments yield to the composition and distribution of the compounds in the sediments of Samaru stream.

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ACRONYMS AND ABBREVIATIONS USED IN TEXT

AAS- Atomic Absorption Spectrometer

Al_2O_3-Aluminium Oxides

AV- Area Velocity

BAL- British Anti-Lewitise

BaO- Barium Oxide

BOD- Biological Oxygen Demand

$CaNa_2$-Calcium Disodium

Cd_1- Dissolved Sediment Concentration

Cd- Cadmium

CaO- Calcium Oxide

CEC- Cation Exchange Capacity

CIA- Central Intelligence Agency

Cl-Chlorine

COD- Chemical Oxygen Demand

CSY- Channel Sediment Yield

CTS- Tropical Continental Air-Mass

DAC- Division of Agricultural Colleges

DICON- Defense Industries Cooperation of Nigeria

DMSA- Dimercaptopropanesifunate

Ds- Dissolved Sediment discharge

EDTA- Ethylenediaminetetraacetate

Eh- Activity of Electrons

EU- European Union

Eu_2O_3– Europtium Oxides

FAO- Food and Agriculture Organization

Fe_2O_3– Iron II Oxides

FEPA- Federal Environmental Protection Agency

GIS- Geographic Information System

INAA- Instrumental Nitrogen Activation Analysis

ITD- Inter-Tropical Discontinuity

K_2O-Potassium Oxide

MDG`s-Millienium Development Goals

MgO- Magnesium Oxide

MnO- Manganese Oxide

MTS- Maritime Southeasterly Air-Mass

Na_2O- Sodium Oxide

NESREA- National Environmental Standard Regulatory and Enforcement Agency

NiO- Nickel Oxide

NPC- National Population Commission

NSDQW- Nigerian Standard for Drinking Water Quality

Pb- Lead

P_2O_5-Phosphorous Oxide

PVC- Polyvinyl Chloride

Q- Discharge

QD- Dissolved Sediment Discharge

Re_2O_7- Rhenium Oxides

RMM- Relative Molecular Mass

SiO_2-Silicon Oxides

SO_3- Sulphur Oxides

SON- Standard Organization of Nigeria

TiO_3- Titanium Oxides

UN- United Nations

UNICEF- United Nations International Children Emergency Fund

V_2O_5-Vanadium Oxides

WHO- World Health Organization

XRD- X-Ray Diffraction

XRF- X-Ray Fluorescence

Y_2O_3- Yitterium Oxides

Yb_2O_3- Yitterbium

ZnO- Zinc Oxide

CHAPTER ONE: INTRODUCTION

1.1 BACKGROUND OF THE STUDY

The importance of water, sanitation and hygiene for health and development has been reflected globally in series of International Policy forum. One of such conferences was the World Water conference held in mar del Plata, Argentina in 1977 and the International Conference on Primary Health Care, held in Alama-Ata, Kazakhstan in 1978, which launched the water supply and sanitation campaigns of the 1981-1990, as well as the Millennium Development Goals adopted by the General Assembly of the United Nations (UN) in 2000 and also, the outcome of the Johannesburg World Summit for Sustainable Development in 2002. In addition, the UN General Assembly developed the period from 2005 to 2015 as the International decade for Action,'' Water for Life''. Most recently, the UN General Assembly declared safety and clean drinking water and sanitation a human right essential to the full enjoyment of life and all other human rights (WHO, 2011) however, despite the numerous calls by the International community on the importance of water to life. Water still remains a scarce commodity in the developing world.

Water is a natural substance which covers 71% of the earth's surface (Central Intelligence Agency Report [CIA], 2013) and it is vital for all known forms of life on earth. 96.5% of the planet's water is found in seas and oceans, 1.7% in groundwater, 1.7% in glaciers and the ice caps of Antarctica and Greenland, a small fraction in other large water bodies, and 0.001% in the air as vapor, clouds (formed of solid and liquid water particles suspended in air) and precipitation. Only 2.5% of the earth's water is freshwater, and 98.8% of that water is in ice and groundwater. Less than 0.3% of all freshwater is in rivers, lakes, and the atmosphere, and an

even smaller amount of the earth's freshwater (0.003%) is contained within biological bodies and manufactured products (Gleick,1993).

It was estimated in Nigeria that more than half of the population have no access to clean water, and many women and children walk hours a day to fetch water. Although, the water sector budgetery allocation by the federal governments between 1999 to 2007 is over 357.86 Billion naira to provide safe drinking water, yet there appears to be no solution in sight (Environment and Health, 2010). Millions of Nigerians depend on dirty and contaminated water for domestic use. Hundreds, die every year from water borne diseases (Garba and Egbe, 2007). According to the joint monitoring programme of the WHO and UNICEF, 53% of household in Nigeria are without adequate clean water (Anonymous, 2008).

Sediment is a naturally occurring material that has been broken down by the processes of weathering and erosion, and is subsequently transported by the action of wind, water, or ice, and /or by the force of gravity acting on the particle itself. Sediments are most often transported by water (fluvial processes), wind (aeolian) and glaciers. The total amount of sediments that are generated within the catchment area of a river and moved to a drainage basin to be deposited into flood plains, storage reservoirs, or carried to the seas is referred to as sediment yield, which is a function of many variables including nature of the geology and soil, relief characteristics, vegetation cover, drainage characteristic, climate, time, and land use pattern within the drainage basin (Prothero, Donald, Schwab and Fred, 1996). The greater part of sediment yield obtained for the Malmo stream is made up of suspended sediment load (Yusuf, 2009).

There are three kinds of sediments which include bed load; this is the portion of sediment load that is transported along the bed by sliding, rolling or hopping. Bed-load moves at velocities

slower than the flow and spends most of its time on or near the stream bed in traction (rolling and sliding) and saltation (hopping) and then suspended load; this is the particulate sediment that is carried in the body of the flow. Suspended load moves at the same velocity as the flow. A small particle (e.g. clay and fine silt), with a large relative surface area, is held in suspension more easily because of the electrostatic attraction between the unsatisfied charges on grain's surface and the water molecules. This force, tending to keep the particle in the flow, is large compared to the weight of the particle and lastly is dissolved load which comprises materials that are chemically carried in the water or solution by a river and capable of passing through a 0.45-μm filter membrane (Trimble, 2008).

There are a number of factors that govern the percentage bedload, dissolved and suspended load of a water body such factors are the climatic condition which comprises mainly of temperature and precipitation and amount of vegetation cover type of the catchment area play significant role in the amount of load present in a water body. Others are human activities such as mining, construction, agriculture etc and rock solubility which arechemical process involving hard water in carbonate terrain and also erodibility of material in the drainage basin. Relief and slope also affect the Potential Energy (PE) of flow (Steven and Daniel, 1997).

Natural and anthropogenic processes are the two main sources of sediment loads. Natural processes of sediment loads occur without any major human interference while the anthropogenic processes involve mainly the activities of humans upon the environment. The major anthropogenic sources of sediment to streams are agriculture (especially row-crop cultivation in floodplains and livestock grazing in riparian zones), forestry (with logging roads contributing far more sediment than other practices, including clear-cutting), mining, and urban development (construction and intensive use of unpaved, sandy roads, especially where such

roads intersected streams). Of these, agriculture is by far the most significant source of anthropogenically derived sediment. It has been estimated that agriculture contributes about 50% of all sediment pollution in the United States while the natural sources of sediments to streams are volcanic eruption (lava flow), earthquakes, landslides etc. Where such natural phenomenon occurs, they add substantial amount of sediment loads to water bodies lying within the proximity of the occurrence of such disasters. Natural sources of sediments like the ones mentioned are usually difficult to control unlike the anthropogenic sources (Steven and Daniel, 1997).

Deposition of sediment load into a water body can have a number of effects on the environment which includes, upsetting the dynamic balance in the biota and ecology of water body; disrupting the aquatic chemistry or natural buffer balance (cationic, anionic, acidic and alkalinity) of a water body; continuous deposition of sediments resulting to siltation into a water body leads to decrease of the depth or bank of a water; and lastly, the form and structure of a water channel (i.e. channel morphology) can change greatly as a result of sediment deposition. A study conducted on four streams at North Carolina near Fayetteville U.S.A on the effect of sediments on channel morphology and stream bottom characteristics between upstream and downstream sites proves this effect.

Another factor that can affect the environment as a result of sediment load is pollution. This is the contamination of a substance or a body that makes it unfit for desire or intended uses. Sediments carry a lot of debris containing harmful materials into water bodies which pollutes the water and makes it unfit for the intended use. Inputs of sediment into water channels may often be associated with dangerous agricultural chemicals from fertilizers such as nitrogen and phosphorus, and also herbicides and pesticides which are washed down into water bodies by sediments (Steven and Daniel, 1997).

All natural substances are linked to one or several of the over 4,660 known minerals identified and approved by International Mineralogical Association (IMA). A mineral is an element or chemical compounds that is normally crystalline and formed as a result of geological processes (Nickel, 1995). The diversity and abundance of mineral species is controlled by the earth`s chemistry. For example, silicate and oxygen constitute about 75% of the earth`s crust, which translate directly into the predominance of Silicate minerals with a base unit of $(SiO_4)^{4-}$ silicate tetrahedral (Dyar and Guntar, 2008). Since, these minerals are found free in nature, they are usually being absorbed through the food chain and/or water cycle by humans subsequently affecting them positively or negatively.

Heavy metals on the other hand are among the most dangerous natural substances that man has concentrated in its immediate environment. This is because they can neither be degraded nor metabolized, which means they persist in the environment for a very long period (Dupler, 2001). Metals enter into the environment or living organism either as inorganic salt or organic metallic derivatives. The metals are classified as "heavy metals" when their specific gravity is more than $5g/cm^3$. There are known 66 heavy metals. They get accumulated in time, in soil, water, and plants which could have negative influence on the physiological activities of their host. For example, in plants, they influence photosynthesis, gaseous exchange, nutrient absorption, and in determining the reduction in plant growth, dry matter accumulation and yield. In small concentration, the traces of heavy metals in plants, or animals are not toxic however in excess amount they are detrimental to health. Lead (Pb), Cadmium (Cd), Mercury (Hg), and Arsenic (As) are an exception, because they are toxic even in very low concentration (Ferner, 2001). Monitoring the endangerment of soil with heavy metals is of interest due to their influence on

groundwater and surface water and also on plants, animals and humans (Clemente, Dickson, and Lepp, 2008).

1.2 STATEMENT OF THE RESEARCH PROBLEM

Prior to 1973, Ahmadu Bello University (ABU) water demand had always been met, though inadequate and irregularly, by the Zaria water treatment plant, located some 25 km south-east of the institution. The desire to achieve equilibrium between water supply and demand led the ABU authority, in 1973, to start the construction of a small earth dam across River Kubanni in order to retain water that would meet the community's present and future needs. At the completion of the dam, in 1974, it had a storage capacity of 2.6×10^6 m^3 with depth of about 8.5m, a catchment area of 57km^2, and a lake surface area of 83.4 ha and supply capacity of 13.64 million litres per day to cater for about 50,000 people (Committee on Water Resources and Supply, 2004). There is a hollow spill way in the dam, constructed to release excess water out of the dam. The utilization of the dam is however being threatened by pollution and siltation (Yusuf, 2006).

Therefore, siltation occurs because most dams are sediment traps and the ABU reservoir is one of them. The dams are usually constructed in such a way that materials such as eroded earth, weathered rocks, sand from erosional processes and other debris from flooding activities are emptied into the dam as sediments and with little or no means of flowing out. These sediments are trapped in the body of the dam andaccumulate over time to reduce the depth of the dam and as well as the volume of water the dam can retain thereby affecting the quantity of water production of the reservoir.A study by Iguisi (1997) on the effect of sedimentation in the ABUreservoir, recorded a reservoir depth of 5.2m as against the initial 8.5m which indicate a loss of about 3.3m that is, about 30% loss in storage capacity which occurred in 23 years and an average annual loss of about 14.3cm. This problem have been shown to be as a result of

sediments transported and deposited into the reservoir from eroded materials of the catchment areas.

A report by the ABU Committee on the protection of the ABU reservoir stated in 2008 that, from the year 2023, a process of rationing water to its consumers will begin; first from the dry season, and later both seasons. Furthermore, the Committee declared that from the year 2039, there will be no more water in the reservoir during dry season, and finally by the year 2059, the reservoir will completely silt up. Which means it will disappear from the map completely.

In conformity with the present problem of sedimentation of the dam, Ologe (1973) remarked before the construction of the dam that there is high sediment generation within the Kubanni basin and therefore likely to silted up like the Daudawa dam in Katsina state, where dredging has been carried out in an attempt to restore the storage capacity of the dam. It also confirms the statement of Ogunrombi (1979) that high rates of sediment supply to the reservoir by sheet erosion and from gullies, which are widespread in the river catchment, should normally be expected.

Yusuf (2006) assessed the magnitude of suspended sediment produced by the northernmost (Malmo) tributary of the Kubanni River. A Channel Sediment Yield (CSY) value of 482 tons/yr was derived for the catchment area of the tributary. Again, Yusuf (2009) attempted a comparative analysis of the suspended and dissolved sediment yields of the same tributary using the suspended sediment yield acquired in his previous study in 2006. From the samples of the filtered river water (i.e. aliquot) from which the dissolved concentration (i.e. total dissolved solids) was derived and the discharge records which have been carefully kept, the dissolved sediment loads provide the basis for estimating the dissolved sediment yield. The results showed

that the dissolved sediment yield is higher than the suspended sediment yield of the tributary. Although there is no statistically significant difference between them, the result is not quite representative of the geology of the study area that is predominantly basement complex; where it is expected that the suspended sediment yield will be higher than the dissolved sediment yield. In a recent study by Yusuf (2012) to assess the sediment delivery into the Kubanni reservoir for the four tributaries (i.e, Malmo, Goruba, Tukurwa and Maigamo), a direct relationship between suspended/dissolved sediment load and discharge was also established with the suspended load being higher than the dissolved load in all cases.

Further studies carried out by Yusuf and Igbinigie (2010) then Yusuf and Iguisi (2012) on the tributaries of the Kubanni reservoir observed that, rainfall plays a significant role in the discharge of water into the streams, and subsequently, influencing the suspended and dissolved sediment loads discharges. These were attributed to human activities such as land cultivation, grazing etc which summed up to aggravate the rate of discharge of suspended/dissolved sediment into the Kubanni reservoir.

It is equally important to note that, while siltation of the Kubanni dam is posing a great risk to the continuous existence of the ABU reservoir as presented by Iguisi (1997), Yusuf (2006 and 2009), Yusuf and Igbinigie (2010), Yusuf and Iguisi (2012), as well as Yusuf (2012) respectively. Pollution which can mainly be examined by looking at the dissolved sediment may be posing an even greater risk to the survival of all forms of life in the dam and those who consume the water directly or indirectly because with the exception of physical pollutant where the polluting parameters are easily identified by the eyes, chemical, bacteriological and radioactive pollutants are not quite easily identified by the naked eyes, making them to be more hazardous and dangerous.

In a recent study of the update on water quality of the Samaru stream by Garba, Yusuf, Arabi, Musa, and Schoeneich (2014), domestic and agricultural wastes were identified as the two main types of pollutants affecting the water quality of the reservoir. The domestic wastes were attributed to badly constructed or leaked latrines from houses, mechanics workshops and battery charging shops from Samaru town which are washed down through Samaru stream during raining season into the Kubanni reservoir while the agricultural pollutants includes organic or inorganic wastes from pesticides and fertilizers applied in farms and washed down into the Kubanni Reservoir during raining season as well and they are mostly from the other tributaries of the dam which therefore affects the quality of the water.

Previous studies on the water quality of the reservoir have somewhat shown the dam to be in a polluted state, works by Udoh, Singh and Omenesa (1986),Yusuf (1992), Jeb (1996), Obamuwe (1998), Udoh (1999), Garba and Schoeneich (2004) have demonstrated this.

Although, a large number of the studies attributed the pollution sources to be from agricultural activities particularly in the area of fertilizer and pesticides application such studies includes Iguisi, Funtua and Obamawe (2001), Garba and Schoeneich(2003),Ewa, Ewa and Ikpokonte(2004),Uzairu, Harrison, Balareba and Nnaji (2008) and Butu and Iguisi (2012).

However, Yusuf and Shuaibu (2009) viewed it differently. In a study conducted by them, on the effect of waste discharges into Samaru Stream, it was observed that solid and liquid waste materials from refuse dumping, domestic waste, market garbages, soak-away pits and open gutters generated in Samaru town are washed down to the major drainage system along Zaria-Sokoto road during raining season into the stream, finding its way into the A.B.U reservoir, thus posing a great danger to aquatic life, irrigated farms, cattles using the water for grazing and some

neighboring villages who use the water for domestic purposes such as molding of bricks, washing clothes and some cases even for drinking purposes. The result obtained from the study infers that the Samaru Stream is, still well oxygenated and can be said to be safe. However, the safety of this stream is being threatened by the continuous deposition of waste into it from Samaru town. It is therefore of doubtful water quality and needs improvement especially as previous research on the stream have found the water to be in a polluted state and of low aesthetic quality.

This research therefore, sets out to investigate the dissolved sediment component of Samaru Stream, a minor tributary contributing into the Kubanni reservoir, A.B.U Zaria, in a view to inform the relevant stakeholders on the pollution state of the water to ensure the good quality of treated water for public consumption.

The research questions therefore include;

1. What is the concentration of the dissolved load of Samaru stream?
2. What is the discharge of the Samaru stream?
3. What is the total dissolved sediment generated by the Samaru stream?
4. What is the chemical composition of the dissolved sediment of Samaru stream?
5. What is the relationship of heavy metals in the dissolved sediment of Samaru stream with the recommended standards?

1.3 AIM AND OBJECTIVES

The aim of the study is assessing the dissolved sediment delivery by the Samaru Stream into the Ahmadu Bello University reservoir Zaria, Nigeria. This aim will be achieved through the following sets of objectives, to;

i. determine the dissolved sediment concentration of Samaru Stream.

ii. determine the discharge of the Samaru Stream.

iii. estimate the dissolved sediment yield of the Samaru Stream.

iv. analyze the mineral composition and heavy metals in the dissolved sediment loads of Samaru Stream.

v. compare result of analysis with NSDQW (2007) and WHO (2011) recommended standards

1.4 RESEARCH HYPOTHESES

Based on the aim and objectives of the study, the following hypotheses are to be tested:

I. There is no significant relationship between stream discharge and rainfall.

II. There is no significant relationship between dissolved sediment concentration load and stream discharge of the Samaru stream.

III. There is no significant relationship between dissolved sediment discharge and stream discharge.

IV. There is no significant relationship between dissolved sediment concentration load and dissolved sediment discharge.

V. There is no significant difference in the mineral composition between the compounds of heavy metals and compounds of non heavy metals in the dissolved sediment load of Samaru stream and the NESREA and WHO recommended standards.

1.5 SCOPE OF THE STUDY

Much emphasis in the recent past has been laid on the suspended load of Samaru stream. This research study however, is limited only to the dissolved sediment delivery of the Samaru stream, a minor tributary of the Kubanni River, with specific interest on its dissolved sediment

concentration, dissolved sediment yield, mineral composition and heavy metals content in order to examine the water quality. The study will cover a monitoring flow period of the Samaru stream, from May to November, 2014.

1.6 JUSTIFICATION OF THE STUDY

The justification of the research project is to assessthe pollution state of the Samaru stream through the dissolved sediment load, which previous studies have shown to be a high contributor of pollutants into the Kubanni reservior (Garba *et al*, 2014) which is the main source of treated water for the ABU community, as well as other communities surrounding the reservior, who still despite the banning and strict warning by the university authority to discontinue activities such as irigation farming, fishing and grazing, still, engage in such practises. Understanding the dissolved sediment load of the Samaru stream will therefore, go a long way in providing useful information to the management of the University in employing measures of hindering or minimizing the rate of sediment load pollution from the Samaru stream in reaching the reservior. Also, it will ensure adequacy of water treatment measures for the University consumption and safer water for other activities being engaged in the Kubanni Basin will be ensured.

1.7 ORGANIZATION OF THE STUDY

The study is divided into five chapters. Chapter one intoduces the study and presents the research problem, aim and objectives, hypotheses and the research justification while chapter two deals with the theoretical framework and review of relevent literatures. Chapter three gives the description of the study area andmethodology for data collection while the result and discussion is presented in chapter four. Chapter five presents the summary, conclusion and recommendation of the study.

CHAPTER TWO: LITERATURE REVIEW

2.1 THE CONCEPT OF SEDIMENT LOAD

The complexity and subjectivity of the concept of water pollution has been a topic of discussion and debate globally as a result of man`s continuous impact upon the bodies of water (Mrowka, 1974).These polluting materials are carried into the rivers or streams as sediment load. It is possible to divide sediment load into these three kinds of sediment.They are:

Suspended load; this is the particulate sediment that is carried in the body of the flow. It consist of organic and inorganic particulate matter in suspension on a moving water. Suspended load moves at the same velocity as the flow as a small particle (e.g. clay and fine silt), with a large relative surface area, is held in suspension more easily because of the electrostatic attraction between the unsatisfied charges on grain's surface and the water molecules. This force, tending to keep the particle in the flow is large compare to the weight of the particle. The quantity and quality of the load is defined in terms of; competence and capacity. Competence is the large size clast that a stream can carry. It is a function of velocity and slope, whereas capacity is the volume of sediment a stream can carry. It is function of velocity and discharge.

Bedload on the other hand consist of coarse materials such as gravels, boulders and stones that move along the bottom of the channel. They move by skipping, rolling and sliding or saltation. Bedload moves at velocities slower than the flow and spends most of its time on or near the stream bed. The mechanism of grain motion involves the following. Traction(rolling and sliding). The important factors in traction are: frictional drag and lift forces exerted by the flow and slope and Saltation(hopping). Which is the grain temporarily suspended by fluid vortices or

by ballistic impact and then released. Grain movement may be continuous or intermittent depending on the flowregime that is the strength of flow and lastly.

Dissolved load; this is the material that is chemically carried in the water or a solution by a river; capable of passing through a 0.45-μm membrane filter.It consist of the organic and inorganic particulate matter in solution by a mobile matrix such as water (Ward, 1975; Painter, 1976; Smith and Stopp, 1978; Trimble, 2008).

Due to turbulent mixing, there is no much distinction between suspended and bedload. The turbulent mixing of waters usually lead to the interchange of materials between the two mode of transport. Therefore, in regards to catchment denudation, the suspended and dissolved load are the important component. However, from geomorphological point of view, bedload is the principal component because it affects river channel adjustment (Knighton, 1998). However Ayoade, (1988) further states that dissolved load is the most important sediment in the assessment of water quality and pollution of which this research is focused.

Sediment containing embedded dissolved load are generally transported based on the strength of the flow that carries it and its own size, volume, density, and shape. Stronger flows will increase the lift and drag on the particle, causing it to rise, while larger or denser particles will be more likely to fall through the flow in fluvial processes such as: rivers, streams, and overland flow. Fluvial sediment transport can result in the formation of ripples and dunes, in fractal-shaped patterns of erosion, in complex patterns of natural river systems, and in the development of floodplains (McPherson, 1975).

Figure 2.1 presents a schematic diagram of the transport rate from where the different types of sediment load are carried in the flow of a waterbody.Dissolved load is captured as composed of disassociated ions moving along with the flow. It may, however, constitute a significant proportion (often several percent, but occasionally not greater than half) of the total amount of material being transported by the stream (McPherson, 1975).

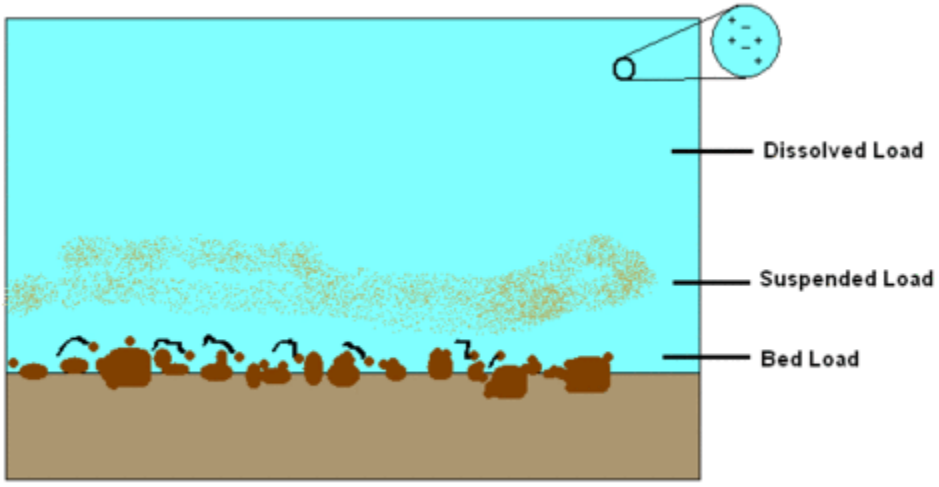


Figure. 2.1:Adopted from Fernandez-Luque and van Beek, 1976

Rivers and streams carry sediment in their flows. This sediment can be in a variety of locations within the flow, depending on the balance between the upwards velocity on the particle (drag and lift forces), and the settling velocity of the particle. These relationships are given in the Rouse number, which is a ratio of sediment fall velocity to upwards velocity (Reading, 1978).

If the upwards velocity approximately equals the settling velocity, sediment will be transported downstream entirely as suspended load. If the upwards velocity is much less than the settling velocity, but still high enough for the sediment to move, it will move along the bed as bed load by rolling, sliding, and saltating (jumping up into the flow, being transported a short

distance then settling again). If the upwards velocity is higher than the settling velocity, the sediment will be transported high in the flow as wash load (Siever, 1988).

Sedimentsare also classified based on their grain size and/or its composition. Sediment size is measured on a log base 2 scale, called the "Phi" scale, which classifies particles by size from "colloid" to "boulder" (Nichols, 1999)

On the other hand the composition of dissolved sediment can be measured in terms of the parent rock lithology, mineral composition and its chemical make-up which means the mineral content of the soil is determined by the parent material, thus a soil derived from a single rock type can often be deficient in one or more minerals while a soil weatherd from a mixed rock will have several minerals present in it (Hall, 1999; Gore, 2011)

Dissolved matter is invisible and is transported in the form of chemical ions into waterbodies. All streams carry some type of dissolved load from mineral alteration of parent rock, chemical erosion, or may even be the result of groundwater seepage into the stream. Minerals comprising the dissolved load have the smallest particle size of the three types of sediment (Strahler and Strahler, 2006).

Common ions from earth material that are dissolved and carried in solution are calcium, bicarbonate, patassium, sulfate, and chloride. These ions may react to form new minerals if proper chemical conditons are encountered during flow. Minerals may also precipitate in trapped pools through evaporation (Aristides and Panos, 2006).

Leached ions or minerals from weathered earth materials (rocks) and erosion processes constitute to form the dissolved load of water sediment. Dissolved sediments are therefore, formed when

rocks are exposed to the sun and rain for a long peroid of time, which makes them to change overtime from cracking, peeling, rusting, fading and ultimately they fall apart. When they fall apart, they become what geologist call regolith. If left alone, regolith becomes soil with their constituent minerals and ions, which when blown or washed away to waterbodies becomes dissolved sediment(Aristides and Panos, 2006).

2.2 FACTORS AFFECTING DISSOLVED SEDIMENT YIELD

Dissolved sediment production and transportation is dependent on the magnitude of various active and passive forces operating within the catchment area. Climate is a major determinant of dissolved sediment of whichever form both at the continental or sub-continental level (Fournier, 1960), other less determinant but equally important factors include; vegetation as controlled by climate (Douglas, 1967), human activities (Milliman and Syvitski, 1992), rock solubility (Khasawneh and Dolls, 1978), erodibility of materials (Yang, Lianyou, Ping and Tong, 2005) and relief and slope (Painter, 1976; Joshua, Perron and James, 2007).

2.2.1 Climate: Temperature and Precipitation.

Weather refers to short-term manifestations of atmospheric activities such as wind, precipitation, and storms. Weather is experienced as wet or dry, warm or cold, windy or calm. While climate is the overall pattern of weather conditions in a place, and includes both predictable seasonal changes in each year, and extreme weather conditions and events over a longer time frame. A region's climate and weather both derive from its latitude and elevation, its topography and landforms, and the movement of heat and moisture in the earth's atmosphere (Strahler, 1960; Monkhouse, 1978). Surface processes for example that sculpt landscapes and geological processes that cause tectonic uplift which in turns produces sediment from denudation of these high uplift are greatly mediated by climate (Roe*et al*,2008).

The two most important elements of climate are precipitation and temperature. Patterns of precipitation involve the timing, amount, and form. The range of temperatures characteristic of a region affect the growth of vegetation, the development of soils, changes in landforms, animal life, and the availability of water. These in turn affect the way humans interact with the environment for shelter, food, clothing, and water.

Precipitation as an element of climate therefore, plays a significant role in sediment generation. For example, in areas where there is a high and heavy precipitation events particularly, in temperate regions where humidity is another major factor of temperature influencing precipitation, erosion is more prone to occur than the tropical regions, where the amount and intensity of rainfall recorded annually is less as well as the humidity. The temperate regions therefore will facilitate and aggravate the activities of gully and stream or channel erosion more which will further promote and enhance the leaching of earth minerals from the soil into water bodies as dissolved sediment (Strahler, 1960; Monkhouse, 1978).

Studies conducted by Corbel (1964) on four temperature zones using rainfall and two relief classes found that erosion rates varies with temperature, with the tropics recording the lowest than the temperate while Fournier (1960) show the effect of climate on erosion to be declining steadily from the tropical regions through the equatorial regions to the temperate and cold regions. It was observed by Yusuf (2006) that the divergence of opinion must be due the lack of adequate data with which to resolve the complex variations of erosion control.

Furthermore, rainfalland temperatureare the most important aspects of climate, and both influence the aquatic environment. The amount and timing of rainfall are strongly linked to hydrological patterns within drainage basins, so seasonally varying precipitation produces

seasonal differences in river discharge and patterns of flooding and thus seasonal differences in the physical and chemical characteristics of the river (Tison, Pope and Boyelen, 1980).

River discharge has important effects on water quality, including the dilution of dissolved substances at high flows and the suspension of sediment particles eroded from the river banks or substrate by high flows. Rainfall as already stated is responsible for erosion processes. It causes erosion within the drainage basin, and elevated surface flows can carry eroded sediment to the river. Flooding on the other hand can result in the exchange of nutrients between flooded river banks and the river itself. Temperature influences the rate of chemical reactions as well as physical processes such as evaporation and the melting of ice and snow (Tison, Pope and Boyelen, 1980).

2.2.2 Vegetation

Vegetation type, amount or density influences greatly the volume of water runoff and sediment that is being generated and dischaged within a catchement area. These however, is dependent on the geology, soil and as well climate of the region (Schumm, 1977).Vegetation represents a healthy plant life and the amount of ground soil that the plants and animals within the vegetative area can provide. Vegetation has no particular taxa, life forms, structure, spatial extend, or any other specific botanical or good characteristics. It is broader than flora which refer exclusive to species and their composition. Plant community is perhaps seen to be the closet synonym than flora, but vegetation can, and often does, refer to a wider range of spatial scales than that term does, including scales as large as the global (Schumm, 1977).

Vegetation goes hand in hand with precipitation because with increasing precipitation, there will be increasing vegetation cover. It was further observed by Schumm (1977) that the annual

rainfall of 250-350mm in the United States, shows erosion to be at a maximum and below the 250-350mm concentration of sediment is higher due to the fact that areas of low rainfall may have high storm intensity as well as decreased total sediment generation. However, vegetal cover will increase with lower erosion and sediment generation at rainfall measurement above 250-350mm but, once vegetation cover is completed it was observed that increase in precipitation may give higher sediment generation as was seen in many upland peat areas in the United Kingdom (Breckle, 2002). The soil is highly protected from raindrops impact in a dense vegetated region than in less dense vegetated region thereby reducing water surface runoff rate, increases transpiration rate, improve soil structure and hold the soil in place.

Furthermore, the effective rainfall energy of raindrops is reduced by interception of leaves and tree branches that are not in contact directly with the soil surface but they affect the velocity of runoff in a prolonged rainfall period. Again, raindrops from tree leaves canopy may regain some appreciable amount of velocity on their way down to the soil surface although, less than the initial velocities of the free falling raindrops thereby increasing surface runoff velocity and transport. However, if the distance between the trees leaves canopy and the ground surface is close, raindrops cannot regain any appreciable amount of falling velocity thereby obstructing runoff by reducing its velocity and transport (Wischmeier and Smith, 1978).

The total rainfall energy expended at the soil surface increases or reduces depending on the height and density of the tree leaves canopy from which the raindrop falls. Erosion may be very effective under tree shaded surfaces of a vegetated region because the soil aggregates may be quite unstable.

The vegetated region therefore characterizes by abundant grasses and humus from decayed leaves allows more infiltration of surface water than a bare surface. This can be evidence in humid tropics characterize by dense and thick vegetation cover will have minimal infiltration rate than the drier tropical savannas with tufted grasses growing as separate clumps, wide expense of bare surfaces especially during dry season. Thus, sediment generation varies from 60-100tons/km^2/yr on lowlands and rises to 200tons/km^2/yr on highlands. Grasslands are therefore liable to severe rain splash and wash erosion particularly at the beginning of the raining period.Fournier (1960), shows in a study of the Sahel vegetation regions of West Africa that it is characterize with thorn scrubs, constitutes one of the most severe water erosion regions of the world, with a denudation rate of 1000 and 2000 tons/km^2/yr.

The above studies therefore highlighted the modification of vegetation types in the humid tropics, tropics and the Sahel regions upon sedimentation specifically the suspended load. This modification also influences the dissolved load since the temporal and spatial dynamic nature of the vegetation greatly modifies the vegetated region with regards to the dissolved sediment. One of such forces operating in the vegetation region which plays a significant role in bringing modification is called dynamics. Dynamism in vegetation is defined primarily as changes in species composition and/or vegetation structure (Davies *et al*, 2012).

These changes can be abrupt or gradual (ubiquitous). Abrupt changes are generally referred to as disturbances which include wildfires, high winds, landslides, floods, avalanches and the like. Such events can change the structure and composition of vegetation very quickly which in-turn will interact with the soil, topography, climate etc of a region from which the dissolved constituent of its sediment is also being modifed.

Finally, it is expected that regions such as the humid tropics or temperate regions with thick evergreen leaves cover, abundant decaying leaves as well as tall trees will have dissolved sediment rich in plant associated minerals than regions such as the sahel, characterized by shrubs and sparsely distributed tress. This is vice verse to the Sahel and other vegetation regions Fournier (1960). Therefore, the concentration of dissolved load is expected to be more in the humid tropics than in the sahel region.

2.2.3 Human Activities

The character and quality of a stream at all locations both upstream and downstream can be affected greatlyeither by man`s alteration or other natural processes. However, man`s alteration seems the most profound which when occurred results to changes in the natural vegetation. Naturally, there is a dynamic balance that exists between the particle size and amount of sediment transported by a stream, and the discharge and slope of the stream. However, a variety of human activities such as agriculture, construction, mining etc, can distabilise and disrupt this balance which leads to the generation of high rates of sediment input into water column (i.e., increased turbidity) and increased deposition of sediment on the stream bottom resulting to the decrease of stream depth. Sediment deposition also causes the upsetting of the balance between the biota and ecology of a water body, disruption of the acquatic chemistry of a water bodyand also pollutes the water. These human factors discussed can have adverse effect on the composition of sediment in a stream particularly the dissolved load(Steven and Daniel, 1997).

The major anthropogenic sources of sediment to streams are agriculture (especially row-crop cultivation in floodplains and livestock grazing in riparian zones), forestry (with logging roads contributing far more sediment than other practices, including clear-cutting), mining, and urban

development. Of these, agriculture is by far the most significant source of anthro-pogenically derived sediment. It has been estimated that agriculture contributes about 50% of all sediment pollution in the United States (Steven and Daniel, 1997).

Domestic and municipal wastes from human activities can affect the quality of water because they can be absorbed into water bodies as dissolved sediment. When household wastes generated from sewages, soak-aways and gutters are not adequately maintainedthey are release into the environment and are subsequently absorbed and carried into water bodies by water run off from precipitation. Continues deposition and absorbption of these waste into water bodies willin turn affects the quality of the water.Thomas (1956) presented a more comprehensive analysis of man`s impact to water quality.These human activities which are of direct impact to water quality influences and alter sediment in water. It can be grouped under the following four major headings:

2.2.3.1 *Man`s direct channel manipulation*

This is perhaps the most obvious, direct and visible physical human activity that influences a waterbody which involves dam and reservoir construction, channelization and river-bank treatment, irrigation diversion effects and modification of watershed characteristics.

The first recorded dam was constructed approximately 5000 years ago in Egypt (Biswas, 1970). Since that time, dams have been built throughout the world for various purposes which includes hydro electricity generation, irrigation, purification and cooling of nuclear reactors etc. Rutter and Engstrom (1964) recognized two distinct purposes of reservoir regulations: (1) storage of excess water, and (2) release of store water for beneficial uses.

In addition to regulating stream- flow, dams and the reservoir behind them exercise an important degree of control over the river quality both upstream and downstream .From the structure of primary importance is the functioning of a reservoir as a sediment trap. Although, a major disadvantage of this process is that, it causes siltation (decrease in depth) of the dam over time. Todd (1970) highlighted the effectiveness of reservoirs within the United State as sediment traps. Also, the release of relatively sediment- free water below a reservoir causes adjustments to take place within the channel system to achieve a new equilibrium, not only in river morphology and river metamorphosis, but also the aquatic ecosystem (Leopold, Wolman and Miller 1964;Wolman, 1967; de Vries and Klavers, 1994; Schumm, 1969; Komura and Simons, 1967).

Channelization simply means straightening and shortening of a natural water channel. The primary effect of this process is to increase gradient and reduce the time of transmission of discharge through the channelized reach, thus steeping the rising segment of the flood hydrograph. Normally, large quantities of water are stored in river banks and on flood plain as the river stage rises and overflows its banks. The water is later released as the stream/river stage falls. However, if the stream/river has been lined with concrete or if the higher stages have been confined to the channel by means of artificial levees or dikes, banks or flood plain storage is not possible and therefore the effect will be to increase the flood peak downstream(Spieker, 1970; Gilbert, 1971).

The impact of channelization on the dissolved sediement of a stream or river can be catastrophic to aquatic community. A major effect of channelization is the reduction of nutrient input from rich leached mineralsdue to destruction of overhanging bank vegetation from which the dissolved component of sediment derived most of its constituent which either makes a stream fertile or poor in nutrient composition.

Iirrigation has being in practice for many years. At least six millennia in the Tigris-Euphrates valleys, five millennia in the Nile valley of Egypt, two and a half millennia in the Hwang and Yangtze valleys and two millennia in the Indus Valley, present day India which spread throughout the world into the humid as well as arid regions, to an estimated of more than 500 million acres during the 1970`s (Beckinsale, 1969). The most prominent effect of irrigation on sedimentation particularly on the dissolved sediment is in the area of fertilizer and pesticide application. Chemicals as pesticide when applied returned to the channel from seepage or peculation and when the water becomes incapable of purifying itself either from aerobic or inaerobic reaction, the chemicals becomes pollutant which are being absorbed as dissolved sediment.

Destruction of native vegetation of watersheds is possibly the most geographically significant modification upon the stream or river that affects sediment generation as well as dissolved sediment composition in a water body. The alteration of catchment vegetation by means of fire may have the earliest, most constant, and universally applied impact upon streams and rivers (Stewart, 1956).During a forest fire, chemical changes that require years of microbial activity can occur within a matter of seconds (Debano *et al*, 1998) and during rainfall, products of these reactions are washed down into water bodies as dissolved sediment.

2.2.3.2 *Urbanization*

Urbanization is the physical growth of urban areas as a result of rural migration and even suburban concentration in cities. Studies conducted by scholars such as Thomas (1956), Savini and Kammer (1961) have shown urbanization to have a serious effect upon the various component of the hydrologic system. Urbanization affects sediment generation as well as the

quality ofstream waters in a number of ways which includes the roofing of watershed surface which reduces infiltration of precipitation thus increasing the peak run-off and shortening the lag time between precipitation and peak run-off. It also causes the reduction in groundwater recharge in response to the decreased infiltration of precipitation reduces the amount of base flow or low water flow in the stream channel,the initial construction accompanying urbanization produces increased sediment loads for the stream channels and lastly there would be channel erosion, enlargement and sedimentation owing to construction activities.

Again, modification of drainage network through the construction of storm drains, thus influencing lag time (shortening real time) between precipitation and peak discharge, channelization, concrete lining of channels, reduction of bed bank, and floodplain storage are human activities that affects sediment generation which will in turn alters the dissolved sediment composition of the water body (Mrowka, 1974).

Apart from agricultural and construction activities, mining is another human activity that contribute enormous amount of dissolved sediment into water bodies. Mining is an activity that involves digging down into the earth crust, in some cases up to several kilometres for the exploration of minerals that are used as raw materials in chemical and petrochemical industries or other manufacturing industries such as the jewelry, steel etc. In the course of mining, tons of earth material are removed from the bottom of the ground and heaped on the surface which is further washed down by precipitation to water bodies as sediment. Also, during mining processes the earth is depleted thereby causing other minerals either toxic or non to be release into the environment. The toxic minerals which are hazardous to human health will eventually find their way to water bodies through any of the sediment transportation means.

Domestic and municipal wastes are other forms of human activities that can affect the quality of water through its dissolved sediment. Sewage, soak-aways and gutters that are not adequately maintained can be drained by precipitation into water bodies which will ultimately upset the quality of the water.

2.2.4 Rock Solubility

This is mostly attained through chemical weathering however, in mechanical process of weathering, frost heaving rocks absorb water, get swelled up and contract in cool weather, breaking down to release lots of minerals in respond. Therefore, minerals that are abundantly found in a weathered rock will form most of the dissolved sediment that will be carried to the nearest water body. For instance, when a rock contains abundant calcium oxide (CaO) minerals, and it undergoes weathering, mineral in the weathered rock will in turn become soluble and go into solution, to be transported as dissolved sediment rich in calcium carbonate. This is the reason why, different streams and rivers have different types and amount of minerals(Khasawneh and Doll. 1978).

Solubility of minerals may be affected by temperature, activity of hydrogen ions (pH) and the activity of electrons (Eh) and the concentrations of other species in the solution except for carbonates, most minerals become more soluble at highertemperatures. The solubility of most minerals in pure water is very low compared to their solubility in weathering procesess (e.g. silicates, oxides, sulfides). Halides, sulfates, and carbonates are generally much more soluble in pure water than in rocks. The relative solubility of halides and sulfates can be inferred from their sequence of precipitation from evaporating seawater (Khasawneh and Doll. 1978).

An illustration of solubility in mineral quartz with a chemical formular SiO_2 is shown in fig 2.3 via a reaction with water. The graph gives the effect of temperature and pH on the dissolution of quartz.

(a) **(b)**

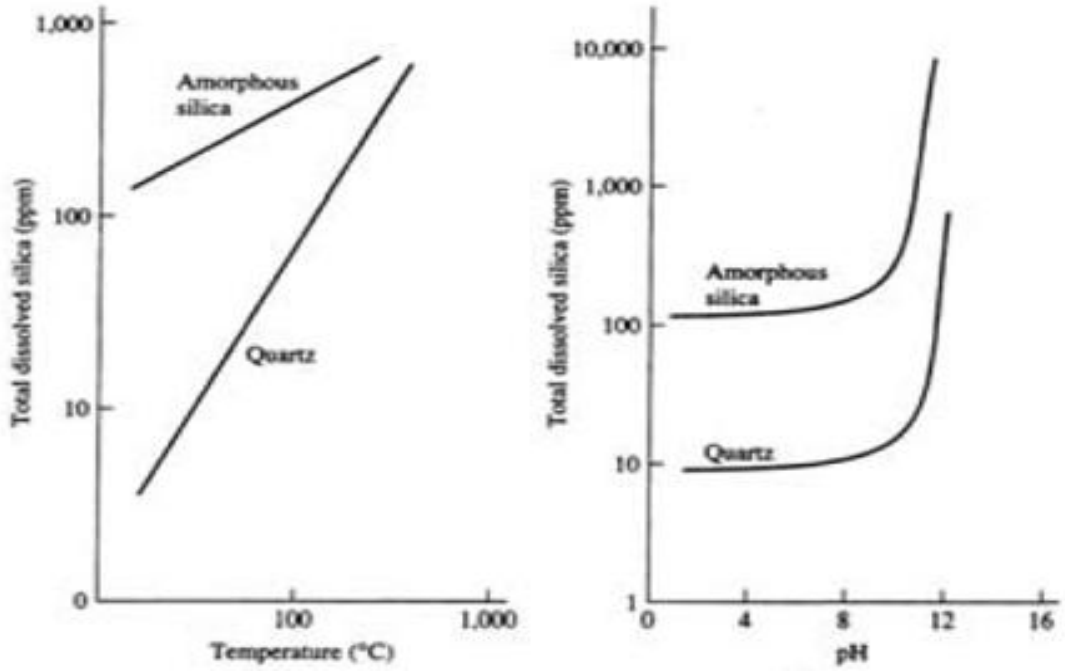


Figure.2.2:Solubility of silica as a function of temperature andpH:
(a) Solubility as a function of temperature less than 7. After Siever 1962.
(b) Solubility as a function of pH at 25^{o}C. After Garrels and Mackenzie (1971, 149).

The degree of completion of these reactions is also affected by pH. This pH further influences the form that Al will take: Al_3+, Al $(OH)^3$, $Al(OH)^{4-}$ Water flow through rock or sediment is also a factor as it can remove the soluble products. Water in general is highly important in silicate weathering.

Dissolution rates for silicates are limited by the kinetics of the various processes involved. The two possible limitations are the same as those for crystallization.

• Transport limitation; limited by the kinetics of diffusion through the leached layer (Diffusion in the adjacent aqueous solution is sufficiently rapid to be ignored here. For other materials this may be different)

• Reaction limitation; -limited by the kinetics of surface reactions (breaking of bonds and formation of new minerals - e.g. hydrolysis) Silicate weathering tends to be reaction-limited.

Note also that reaction rates (and the equilibrium conditions) are affected by both temperature and pH. Biological processes are also important for enhancing silicate weathering through the production of acids, for example; in the formation of clay.

In the formation of clays from weathering process an example of a product commonly obtained are the silicate rocks, particularly those containing feldspars.Of course, in its mineralogical definition clay minerals have sheet structures (broadly similar to micas), and are typically identified using X-Ray Diffraction (XRD) (Chen*et al,* 2013).

Minerals after undergoing dissolution which involves some basic chemical reactions are leached out from rocks or other earth surfaces to be transported mostly in dissolved form into streams and rivers. An experiment to illustrate surface leaching is presented below. It is a simplified representation of leached layer formation on an albite surface in an experimental dissolution process. An example of a mineral leaching is presented in Fig. 2.3 below.

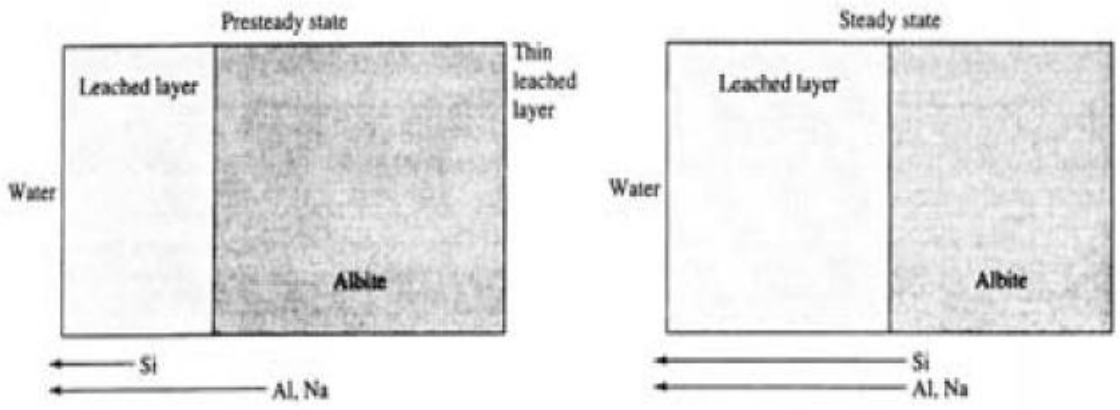


Figure. 2.3: Minerals Surface leaching: Adopted from (Hellman, 1997).

Initially, sodium and aluminum are preferentially leached with respect to silica because Na-O and Al-O bonds are broken more rapidly than Si-O bond. The thickness of the leached layer which is porous and open structure increases during this initial period. Eventually, a steady state is reached with detachment reactions occurring at equal stoichiometric rates for all three bond types. The dissolution rate is surface reaction controlled (reaction at the solid-liquid interface controlled the rate) rather than diffusion controlled (diffusion of reaction product through the leached layered, control the rate). Experimental result shows that the thickness of the leached layered are a function of pH. The data suggest that dissolution occur non-uniformly with greater leaching at the dislocations, microcracks and other defects at the albite crystal (Chen *et al*, 2013). Oxidation-reduction reaction is the common reaction type that occurs during dissolution and leaching of weathered minerals from the rock or any other earth surfaces. It involves the addition of oxygen atom to a compound or the subtraction of hydrogen atom to a compound (Hogan, 2010).

Biological processes play an important role, especially during photosynthesis. It produces both free oxygen (an oxidizing agent) and organic matter (a strong reducing agent during respiration and decomposition). C, O, N, S, Fe, and Mn are key elements involved in oxidation-reduction

reactions under near-surface conditions. All have more than reduction near one oxidation state, and all four are sufficiently abundant to be important. Cr, V, As, and Ce also undergo redox reactions, but these are generally present at trace abundances. Elements that react strongly with the above can also be affected by redox conditions. For example, Cu and Ni abundances in solution drop dramatically at low Eh since reduced S combines with Cu and Ni to form solid sulfides (Zambell, Adams, Gorring, and Schwartman, 2012).

Oxidation-reduction reactions are common at/near the Earth's surface as it is the interface between the atmosphere (which contains free oxygen) and the Earth's interior (where free oxygen is absent). Thus, there is a transition from more oxidizing to more reducing conditions with depth. As igneous and metamorphic rocks largely form under more reducing conditions, rock weathering often includes significant oxidation (Chen *et al*, 2013). Table 2.1 presents an example of the stability of some common minerals under weathering condition.

Table 2.1 Stability of common minerals under weathering			
Stability of Minerals	**Rate of Weathering**	**Stability of Minerals**	**Rate of Weathering**
Most Stable Iron oxide (heamatite) Aluminium hydroxide (gibbsite) Quartz Clay Minerals Muscovite Potassium feldspar (orthoclase) Biotite		Sodium rich Feldspar (albite) Amphiboles Pyroxene Calcium- rich Feldspar (anorthite) Olivine Calcite Halite **Least Stable**	

Sources: Historial Geology/Chemical Weathering. En.wikibooks.org

2.2.5 Erodibilty of Material

Erodibilty is the colapse, detachment or removal of earth materials as a result of anthropogenic (construction, mining, agriculture etc) and natural processes such as weathering. It is also, defined by its resistance to two energy sources: the impact of raindrops on the soil surface, and

the shearing action of runoff between clods in grooves or rills. Erosion which is considered and identified as the principal process that causes erodibility of soil occurs as a result of several factors including rainfall intensity, steepness of slope, length of slope, vegetative cover, and management practise. Besides all this, the inherent properties of a soil play a major role in the ability of water to detach and transport its soil particles. This intrinsic property of soil is the soil erodibility (O`Green, Elkins and Lewis, 2012).

An example of a study that gave the relationship between soil erodibility, transportation and deposition of sediment into a drainage basin was conducted by Filip Hjulstrom and called the Hjulstrom curve in canals (Gretener, 1935). The curve presented in figure 2.6 shows the critical erosion velocity in cm/s as a function of particle size in mm, while the lower curve shows the deposition velocity as a function of particle size. The graph further shows the three sectors, depending on water velocity and the diameter of soil particles. Analysis of the erosion sector shows that the diameter of the particles of the most fragile matter is about 100 microns, i.e. fine sand. With finer matter, cohesion develops simply as the surfaces of the clays rub together, while coarser clumps become increasingly heavy and therefore harder to transport. This kind of trial is concerned with resistance to the erosive force of river or runoff in a wet environment.

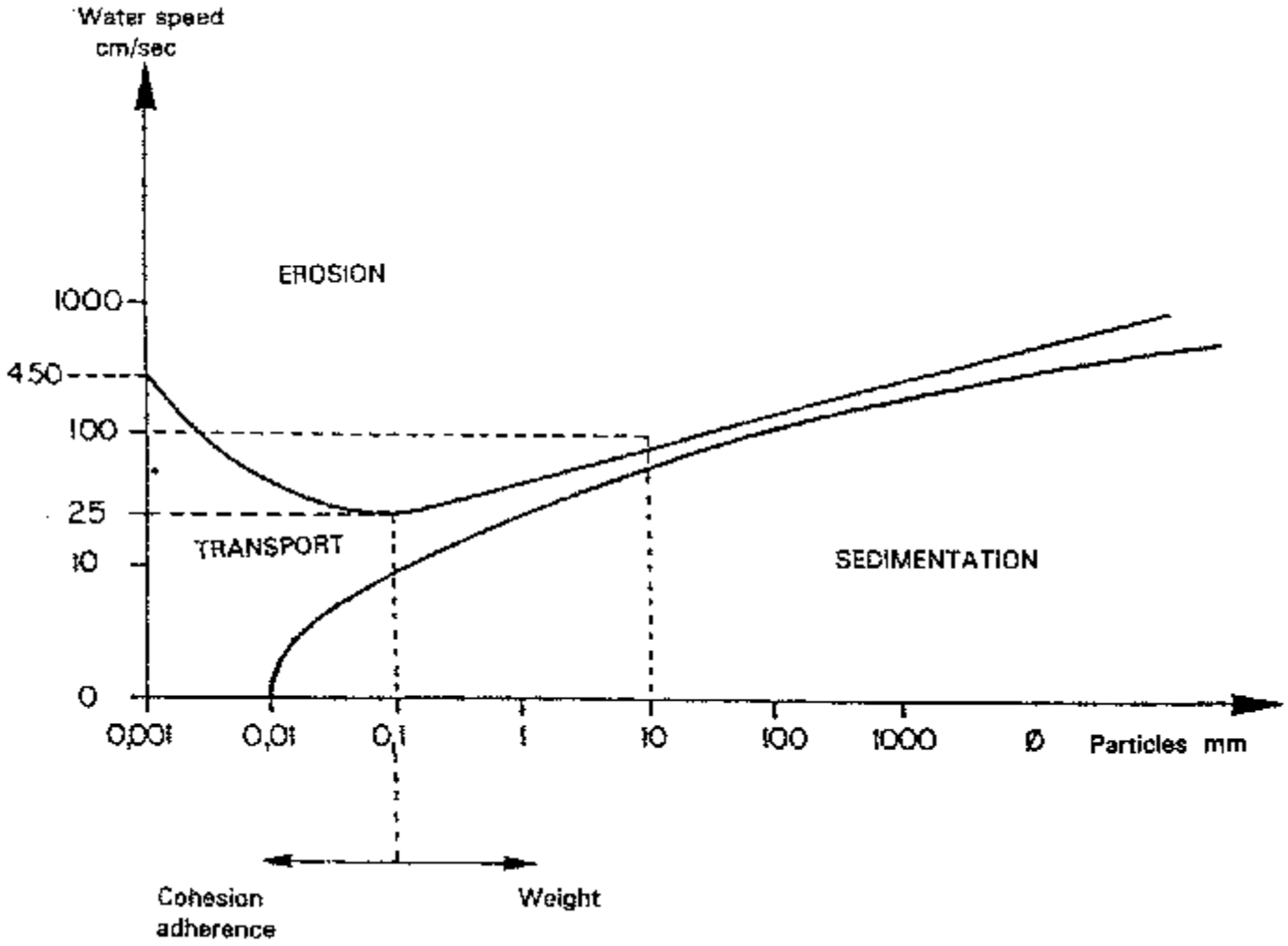


Figure. 2.4: Hjulström's diagram (Hjulstrom, 1935)

The information provided by the diagram indicates that the material most easily dislodged by runoff has a texture close to that of fine (100 macrons) sand. The coarser material has heavy particles which can only be moved at higher fluid speed. Also, as long as the flow is slow (25 cm/sec), it cannot erode. Measures will therefore have to be taken to spread and slow down the flow, in order to prevent linear erosion. This is the basis of the theory of dissipation of runoff energy. Again, fine clay and loam particles are easily transported, even at low speeds, but in the case of anything coarser than fine sand, it is a short distance from erosion site to sedimentation

site. This explains why ditches to channel runoff water either erode if they are too narrow or steep, or silt up with coarse material which cannot be moved. This is one of the reasons why diversion ditches are unpopular in developing countries, for such ditches and channel terraces have to be regularly cleared and maintained.

Soil erodiblity is an important index to evaluate the soil sensitivity to erosion and it helps in understanding the mechanisim of soil erosion. It is usually evaluated by measuring the soil physiochemical properties, scouring effect, simulated rainfall experiment and wind tunnel experiment (Yang, Lianyou, Ping and Tong, 2005).

Furthermore, soil scientists have long realized that soils react at varying speeds to raindrop attack and structural degradation. A whole series of laboratory and field tests has been set up to try to define structural stability with respect to water - for example, Ellison's capsules (1944) where sifted aggregates are exposed to raindrop energy, Hénin's structural stability test where aggregates are submerged and sifted under water, the waterdrop test where graded clods (30 gr) are exposed to drops of water falling from a specific height and Middleton's dispersion test (1930) which seeks to compare the content of particles naturally dispersed in water with and without dispersant (FAO, 2013).

Soil erosion is a three step process. It begins with particle detachment (erodibility), followed by particle transport and finally deposition of transported particles in a new location. The first two steps are influenced to a large extent by the nature and properties of the soil. Four major properties that governed erodibility are texture (particle size distribution), structure, organic matter content, and permeability (FAO, 2013).

2.2.5.1`Soil *Texture*

Soil texture is determined by the percentage weight of sand, silt, and clay particles in a soil sample. The size of a soil particle determines whether it is sand, silt, or clay. Sand particles have a diameter of 0.05 to 2mm; silt particles can range from 0.002 to 0.05mm. Clay particles are smaller than 0.002mm in diameter. Soil texture is an important property contributing to soil`s erodibility. Soil with high content of silt, very fine sand (0.05 to 0.10mm in diameter) or expanding clay materials tend to have high erodibily. Erodibility is low for clay-rich soils with low shrink-swell capacity because these clay particles mass together into larger aggregate that resist detachment and transport (FAO, 2013; Mepas, 2013).

Sandy soils with large amount of fine, medium, or coarse sand particles (0.01 to 2.0mm in diameter) also have low erodiblity. Again sandy particles lack the ability to aggregate together, but because most sandy soils are highly permeable, water runoff is low therefore, erosion is often slight. Medium textured soils (loamy soils) tend to be most erodible due to their high amount of silt and very find sand because these soils tend to have moderate to low permeability and low resistance to particle detachment(FAO, 2013; Mepas, 2013).

2.2.5.2`Soil *Structure*

Soil structure is the aggregation of individual soil particles into larger aggregates of identifiable shape. Well developed soil structure promotes a network of cracks and large pores that accommodate infiltrating water, resulting in reduced erosion due to decreased runoff. Good aggregation therefore holds particles together enabling the soil to resist the detachment forces of water and raindrop impact(FAO, 2013; Mepas, 2013).

2.2.5.3`*Soil Organic Matter*

Soil Organic Matter (SOM) is an aggregate agent that binds mineral particles together to develop structure in the soil. Un-decomposed organic residue present at the soil surface protects the soil against raindrop impact. Highly decomposed organic matter in the soil called humus act as a glue to bind soil particles together into aggregate. Soils that are higher in organic matter are more resistant to erosion and therefore, less deposition of sediments (dissolved) into water bodies(FAO, 2013; Mepas, 2013).

2.2.5.4`*Permeability*

Permeability is a measure of the rate at which water percolates through a soil. It is a function of texture, structure, and soil bulk density. Water rapidly enters highly permeable soils reducing runoff and therefore, soil erosion. The terms permeability and infiltration are not synonymous. Infiltration describes the entry of water into soils whereas, permeability describes the ease with which water or other materials move through soils (FAO, 2013; Mepas, 2013).

In erodibility of soil, the K-factor is an important component. It is a measure of the soils particles susceptibility to detachment and be transported as a result of raindrop impact, runoff and other erosional processes.

Permeability of the soil profile affects K because it affects runoff rates, detachment and infiltration rates. Mineralogy which associated with permeability has a significant effect on K as well for some soils, including subsoils. For example, soils dominated by kaolinite normally have greater permeability than those dominated by montmorillonite. Sodic soils seal quickly, causing decreasing permeability.

2.2.5.5`*Relief and Slope*

Relief is the difference in the height and lowest elevation of a region. It is measure in units of length (e.g meters). Relief controls the erosional rate of an area. It can be described for example, as saying the distance from the top of a mountain to the bottom of the valley is 500meters (wiki.answer). Slope on the other hand is the spatial variability of an elevation or, a measure in the change in elevation. It is measure in units of length per length (e.g cm/km). Slope controls the local stability of landscapes and therefore, sediment transport (England and Molnar, 1990; Montgomery, 1994; Bonnet and Crave, 2006).

Slope and relief influence surface runoffs which in turn combine to influence weathering, erosion and sediment transport processes. This was investigated in a study by Harden (2006) to examine the sediment generation rates and its response to control variables (runoff and relief ratio) in the principal Rivers of Colombia and the Pacific coasts in the Andres. This is an important river on a worldwide basis due to their contribution of sediment fluxes for the global budget (Milliman and Meade, 1983; Milliman and Syvitski 1992; Restrepo, Kjerfe and Hermelin, 2002).

The Andres is a tectonically active region characterized by active volcanism, ongoing uplift, earthquake and high magnitude mass movement (Harden, 2006). The Andrean rivers of the Colombia was found to exhibit the highest sediment yields of all medium-large rivers of South America due to the interplay of (1) high rates runoff (1,750-7,300mm yr-1) (2)Steep relief within the catchments (3)Low values of discharge variability (Qmax-Qmin) and, (4) Episodic sediment delivery due to either geologic events or climate anomalies.

Milliman and Syvitski (1992) observed that topography and basin area exert the major influence on sediment generation of most rivers, while climate, geology, and land use being the second. A robust correlation between sediment generation and maximum elevation was demonstrated for

mountainous rivers in North and South America, Asia and Oceania, and showed that mountainous rivers have greater loads (dissolved) and yield than do upland rivers, which in turn have higher loads (dissolved) and yield than lowland rivers.Another study to stimulate sediment load to coastal ocean by Moulder and Syvitski (1996) Syvitski and Milliman (2007) have shown that sediment fluxes is condition by geomorphic and tectonic influence, which includes area and relief.

Furthermore, hillslope erosion processes was found to be controlled in part by topographic variables such as mean model elevation, maximum elevation, relief ratio and slope angle of the riverbed. The relief ratio and slope angle of the river are possibly more relevant to fluvial transport of sediment (Hovius, 1998).Similar observation for catchment area of Colorado USA by Schumn(1977) and Summerfield and Hullton(1994) attribute relief to represent the potential energy available for erosion to influence deposition of sediment loads into basin and finally to water bodies. Again, Summerfield and Hulton (1994) noted the strong role of relief and runoff in influencing denudation rates for major basins worldwide. Also, their data showed that relief and climate account for a remarkably high amount of explained variance from the main Colorado Rivers. These studies have therefore, demonstrated that a high relief ratio and slope angle corresponds to a more pronounced topography and thus a higher erosion and sediment deposition analysis (Harden, 2006).

2.3 WATER QUALITY

Water quality is an important component in water treatment because it is used to asses the pollution state of a water.And as earlier stated that the dissolved sediment is the most important component in the assesement of water quality (Ayoade, 1988). It is therefore important to

highlight some concept on the quality of water because it can be perceived by the investigator and his particular value system which is subject to change with time (Mrowka, 1974). However, Wolman (1971) demonstrated water quality as embodying both the character of the fluid in transit and physical attributes of the channel. Therefore, water quality can be defined as the totality of all the physical and chemical characteristic of the fluid and the physical channel at any given cross section along the length of the water course.

Furthermore, results on debates and discussions on the various subjectivity and complex issues in relation to water quality have produced a more better and acceptable approaches to the studying and understanding of the quality of water. These can be seen from the standards guidelines for water quality which is being accepted to be used globally for measuring the quality of water for domestic use and industrial discharges into waterways because diseases related to contamination of drinking-water constitute a major burden on human health. Interventions to improve the quality of drinking-water provide significant benefits to health. Guideline values are derived for many chemical constituents of drinking-water. Guideline values normally represent the concentration of a constituent that does not result in any significant risk to health over a lifetime of consumption. A number of provisional guideline values have been established based on the practical level of treatment performance or analytical achievability (WHO, 2011).

The nature and form of drinking-water guideline may vary among countries and regions. Approaches that may work in one country or region will not necessarily transfer to other countries or regions. Therefore, each country usually reviews its needs and capacities in developing a regulatory framework. This approach entails systematic assessment of risks throughout a drinking-water supply—from the catchment and its source through to the consumer.

Example of bodies involved in providing guidelines in regulating and ensuring the quality of water are the World Health Organization (WHO), European Union (EU), US Environmenatal Protection Agency, and Federal Environmatal Protection Agency (FEPA) in Nigeria water guidelines etc. The guidelines provides a holistic framework for safe drinking-water which includes supporting information on microbial aspects, chemical aspects, radiological aspects acceptability aspects, and aspects which provides an overview of the interrelationships amongthe individual aspects of the guidelines in ensuring drinking-water safety (WHO, 2011).

2.3.1 Microbial Aspects

The primary emphasis of microbial aspect is on prevention or reduction of the entry of pathogens into water sources and reducing reliance on treatment processes for removal of pathogens. The greatest microbial risks are associated with ingestion of water that is contaminated with faeces from humans or animals (including birds).Faeces can be a source of pathogenic bacteria, viruses, protozoa and helminths. Faecally derived pathogens are the principal concerns in setting health-based targets for microbial safety. Microbial water quality often varies rapidly and over a wide range. Short-term peaks in pathogen concentration may increase disease risks considerably and may trigger outbreaks of waterborne disease which are particularly to be avoided because of their capacity to result in the simultaneous infection of a large number of persons and potentially a high proportion of the community (WHO, 2011).

Microbial water quality is therefore based on the analysis of faecal indicator microorganisms, with the organism of choice being *Escherichia coli* or, alternatively, thermotolerant coliforms etc. Microbial infection through unsafe drinking-water contaminated with soil or faeces could act as a carrier of other infectious parasites, such as *Balantidium coli* (balantidiasis) and certain helminths (species of *Fasciola*, *Fasciolopsis*, *Echinococcus*, *Spirometra*, *Ascaris*, *Trichuris*,

Toxocara, *Necator*, *Ancylostoma*, *Strongyloides* and *Taenia solium*. Some commonly encountered microbial tests in water quality are Chemical Oxygen Demand (COD), coliforms and Biological Oxygen Demand (BOD) (WHO, 2011).

2.3.2 Chemical Aspects

The health concerns associated with chemical constituents of drinking-water in which this study is based differ from those associated with microbial contamination and they arise primarily from the ability of chemical constituents to cause adverse health effects after prolonged periods of exposure.Changes in water quality occur progressively, except for those substances that are discharged or leached intermittently to flowing surface waters or groundwater supplies from, for example, contaminated landfill sites etc.

Chemical water quality therefore involves the assessment of the adequacy of the chemical quality of drinking-water with comparison of the results of water quality analysis with guideline values. Table 2.2 below gives example of chemicals that are of concern to water quality and their recommended valuess.The following are some techniques that are used to ascertain or investigate the toxic chemical quality of water. They are; X-Ray Flourseneece (XRF) analysis, Atomic Absorption Spectrometry (AAS) analysis etc.Example of some hazardeous chemicals that are found in water arefluoride, arsenic, lead, cadmium, mercury, nickel etc (WHO, 2011)

Table 2.2 Guideline values for naturally occurring chemicals that are of health significance In drinking-water.

	Guideline Value		
Chemical	**µg/l**	**mg/l**	**Remarks**
Inorganic			
Arsenic	10 (A, T)	0.01 (A,T)	
Barium	700	0.7	
Boron	2400	2.4	
Chromium	50 (P)	0.05 (P)	For total chromium
Fluoride	1500	1.5	Volume of water consumed and intake from other sources should be considered when setting
national standards			
Selenium	40 (P)	0.04 (P)	
Uranium Addressed	30 (P)	0.03 (P)	Only chemical aspects of uranium
Organic			
Microcystin-LR	1 (P)	0.001 (P)	For total microcystin-LR (free plus cell- bound)

A, provisional guideline value because calculated guideline value is below the achievable quantification level; P, provisional guideline value because of uncertainties in the health database; T, provisional guideline value because calculated guideline value is below the level that can be achieved through practical treatment methods, source protection, etc

2.3.3 Radiological Aspects

This involves the health risks associated with the presence of naturally occurring radionuclides in drinking-water, although the contribution of drinking-water to total exposure to radionuclides is very small under normal circumstances. The guideline values were still set but not for individual radionuclides in drinkingwater which was based on screening drinking-water for gross alpha and gross beta radiation activity (WHO, 2011).

2.3.4 Acceptability Aspects: Taste, Odour and Appearance

Water should be free of tastes and odours that would be objectionable. In assessing the quality of drinking-water, it is principallyrelied upon the senses. Microbial, chemical and physical constituents of water may affect the appearance, odour or taste of the water,which quality and accepatability can easily be evaluate on the basis of these criteria. Although these constituents mayhave no direct health effects, water that is highly turbid, is highly coloured or has an objectionable taste or odour may be regarded as unsafe and rejected (WHO, 2011).

2.4 THE CONCEPT OF WATERPOLLUTION

Pollution is the introduction of contaminants into the natural environment that causes adverse change. Pollution can take the form of chemical substances or energy, such as noise, heat or light. Pollutants, the components of pollution, can be either foreign substances/energies or naturally occurring contaminants. Pollution is often classed as point source or nonpoint source (Merriam-Webster, 2013). There are three major forms of pollution. They are air, land and water. Water pollution is however, the focused of this study.

Water pollution is therefore, the discharge of wastewater directly or indirectly from commercial and industrial waste (intentionally or through spills), or discharges of untreated domestic sewage, and chemical contaminants such as chlorine, from treated sewage into water bodies without adequate treatment to remove the harmful compound. Also, it is the release of waste and contaminants into surface runoff flowing to surface waters (including urban runoff and agricultural runoff, which may contain chemical fertilizer and pesticides). There are two main sources of water pollution which are based on their origin. They are;

2.4.1 Point Source

Direct (Point source) water pollution refers to contaminants that enter a waterway from a single, identifiable source, such as a pipe or ditch. For example, discharges from a sewage treatment plant, a factory, or a city storm drain. Others are: municipal storm sewer systems and industrial storm water, such as from construction sites (Hogan, 2010).

2.4.2 Non-Point Source

Indirect (Non-source Point) Non–point source pollution refers to diffuse contamination that does not originate from a single discrete source and similarly not directly from human activities. Rather Non-Point Source pollution is often the cumulative effect of small amounts of contaminants gathered from a large area (Hogan, 2010).

Furthermore, based on Wolman (1971) definition of water quality to consist of at least two broad spectra of attributes; thus associated with the fluid transported through a stream channel and those associated with the physical channel itself. Water pollution therefore, owing to their different spatial distributions may be divided into natural and man-made categories.

2.4.3 Man made Pollution

Whatever we put down into our homes or communities eventually ends up in our water sources. It may be home cleaning products, prescription drugs, food garbages from the markets, office waste or whatever which eventually causes water pollution. Example is sediments.

Again, manufacturing has always been a great tool for the economy of any country but slack regulations have allowed companies to severely pollute our air and water, and the output makes a lot of difference to the environment. In general practice, almost all the manufacturing unit dump waste directly into rivers and lakes, polluting the water. As a result of which the water source for millions of people has been found to be contaminated with hundreds of toxic chemicals from industrial waste.

In recent years, chemicals have been used extensively in the agricultural sector which causes large quantities of pesticides and herbicides to be released or drained into the main sources of water therebypollutingthe water. An example is fertilizers(Mrowka, 1974).

Another form of pollution by man is thermal pollution. Thermal pollution may be as the result of direct or indirect human action. Man may directly increase the temperature of a stream by injecting cooling water from an industrial plant back into the stream or remove the riparian vegetation shading the channel, thus increasing the incidence of solar radiation received by the channel and therefore increasing the temperature of the stream indirectly (Pluhowski, 1970).

2.4.4 Natural pollution

Natural phenomenon such as run-off lava from volcanic eruption can increase the temperature as well as introducetoxic chemicals into a water body which may have adverse affect on the quality

of the water. Algabloom is another natural phenomenon that occurs on the surface of the water. This happens when there is an abnormal growth of algae plant species on the entire surface of a water body that prevent adequate transfer of sunlight and air into the water affecting aerobic reaction in the water, therefore disrupting the natural buffer balance in the water. During earthquakes and tsunamis the earth crust splits open into several depths below the earth surface. Debris, sand and broken rock materials are subsequently transported as sediments into water bodies. Harmful, toxic, hazardous and contaminated substances are also transported during these processes (Enviropedia, 2014)

2.4.5 Water Pollutants

Out of all pollutants of water, heavy metals such as lead, cadmium, and mercury, and toxic organic chemicals such as pesticides, polychlorinated biphenyls (PCBs), dioxins, polycyclic aromatic hydrocarbons (PAHs), petrochemicals and phenolic compounds pose the greatest threat to man and the environment because they are not easily removed from water in conventional treatment processes, with resultant adverse effects upon exposure to them (Enviropedia, 2014).

The term heavy metal was used as far back in 1817 when Gmelin (1849) divided the elements into nonmetal, light metal and heavy metal. Although, there is no widely agreed definition of heavy metal however some basic criteria is being used to define heavy metals which includes; density, atomic weight, atomic number or position in the periodic table (Duffus, 2002). Density ranges from above $3g/cm^3$ to above $7g/cm^3$, atomic weight starts from greater than 40, atomic number are usually given as greater than 20 and ends at 92 (Uranium) (Habashi, 2009,). Heavy metals can therefore be defined as chemical elements with specific gravity that is atleast 5 times the specific gravity of water. The specific gravity of a substance is the ratio of the density of the

substance to the density of water at 4^{o}C (39^{o}F). Simply stated, specific gravity is a measure of density of a given amount of a solid substance when it is compared to an equal amount of water. Some well known toxic metallic elements with specific gravity that is 5 times or more times that of water are arsenic, 5.7; cadmium, 8.65; iron, 7.9; lead, 11.34; mercury, 13.546 etc (Lide, 1992). A metal is also called heavy metal if, in its standard state it has a specific gravity of more than 5g/cm^{3}. Hawkes (1997) went further to define heavy metal as all metals in group 3 to 16 and period 4 and greater in the periodic table.

Every 1000kg of normal soil contains 200g chromium, 80g nickel, 16g, lead, 0.5g mercury and 0.2g cadmium (Caobisco, 1996). There are sixty known heavy metals but 35 of these metals are of concern to us because of their occupational or residential exposure. However, 23 of these heavy metals which includes; antimony, arsenic, bismuth, cadmium, cerium, chromium, cobalt, copper, gallium, gold, iron, lead, manganese, mercury, nickel, platinum, silver, tellurium, thallium, tin, uranium, vanadium, and zinc are of more significant concern because they persist for longer period without degrading and metabolizing in the environment (Glanze, 1996).

Heavy metals are present naturally in all components of the environment: atmosphere, land and water bodies and become concentrated as a result of human caused activities. Common sources of these human activities are mining, industrial waste, vehicle emissions, lead-acid batteries, fertilizers, paints and treated wood (Di Maio, 2001). Heavy metal effect upon the water body is perhaps the most pronounced. This is because a significant amount of these heavy metals present in the soil are leaches and eroded out during erosion and weathering to be deposited into waterbodies. Also, the atmospheric components of heavy metals enter the waterbodies through precipitation while the heavy metals on the land are equally washed down to water bodies by run-off during storm events. Therefore, it is evident that the water bodies are the final sink of

large concentration heavy metals.Although, small amount of heavy elements are common in our environment, diet and they are even necessary for good health, but large amount of any of them can cause acute and chronic toxicity (poisoning).

2.4.5.1 *Toxicity*

Heavy metals become toxic when they accumulate in the soft tissue and are not metabolized by the body. They enter the body through food, water, air and or through absorption through the skin when they come in contact with humans in activities such as agriculture, manufacturing industries (mining, textile, pharmaceutical, petrochemicals, agrochemicals, cosmetics etc) and residential settings. Industrial exposure accounts for the common route of exposure for adults while ingestion is the common route of exposure in children (Roberts, 1999). Children may develop toxic levels from the normal hand-to-mouth activity of children who come in contact with contaminated soil or by actually eating objects that are not food (dirt, paint chips etc). Other common routes of exposure are during radiological procedures in hospitals from inappropriate dosing or monitoring during intravenous (parental) nutrition/breast feeding, from chemotherapy of cancer patients and radioactive operations in nuclear reactors (Dupler, 2001; Smith and Stopp, 1997; Lupton, Kao, Johnson, Graham and Helwig, 1985).

Acute poisoning is more likely to result from inhalation or skin contact of dust, fumes or vapors, or materials in the workplace as well as from agricultural practices where plants absorb heavy metals from the soil, as well as from fertilizer application etc, (example, is Ita-Itai poisoning from indigestion of rice irrigated with water containing the toxic metal cadmium)

2.4.5.2 *Symptoms*

Indicative of acute toxicity is not difficult to recognize because the symptoms are usually severe, rapid in onset (Ferner, 2001). Acute poisoning is often associated with cramping, nausea, vomiting, pain, sweating, headaches, difficulty breathing, convulsion, impaired cognitive, motor, and language skill etc. The symptoms of toxicity resulting from chronic exposure such as impaired cognitive, motor, and language skills, leaning difficulties, nervousness and emotional instability, insomnia, nausea, lethargy, and feeling ill are also easily recognized however, they much more difficult to associate with their causes. Symptoms of chronic exposure are very similar to symptoms of other health conditions and they often develop slowly over the months or even years. Sometimes the symptoms of chronic exposure actually abate from time to time, leading the person to postpone seeking treatment, thinking the symptoms are related to something else.

2.4.5.3 *Detrimental Effects*

Heavy metals can bind to vital cellular components, such as structural proteins, enzymes, and nucleic acids, and interfere with their functioning (Landis, Sofield and Yu, 2000). Effects and symptoms of heavy metal poisoning can vary according to the metal or metal compound and the dose involved. Broadly, long-term exposure to heavy metal can result to various health implications (Nielen and Marvin, 2008).

In general, heavy metals toxicity can result in damage or reduced mental and central nervous function, lower energy levels, and damage to blood composition, lungs, kidney, liver and other vital organs. Long-term exposure may result in slowly progressing physical, muscular and neurological degenerative process that mimic Alzheimer`s disease, Parkinson`s disease,

muscular dystrophy, and multiple sclerosis. Allergies are not uncommon and repeated long-term contact with some metals or their compounds are carcinogenic and affect the circulation of blood (Amirah, Afiza, Faizal, Nurliyana and Laili**,** 2013**)** Beryllium and aluminum although light metals are sometimes considered as heavy metals in view of their toxicity (Volesky, 1990). Beryllium exposure can result to lung and heart disorder. Aluminum on the other hand is a major inhibitor of crop growth (Saxena and Misra, 2010). Table 2.3 presents some toxic elements with their detrimental effects.

Table 2.3 Elements and their Detrimental Effects

Element	**Acute exposure**	**Chronic exposure**	**Main article**
Cadmium	Pneumonitis (lung inflammation)	Lung cancer Osteomalacia (softening of bones) Proteinuria (excess protein in urine; possible kidney damage)	Cadmium poisoning
Mercury	Diarrhea Fever Vomiting	Stomatitis (inflammation of gums and mouth) Nausea Nephrotic syndrome (nonspecific kidney disorder) Neurasthenia (neurotic disorder) Parageusia (metallic taste) Pink Disease (pain and pink discoloration of hands and feet) Tremor	Mercury poisoning
Lead	Encephalopathy (brain dysfunction) Nausea	Anemia Encephalopathy Foot drop/wrist drop (palsy)	Lead poisoning

	Vomiting	Nephropathy (kidney disease)	
Chromium	Gastrointestinal hemorrhage(bleeding) Hemolysis (red blood cell destruction) Acute renal failure	Pulmonary fibrosis (lung scarring) Lung cancer	Chromium toxicity
Arsenic	Nausea Vomiting Diarrhea Encephalopathy Multi-organ effects Arrhythmia Painful neuropathy	Diabetes Hypopigmentation/Hyperkeratosis Cancer	Arsenic poisoning

2.4.3.4 *Remediation*

In humans, heavy metal poisoning is generally treated by the administration of chelating agents (Blannn and Ahmed, 2014). These are chemical compounds, such as $CaNa_2$ EDTA (calcium disodium ethylenediaminetetraacetate) that convert heavy metals to chemically inert forms that can be excreted without further interaction with the body. Chelates are not without side effects and can also remove beneficial metals from the body. Vitamin and mineral supplements are sometimes co-administered for this reason (American Cancer Society, 2008). Other chelating agents frequently used in therapy are dimercaprol (also known as BAL or British Anti-Lewitise). Oral chelating agents used as alternative to BAL are 2, 3- demercaptosuccinic acid (DMSA), dimercaptopropanesifunate (DMPS), and D-penicillamine. Another agent, deferoxamine is often used to chelate iron (Wentz, 2000).

Soils contaminated by heavy metals can be remediated by one or more of the following technologies: isolation; immobilization; toxicity reduction; physical separation; or

extraction.Isolation involves the use of caps, membranes or below-ground barriers in an attempt to quarantine the contaminated soil. Immobilization aims to alter the properties of the soil so as to hinder the mobility of the heavy contaminants. Toxicity reduction attempts to oxidise or reduce the heavy metal ions, via chemical or biological means into less toxic or mobile forms. Physical separation involves the removal of the contaminated soil and the separation of the metal contaminants by mechanical means. Extraction is an on or off-site process that uses chemicals, high-temperature volatization, or electrolysis to extract contaminants from soils. The process or processes used will vary according to contaminant and the characteristics of the site (Evanko and Dzombak, 1997).

2.4.3.5 *Benefits*

Heavy metals despite their toxic nature are essential in small quantities, for human health. These elements include vanadium, manganese, iron, copper, cobalt, zinc, selenium, strontium, and molybdenum (Banfalvi, 2011). A deficiency of these essential elements may increase susceptibility of heavy metal poisoning (Chowdhury and Chandra, 1997).

2.5 Related Previous Studies

In large amount, heavy metals are dangerous to health asalready highlighted and when they are washed into waterbodies they become absorbed as dissolved sediment load. An example was the "Minamata" Bay disaster, at Japan in the 60s caused by mercury poisoning of consumers of fish harvested from the Minamata Bay Japan, which had received untreated effluent from a plastic factory.

Also, was the case of "ita-itai" poisoning from ingestion of rice irrigated with effluent containing the toxic metal cadmium leading to the lost of several life's (FEPA, 1988). Heavy metals are

also, known to be carcinogenic and fatal because of their bio-accumulation in nature (Gower, 1980). Nigeria also has been a victim of this illegal act, when in 1988 about 3,880tons of toxic and hazardous waste were dumped in Koko, the then Benue state and now Edo by an Italian company (FEPA, 1988).

Man's activities have also increased in the loading of contaminants to the Kubanni River, a major drainage basin in Zaria town. It was observed by Hankouraou (1998) that the increased loading of the river channel bed with wastes could result in increased concentration of many metal contaminants in the water, consequently affecting the survival of aquatic organism and human beings that use such waters for domestic purposes.

Studies on the water quality of Samaru stream as well as the Kubanni reservoir where it empties have being conducted by several researchers with the use of different techniques and methodologies.Such researchers includes; Udoh, Singh and Omenesa (1986), Yusuf (1992), Jeb (1996), Obamuwe (1998), Udoh (1999), Garba (2000), Iguisi, Funtua and Obamawe (2001), Ewa, Ewa and Ikpokonte (2004), Butu and Iguisi (2012),and Garba *et al* (2014).

Udoh *et al* (1986) analysed heavy metals in the Kubanni reservoir and found the concentration of lead (Pb) to be 500ppb. Yusuf (1992) analysed nine samples of the raw Kubanni reservoir sediment sample and found the concentration of lead to be in the range of 243 to 409 ppb, with average of 279 ppb.Jeb (1996) sampled and analysed the head waters of the Kubanni reservoir and found a lead concentration of between 1and 5ppb. Furthermore, Obamuwe (1998) used the XRF technique to analysed the raw water of Kubanni reservoir and found the concentration of lead to be in the range of 17 and 97 ppb. Also, Udoh (1999) analysed treated and untreated water of Kubanni reservoir and found an insignificant difference in the two groups, with lead

concentration values ranging between 0 and 37 ppb. Again, a study by Garba and Schoeneich (2004) on the actual lead (Pb) content of Kubanni reservoir and areas within its drainage basin considered by the researchers as non-polluted regions indicated a lead concentration value in the range of<0.024 ppm to □ 0.01 ppm for the reservoir, and from < 0.014 ppm to □ 0.008 ppm lead (Pb) for the areas considered as non-polluted. This shows a concentration in the non-polluted water of Kubanni drainage basin to be less than 14 ppb (0.014ppm) and not more than 24ppb (0.024ppm) for the reservoir. While these studies on heavy metals in the Kubanni reservoirshows the concentration value of toxic metals such as lead (Pb), cadmium (Cd) and mercury (Hg) to be above the WHO recommended standards,Uzairu, Harrision, Balarabe and Nnaji (2008) shows their concentration to be within the recommended standards on a study on the Kubanni reservoir.

Similarly, Garba (2000) and Garba and Schoeneich (2003) using two different methodologies to analysed the raw water of Kubanni reservoir found a lead value ranging between 14 and 8 ppb while Iguisi, Funtua and Obamawe (2001) analysed the surface waters of Kubanni reservoir using X-Ray Fluorescene (XRF) technique and found a total number of 18 metals in various level of concentration. Ewa, Ewa and Ikpokonte (2004) on the other hand analysed the sediments from the entire course of the River Kubanni using X-Ray Fluorescene (XRF) technique and determined 11 metals of interest in various concentration. Butu and Iguisi (2012) analysed 29 metals in the sediments of the Kubanni river using the most sophisticated and highly accurate method; the instrumental Nitrogen Activation Analysis (INAA) because of its capability of detecting all the metal pollutants that are present in the river sediments in a more accurate manner.

An important stream to the Kubanni reservoir is the Samaru stream. Usman (1998) analysed for lead in Samaru stream, a tributary of Kubanni reservoir and found a concentration level of lead

to be 2160 ppb while an updated study by Garba *et al* (2014) on the update of water quality of Samaru stream using a multi analyte photometer found an average concentration value of lead to be 0.95mg/l from ten sampling points while the WHO (2011) recommended standard for lead is 0.01mg/l.

It was observed from these studies carried out on Kubanni reservoir from 1986-2014 that there is a gradual decrease in concentration level of metal pollutants such as lead. The decrease in the concentrationof lead in the Kubanni reservoir and as well as the Samaru stream can be attributed to the decreasingwaste discharges, washing of debris and effluents containing lead from the catchment areas into the river.

Lastly, a most recent study that attempted to investigate the dissolved load (Cd_1) also, known and referred to as total dissolved solid (TDS) of Samaru stream was carried out by Yusuf and Igbinigie (2010) where they examined the relationship amongst discharge (Q), suspended sediment discharge (Cs) and dissolved sediment discharge (Qd) of Samaru stream in which the dissolved sediment discharges was derived from the dissolved sediment concentration. Result from the rating equation shows that there is a direct relationship between dissolved sediment concentration (Cd_1) and discharge (Q) while the rating curve produced a straight line scatter curve which however did not start from the origin, indicating a weak relationship.

CHAPTER THREE: THE STUDY AREA& METHODOLOGY

3.1 STUDY AREA

3.1.1 Location

The study area is in Samaru Zaria, Kaduna State, Nigeria. The study site is a 1st order minor tributary of the Kubanni River located within the Kubanni drainage basin, lying about $11^0$08'32"-$11^0$09'38"N and $7^0$38'36"- $7^0$38'48"E.It has a stream length of 1.05km, a basin area of 2.28km^2, a drainage density of 0.4605m/km^2, a relative relief of 30.48m (Yusuf and Igbinige, 2010); maximum depth of 3.01m and a maximum width of 10.8m The Kubanni River have its source from the Kampagi Hill, in Biye, near Zaria. It flows in southeast direction of Samaru through Ahmadu Bello University. The Kubanni River which forms one of the main drainage systems in Zaria carries water almost throughout the year.

The drainage systems of Zaria focus mainly on River Galma which originates from the Jos plateau in the South Western area of the Shetu hills, some 350km away from Zaria (Abdulrafiu, 1977). Except for Galma River, all streams in the area are seasonal, flowing only during and after rains, although the larger ones have surface water along stretches for much of the year.

The study area is at an altitude of 550-700 meters. It is about 13km from Zaria-city on the Sokoto road, 8km to Shika and 7km from Basawa. Samaru evolved from a small colonial farming settlement to become a large community, a melting-pot, often referred to as "the University village". It is cosmopolitan in nature, drawing and fusing people of divergent national and international backgrounds. A picture depicting the study area is shown in Plate 3.1 and Plate 3.2.



Plate 3.1:Samaru Stream at Location 11^{o}08'38"N-007^{o}38'47"E



Plate 3.2: Samaru Stream during an Overflow at Location 11^{o}08'32"N-007^{o}38'48"E

3.1.2 Climate

The study area belongs to the tropical continental type of climate corresponding to Koppen's tropical savannah or tropical wet and dry climate zone (Aw), characterized by strong seasonality in rainfall and temperature distributions. The rainy season starts around May and ends early mid-October, while the dry season starts in November and ends in April. The season coincide with the southward and northward movement of the surface transition between the hot, moist tropical maritime southeasterly air-mass (MTS) of the sourthen hermisphere of the Atlantic ocean origin and the cold, drier tropical continental air-mass (CTS) which is blown by the northeast trade winds from the sahara desert known as the Inter-tropical Discontinuity (ITD) (Oladipo, 1985).

The area has a relatively high humidity in the rainy season (90%) and low during the dry months, reaching as low as 30% during harmatten period. Evaporation rate as high as 2940.7mm/a, has been recorded (Kaduna State Water Board, 1987)

The number of rainy days varies considerably from year to year, but appears to have a long term average of about 92 days (Hocking and Thomas 1979). However, in the recent years the number of rainy days has appeared to have reduced considerably. This was observed from the calculation of the annual record data of rainfall days of Samaru town, covering a peroid of 7yrs that is 2008 to 2014, which shows a diminshing average rainfall of 74days (Authors Computation, 2015) instead of the 92 days recorded by Hocking and Thomas (1979) (appendice 2).

The movement of the Intertropical Discontinuity (ITD) has lead to seasonal changes. Zaria is located north of the ITD. The ITD moves to south of Zaria around the middle of November causing the replacement of the dry continental north easterly by the moist south westerly air which is on the surface. The ITD oscillates forward and backward before finally moving south of Zaria. This movement of the ITD north and south of Zaria is usually associated with the varying attendant temperature changes therefore, the region experiences cold and hot weather. Mean daily temperature shows a peak of 39^0C in October while the mean minimum temperature rises from its lowest values of 7^0C to 8^0C in December and January respectively with the highest in July having 11^0C and August 11.3^0C. The onset of harmattan is normally marked by sudden drop of both relative humidity and vapour presuure (Ojo, 1982; Ati, 1990).

3.1.3 Geology

The geological features are characterized as follows; the basement gneiss, porphyritic granite and medium grained granite (Fig.3.2).The last two were intruded into the basement gneiss during the Pan African. The greater part ofthe area is covered with thick regolith mainly derived from in-situ weathering of the basementrocks, which in some areas on the watershed is up to 30 metres thick (Garba, 2000).

The region is also characterized with superficial and alluvium deposits. The superficial deposits comprises of the young and old laterites, as well as the young and old alluvium. In the some places the laterites formed duricrust (hard iron pan). Superficial deposits are noticeable along the down cuts of river valleys. Furthermore, thick lateritic regolith soil has developed in the region from chemical weathering. Massive and hardened laterites from older (vermicular and vesicular types) occur at high levels on the upland close to the interfuves as measas and buttes. During erosion the older laterites are destroyed and the rubbles from the erosion process are transferred

to a gentler sloping surface at lower levels where it undergoes some geological processes to form the younger laterites (Wright and McCurry, 1970; Ologe 1972; Bello, 1973; Yusuf, 2006)

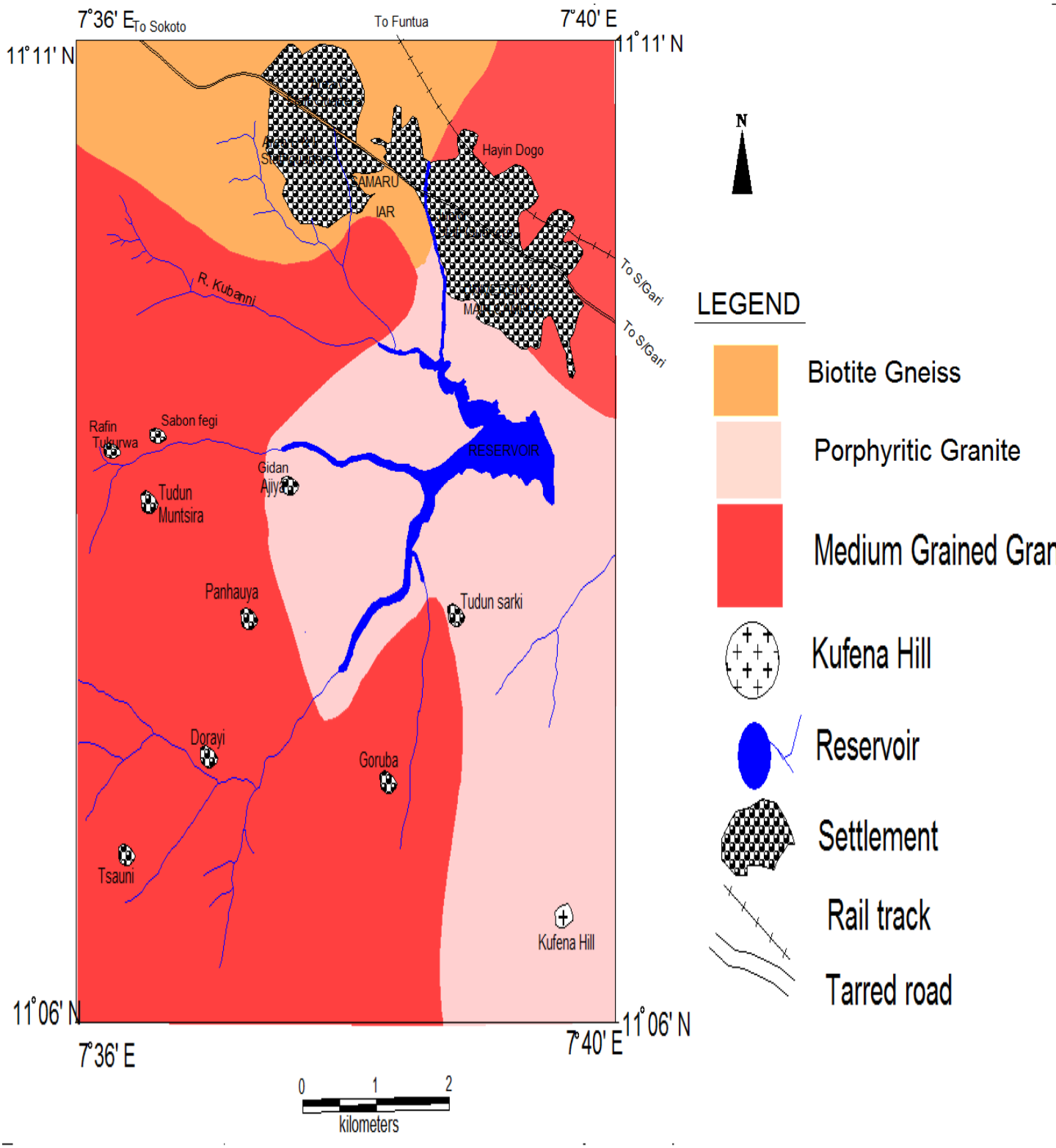


Figure 3.1: Geological map of part of Kubanni drainage basin showing the reservoir and Samaru stream. After Garba *et al*. (2014)

The alluvial deposits in the study area on the other hand are exogenic terrigenous materials that are transported from a river and deposited by flooding water over the banks of a river. The alluvium deposits are quite extensively wide open consisting of brown to brownish red sands, silts and clay. Thorp (1970) described these sites of the older alluvium deposits within the study area as where gullies erosion is incised into them. The shallowness of the streams around the region enables the formation of extensive flood plains along the rivers which often floods during the rainy seasons (Nassef and Olugboye, 1979).

Furthermore, Ololobou (1982) observed a site along the Zaria by-pass, 0.5km from the bridge within the Kubanni basin where the presence of younger laterites with recent alluvial deposits along the Kubanni River was prominent.

3.1.4 Soils

The soil type is highly leached ferruginous tropical soils, developed on weathered regolith overlain by a thin deposit of windblown silt from the Sahara desert during many decades of the propagation of the tropical Continental air mass into the area (Wright and McCurry, 1970). The soil occurs as loess, covering pre-Cambrian rocks (mainly crystalline acid rocks). These ferruginous soils exhibits a marked differentiation of the horizon and are characterized by the separation of free iron oxides (Fe_2) which may hinder the infiltration of rain water from the formation mottles and concretion in the soil thereby enhancing surface run-off.

The soil texture in the study area is sandy clay loam with clay dominating as kaolinite with the presence of mica and feldspar, having an average pH of 7.1 and fairly neutral in reaction and an organic matter content that is low (Harpstead, 1973). This has implication on soil structure stability, organic nutrient and soil retention capacity.

Klinkenberg (1970) described the soil pattern of Zaria according to the geological units identified by Wright and McCurry (1970). They are; (a) Fadama soils: in a valley system, an extensive wide fadama soils are usually developed. These are dark grey clays with a poor drainage formed from alluvial materials. They are widespread within the Galma, Shika and Kubanni Basins. Ipinmidum (1972) classified them as hydromorphic; (b) Soils developed on Metasediments (Schists and Quartzites): soils, west of Zaria are shallow and stony in the interfluves crests as a result of the widespread elongated quartzite ridges. Although, at the middle and lower slope the soil profile are deeper, with signs of clay accumulation, reddish-grey in color and concretions of iron (laterites) are found and lastly; (c) Soils developed on Granites: these are soils that are close to the granitic outcrops which appears deep and consisting mainly of weathered material which does not show a distinct profile development. Fragments of unweathered quartz and feldspar are found while deep clayer soils further away the granite hills are also found. Mottled soils with grayish color are found in the lower sloping and poorly drained areas (Yusuf, 2006).

The major developmental processes occurring in the soil major profile involve the leaching of clay minerals and ions. The soil profile is occasion with marked horizon differentiation with iron oxides deposits in the clay-rich B-horizon, underlying the A-horizon, in form of mottles, concretion or as ferruginous hard pans called duricrusts. Due to alleviation of the fines of the A-horizon, the topsoil is coarse (Nyagba, 1986).

It was observed by Kowal and Kassam (1978) and Jaiyeoba (1986) that human activities such as bush burning, overgrazing, continuous cultivation and rapid oxidation decomposition of humified organic matter of the soil have reduced by about (1-2%) the organic matter and

nitrogen content of the soil. There is low activity of the clay particles which resulted in the lowing of the cation exchange capacity (CEC) of the soil and exchangeable bases.

3.1.5 Vegetation

Natural vegetation of the study area is the Northern Guinea Savannah. Unfortunately this characteristic vegetation cover is hardly preserved due to urbanization and poor management practices, like fuelwood harvesting, annual bush burning, cultivation and intensive grazing (Ologe, 1971). The Northern Guinea Savannah zone is the largest natural vegetation zone in Nigeria and is boardered on the north by the Sudan Savannah and to the south by the derived savannah. It is characterized by scenty deciduous trees, herbs, shrubs and grasses (Olowu, 1986; Ogunjobi, 1993).The herbs and grasses grow very tall in some places particularly around the basins where water retention and moisture is high. There is presence of evergreen trees along the Perennial river and streams, mangoes tress are the common tress seen dotting the region. This is due to the seasonal character of rainfall which favors the growth of the tree species. These mangoes trees are planted by locals for their fruits and shades.

The vegetation of the region is usually green in color during the rainy season and yellowish or brownish in dry season.*Isoberlina doka* with an average height of 0.5m is the dominant shrub in the region. Other shrub species are the *Butryspermum* spp, *Pilliostigma* spp,*Terminalia avicenniodes* and *Vitea* spp. Some other tree plants found include*Mangniferaindica, Parkiaclappertononia* and several others which are found to be useful by man. It is a common feature to see these trees left standing during cultivation.A common grass community is the *Andropogon spp* (Kwabe, 1987) which dried up during the dry season and reappears when the wet season returns. Grazing for livestock and grass cutting for local mud house construction are the common human activities that contribute to the absence of the grass.

3.1.7 Landforms

The study area is within the Galma basin situated on an extensive peneplain developed on crystalline metamorphic rocks of the basement complex which extends uninterrupted from Sokoto to Lake Chad and northwards from Southern Kaduna to Tigueddi Scarp near Agadas in Niger Republic.It is located at Zaria plain, a dissected part of the Zaria – Kano Portions and believed to be overlain by wind, drift sediments(Wright and McCurry, 1970). The peneplain is a gently undulating erosional surface that was capped by the development of an extensive laterites cover, identified as possibily of the Pliocene age, according to Du Preez (1952). It varies in altitude, from 550m to 740m above sea level, dotted with outcrops of rocky inselbergs and lateritic iron stone, with the Kufena hill attaining a height of 820m and a flat top lateritic ironstone capped residuals. Iguisi (1996) identified the study area to be close to the Kampagi Hill which is about 708m above sea level. The laterite cover has been reduced to scattered layers, separated by a thin but highly variable succession of wind and water sediments.The shape of the valley side slopes shows a convex-concave form with some rectilinear elements.

3.1.8 Land Use

Prior to the year 2000, agriculture (both upland fields and fadama or irrigation farming), grazing and fishing are the predominant human activities within the basin of the study area. These activities were however stopped, in an effort to reduce the rate of siltation of the A.B.U dam or reservoir which researchers such Iguisi (1997) and Yusuf (2006) have shown to be responsible for the silting of the reservoir from sediment generated from the catchment areas and deposited into the basin. The university authority adhered to the recommendation on the research carried out on the Kubanni reservoir and then banned all forms of human activities such as agriculture,

grazing etc that were taking place in the area. This was done in order to protect the reservoir from silting completely like the Daudawa dam in Katsina state. The measure taken to tackle the problem was by embarking on an intensive conservation campaign. Tree plantations have since taken over the basin in order to reduce erosion rate from water run-off which influences soil erodibility and sediment generation which is ultimately being transported and deposited into the basin.

In the absence of agriculture and grazing activities therefore, the most obvious human activities that are of concern to the Kubanni reservoir are those that take place in Samaru, a satellite town bordering the northern tributary of the Kubanni reservoir. Human activities such as wastes generation from market garbage's (rotten and decaying vegetables, fruits etc), domestic wastes (gutters, soak-aways, and latrines), plastics wastes (polythene bags etc) as well as wastes from such activities like carpentry, mechanic workshop discharges are all washed down during the raining season into the Kubanni dam through Samaru stream.

3.1.8 Drainage Characteristics

The Samaru stream linking at the northernmost tributary of the Kubanni river is a 1^{st} order stream with a total stream length of 1.05km, a basin area of $2.28km^2$, drainage density of $0.4605m/km^2$ and a relative relief of about $30.48m^2$ (Yusuf and Igbinigie, 2010). The Samaru stream flows into the Malmo River and finally, all drain into the A.B.U reservoir. The Samaru stream is seasonal that is, it flows only during wet season and seize during the dry season, although groundwater is usually found at or near surface in some cases throughout the year. Water draining into the Samaru stream from part of the A.B.U University (Danfodio hostel,

ICSA Ramat hostel, Block of 9 flats, Area 2 Quarters andCommunity Market), helps in sustaining the flowing water during the dry seasons.

Evidence of poor conservation and landuse practices from faming activities and overgrazing in the past has resulted into the development of gullies and steep slope in the basin which makes transportation of soil and rainwater disposal into the stream especially, the valley sides encourage a high velocity runoff down the slope, thereby increasing mass movement or high rate of soil wash (Ologe, 1971; 1972; Bello 1973; Ogunrombi, 1979; Iguisi, 1997). Recurrent undermining and collapse of gullyside walls headscarp recession due to energy increase of concentrated runoff leads to gully growth which results to the development of micropediments, mounds and hillocks (Bello, 1973).A map showing the drainage location of the study area is presented in Figure 3.2.

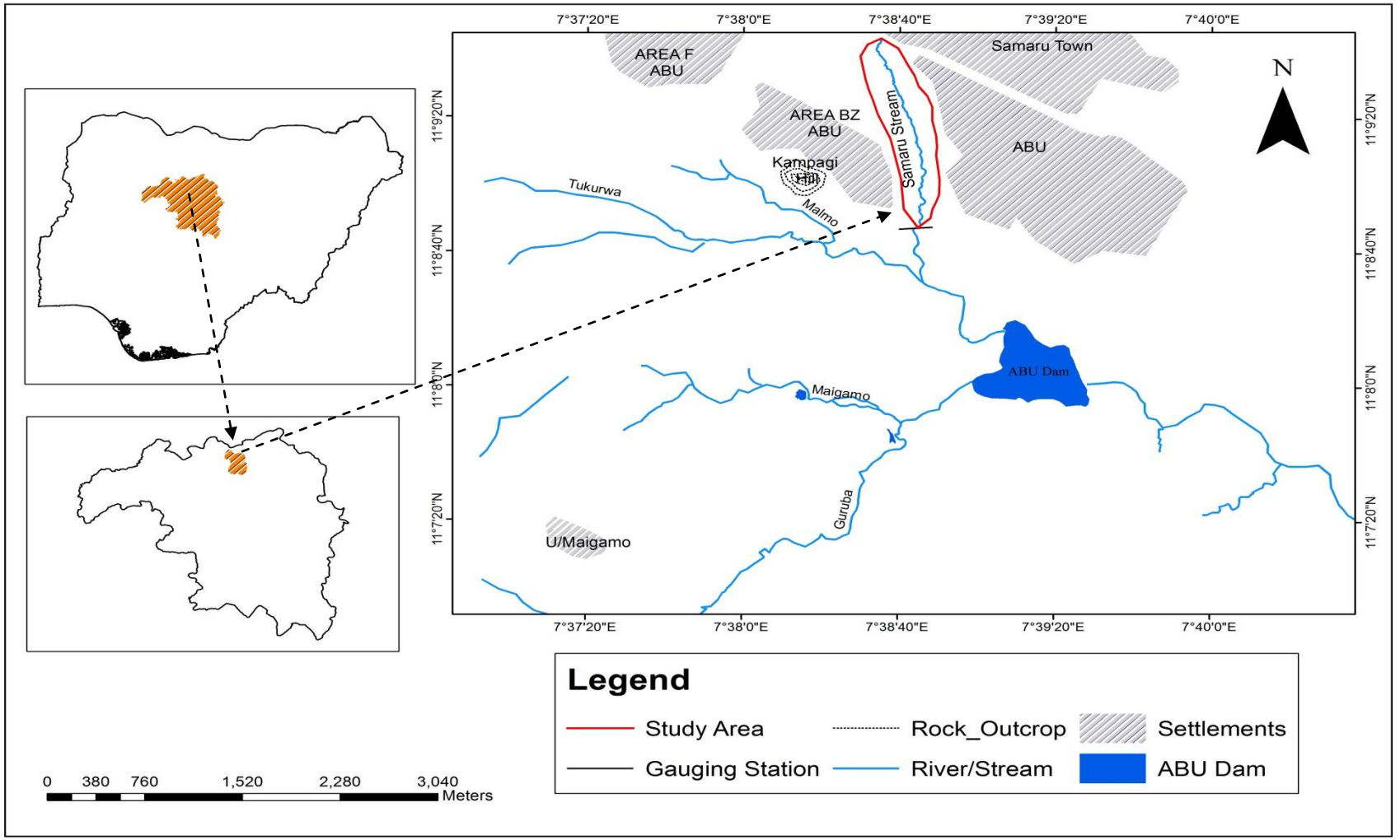


Fig. 3.2: Location of the Study Area on the Kubanni River Basin

Source: Zaria SHEET 102 South-West.

3.2 METHODOLOGY

This section will discuss the various methods that was employed in generating and analysing data for the study, in order to achieve the aim of this study, a reconnaissance survey was carried out in order to be well acquainted with the study area. These provided useful information in the mapping and identifying the location for the gauging station where daily stream data and sample collection would be carried out.

3.2.1 RECONNAISSANCE SURVEY

After the reconnaissance survey a stream depth and width was found to vary almost throughout the stream. This was attributed to uneven uniform spread of streambed. Therefore, stream depth measurement was taken between 180-200m upstream from the intersection of the Samaru stream and the Malmo River. The stream depth measured at the gauging station during the period of lowest water flow was 0.80m while 2.5m was recorded during the constant water flowing in the month of August and 3.01m depth during overflow. Furthermore, a stream width of 10.8m was recorded.

It is equally important to note that despite the banning of all human activities at the Kubanni basin by the ABU committee on the protection of the Kubanni reservoir, there is still illegal grazing from migrating herdsman's as well as cattle's from staff that stray into the basin. Also, small scale fishing activities are seen taking place around the basin.

3.2.2 TYPES AND SOURCES OF DATA:

(i) Primary data:This includes data on stream discharge, mineral composition, heavy metal and sediment concentration that was acquired from the field and the laboratory.

(ii) Secondary Data: The secondary data on rainfall and water quality parameters were obtained from Institute of Agricultural Research (IAR), ABU, Zaria, Division of Agricultural Colleges (DAC) and the World Health Organisation (WHO, 2011) and National Environmental Standards and Regulatory Enforcement Agency (NSDQW, 2007) standards for water pollutants.

3.2.3 TECHNIQUES OF DATA COLLECTION

3.2.3.1*Collection, Preservation and Storage of the Samples*

These involved going to the gauging station at the site of the study area to collect daily data on stream discharges. This was done at 7am and 6pm of every day respectively. However, if between the stipulated time, rainfall was experienced, an additional stream discharge reading was recorded, and the average reading taken, as well as collecting a representative sediment sample of water from the Samaru stream using a USDH sediment sampler. The depth-integrated sample was collected at a velocity similar to the stream flow velocity. The sediment sample was taken after each rainfall, for the entire raining season. Sample collected from the sediment sampler was transfered into a 500ml plastic container, labelled and taken into the physical laboratory in Geography department, A.B.U to be prepared and runned. The choice of sample volume collected is to ensure having a substantial amount of dissolved sediment residue of atleast 0.2g that is sufficient in carrying out the analysis in the lab. Sample collected were preserved in the refrigerator when analysis wasnot conducted immediately (Water Pollution Control Federation, 1986).

3.2.3.2*Stream Discharge (Q)*

This is the volume of water passing through a given cross-section of a river during a given period of time. Units used are those of volume/time, and values are usually reported in cubic meters per

second (m^3/s) or in litres per second (1/s).The measurement of stream discharge usually involves consideration of both stage and velocity. There are a number of ways in which river discharge can be measured. These include velocity-area technique, dilution gauging, volumetric gauging, the slope area technique, weirs and flumes (control structure method) and the rated section. The velocity-area technique used by Yusuf and Iguisi (2012) was adopted. This is based on the fact that discharge, Q, is a function of average stream velocity, V, and the cross-sectional area of the channel, A, at the point of measurement.

Stream discharge measurements were observed after rainfall events and twice a day; in the morning (around 7.00am) and in the evening (around 6.00pm) everyday, which represent instantaneous and regular interval monitoring (Ogunkoya, 2000). Subsequently, the daily average readings were calculated in order to obtain the stream discharge. The velocity-area technique is represented as;

$Q=AV$…….....3.1

where,

Q= Stream discharge

A= cross-sectional area; is the product of the stream width and stream depth.And,

V= average stream velocity; is the product of the time taken fora polyvinyl chloride (PVC) material to flow unobstructed for a stipulated length within the stream. The PVC is a weightless piece of object that can float effortlessly on water. This provided the choice of using it to take the stream velocity. Plate 3.1 shows a staff guagefor stream discharge measurement at the gauging station for stream depth measurement.

3.2.4 Dissolved Sediment Concentration (Cd_1)

(i) Laboratory Analyses

The dissolved sediment concentration was obtained by filtering the sample collected from the field by an automated filtering pump using a Whatman cellulose nitrate membrane 0.45µm filter paper to dissociate the suspended sediment from the dissolved sediment. The filtered dissolved sediment was poured into a beaker to be evaporatedto dryness in the oven. The weight of the beaker that was used in drying the sample was taken, before and after the drying process. The difference in weight of the beaker/crucible will give the concentration of the dissolved sediment, following the procedure of Smith and Stopp (1978). The data obtained in (g/ml) is converted to (mg/l) by multiplying each value by 4 and 100. Plate 3.2 shows a set of filtration equipment at the Physical Geography lab.



Plate 3.1:InstalledStaff Guage at Location 11^{o}08'38"N-007^{o}38'47"E



Plate 3.2: Set of Filtration Equipment

3.2.5 Mineral Composition and Heavy Metal Test

(i) Preparation of Sample

Samples were collected from the field and filtered at the Geography department laboratory by an automated filtering pump using the Whatman cellulose nitrate membrane 0.45µm filter paper and evaporated to dryness. The dry residue samplewas carefully scrapped out of the crucible and taken to Defence Industries Kaduna (DICON) where it was runned by an X- Ray Fluorescence (XRF) machine for mineral compositon as well as the heavy metals in the sediment. Plate 3.3 shows a residue sediment sample shortly before the XRF analysis.



Plate 3.3: Residue of Dissolved sediment ready for Analysis

(ii) Laboratory Analyses:

Samples collected, for the mineral composition and heavy metals test was analyzed by the use of an XRF machine at DICON in Kakuri, Kaduna. The XRF technique operates in an electromagnetic wave frequency such as the visible light ray, but the key difference is its extremely short wavelength, measuring from 100A to 0.1A. Compared to normal electromagnetic waves, X-ray easily passes through material and it becomes stronger as the material's atomic number decreases. X-ray Fluorescence analysis is a method that uses the Characteristic X-ray (fluorescent X-ray) that is generated when X-ray is irradiated on a substance. The fluorescence X-ray is the excess energy irradiated as electromagnetic field, which is generated when the irradiated X-ray forces the constituent atom's inner-shell electrons to the outer shell and the vacant space (acceptor) falls on the outer-shell electrons. These rays possess energy characteristic to each element and qualitative analysis using Mosley's Equation and quantitative analysis using the energy's X-ray intensity (number of photons) are possible. It captures minerals in a sample (Seiko,2013). Examples, of minerals thatcan be identified by an XRF are; Na_2O, MgO, Al_2O_3, SiO_2, P_2O_5, K_2O, SO_3, CaO, TiO_2, Cr_2O_3, Mn_2O_3, Fe_2O_3, ZnO,

SrO and Cl. Furthermore, the XRF technique also have the capability of producing result of analysis in elemental form.

(iii)Sample Size to be Analysed

Systematic sampling procedure was employed to achieve an appreciable analytical sampling size in the study in order to get a good resultof analysis of data within the designed and stipulated time frame of the research work. Furthermore, because of the variability of analytical and sampling procedures (population variability), a single sample,is insufficient to reach any reasonable desired level of confidence. Therefore, the required number of samples for a mobile matrix such as water was estimated as follows (Keith, Patton, and Edward, 1996; Sigma, 2012).

$$N \geq \left(\frac{Z^{a/2} \times S^2}{U} \right) \quad \text{.....3.2}$$

Where:

N= number of samples.

$Z^{a/2}$= Student-z statistic for a given confidence level.

S= overall standard deviation, and

U= acceptable level of uncertainty of margin of error .

A 95% degree of confidence correspond to a=0.05. From the normal curve of the Z-distrubution. Each of the shaded tails has an area of a/2=0.025.The region to the left of $Z^{a/2}$ and to the right of Z=0 is 0.5-0.025, or 0.475. In the table of the standard normal(Z) distribution, an area of 0.475 corresponds to a Z value of 1.96.

Therefore, if U is ±2, and $Z^{a/2}$= 95% confidence level as desired, which correspond to 1.96 and S= 4.12, calculated from the annual record data of rainfall days of Samaru town, covering a period of 5yrs that is 2008 to 2012 with an average rainfall of 77days. Applying the above formula will give approximately 33 samples.

Furthermore, the 33 samples obtained from the procedure of Keith, Patton and Edward (1996) werereduced systematically into 3 samples by grouping the entire 33 samples into 3 groups, of 11 samples each. One sample was taken from eachof the 3 groups to give 3 samples.

Therefore, 3 samples were collected for the XRF mineral compounds and heavy Metals analysis. These 3 samples were spread through the raining season from the month of April to October according to this order. That is, the 1st rain of April was collected, the second sample was collected on 18thJuly and the third and last sample was collected on the 10thof October.

3.2.6 Data Analysis

3.2.5.1 *Rainfall-Discharge Relationship*

A precise form of rating curve as proposed by Bauer and Tille (1996) was used to regress rainfall on stream discharge, by using their log exponents (log) as shown below.

Log Q= log a + b log R……..3.3

Where Q = Stream Discharge in m^3/s

R = Rainfall in mm

a + b = Constants representing the intercept and slope of the rating plot respectively.

Furthermore, rainfall records for analysis were obtained from two meteorological stations for comparison. The two stations are the Soil Science Department and Divisional of Agricultural

College (DAC), both in A.B.U Zaria (see appendix). However, the rainfall data of DAC was used for these analyses because it was found to pick the lowest measurement of rainfall 0.20mm as aginst the 0.04mm of the soil science records while a total of 71days of rainfall were recoreded for the DAC measurment against the 70days for Soil Science.

3.2.5.2 *Estimation of Dissolved Sediment Yield*

As dissolved sediment measurements are rarely continuous, temporal extrapolation is often required to enable a reasonable estimate of dissolved sediment yield to be made. This is the total amount of dissolved sediment load that was generated within the catchment area of the Samaru stream. It involved all data on dissolved sediment concentration and dissolved sediment discharge; a product of dissolved sediment concentration and discharge to stream discharge on the basis of a limited number of sediment measurements (Yusuf, 2006).

A precise form of rating curve as proposed by Bauer and Tille (1969) was used to regressed stream discharge on the dissolved sediment discharge, by using their log exponents (log) as shown below:

Log Qd= log a + b log Q ……..3.4

Where Qd = Dissolved Sediment discharge in mg/s

Q = Stream Discharge in m^3/s

a + b = Constants representing the intercept and slope of the rating plot respectively.

The dissolved sediment discharge (Qd) in mg/s, a product of discharge and concentration would be then converted to kg/day thus:

$$Qd = \frac{QCd}{1000} * 60 * 60 * 24 \quad \ldots\ldots 3.5$$

Where Qd = Dissolved Sediment Discharge in kg/day

Q = Stream Discharge in m^3/s

Cd = Dissolved Sediment Concentration in mg^3/l

Therefore, a continuous record of dissolved sediment discharges provided an estimate of the dissolved sediment yield throughout the year (Ferguson, 1987).

3.2.5.3 *Dissolved Sediment Concentration-Discharge Relationship*

Log Cd= log a + b log Q……..3.6

Where Cd = Dissolved Sediment Concentration in mg/l

Q = Discharge in m^3/s

a + b = Constants representing the intercept and slope of the rating plot respectively.

3.2.5.4*Dissolved Sediment Discharge-Discharge Relationship*

Log Qd= log a + b log Q…….3.7

Where Qd = Dissolved Sediment Discharge in mg/s

Q = Dissolved Sediment Discharge in m^3/s

a + b = Constants representing the intercept and slope of the rating plot respectively.

3.2.5.5*Dissolved Sediment Concentration-Dissolved Sediment Discharge Relationship*

A precise form of rating curve as proposed by Bauer and Tille (1996) was used to regressed dissolved sediment discharge on dissolved sediment concentration, by using their log exponents (log) as shown below.

Log Cd= log a + b log Qd……..3.8

Where Cd = Dissolved Sediment Concentration in mg/l

Qd = Dissolved Sediment Discharge in mg/s

a + b = Constants representing the intercept and slope of the rating plot respectively.

3.2.5.5 *Conversion of % Residue Sample to Mg/l*

In order to get the basis for comparision of result with the recommended standards, the equivalent concentration of the XRF analysis obtained in % was converted to mg/l. This was obtainedfrom the initial volume of sediment samples used in generating the residue by the filtration and evaporation procedures. The volumes of sediment used for the XRF analysis to generate 1g of residue sample from each of the three rainfalls collected are 3.5 litres, 5 litres and 7.5 litres in this order because as rainfall progresses the dissolved sediment values as deposits in the samples were also decreasing. The calculation and conversion work is presented in appendix 4, and was done for each compound and element obtained from the XRF analysis.

3.2.5.6*Statistical Analysis*

Result of the samples analysed in the laboratory was interpretated using both descriptive and inferential statistical test and compared with the WHO and NSDQW standards for metal pollutants. The inferential statistical test used is the regression analysis, t-test, f-ratio and the z-test (sample size) and Analysis of Variance (ANOVA). The ANOVAtest is a statistical tool for measuring the significant difference between two unequal groups of data with normal and independent distribution. It was used in measuring the significant difference between the mineral composition and inorganic heavy metals pollutant of the dissolved sediment load of the Samaru stream. The z-test was employed in determination of sample size while the correlation and regression analysis on the other hand was used to see if, there is any significant relationship between the stream discharge and dissolved sediment load of the Samaru stream. All analyses were carried out by the use of Excel and the SPSS statistical package. The confidence level used

in accepting or rejecting the hypotheses is 95% corresponding to an alpha value of 0.05. For instance;

i. In determining the dissolved sediment concentration of the stream. The statistical tool used in the analysis was descriptive (mean, standard deviation etc) analysis.

ii. In determining the discharge of the stream. The statistical tool used in the analysis was descriptive (mean, standard deviation etc) analysis.

iii. In estimation of the dissolved sediment yield of the stream. The statistical tool used in the analysis was descriptive (mean, standard, deviation etc) and regression analysis.

iv. In analyzing the mineral composition and heavy metals in the dissolved sediment of stream. The statistical tool used in the analysis was descriptive (mean) analysis.

v. In establishing the hypotheses. The statistical tool used was the t-test, f-ratio and regression analysis.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Stream Discharge

Stream discharge measurement and observation of Samaru stream started on the 1st of April, 2014 and ended on the 31st ofOctober, 2014 covering a period of 7 months and total of 214 days which corresponded to the raining season duration of the study area. The velocity-cross-sectional area (AV) method was employed in obtaining and recording the stream discharge which involves the used of a meter rule and a lighted weight Polyvinyl Chloride (PVC) material that could easily float on water surface. This object was allowed to float freely on the water surface; to cover a given distance, in this case 8 meters was chosen to be the distance to be covered. The time taken to cover the distance is taken. Time taken recorded in seconds (s) provided the variable that was used to calculate the stream velocity, a function of distance (m) and time (s).

Data on daily mean instantaneous discharge in m^3/s is presented in table 4.1a and the summary statistic is presented in Table 4.1bwhile the daily stream discharge also in m^3/s is presented in table 4.1c and the summary statistic is in Table 4.1d. Also, the daily discharge values were converted to m^3/day and the result is shown in Table 4.1e with the regime table in 4.1f and fig. 4.1a.

Therefore, a total of 52.078m^3/s daily mean instantaneous recording was obtained for 71 rainfall days varying with the lowest value of 0.057m^3/s recorded in April and the highest of 4.133m^3/s recorded in August which gives a mean value of 0.7335m^3/s, a std. error of mean value of 0.9210, a standard deviation of 0.7761 and a variance of 0.602 while the daily mean instanstaneous discharge values available for 44 days with a missing values of 142 was recorded for the same stream by Yusuf and Igbinige (2010) showing a varying value starting from as low

as 0.01m^3/s to 0.42m^3/s with a mean value of 0.165m^3/s, a standard error of mean 0.014, a standard deviation of 0.092 and a variance of 0.008. Also, the daily discharge values obtained for 214 days gave a total of 54.107m^3/s with the lowest value of 0.010m^3/s recorded in October and the highest value of 4.133m^3/s recorded in August with a mean value of 0.2528 m^3/s, a std. error of mean value of 0.0383, a std. deviation of 0.5597 and a variance of 0.313.

Furthermore, converting the daily mean instantaneous values from m^3/s to m^3/day as seen in Table 4.1e and the regime graph in Fig.4.1a gave a total stream discharge value of 4,805,232m^3/yr for the year 2014 with October having the lowest percentage discharge of 1% and August with the highest percentage discharge of 38% as shown in the discharge regime diagram in Fig. 4.1f.There are days which the measurement is impossible because the water flow is too low and therefore difficult to observe.

Table 4.1a Instantaneous Daily Discharge Values of Samaru Stream for 2014 (m^3/s)

DATE	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1								**1.557**	**0.137**	**0.143**		
2					**0.245**	**0.078**		**4.133**	**1.112**			
3					**1.072**		**1.378**	**0.667**				
4									**0.128**	**0.057**		
5					**1.292**	**1.292**		**4.068**	**1.553**			
6							**0.375**					
7				**0.057**					**0.130**			
8				**0.500**			**1.173**		**0.917**			
9					**0.282**			**0.157**	**1.112**			
10										**0.305**		
11							**0.258**	**1.288**	**0.655**			
12							**0.950**	**0.187**	**0.138**			
13						**0.315**		**0.147**				
14						**1.353**		**0.592**				
15				**1.095**					**0.663**			
16						**0.838**	**0.167**		**0.752**			
17						**0.700**		**0.612**	**0.362**			
18							**0.762**	**0.862**				
19								**0.142**	**0.195**			
20				**0.707**				**0.147**				
21							**0.120**	**2.590**				
22						**0.112**		**0.430**				
23					**0.108**							
24												
25								**1.097**				
26				**0.922**								
27					**1.388**	**0.138**						
28				**0.637**	**0.488**	**0.685**	**1.012**					
29					**0.535**				**0.433**			
30				**0.125**				**0.123**	**0.890**			
31					**0.288**		**0.172**	**1.978**				
TOTAL				**4.043**	**5.698**	**5.511**	**6.367**	**20.777**	**9.177**	**0.505**		

Table 4.1b: Summary Statistics of Table 4.1a

STATISTICS		VALUE
N	**VALID**	71
	MISSING	143
Mean		.7335
Std. Error of Mean		.9210
Std. Deviation		.77605
Variance		.602
Range		4.08
Minimum		.06
Maximum		4.13
Sum		**52.078**

Table 4.1c Daily Discharge Values of Samaru Stream for 2014 (m^3/s).

DATE	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1					0.020	0.020	0.016	**1.557**	**0.137**	**0.143**		
2					**0.245**	**0.078**	0.014	**4.133**	**1.112**	0.030		
3					**1.072**	0.010	**1.378**	**0.667**	0.030	0.025		
4					0.020	0.008	0.020	0.030	**0.128**	**0.057**		
5					**1.292**	**1.292**	0.018	**4.068**	**1.553**	0.020		
6					0.020	0.020	**0.375**	0.030	0.030	0.018		
7				**0.057**	0.018	0.015	0.020	0.025	**0.130**	0.016		
8				**0.500**	0.016	0.013	**1.173**	0.020	**0.917**	0.014		
9				0.020	**0.282**	0.010	0.020	**0.157**	**1.112**	0.012		
10				0.018	0.020	0.008	0.018	0.020	0.030	**0.305**		
11				0.016	0.018	0.006	**0.258**	**1.288**	**0.655**	0.014		
12				0.014	0.014	0.004	**0.950**	**0.187**	**0.138**	0.012		
13				0.012	0.012	**0.315**	0.020	**0.147**	0.030	0.010		
14				0.010	0.010	**1.353**	0.018	**0.592**	0.025	0.008		
15				**1.095**	0.008	0.020	0.016	0.030	**0.663**	0.006		
16				0.022	0.006	**0.838**	**0.167**	0.025	**0.752**	0.004		
17				0.018	0.004	**0.700**	0.018	**0.612**	**0.362**	0.004		
18				0.016	0.002	0.020	**0.762**	**0.862**	**0.195**	0.003		
19				0.014	0.002	0.018	0.020	**0.142**	0.030	0.003		
20				**0.707**	0.002	0.016	0.018	**0.147**	0.025	0.003		
21				0.020	0.000	0.014	**0.120**	**2.590**	0.023	0.002		
22				0.018	0.000	**0.112**	0.018	**0.430**	0.020	0.002		
23				0.016	**0.108**	0.014	0.016	0.030	0.018	0.002		
24				0.014	0.020	0.012	0.014	0.025	0.016	0.002		
25				0.012	0.018	0.010	0.012	**1.097**	0.014	0.002		
26				**0.922**	0.016	0.008	0.010	0.025	0.012			
27				0.020	**1.388**	**0.138**	0.008	0.020	0.010			
28				**0.637**	**0.488**	**0.685**	**1.012**	0.018	0.008			
29				0.020	**0.535**	0.020	0.020	0.016	**0.433**			
30				**0.125**	0.020	0.018	0.018	**0.123**	**0.890**			
31					**0.288**		**0.172**	**1.978**				
TOTAL				**4.323**	**5.964**	**5.795**	**6.719**	**21.091**	**9.498**	**0.717**		

Table 4.1d: Summary Statistics of Table 4.1c (m^3/s)

STATISTICS		VALUE
N	**VALID**	214
	MISSING	149
Mean		.2528
Std. Error of Mean		.03826
Std. Deviation		.55966
Variance		.313
Range		4.13
Minimum		0.00
Maximum		4.13
Sum		**54.107**

Table 4.1e: Daily Discharge values of Samaru Stream for 2014 (m^3/day)

DATE	JN	FB	MR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NV	DC
1				0.000	1728	1728	1382.4	**134524.8**	**11836.8**	**12355.2**		
2				0.000	**21168**	**6739.2**	1209.6	**357091.2**	**96076.8**	2592		
3				0.000	**92620.8**	864	**119059.2**	**57628.8**	2592	2160		
4				0.000	1728	691.2	1728	2592	**11059.2**	**4924.8**		
5				0.000	**111628.8**	**111628.8**	1555.2	**351475.2**	**134179.2**	1728		
6				0.000	1728	1728	**32400**	2592	2592	1555.2		
7				**4924.8**	1555.2	1296	1728	2160	**11232**	1382.4		
8				**43200**	1382.4	1123.2	**101347.2**	1728	**79228.8**	1209.6		
9				1728	**24364.8**	864	1728	**13564.8**	**96076.8**	1036.8		
10				1555.2	1728	691.2	1555.2	1728	2592	**26352**		
11				1382.4	1555.2	518.4	**22291.2**	**111283.2**	**56592**	1209.6		
12				1209.6	1209.6	345.6	**82080**	**16156.8**	**11923.2**	1036.8		
13				1036.8	1036.8	**27216**	1728	**12700.8**	2592	864		
14				864	864	**116899.2**	1555.2	**51148.8**	2160	691.2		
15				**94608**	691.2	1728	1382.4	2592	**57283.2**	518.4		
16				1900.8	518.4	**72403.2**	**144288**	2160	**64972.8**	345.6		
17				1728	345.6	**60480**	1555.2	**52876.8**	**31276.8**	345.6		
18				1555.2	172.8	1728	**65836.8**	**74476.8**	**16848**	259.2		
19				1382.4	172.8	1555.2	1728	**12268.8**	2592	259.2		
20				**61084.8**	172.8	1382.4	1555.2	**12700.8**	2160	259.2		
21				1728	0.000	1209.6	**10368**	**223776**	1987.2	172.8		
22				1555.2	0.000	**9676.8**	1555.2	**37152**	1728	172.8		
23				1382.4	**9331.2**	1209.6	1382.4	2592	1555.2	172.8		
24				1209.6	1728	1036.8	1209.6	2160	1382.4	172.8		
25				1036.8	1555.2	864	1036.8	**94790.8**	1209.6	172.8		
26				**79660.8**	1382.4	691.2	864	2160	1036.8	0.000		
27				1728	**119923.2**	**11923.2**	691.2	1728	864	0.000		
28				**55036.8**	**42163.2**	**59184**	**87436.8**	1555.2	691.2	0.000		
29				1728	**46224**	1728	1728	1382.4	**37411.2**	0.000		
30				**10800**	1728	1555.2	1555.2	**10627.2**	**76896**	0.000		
31					**24883.2**		**14860.8**	**170899.2**		0.000		
TOTAL				**374025.6**	**515289.6**	**500688**	**710380.8**	**1822272.4**	**820627.2**	**61948.8**		

Sum Total=4,805,232.2m^3/yr

Table 4.1f: Discharge Regime Table for table 4.1e (m^3/month)

NO:	MONTHS	DISCHARGE (m^3/months)	FRACTION OF TOTAL DISCHARGE	PERCENT OF TOTAL DISCHARGE (%)
1	**JAN**	--	--	--
2	**FEB**	--	--	--
3	**MARCH**	--	--	--
4	**APRIL**	374025.6	0.08	8
5	**MAY**	515289.6	0.11	11
6	**JUNE**	500688	0.10	10
7	**JULY**	710380.8	0.15	15
8	**AUG**	1822272.4	0.38	38
9	**SEPT**	820627.2	0.17	17
10	**OCT**	61948.8	0.01	1
11	**NOV**	--	--	--
12	**DEC**	--	--	--
TOTAL		**4,805,232.2**	**1**	**100**

Sum Total=4,805,232 m^3/yr

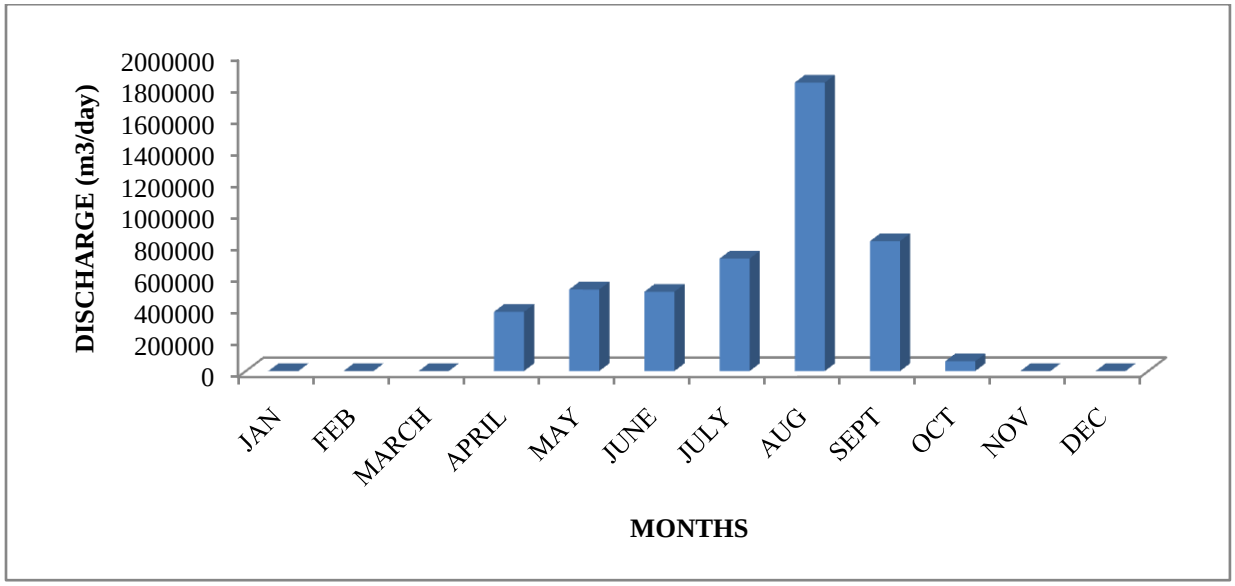


Fig. 4.1a: Discharge Regime Graph for Table 4.1e (m^3/day)

It is worth noting that the annual total discharge of 4,805,232 m^3/yr obtained using the AV method is higher in relation to the total annual discharge of 1,204,200 m^3/yr obtained by Yusuf (2006) in a study of the Samaru stream using both the weir and AV method in the year 2006. The difference can be attributed to the difference in the position of the gauging station with increasing volume of water passing down the stream.

4.1.1: Rainfall –Discharge Relationship

Rainfall data from Division of Agricultural Colleges (DAC), ABU Zaria provides the rainfall measurement in (mm) that was used in the study for sample collection which began on the 7April and ended on 10October as presented in Table 4.1.1a,regime diagram Table 4.1.1b and Fig.4.1.1a. A total of 1017mm rainfall was recorded for 71days in 2014, showing August with the highest rate of rainfalls for the year with 397.5mm and October the least with 9.4mm.The rain varies from as low as 0.20mm observed in 27June, 2014 to as high as 97.60mm observed on 2August, 2014.

Furthermore, regime diagram Table 4.1.1b shows a peak rainfall of 39% recorded in August, followed by September with 18%. The two months alone contribute 57% of the total annual rainfall in 2014 while the lowest recorded was in October with 1%.Also, the highest peak rainfall per day of 97.60 mm was recorded in August while the lowest is 0.2mm recorded in June as demonstrated in Fig.4.1.1a.

Therefore, Table 4.1.1a and Table 4.1.1bwithFig.4.1.1a shows that Samaru stream is indeed a seasonal stream which flows in relation to the amount and duration of rainfall pattern of the season. August has total rainfall record of 396.7mm with a stream discharge of 1822272.2m^3/month representing 38% of the annually discharge which contributes more than a

quarter of volume of discharge into the stream. September followed by a rainfall record of 186.3mm with a discharge value of 820627.2m^3/month and 18% contribution of discharge into the stream. The least is October with a total rainfall of 10.4mm, a discharge value of 61948.8m^3/month and contributing just 1% of discharge into the stream. The two months of August and September alone contribute about 60% of the stream discharges for the year 2014 while the remaining months contribute 30% of the stream discharges.

Table 4.1.1a: Mean Daily Rainfall Values in mm for 2014

DAYS	JN	FB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NV	DC
1								32.7	3.5	3.6		
2					4.4	3.7		97.6	22.9			
3					24.0		30.2	11.9				
4									3.3	0.6		
5					27.7	23.6		56.0	34.2			
6							7.6					
7				1.6					0.8			
8				11.7			23.2		17.4			
9					6.3			2.7	24.3			
10										6.2		
11							5.1	26.2	10.5			
12							7.0	4.8	2.0			
13					TR	6.4		0.4				
14						17.9		12.0				
15				20.1					13.6			
16						15.8	4.4		14.5			
17						4.1		13.3	9.1			
18					TR		14.7	17.7				
19								0.5	4.2			
20				13.6				2.1				
21							4.7	51.0				
22						9.4	TR	6.2				
23					2.3		TR					
24												
25								20.2				
26				17.4								
27					29.0	0.2						
28				14.5	9.6	16.8	22.7					
29					10.7				7.9			
30				2.5				1.6	18.1			
31					5.2		5.0	40.5				
TOTAL				**81.4**	**119.2**	**97.9**	**124.6**	**397.4**	**186.3**	**10.4**		

Total= 1017mm; 71rain days.

Adopted from Division of Agricultural Colleges Metrological Station (DAC), A.B.U Zaria

Table 4.1.1b: Regime Diagram of Rainfall (mm) in Table 4.1.1a

NO:	MONTHS	RAINFALL (MM)	FRACTION OF TOTAL RAINFALL	PERCENT OF TOTAL RAINFALL (%)
1	JAN	--	--	--
2	FEB	--	--	--
3	MARCH	--	--	--
4	APRIL	81.4	0.08	8
5	MAY	119.2	0.12	12
6	JUNE	97.9	0.10	10
7	JULY	124.6	0.12	12
8	AUG	397.4	0.39	39
9	SEPT	186.3	0.18	18
10	OCT	10.4	0.01	1
11	NOV	--	--	--
12	DEC	--	--	--
TOTAL		1017	1	100

Sum Total=1017mm

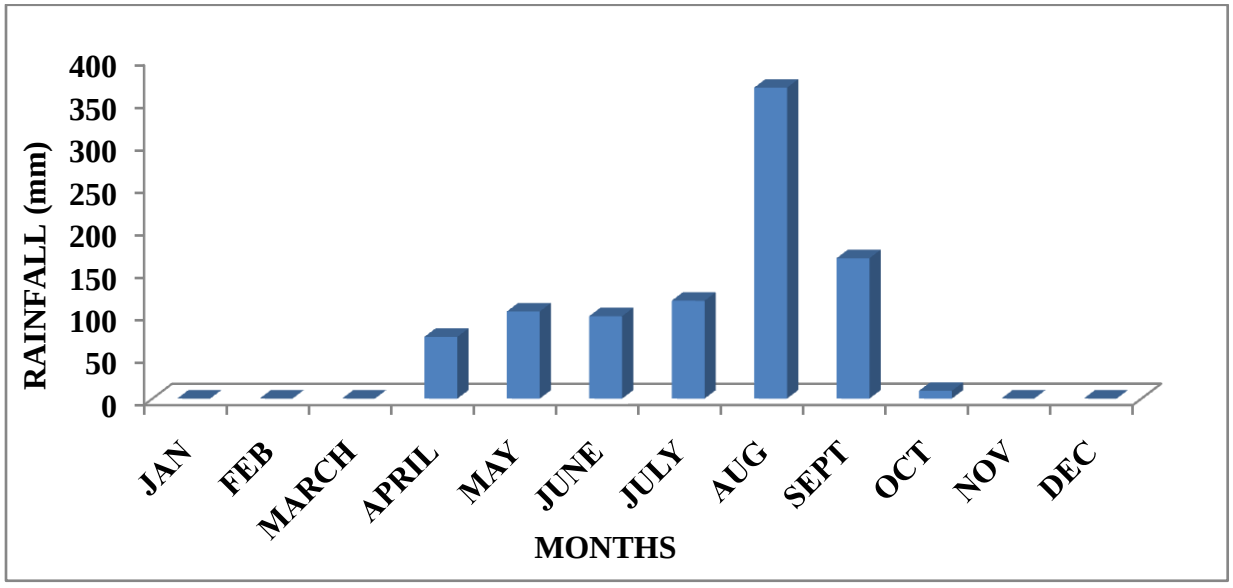


Fig. 4.1b: Rainfall Regime Diagram for 2014

Lastly, another reason observed for the difference in stream discharge was that a total of 58 days of rainfall was recorded in 2006 with the highest rain of 45.30mm while a total of 71 days and the highest rainfall of 97.60mm (Table 4.1.1a) rainfall were recorded in 2014. This gives a rainfall difference of 13days, representing days without instantenous stream discharge measurement records for 2006 against 2014. Therefore, duration and intensity of rainfall occurance plays a significant role in the flow of water in a stream.

Furthermore, a log-log relationship of a rating curve relating the daily mean instantaneous rainfall values to stream discharge is shown in fig.4.1c.

The rating equation derived from the relationship, using their log exponents, as shown in table 4.1.1c is of the form:

$LogQ=10^{0.552}R^{0.036}$(i.e $Q= 3.5645\ R^{0.036}$)…….4.1a

While the regression equation is of the form:

Log Q= 0.552+0.036 log R…...…….4.2b

Therefore, the regression coefficient of correlation (r) value of 0.913 and coefficient of determination (r^2) of 0.834 as shown in Table 4.1.1d

The equations 4.1 and 4.2 illustrated that there is a direct relationship between stream discharge and rainfall which can be verified by checking the significance of the regression coefficient, the t-ratio test was conducted for a and b (intercept and slope) and it was found in both cases that t_a andt_b were statistically significant at the 0.05 level of significance as presented in Table 4.1c. Therefore, we concluded that there is strong relationship between the regression coefficients in both cases.

Furthermore, the coefficient of correlation (r) and the coefficient of determination (r^2) both measure the strength of the linear correlation between the two variables. Both of the values of (r) and (r^2) are high suggesting thestrenght of rainfall in determination of the stream discharge. Also, plot of rainfall (mm) against discharge (m^3/s) of the stream in Fig.4.1.1b gave a lower peak discharge of $0.001m^3/s$ and a higher peak discharge of $4.150m^3/s$ while the log-log relationship between rainfall and discharge shows that there is a direct relationship between discharges and rainfall at 0.05 level of significance.

Table 4.1.1c: Coefficient of R-Q Relation

Factor	Coefficients	Std. Error	T	Sig.
(Constant)	0.552	0.047	11.755	0.000
LOGR	0.036	0.003	11.846	0 .000

a. Dependent Variable: Discharge

Table 4.1.1d: Model Summary for R-Q Relation

R	r^2	Std. Error of The Estimate	F	Sig
0.913	0.834	0.13510	140.334	.000

a. Predictors: (Constant), Rainfall
b. Dependent Variable: Discharge

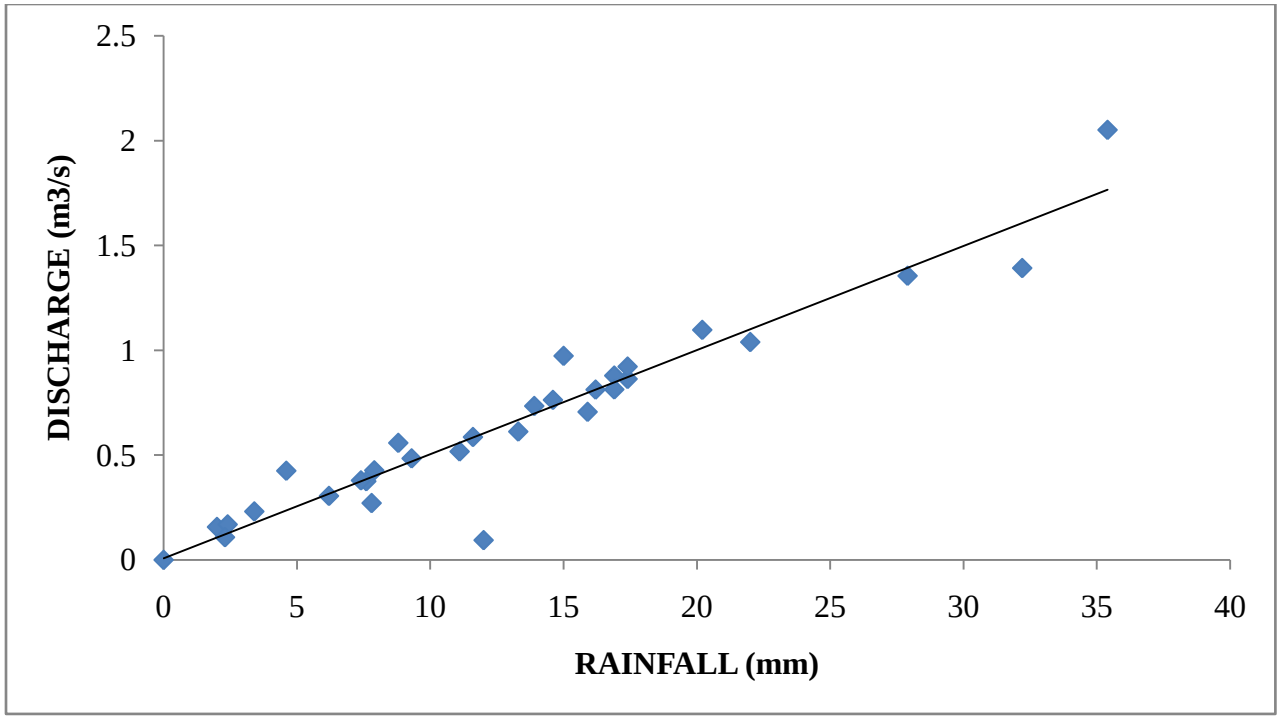


Fig. 4.1.1b: Relationship between Rainfall- Discharges

Comparing the rainfall-discharge relationship obtained by Yusuf (2006) shows that both relationship are strong except for the fact that the values of (r) 0.295 and (r^2) 0.087 are lower for Yusuf (2006) against the coefficient of correlation (r) 0.913 and coefficient of determination (r^2) 0.834 in this study which produces a straight line graph starting from the origin while the former gave a straight line graph which however did not start from the origin, indicating the higher values of (r) and (r^2).

4.2 Dissolved Sediment Concentration (Cd_1)

Data collected on dissolved sediment concentration began on the 7 April, 2014 and ended on 10 October, 2014. These values were the difference in weight of filtered sediment before and after

evaporation in an oven (i.e. filtrate + crucible). The data in (mg/l) is presented in table 4.2a with the summary statistics in table 4.2b.

The result obtained from the summary statistics shows that the range is 100mg/l, a mean value of 58.87mg/l, with a standard error of mean of 3.47, a standard deviation of 292550, a variance of855.855 and a minimum and maximum values of 20mg/l and 120mg/l respectively. These minimum and maximum dissolved sediment concentration values were spread across the year with April marking the commencement of the rainfall season having more of 120mg/l dissolved sediment concentration values while October has values of 20mg/l.

The variation in distributioan of the dissolved sediment values can be explained to the fact that before the commencement of rainfall in April, more mineral compounds or constituents as dissolved materials are being concentrated in the soil surfaces and as the rain commences in April, the mineral matters concentrates are being washed down into the stream as dissolved sediments loads. Another observation is that the rate of dilution of minerals increases as rainfall progresess.

Table 4.2a: Dissolved Sediment Concentration Values of Samaru Stream (mg/l)

DATE	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1								40	40	20		
2					80	40		40	80			
3					80		40	40				
4									40	20		
5					80	40		80	40			
6							40					
7				120					40			
8				120			80		40			
9					40			80	40			
10										40		
11							40	80	20			
12							40	40	20			
13						80		40				
14						80		40				
15				120					40			
16						80	40	40	40			
17						80		40	40			
18							120	40	20			
19												
20				120				40				
21						80	40	40				
22								40				
23					80							
24												
25								40				
26				120								
27					80	120						
28				120	80	80	80					
29					40				40			
30				80				40	40			
31					80		40	40				
TOTAL				**800**	**640**	**680**	**560**	**840**	**580**	**80**		

Sum Total= 4180mg/l

Table 4.2b: Summary Statistics of Table 4.2a

	STATISTICS	VALUE
N	**VALID**	71
	MISSING	143
Mean		58.8732
Std. Error of Mean		3.47193
Std. Deviation		292550
Variance		855.855
Range		100.00
Minimum		20.00
Maximum		120.00
Sum		**4180.00**

Furthermore, values of derived dissolved sediment discharge, a product of dissolved sediment concentration and discharge is presented in table 4.2c and the summary statistics in table 4.2d.

The summary statistics illustrates that derived dissolved sediment discharges varied from as low as 1.14mg/s on 4th of October 2014 to 325.44mg/s on the 5th of August 2014 giving a range of 324.30mg/s, a mean value 44.52mg/s, a standard error of mean of 6.07, a standard deviation of 51.132, a variance of 2615 and a minimum and maximum values of 1.14mg/l and 325.44mg/l respevtively.

Therefore, from the result of the derived dissolved sediment discharge in Table 4.2c, August has the highest value of 1051.6mg/s, followed by April with 480.16mg/s and May with 423.16mg/s. The least monthly dissolved sediment discharge of 16.2mg/s was recorded in October while a total dissolved sediment discharge value of 3161.9mg/s was obtained.

Table 4.2c: Derived Dissolved Sediment Discharge Values of Samaru Stream (mg/s)

DATE	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1								62.28	5.48	2.86		
2					19.6	3.12		165.32	88.96			
3					85.76		55.12	26.68				
4									5.12	1.14		
5					103.36	51.68		325.44	62.12			
6							15					
7				6.84					5.2			
8				60			93.84		36.68			
9					11.28			12.56	44.48			
10										12.2		
11							10.32	103.04	13.1			
12							38	7.48	2.76			
13						25.2		5.88				
14						108.24		23.68				
15				131.4					26.52			
16						67.04	6.68		30.08			
17						56		24.48	14.48			
18							91.44	34.48	7.24			
19								5.68				
20				84.84				5.88				
21							4.8	103.6				
22						8.96		17.2				
23					8.64							
24												
25								43.88				
26				110.64								
27					111.04	16.56						
28				76.44	39.04	54.8	80.96					
29					21.4				17.32			
30				10				4.92	35.6			
31					23.04		6.88	79.12				
TOTAL				**480.16**	**423.16**	**391.6**	**403.04**	**1051.6**	**395.14**	**16.2**		

Table 4.2d: Summary Statistics of Table 4.2c

	STATISTICS	VALUE
N	**VALID**	71
	MISSING	143
Mean		44.5197
Std. Error of Mean		6.06830
Std. Deviation		51.132
Variance		2615
Range		324.30
Minimum		1.14
Maximum		325.44
Sum		**3161.9**

4.3 Dissolved Sediment Concentration, Dissolved Sediment Discharge and Discharge Relationships

4.3.1 Dissolved Sediment Concentration (Cd_1)-Discharge (Q) Relation

A log-log relationship of a rating curve relating the daily mean instantaneous stream discharge values to dissolved sediment concentration is shown in Figure4.3a.

The rating equation derived from the relationship, using their log exponents, as shown in Table 4.3a is of the form:

$LogCd_1=10^{1.737}Q^{0.059}$(i.e $Cd_1= 54.5758\ Q^{0.059}$).....4.3a

While the regression equation is of the form:

Log Cd_1= Log 1.737+0.059log Q……..4.3b

Therefore, the regression coefficient of correlation (r) value of 0.122 and coefficient of determination (r^2) of 0.015 as shown in Table 4.3b.

The equations 4.3a and 4.3b illustrated that there is a direct relationship between dissolved sediment concentration and stream discharge which can be verify by checking the significance of the regression coefficient, the t-ratio test was conducted for a and b (intercept and slope). It was found in both cases that t_a 55.260 and t_b 1.024 were statistically significant at the 0.05 level of significance as presented in Table 4.3a. Therefore, we concluded that there is poor relationship between the regression coefficients in both cases.

As indicated earlier, the coefficient of correlation (r) and coefficient of determination (r^2) measure the strength of the linear correlation between the two variables and the ratio of

explained variation to the total variation. And, both of the values of (r) and (r^2) are low, suggesting that discharge wasnota strong determinant of dissolved sediment concentration (Cs) as seen in Table 4.3b.

The low value of r(0.122) and r^2(0.015) observed which according to a study of sediment yield by Walling (1971), Gregory and Walling (1973) is being attributed as one of the several problems being encountered in studying of sediments.The low r and r^2 may however be linked to the poor relationship between discharge and dissolved sediment concentration values which decreasesas the rain progresses into the year. Furthermore, the graph of relationship between dissolved sediment concentration and discharge in Fig.4.3a gave a low peak dissolved sediment concentration scatter of 20mg/l and a high peak scatter of 120mg/l.

Table 4.3a: Coefficient of Cd_1-Q Relation

Factor	Coefficients	Std. Error	t	Sig.
(Constant)	1.737	0.031	55.260	0.000
LOGQ	0.059	0.058	1.024	0.309

a. Dependent Variable: $LOGCd_1$

Table 4.3b: Model Summary for Cd_1-Q Relation

R	r^2	Std. Error of the Estimate	F	Sig.
0.122	0.015	0.21083	1.049	0.309

a. Predictors: (Constant),LOGQ

b. Dependent Variable:$LOGCd_1$

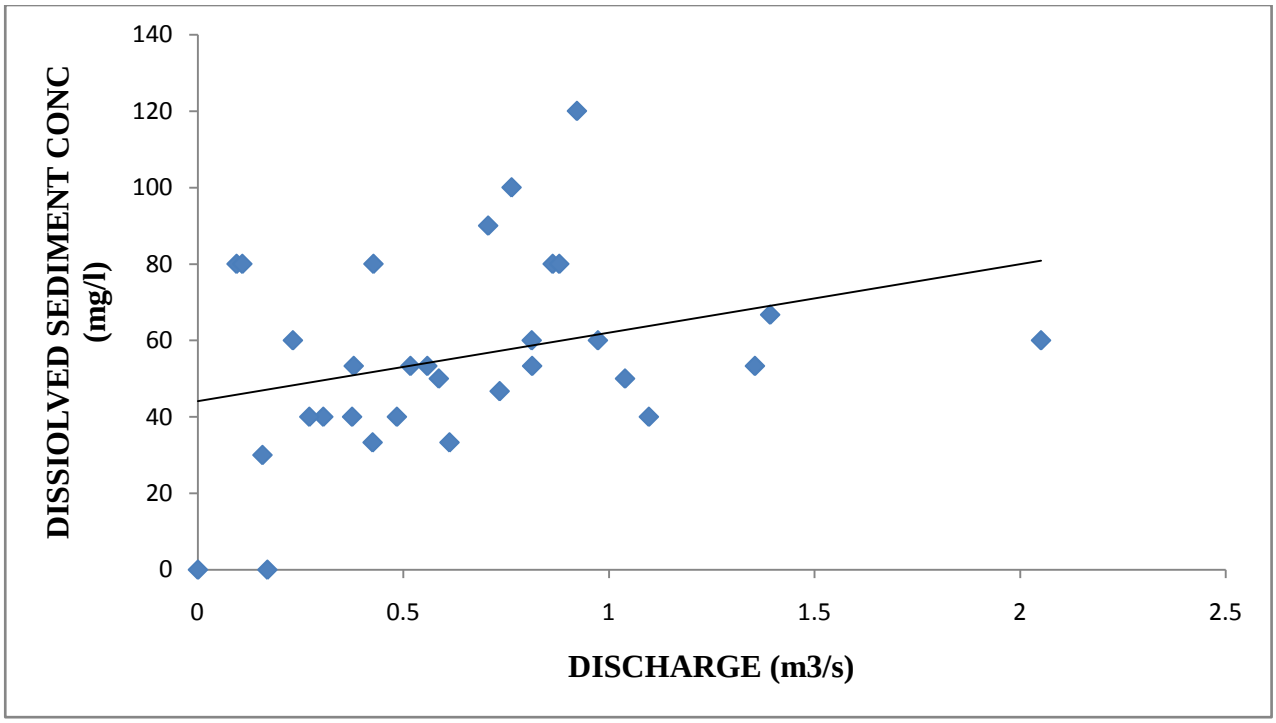


Fig.4.3a: Graph of Relationship Between Dissolved Sediment Concentration (Cd_1) and Discharge (Q)

Comparing the relationship between dissolved sediment concentration (Cd_1) and discharge (Q) of Samaru stream with a study by Yusuf and Igbinigie (2010) where they found that there is a direct relationship between dissolved sediment concentration and discharge with (r) 0.042 and (r^2) 0.002 against the (r) 0.122 and (r^2) 0.015 of this study. Both values were however low which indicates that the relationship is a weak one.

4.3.2 Dissolved Sediment Discharge (Qd) - Discharge (Q) Relation

A log-log relationship of a rating curve relating the daily mean instantaneous discharge values to dissolved sediment discharge is shown in Fig. 4.3b.

The rating equation derived from the relationship, using their log exponents, as shown in Table 4.3c is of the form:

Log Qd=$10^{2.068}Q^{57.576}$(i.e Qd= 52.845 $Q^{57.576}$…….4.3c

While the regression equation is of the form:

Log Qd= Log 2.068+ 57.576 log Q…….4.3d

Therefore, the regression coefficient of correlation (r) value of 0.866 and coefficient of determination (r^2) of 0.749 as shown in Table 4.3c.

The equations 4.3c and 4.3d illustrated that there is a direct relationship between dissolved sediment discharge and discharge which can be verify by checking the significance of the regression coefficient, the t-ratio test was conducted for a and b (intercept and slope). It was found in both cases that t_a 43.689 and t_b 14.361 were statically significant at the 0.05 level of significance as presented in Table 4.3c. Therefore, we concluded that there is strong relationship between the regression coefficients in both cases. Furthermore, the graph of relationship between dissolved sediment discharge and discharge in Fig. 4.3b gave a low peak dissolved sediment discharge scatter of 0.1mg/s and a high peak scatter of 325mg/s.

Table 4.3c: Coefficient of Qd-Q Relation

Factor	Coefficients	Std. Error	T	Sig.
(Constant)	2.068	0.060	23.631	0.000
LOGQ	57.576	0.073	14.361	0.000

a. Dependent Variable: Qd

Table 4.3d: Model Summary for Qd-Q Relation

R	r^2	Std. Error of the Estimate	F	Sig.
0.866	0.749	0.26446	206.248	0.000

a. Predictors: (Constant), LOGQ

b. Dependent Variable: LOGQd

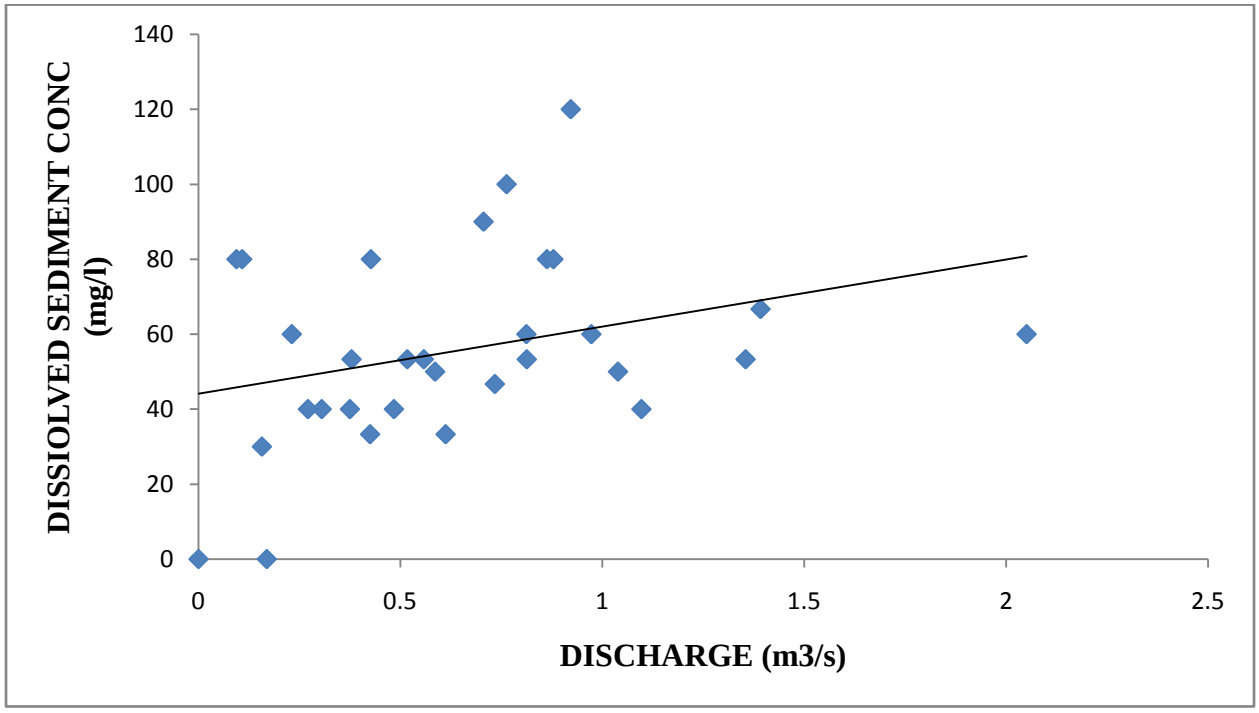


Figure 4.3b: Graph of Relationship between Dissolved Sediment Discharge (Qd) and Discharge (Q)

Comparing this relationship with a study by Yusuf and Igbinigie (2010) where they examined the relationship between dissolved sediment discharges (Qd) and discharge (Q) of Samaru stream and found that there is a direct relationship between Qd and Q with (r) 0.901 and (r^2) 0.812 values which corresponded to a (r) 0.866 and (r^2) 0.749 values obatined in this study. Both relationships ofQd and Q are however strong. The 2014 study was therefore found to be in agreement with the 2010 study of Yusuf and Igbinigie.

4.3.3 Dissolved Sediment Concentration (Cd_1)- Dissolved Sediment Discharge (Qd) Relation

A log-log relationship of a rating curve relating the daily mean instantaneous dissolved sediment discharge values to dissolved sediment concentration is shown in Figure 4.3c.

The rating equation derived from the relationship, using their log exponents, as shown in Table 4.3e is of the form:

$\text{Log } Cd_1 = 10^{1.415} Qd^{0.219}$ (i.e $Cd_1 = 26.002\ Qd^{0.020}$ ……4.3e

While the regression equation is of the form:

$\text{Log } Cd_1 = \text{Log } 1.4150 + 0.020 \log Qd$……4.3f

Therefore, the regression coefficient of correlation (r) value of 0.545 and coefficient of determination (r^2) of 0.296 as shown in table 4.3f.

The equations 4.3e and 4.3f illustrated that there is a direct relationship between dissolved sediment concentration and dissolved sediment discharge which can be verified by checking the significance of the regression coefficient, the t-ratio test was conducted for a and b (intercept and slope). Both values of r (0.545) and r^2 (0.296) were not very high as seen from the straight line graph in Figure 4.3c which did not start from the origin. Also, it was found that t_a 23.631 and t_b 5.393 were statically significant at the 0.05 level of significance as presented in Table 4.3e. Therefore, we concluded that there is weak relationship between the regression coefficients in both cases. Furthermore, the graph of relationship between dissolved sediment concentration and dissolved sediment discharge in Figure 4.3c, gave a low peak dissolved sediment concentration scatter of 20mg/l and a high peak scatter of

120 mg/l which corresponded to 0.1mg/s low peak scatter and 325mg/s high peak scatter of dissolved sediment discharges.

Table 4.3e: Coefficient of Cd_1- Qd Relation.

Factor	Coefficients	Std. Error	t	Sig.
(Constant)	1.415	0.060	23.631	0.000
LOGQd	0.219	0.041	5.393	0.000

a. Dependent Variable: $LOQCd_1$

Table 4.3f: Model Summary for Cd_1- Qd Relation

R	r^2	Std. Error of the Estimate	F	Sig.
0.545	0.296	0.17817	29.080	0.000

a. Predictors: (Constant), LOGQd

b. Dependent Variable: $LOGCd_1$

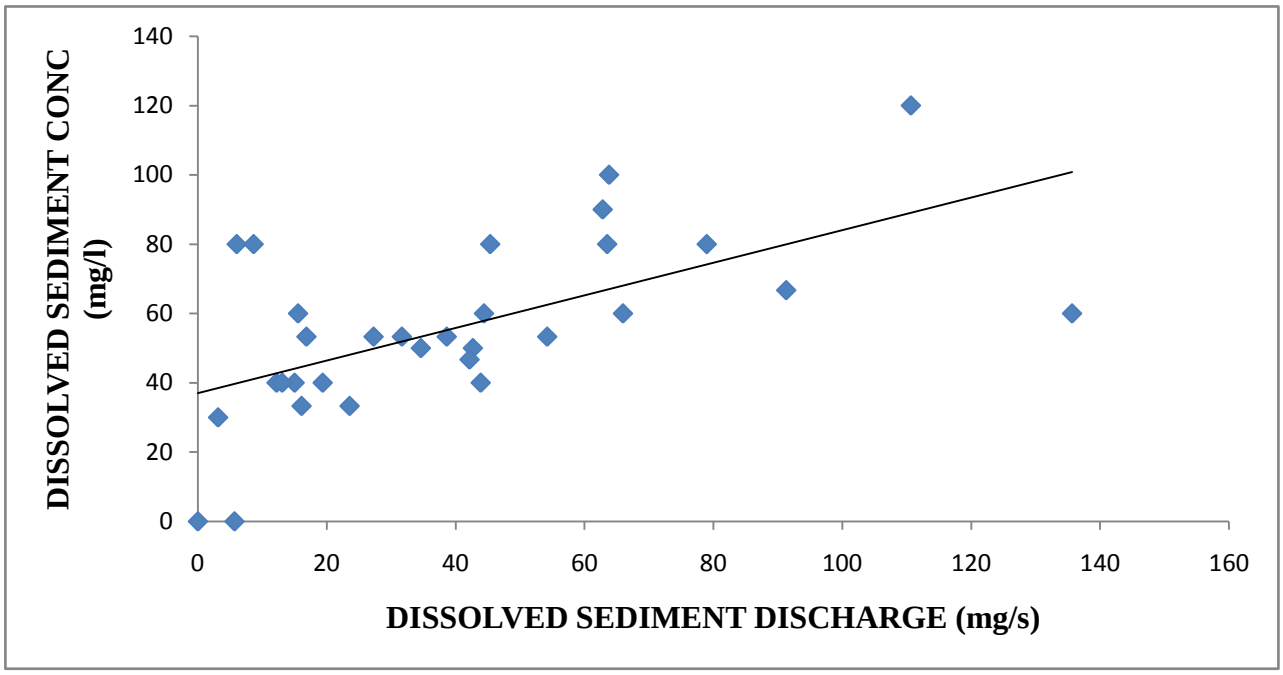


Fig. 4.3c: Graph of Relationship between Dissolved Sediment Concentration (Cd) and Dissolved Sediment Discharge (Qd)

4.3.4 Estimation of Dissolved Sediment Yield

In order to find the dissolved sediment yield for the period of study, equation 4.3d, was used in estimatingthe dissolved sediment discharges in mg/s which gave a total of 3085.1mg/s as presented in the Table 4.3.4a while using equation 3.5, dissolved sediment discharges in mg/s is converted to kg/day as displayed in Table 4.3.4b and the summary statistics in Table 4.3.4c which gives a total dissolved sediment discharge (Qd) of 174,000kg/yr varying from as low as 27.65kg/day on the 21st and 22nd of May, 2014 to 20,600kg/day on the 2nd of August, 2014 which gives a range of 20,600kg/day with a mean daily value of 861.13kg/day, a standard deviation of 2432, a variance of 5915000.

Table 4.3.4d gives the derived monthly distribution of dissolved sediment discharge while the regime graph is illustrated in Figure 4.3.4a. It was observed that high dissolved sediment discharges were experienced in August with peak dissolved sediment discharges of 52% then followed by September with 28 % and April with 7 % while the lowest dissolved sediment discharges was experienced in the month of May and October with just 3% contributaion respectively of dissolved sediment discharges. Figure 4.3.4a further shows the graphical representation of the percent dissolved sediment discharge values of the months in the year.

Table 4.3.4a: Dissolved Sediment Discharge Values of Samaru Stream (mg/s)

DATE	JN	FB	MR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NV	DC
1					1.47	1.47	1.24	89.96	8.20	8.55		
2					14.42	4.81	1.12	238.28	64.34	2.04		
3					62.04	0.89	79.66	38.72	2.04	1.75		
4					1.47	0.78	1.47	2.04	7.69	3.60		
5					74.70	74.70	1.35	234.53	89.73	1.47		
6					1.47	1.47	21.91	2.043	2.04	1.35		
7				3.60	1.35	1.18	1.47	1.75	7.80	1.24		
8				29.10	1.24	1.06	67.85	1.47	53.11	1.12		
9				1.47	16.55	0.89	1.47	9.35	64.34	1.01		
10				1.35	1.47	0.78	1.35	1.47	2.04	17.88		
11				1.24	1.35	0.66	15.17	74.47	38.03	1.47		
12				1.12	1.12	0.55	55.01	11.08	8.26	1.47		
13				1.01	1.01	18.45	1.47	8.78	2.04	1.47		
14				0.89	0.89	78.22	1.35	34.40	1.75	1.47		
15				63.36	0.78	1.47	1.24	2.04	38.49	1.47		
16				1.58	0.66	48.56	9.93	1.75	43.61	0.89		
17				1.35	0.55	40.62	1.35	35.55	21.16	0.89		
18				1.24	0.43	1.46	44.19	49.95	11.54	0.89		
19				1.12	0.43	1.35	1.47	8.49	2.04	0.89		
20				41.02	0.43	1.24	1.35	8.78	1.75	0.89		
21				1.47	0.32	1.12	7.22	49.44	1.64	0.89		
22				1.35	0.32	6.76	1.35	25.07	1.47	0.89		
23				1.24	6.54	1.12	1.24	2.04	1.35	0.89		
24				1.12	1.47	1.01	1.12	1.75	1.23	0.89		
25				1.01	1.35	0.89	1.01	63.48	1.12	0.89		
26				53.40	1.24	0.78	0.89	1.75	1.01			
27				1.47	80.23	8.26	0.77	1.47	0.89			
28				36.99	28.41	39.76	58.58	1.35	0.78			
29				1.47	31.12	1.47	1.47	1.24	25.25			
30				7.51	1.47	1.35	1.35	7.40	51.56			
31					16.90		10.22	114.20				
TOTAL				**256.48**	**352.20**	**343.13**	**396.64**	**1124.09**	**556.30**	**56.26**		

Sum Total= 3085.1mg/s

Table 4.3.4b: Dissolved Sediment Discharge Values kg/day for 2014

DATE	JN	FB	MR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NV	DC
1					127.01	127.01	107.14	777.25	708.48	738.72		
2					124.59	415.58	96.77	20587.39	5472.58	176.26		
3					536.03	76.90	688.26	3345.41	176.27	151.20		
4					127.01	67.39	127.01	176.26	664.42	311.04		
5					745.41	645.41	116.64	20263.39	7752.67	127.01		
6					127.01	127.01	189.30	176.26	176.26	116.64		
7				311.04	116.64	101.95	127.01	151.20	673.92	107.14		
8				2514.24	107.14	91.59	586.22	127.01	4588.70	96.77		
9				127.01	142.99	76.90	127.01	807.84	5558.98	87.26		
10				116.64	127.01	67.39	116.40	127.01	176.26	1544.83		
11				107.14	116.64	57.02	131.07	6434.21	3285.80	127.01		
12				96.77	96.77	47.52	475.29	957.31	713.66	127.01		
13				87.26	87.26	159.41	127.01	758.59	176.26	127.01		
14				76.90	74.30	675.21	116.64	2972.16	151.20	127.01		
15				5474.30	67.39	127.01	107.14	1762.56	3325.54	127.01		
16				136.51	57.02	419.56	85.80	151.20	3767.90	76.90		
17				116.64	47.52	350.96	116.64	3071.52	1828.22	76.90		
18				107.14	37.15	126.14	381.80	4315.68	997.06	76.90		
19				96.77	37.15	116.64	127.01	733.54	176.26	76.90		
20				354.41	37.15	107.14	116.64	758.59	151.20	76.90		
21				127.01	27.65	96.77	623.81	4271.62	141.70	76.90		
22				116.64	27.65	584.06	116.64	2166.05	127.01	76.90		
23				107.14	56.51	96.77	107.14	176.26	116.64	76.90		
24				96.77	127.01	87.26	103.68	151.20	106.27	76.90		
25				87.26	107.14	76.90	87.26	5484.67	96.77	76.90		
26				461.38	107.14	67.39	76.90	151.20	87.26			
27				127.01	693.19	713.66	66.53	127.01	76.90			
28				319.60	245.46	343.53	506.13	116.64	67.39			
29				127.01	268.88	127.01	127.01	107.14	2181.60			
30				64.89	127.01	116.64	107.14	639.36	4454.78			
31					146.01		883.01	9866.88				
TOTAL				**11357.48**	**4872.84**	**6293.73**	**6872.05**	**91712.41**	**47977.96**	**4860.92**		

Sum Total= 174, 000 kg/yr

Table 4.3.4c: Summary Statistics of Table 4.2f

	STATISTICS	VALUE
N	**VALID**	202
	MISSING	12
Mean		861.13
Std. Error of Mean		171.11
Std. Deviation		2432
Variance		5915000
Range		20600
Minimum		27.65
Maximum		20600
Sum		174000

Table 4.3.4d: Regime Diagram Table for Dissolved Sediment Dicharge (kg/day)

NO:	MONTHS	DISSOLVED SEDIMENT DISCHARGE (g/month)	FRACTION OF TOTAL DISSOLVED DISCHARGE (g/month)	PERCENT OF TOTAL DISSOLVED DISCHARGE (%)
1	**JAN**	--	--	--
2	**FEB**	--	--	--
3	**MARCH**	--	--	--
4	**APRIL**	11357.48	0.07	7
5	**MAY**	4872.84	0.03	3
6	**JUNE**	6293.73	0.04	4
7	**JULY**	6872.05	0.04	4
8	**AUG**	91712.41	0.52	52
9	**SEPT**	47977.96	0.28	28
10	**OCT**	4860.92	0.03	3
11	**NOV**	--	--	--
12	**DEC**	--	--	--
TOTAL		**174 000**	**1.0**	**100**

Sum Total= 174,000 kg/yr

Lastly, in order to estimate the dissolved sediment yield produced, the annual total dissolved sediment yield of 174,000kg/yr derived from equation 3.5 and presented in Table 4.3.4b is divided by 1000 which gives a Channel Sediment Yield (CYS) value of 174tons/km^2/yr. The amount is high and can be attributed to the anthropogenic activities taking place upstream.

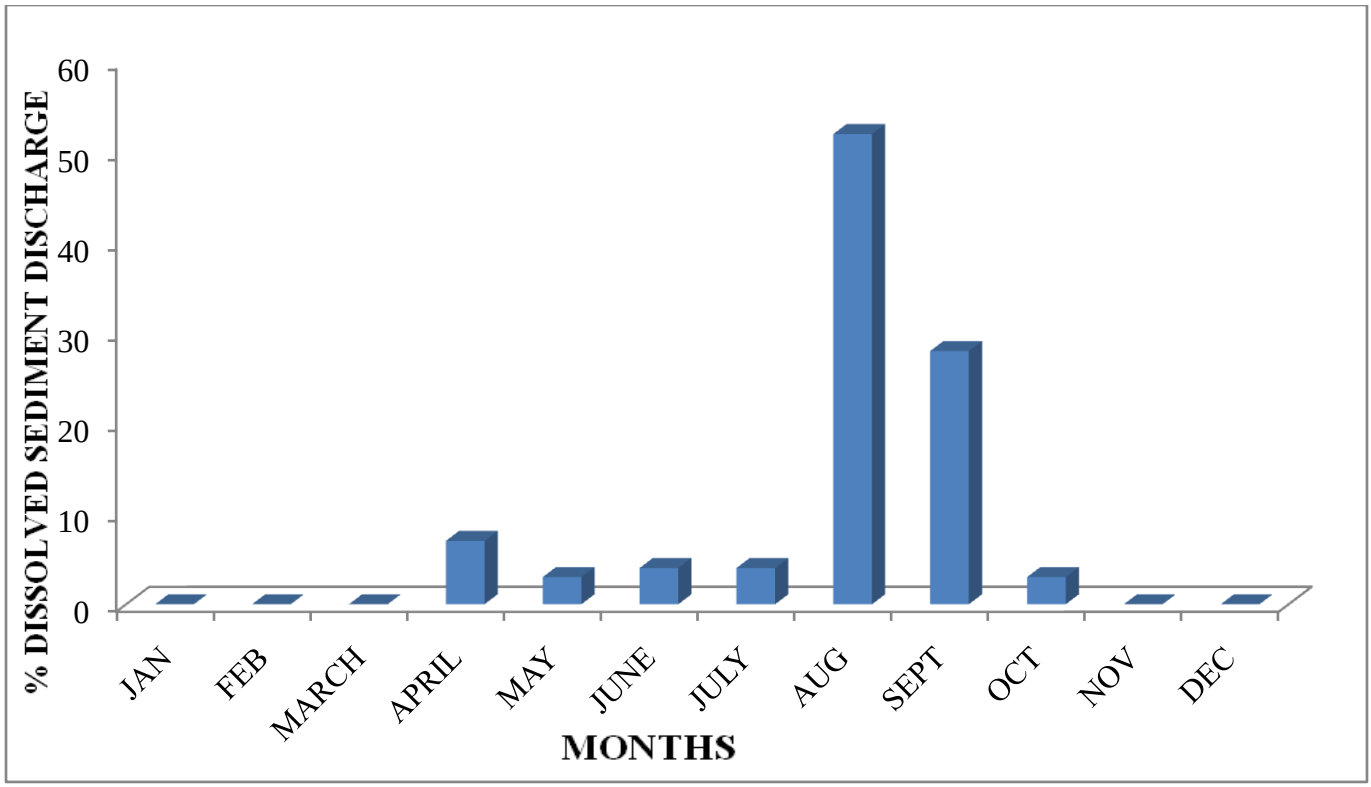


Fig. 4.3.4a: Regime Graph of Dissolved Sediment Discharge (kg/month) for 2014

4.4: Mineral Composition and Heavy Metals.

Based on the sample size for a mobile matrix by Keith, Patton and Edward (1996) of 33 samples calculated and applying systematic random sampling gave a total of 3 samples that were analysed throughout the year. The sediment samples therefore, analyzed by the XRF includessample collected on the first day of rainfall on the 7th of April, 2014, the middle day of rainfall on the 18th ofJuly, 2014 and the last day of rainfall collected on 10th of October, 2014which were prepared into residual form in the Geography department physical laboratory before taking to Defense Industries Cooperation of Nigeria (DICON).

After the analysis, 14 compounds were found in sediment one; with 8 heavy metals while 15 mineral compounds were found in sediment two; with also 8 heavy metals present and lastly,16 mineral compounds were found in sediment three which contains 10 heavy metals. The results of the analyses are presented in Table 4.4a and 4.4b for the compounds and elements obtained while their mean values is presented in Table 4.4c and 4.4d respectively. Altogether, a total of 17 mineral compounds were identified for the three samples. They are; Al_2O_3, SiO_2, SO_3, Cl, K_2O, CaO, TiO_2, V_2O_5, MnO, Fe_2O_3, NiO, ZnO, Y_2O_3, BaO, Eu_2O_3, Yb_2O_3 and Re_2O_7. Out of the 16 compounds identified, 11 are heavy metals derivatives. They include; Al_2O_3, TiO_2, V_2O_5, MnO, Fe_2O_3, NiO, ZnO, Y_2O_3, Eu_2O_3, Yb_2O_3 and Re_2O_7. Aluminum and titanium although, light metals are sometimes referred to as heavy metals in view of their toxicity to health. They are heavy metals because at low concentration they are regarded toxic and hazardous to health. The remaining 5 compounds such as chlorine (Cl), sulphur oxides (SO_3), silicon oxide (SiO) are classified as non-metallic oxides.

Table 4.4a: Concentration of Compounds From XRF Analysis of Residue Sample

Sediment 1			Sediment 2			Sediment 3		
	%	Mg/l	%	Mg/l	%	Mg/l			
SiO_2	10.5	3			Al_2O_3	1.9	0.38	SiO_2	9.62	1.28
SO_3	11.9	3.4			SiO_2	6.74	1.35	SO_3	13.0	1.73
Cl	25.3	7.23			SO3	9.61	1.92	Cl	24.6	3.28
K_2O	8.09	2.3			Cl	22.0	4.4	K_2O	9.36	1.25
CaO	42.49	12.14			K_2O	13.4	2.68	CaO	41.95	5.59
TiO_2	0.10	0.03			CaO	44.61	8.92	TiO_2	0.11	0.015
V_2O_5	0.004	0.001			TiO_2	0.071	0.014	V_2O_5	0.004	0.0005
MnO	0.063	0.018			MnO	0.03	0.006	MnO	0.029	0.004
Fe_2O_3	0.522	0.15			Fe_2O_3	0.560	0.112	Fe_2O_3	0.512	0.07
NiO	0.341	0.10			NiO	0.349	0.07	NiO	0.15	0.02
ZnO	0.040	0.01			ZnO	0.02	0.004	ZnO	0.038	0.005
Y_2O_3	0.45	0.13			Y_2O_3	0.29	0.06	Y_2O_3	0.3	0.04
BaO	0.12	0.03			BaO	0.14	0.03	BaO	0.13	0.017
Re_2O_7	0.08	0.02			Eu_2O_3	0.11	0.02	Eu_2O_3	0.11	0.015
					Re_2O_7	0.15	0.03	Yb_2O_3	0.01	0.001
								Re_2O_7	0.15	0.02
Total	**100**	**28.559**				**99.98**	**19.996**		**100.073**	**13.338**

Table 4.4b: Concentration of Elements From XRF Analysis of Residue Sample

Sediment 1			Sediment 2			Sediment 3		
	%	Mg/l	%	Mg/l				
Si	4.74	1.35	**Al**	0.81	0.16	**Si**	4.22	0.56
S	5.41	1.55	**Si**	2.92	0.58	**S**	6.03	0.84
Cl	33.1	9.46	**S**	4.32	0.86	**Cl**	31.1	4.15
K	9.57	2.73	**Cl**	27.00	5.4	**K**	11.1	1.48
Ca	45.24	12.93	**K**	15.5	3.1	**Ca**	45.73	6.10
Ti	0.10	0.03	**Ca**	47.31	9.46	**Ti**	0.097	0.013
V	0.007	0.002	**Ti**	0.069	0.014	**V**	0.0	0.0
Mn	0.071	0.02	**Mn**	0.03	0.006	**Mn**	0.03	0.004
Fe	0.561	0.16	**Fe**	0.670	0.134	**Fe**	0.614	0.08
Ni	0.417	0.12	**Ni**	0.457	0.09	**Ni**	0.20	0.03
Zn	0.033	0.009	**Zn**	0.04	0.008	**Zn**	0.061	0.008
Y	0.41	0.12	**Y**	0.25	0.05	**Y**	0.2	0.03
Ba	0.17	0.05	**Ba**	0.21	0.042	**Ba**	0.21	0.03
Re	0.16	0.05	**Eu**	0.21	0.042	**Eu**	0.17	0.02
			Re	0.2	0.04	**Yb**	0.0	0.0
						Re	0.2	0.03
Total	**99.989**	**28.581**		**99.996**	**19.986**		**99.96**	**13.375**

The variation in the number of compounds indentified for each sediment sample can be attributed to the factors that influence dissolved sediment load and the volume and intensity of rainfall experienced because it was observed that the sample taken at the first rainfall of the year contains 14 compounds, the middle rain contains 15 compounds while the third rain contians 16 compounds in that order. These suggest that as the rain progresses there are more particles that are being eroded from the earth as dissolved sediment to become mineral compounds in the stream.

Table 4.4a gives the total concentration values obtained in the residue sediment samples in their compoundform which shows that sediment one has calcium oxide (CaO) as the most abundant mineral with 42.49% and vanadium oxide (V_2O_5) is the least abundant with 0.004% and a total percent concentration of 99.989%.

Sediment two again has calcium oxide (CaO) as the most abundant mineral with 44.61% while manganese oxide (MnO) is the least abundant mineral with 0.03% and a total percent concentration of 99.996%.

Lastly, the third and final sediment three also has calcium oxide (CaO) as the most abundant mineral compound with 41.95% and vanadium oxide (V_2O_5) is the least in abundance with 0.004% and a total percent concentration of 99.96%.

Also, Table 4.4c and Table 4.4d gives the three combined sediments in summed and the average taken. This was done in order to get a good representation of each element in the three sediments analysed.

Therefore, Table 4.4c and Figure 4.4a showsCaO as the most abundant mineral compound found with a mean concentration value of 8.8mg/l while the least are V_2O_5 and Re_2O_7 with mean value of 0.001mg/l. A total mean concentration value of 25.621mg/l was calculated for all compounds identified from the XRF analysis of the residue sample.

Table 4.4d and Figure 4.4b on the other hand identified Ca as the most abundant element found with a mean concentration value of 9.50mg/l and the least is V with 0.002mg/l while a total mean concentration value of 21.839mg/l was calculated for all the elements identified from the XRF analysis of the residue sample. The mean concentration value of Ca when compare with a recent study of the stream by Garba *et al*. (2014) using a V2000 multi analyte photometer gave a mean concentration value of Ca as 10.02mg/l indicating a close similarities in abundance and that the concentration of Ca have reduced with about 0.52mg/l.

Table 4.4c: Mean of Compounds from Residue Sample

NO	COMPOUNDS	MEAN (mg/l)
1	Al_2O_3	0.38
2	SiO_2	1.88
3	SO_3	2.35
4	Cl	4.97
5	K_2O	5.40
6	CaO	8.88
7	TiO_2	0.02
8	V_2O_5	0.001
9	MnO	0.025
10	Fe_2O_3	1.29
11	NiO	0.06
12	ZnO	0.006
13	Y_2O_3	0.20
14	BaO	0.07
15	Eu_2O_3	0.028
16	Re_2O_7	0.001
17	Yb_2O_3	0.06
TOTAL		**25.621**

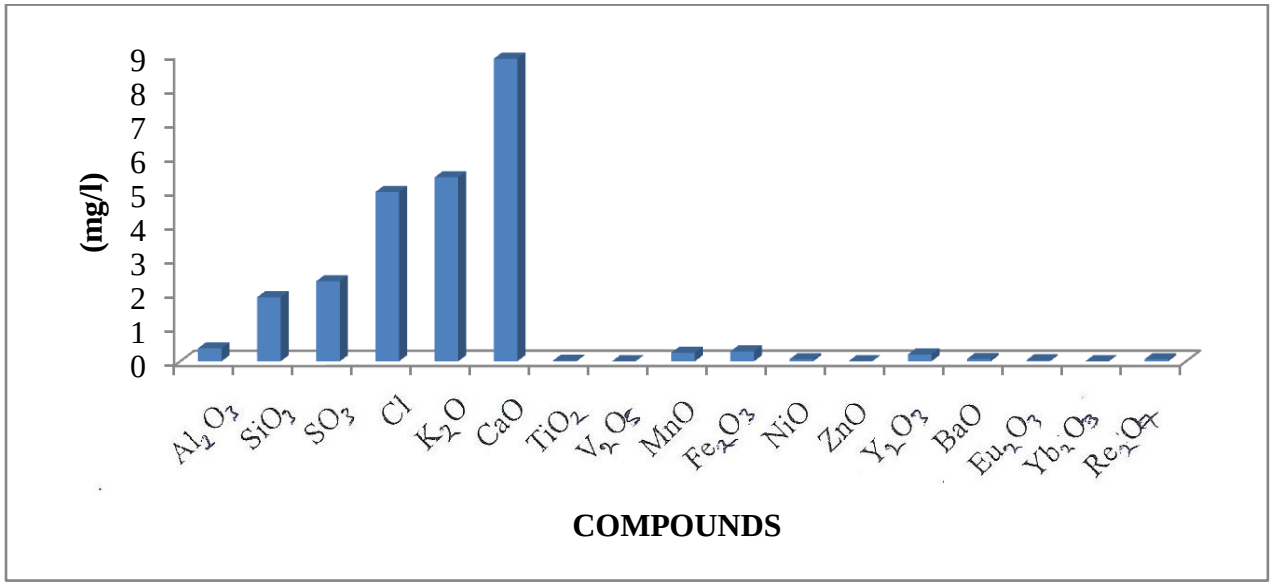


Figure. 4.4a: Mean Regime Graph of Compounds from Residue

Table 4.4d: Mean of Elements from Residue Sample

NO	ELEMENTS	MEAN (mg/l)
1	Al	0.16
2	Si	0.83
3	S	1.02
4	Cl	6.34
5	K	2.44
6	Ca	9.50
7	Ti	0.019
8	V	0.002
9	Mn	0.01
10	Fe	1.25
11	Ni	0.08
12	Zn	0.008
13	Y	0.07
14	Ba	0.04
15	Eu	0.03
16	Re	0.0
17	Yb	0.04
TOTAL		**21.839**

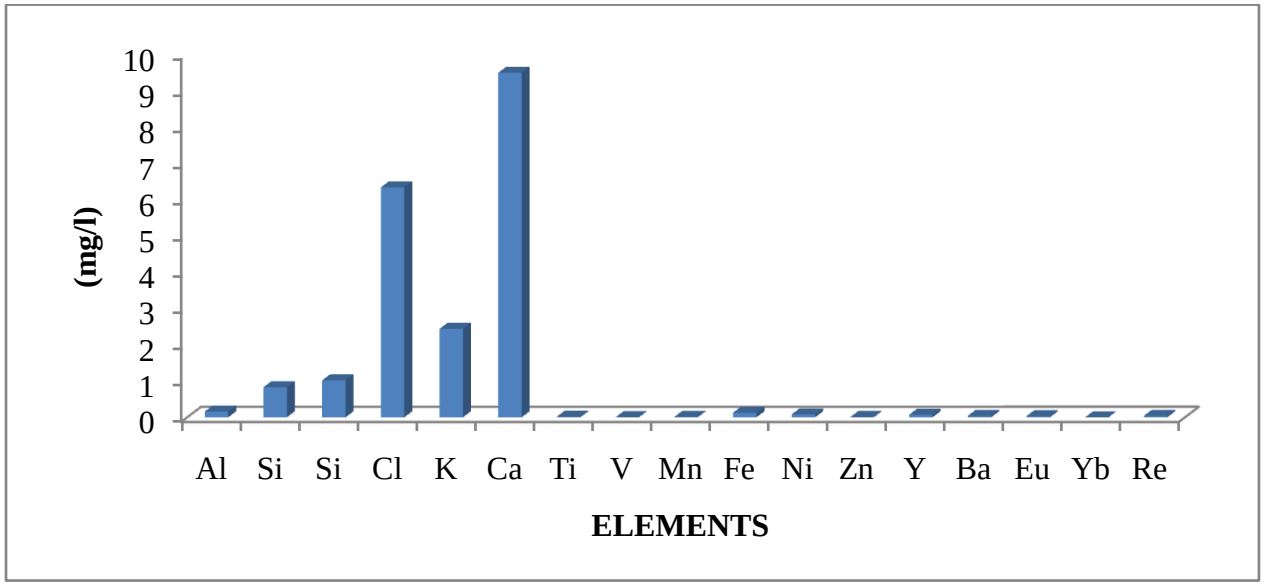


Figure.4.4b: Mean Regime Graph of Elements from Residue

Oxides are binary components of oxygen (O_2) with another element to form compounds of oxygen (e.g. CO_2, ZnO and SO_2) which occurs under various reaction processes such as; direct heating with O_2 (e.g.bush burning: $2Mg + O_2 \rightarrow 2MgO$), reaction of O_2 with compounds at higher temperature ($2PbS + 3O_2 \rightarrow 2PbO + 2SO_2$) etc.Compounds of O_2 can be form from metals and non-metals as acidic, basic, amphoteric, neutral and or compound oxides depending on their reaction with water (H_2O) to give an acid, base, salt and water or a mixture of salts (Emsley, 1971; Greenwood and Earnshaw, 2002; Zumbahl, 2014; Helmenstine, 2014).

As earlier discussed under "Water Pollutants" in Page 48 of this study that the criteria used in defining heavy metals are; density ranging from $3g/cm^3$ to $7g/cm^3$, atomic weight starts from greater than 40, atomic number greater than 20 and ends at 90 (Harbashi, 2009) and specific gravity that is atleast 5 times the specific gravity of water (Lide, 1992) while Hawkes (1997) defined all metalsin group 3 to 16 and period 4 and greater in the periodic table as heavy metals. Based on these classification Ca, Ba and K although, alkali metals are not considered and reffered to as heavy metals. Therefore, the following; CaO, BaO and K_2O are classified as non-heavy metal compounds. Al on the other hand, an alkaline earth metal in group 3 and period 2 of the periodic table, atomic number of 13 and specific gravity of 2.56 is being referred to as an heavy metal because it is injurious in excess amount to human health and does not metabolise and degrade fast in the environment.Therefore, Al_2O_3 is classified as a heavy metal and assigned a NESREA and WHO standard.

Table 4.4e therefore, presents the classification of the sediments identified from the XRF analysis of the residue sample into compounds of heavy metals and compounds of non-heavy metals in (mg/l) in order to provide information on the nature of mineral composition and distribution in the sediments in regards to toxicity.

Table 4.4e: Compounds of Heavy Metals and compounds of Non-Heavy Metalsfrom Residue of Sediment Sample (Mg/l)

NO:	HEAVY-METAL COMPOUNDS	Mg/L	NON-HEAVY METAL COMPOUNDS	Mg/L
1	Al_2O_3	0.38	SiO_2	1.88
2	TiO_2	0.02	SO_3	2.35
3	V_2O_5	0.0013	Cl	4.97
4	MnO	0.25	K_2O	5.40
5	Fe_2O_3	1.25	CaO	8.88
6	NiO	0.06	BaO	0.07
7	ZnO	0.006	----	0
8	Y_2O_3	0.20	----	0
9	Eu_2O_3	0.28	----	0
10	Yb_2O_3	0.001	----	0
11	Re_2O_7	0.06	----	0
TOTAL		**2.5803**		**14.67**

4.5 Comparison of Analysis with NSDQW and WHO standard

In order to achieve an adequate environmental protection measure with consideration to countries socio-economic and climatic differences, standards are therefore set based on nationally environmental baseline data (WHO, 2011). For this study, the(WHO, 2011) and (NSDQW, 2007)standards were adopted for water quality which comprises recommended standards for drinking water, domestic use and discharges into the stream.

The result of the analysis as shown in Table 4.5a, level of concentration of Al, Mn, Fe,and Ni are above the (WHO, 2011) and (NSDQW, 2007) recommended standards for both drinking and discharges into stream except for Zn and Ti which were found to be below limits while the remaining metals V, Y, Eu, Yb and Re are however not specified for (WHO, 2011) and (NSDQW, 2007) comparison. The heavy metals therefore identified and their corresponding

accepatable limits for drinking purposes or discharges into stream are; Al, Mn, Fe, Ni, Zn and Ti (FEPA, 1988; NSDQW, 2007; WHO, 2011).

Table 4.5a: Heavy Metals Present and Their Acceptable Limits for Drinking Water

NO:	HEAV METAL	PPM	PPB	Mg/l	NSDQW STANDARD (mg/l)	WHO STANDARD (mg/l)
1	Al	0.38	380	0.16	Below 0.2	Below 0.2
2	Ti	0.02	20	0.02	Not specified	Not specified
3	V	0.0013	1.3	0.002	Not specified	Not specified
4	Mn	0.25	250	0.01	Below 0.2	Below 0.1
5	Fe	1.25	1250	1.25	Below 0.3	Below 0.3
6	Ni	0.08	80	0.08	Below 0.02	Below 0.07
7	Zn	0.06	60	0.008	Below 3	Below 3
8	Y	0.20	200	0.07	Not specified	Not specified
9	Eu	0.028	28	0.03	Not specified	Not specified
10	Re	0.06	60	0.0	Not specified	Not specified

Adopted from World Health Organization (WHO) and Nigerian Standard for Drinking Water Quality (NSDQW) water quality guidelines

Table 4.5a givesthe average values of heavy metals identified in the three sediments for the XRF analysis and their recommended limits fordrinking purposes into the stream by (WHO, 2011) and (NSDQW, 2007).The table shows that most of the elements with the exception of those not specified are above the threshold limits. Nickel (Ni) which has been identified as one of the most toxic heavy metal was found to contain a value of 0.08mg/l while its acceptable limit is 0.02 and 0.07 by (WHO, 2011) and (NSDQW, 2007) respectively. Others are iron (Fe) with a value of 1.25mg/l and a recommended limits of 0.3mg/l. However, Zinc (Zn) which has a value of 0.09mg/l and a recommended limit of 3mg/l was found to be within the limits recommended.

Table 4.5b on the other hand presents the average values of heavy metals identified in the three sediments from the XRF analysis and their recommended limits for discharges into the stream by (WHO, 2011) and (NSDQW, 2007).

Table 4.5b: Heavy Metals Present and Their Acceptable Limits for Discharge into Streams

NO:	HEAVY METAL	PPM	PPB	Mg/l	NSDQW STANDARD (mg/l)	WHO STANDARD (mg/l)
1	Al	0.38	380	0.38	Not Specified	Not specified
2	Ti	0.02	20	0.02	Below 10	Not specified
3	V	0.0013	1.3	0.0013	Not specified	Not specified
4	Mn	0.25	250	0.25	Below 5	Not specified
5	Fe	1.25	1250	1.25	Below 20	Not specified
6	Ni	0.08	80	0.08	Below 1	Not specified
7	Zn	0.06	60	0.06	Below 1	Not specified
8	Y	0.20	200	0.20	Not specified	Not specified
9	Eu	0.028	28	0.028	Not specified	Not specified
10	Re	0.06	60	0.06	Not specified	Not specified
					Not specified	Not specified

Adopted from World Health Organization (WHO) and Nigerian Standard for Drinking Water Quality (NSDQW) water quality guidelines

The Table therefore shows that all the heavy metals identified and their recommended limits being specified by (WHO, 2011) and (NSDQW, 2007) are below the recommended limits. Titanium (Ti) has a value of 0.19mg/l and the recommended limits is below 10mg/l, manganese (Mn) has a value of 0.10mg/l and the recommended limits is below 5mg/l, Iron (Fe) has a value of 1.25mg/l and the recommended limits is below 20mg/l, Nickel (Ni) has a value of 0.70mg/l and the recommended limits is below 1mg/l and lastly, Zinc (Zn) with a value of 0.08mg/l has a recommended limts of below 1mg/l.

It is important to note that there are some heavy metals in the table whose acceptable limits have not being specified; this is because they are categorized as elements with no practical significance to sanitation or health. For instance the US Environmental Protection Agency (USEPA, 2011) report says Vanadium cause no hazard of significance in water.

Comparing the result of analysis with that of Garba *et al* (2014) for Samaru stream shows that there is a decreasing concentration of metal pollutants particularly Zn and Fe which they analysed using a V2000 multi analyte photometer to be 0.31mg/l and 1.51mg/l respectively against the 0.08mg/l and 1.25mg/l analysed using the XRF analysis. Other heavy metals identified by Garba *et al* (2014) include, lead (Pb), Cadmium (Cd) and Mercury (Hg) which were however, not identified using the XRF analysis because they are below the detection limits.

4.5.1 Aluminium (Al)

From the XRF result of sediment analysis of Samaru stream. Al was detected with a mean value of 0.38mg/l while the NESREA and WHO reccomemded standards is 0.2mg/l while a study by Butu and Iguisi (2012) on the increasing levels of metal pollutants in River Kubanni using the INAA technique shows Al to have a concentration level of 40000mg/l while another study by Butu and Ati (2013) on the sources and levels of concentration of metal pollutants in the Kubanni dam from sediment samples still using the INAA shows Alto have a mean concentration value of 32025mg/l and lastly a study by Butu (2013) on the spatial variation in the levels of contaminat in River Kubanni from sediment samples using the INAA method found Al to have a concentration level of 34900mg/l. In accidental intake of a large amount of aluminium, chelation is employed to detoxify it from the body by deferoxamine mesylate (Igor, 2012). Comparing the XRF result of the Samaru stream therefore shows that Samaru stream

contributesan insignificant amount of Al into the Kubanni dam out of the five main tributaries of the dam.

4.5.2 Manganese (Mn)

A mean value of 0.25mg/l of Mn was obtained from the XRF analysis of the sediment samples of Samaru stream which was found to be above the recommended standards by both NESREA and WHO of 0.2mg/l and 0.1mg/l respectively.

In the same study by Butu and Iguisi (2012) on the increasing levels of metal pollutants in River Kubanni using the INAA technique shows Mn to have a concentration level of 247.75mg/l while a study by Butu (2013) on the spatial variation in the levels of contaminat in River Kubanni from sediment samples using the INAA method found a concentration value of Mn to be 293.25mg/l. Again a study by Butu and Ati (2013) on the sources and levels of concentration of metal pollutants in the Kubanni dam from sediment samples still using the INAA shows Mn to have a mean concentration value of 2200mg/l.Although, values obtained are all above the recommended standards by NESREA and WHO. The concentration of Mn on the Kubanni basin can generally be said to be increasing from 2012 to 2014 however, Samaru stream can still be said to be contributing an insignificant amount into the reservoir.

4.5.3 Iron (Fe)

Iron is by mass the most common element on the Earth, forming much of Earth's outer and innercore (Demazeau, Buffat, Pouchard and Hagenmuller, 1982). Humans experience iron toxicity above 0.2 mg/l of iron for every kilogram of mass, and 0.6 mg/l per kilogram is considered a lethal dose(Cheney, Gumbiner, Benson and Tenenbein, 1995). The Dietary

Reference Intake (DRI) lists the Tolerable Upper Intake Level (UL) for adults as 45 mg/day. For children under fourteen years old the UL is 40 mg/day.

The Fe value obtained from the XRF analysis of the sediment samples of Samaru stream was 1.25mg/l which is above the recommended standards by both NESREA and WHO of 0.3mg/l respectively while a study by Butu and Iguisi (2013) to assessd the level of heavy metals in the sediment samples of River Kubanni by the use of an INAA technique shows that Fe has a mean value of 16500mg/l. Also, a study by Butu and Ati (2013) on the sources and levels of concentration of metal pollutants in the Kubanni dam from sediment samples still using the INAA shows Fe to have a mean concentration value of 15562.50mg/l. The two studies of Butu and Iguisi (2013) and Butu and Ati (2013) shows a slight decrease in the concentration of Fe in the Kubanni dam and all the values obtained are also far above the recommended standards. The result of the XRF analysis of Samaru stream therefore shows that the stream contributes an insignificant amount of Fe into the Kubanni dam.

Furthermore, a recent study on Samaru stream by Garba *et al* (2014) found Fe to have a concentration value of 1.37mg/l. This suggests that the concentration of Fe in the stream is gradually reducing. The medical management of iron toxicity is complicated, and can include use of a specific chelating agent called deferoxamine to bind and expel excess iron from the body (Tenenbein, 1996)

4.5.4 Nickel (Ni)

Nickel is commonly found in association with iron ore limonite, which often contains 1-2% nickel. Nickel is believed carcinogenic and therefore a toxic metal. In the US, the minimal risk level of nickel and its compounds is set to 0.2 µg/m^3 for inhalation during 15–364 days while the

Tolerable Upper Limit of dietary nickel is 1000 µg/day, and the estimated average ingestion is 69-162 µg/day (Trumbo, Yates, Schlicker and Poos, 2001).

The sediment analysis of Samaru stream using the XRF technique gave a mean concentration value of Ni at 0.08mg/l against the 0.02mg/l and 0.07mg/l recommendard standards byNESREA and WHO which indicates that it is above the limits while a study by Iguisi and Funtua (2001) on the concentration level of heavy metals on the sediment samples of kubanni dam shows a concentration value for Ni as 0.02mg/l. Another study by Abolude, Davies and Chia (2009) on the distribution and concentration of trace elements in Kubanni reservoir using the Atomic Absorption Spectrophotometer (AAS) technique shows nickel to have a concentration value of 1.80mg/l. From the following results of analysis it shows that Ni is above the recommended standards by both NESREA and WHO.However, comparing the result of the analysis from 2001-2014 shows a that the concentration of Ni in the Kubanni basin especially the Samaru stream a minor tributary of the dam have relatively increased although, below the Abolude, Davies and Chia (2009) result.

4.5.5 Zinc (Zn)

Soil contains 5–770 mg/l of zinc with an average of 64 mg/l. seawater has only 30 mg/l zinc and the atmosphere contains 0.1–4 µg/m^3. Zinc deficiency is associated with many diseases. In children it causes growth retardation, delayed sexual maturation, infection susceptibility, and diarrhea. Consumption of excess zinc can cause ataxia, lethargy and copper deficiency (Hambidge and Krebs, 2007).

Concentrations of zinc as low as 2 mg/l can adversely affects the amount of oxygen that fish can carry in their blood while levels of zinc in excess of 500 ppm in soil interfere with the ability of

plants to absorb other essential metals, such as iron and manganese (Heath, 1995).The Recommended dietary Allowance (RDA) intake in the US is 8 mg/day for women and 11 mg/day for men while the U.S. National Research Council set a Tolerable Upper Intake of 40 mg/day (Connie and Christine, 2009).

The result of XRF analysis of the sediment samples of Samaru stream was0.06mg/l for mean concentration of Zn while the NESREA and WHO recommendard standard is 3mg/l. This indicates that the concentration of Zn in the sediment of Samaru stream is above the recommendard standards.Furthermore, Abolude, Davies and Chia (2009) on a study of the the distribution and concentration of trace elements in Kubanni reservoir found a concentration level of Zn to be 0.51mg/l by using the Atomic Absorption Spectrophotometer (AAS) technique and a study by Butu and Ati (2013) on the sources and levels of concentration of metal pollutants in the Kubanni reservoir from sediment samples using the INAA method shows Zn to have a mean concentration value of 35.40mg/l. Butu and Iguisi (2013) analysed the concentration of heavy metals in sediment of river Kubanni and found Zn to have a mean concentration of 103.7mg/l while Garba et al (2014) found the concentration of Zn in the Samaru stream to be 0.56mg/lComparing these resultsshows that there is a decrease in the concentration of Zn in the Kubanni basin particularly Samaru stream.

4.5.6 Titanium (Ti)

Titanium (Ti) is not a toxic metal and therefore not rejected by the body however, it has a tendency to bio-accumulate in tissues that contain silica with a possible connection to yellow nail syndrome (yellow to yellow-green discoloration of the nails) (Berglund and Bjorn, 2011).

Ti is the only metal that was assigned limits by NESREA for discharges into a stream. Result of the XRF analysis of Samaru stream sediment was a mean concentration value of Ti to be

0.02mg/l while the recommended standard is 10mg/l. The value obtained is therefore below the recommended limit.

Furthermore, a study by Iguisi and Butu (2012) on the increasing levels of metal pollutants in Kubanni reservoir using the INAA technique shows Ti to have mean concentration of 2900mg/l and in another study by Butu and Iguisi (2013)analysed the concentration of heavy metals in sediment of river Kubanni and found a mean value is 3000 mg/l while Butu and Ati (2013) also analysed the concentration of heavy metals in sediment of river Kubanni and found Ti to have a mean concentration of 2737.50mg/l.Comparising the result obtained with previous analysis of the sediments of Kubanni dam and basins indicates that there is a decrease in the concentration of Ti.

Lastly, the F-ratio (ANOVA) test to find the significance difference between the compounds of heavy metals and the compounds of non- heavy metals in all sediments was conducted and the result is presented in Table 4.5c.

Table 4.5c: OneWay Anova on Heavy Metal and Non-Heavy Metal

	Sum of Squares	**Df**	**Mean Square**	**F**	**Sig.**
Between Groups	20.278	1	20.278	5.044	.036
Within Groups	80.401	20	4.020		
Total	100.679	21			

With asignificance value 0.036 which is less than 0.05,there isa significant difference between the compoundsof heavy metals and those of non-heavy metals in the sedimentat 0.05

significance level. In order words the null hypothesis wasaccepted and the alternative hypothesis rejected.Therefore, this shows that the distributions of compounds are independent of the factors that contribute to dissolved sediment formation and composition in the sediment.

4.5.7 Results of Major Findings

1. Dissolved sediment concentration (Cd) obtained vary from a minimum value of 20mg/l to a maximum. value of 120mg/l with a mean value of 58.87mg/l, and total sum of 4180mg/l. Derived dissolved sediment discharge (Qd) using the rating curve varied from a minimum value of 1.14mg/s to a maximum value of 325.44mg/s, and a total value of 3162mg/s.
2. The AV method was employed for the discharge measurement of the stream which gave a mean value of 0.2528m^3/s, and an annual total discharge value of 4,850,232m^3/yr. The lowest discharge of 0.057m^3/s was recorded in April and the highest discharge of 4.133m^3/s was recorded in August.
3. A total value of 174,000 kg/yr was estimated as the dissolved sediment yield of the stream with a Channel Sediment Yield (CSY) of 174 tons/yr. The amount is high and can be attributed to the anthropogenic activities upstream.
4. A total of 17 elements with varying degree of concentrations ranging from as low as 0.0 for Re to 9.50mg/l for Ca was detected by the XRF analysis.
5. 11out of 17 elements identified were heavy metals with nickel (Ni) as the most toxic with a mean concentration value of 0.08mg/l while the WHO (2011) and NSDQW recommended standards for drinking and domestic use are 0.02mg/l and 0.07mg/l respectively and the limits to discharges into a stream is below 1mg/l

CHAPTER FIVE: SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 SUMMARY

This study was aimed investigating the dissolved sediment delivery by the Samaru stream into the Kubanni reservoir, ABU Zaria andalso to measure the stream discharge by the AV method which was achieved by monitoring the stream for a 7 months periods which corresponds to the raining season of the study area.The total annually discharge of 4,805,232m^3/yr was obtained with August having the total mean discharges of 58783m^3/yr and discharge regime of 38% while October is the least with a mean value of 27354m^3/yr and a discharge regime of 1%. Relating stream discharges and rainfall by a rating curve gave a lower peak discharge of 0.001m^3/s and a higher peak discharge of 4.150m^3/s while the log-log equation shows that there is a strong and direct relationship between discharges and rainfall at 0.05 significant levels. Furthermore, the dissolved sediment concentration values were obtained which gave a total value of 4180mg/l with the highest value of 120mg/l and the lowest of 20mg/l. Also, the dissolved sediment concentration values were converted to dissolved sediment discharge by multiplying dissolved sediment concentration with discharge values which gave a total dissolved sediment discharge of 3161.9mg/s with August having the highest value of 1051.6mg/s and October the least with 16.2mg/s.

Relating dissolved sediment concentration with discharges by a rating curve gave a lower peak value of 20mg/l and a higer peak value of 120mg/l while the log-log equation shows that there is a weak but direct relationship between dissolved sediment concentration and discharges at 0.05 significant levels while relating dissolved sediment concentration and dissolved sediment discharge and also relating dissolved sediment discharge with discharges all produced a straight line scatter graph indicating a strong relationship in each case. The annually total dissolved

sediment discharge of 174, 000kg/yr was produced as an estimate of the total dissolved sediment yield of the stream which gives a channel sediment yield of 174tons/yr.

XRF analysis was conducted to find the constituent nature of the dissolved sediment concentration of Samaru stream. This was achieved by preparing the dissolved sediment into residual form that was used for the XRF analysis. A total of 17 compounds were found with calcium oxide (CaO) found to be the most abundant mineral with a mean concentration value of 8.88mg/l while the least abundant compound was vanadiumoxides (V_2O_5) and rhenium oxides (Re_2O_7) with a mean concentration value of 0.001mg/lrespectively.Next to CaO as the most abundant compound identified is potassium oxide (K_2O) which has a mean concentration value of 5.40mg/l.

Furthermore, from the element of residue identified from the sediment samples, calcium (Ca) is found to be the most abundant with a mean concentration value of 9.50mg/l while the least is rhenium (Re) with a mean concentration value of 0.0mg/l. Next to Ca as the most abundant element found is chlorine (Cl) although, a non-metal it has a mean concentration value of 6.34mg/l. Nickel (Ni) is considered as the most toxic element identified because in small amount it is hazardeous to humans and animals.It was found to have amean concentration value of0.08mg/l.while its acceptable limit by NESREA, FEPA and SON is 0.02mg/l while the WHO limit is 0.07mg/l.

Lastly, anF-ratio test (ANOVA)was conducted to find if there is a significant difference between the concentration of the compounds of heavy metals identified and the concentration of the compounds of non-heavy metalsidentified in the XRF analysis, and the result shows that there is a significant difference between the two at 0.05 significant levels.

It is however important to note that some of the most toxic metals like Arsenic (Ar), Lead (Pb), Cadmium (Cd_2) and Mercury (Hg) which were previously being detected in the basin were not identified by the XRF analysis and the most probable explanation is that they are below detection limits. This implies that there is a decrease in concentration of these dangerous metal pollutants in the Samaru stream, suggesting that the stream isnot very polluted.

5.2 CONCLUSION

The research conducted was on the dissolved sediment of Samaru streamwhere the mineral composition, concentration of metals and estimated yield were investigated. The discharge measurement of the Samaru stream was observed beginning in 7 April, 2014 and ended on the 10 October, 2014. The stream was found to produced a total of 4,805,232m^3/yr of discharges by using the AV method with a peak discharge of 4.133m^3/s in August and a low peak discharge of 0.057m^3/s recorded in October. This implies an increased of stream discharge over the years when compareto a total discharge of 1,204,200 obatined by Yusuf (2006) for the Malmo stream where the Samaru stream flows before finally emptying into the ABU reservoir.

Also, the stream discharge and rainfall relationship were looked at which shows that there is a direct relationship between rainfall and discharge. Again, the following relationships were established they are; relationship between dissolved sediment concentration and discharge, dissolved sediment concentration and dissolved sediment discharge and lastly, the relationship between dissolved sediment discharge and discharge which all shows that there is a direct relationship in each case therefore,establishing the fact that the rating curve is of great advantage to the basin in providing useful information on the relationship between dissolved sediment concentration, dissolved sediment discharge and discharges. However, over the years the

strength of the relationship is steadily increasing as observed from the r and r^2 values to suggest that despite the intervention effort by the ABU authority to protect the reservoir from siltation and pollution other human activities taken place upstream especially from Samaru town is affecting sediment generation, transportation and deposition into the basin.

A Channel Sediment Yield (CSY) of 174tons/yr was calculated from the 174,000kg/yr of dissolved sediment estimated for the period of study. Thedissolved sediment discharges (Qd) in kg/yr produced vary from as low as 27.65kg/dayin May to 20,600kg/day in August. It was observed that April has the highest peakdissolved sediment discharge from the regime Table with 52%while the least is May and October with 3% dissolved sediment discharge peak value.

The XRF analysis provided an insight on the types and nature of minerals presents in the dissolved sediment. The minerals identified were in their oxides form with the exception of Chlorine (Cl) which was found in uncombined states. Calciumoxide (CaO) was found to be the most abundant minerals with an average residual % weight of 43.02which correspond to8.88mg/l. However, the minerals identified by the XRF were not free from heavy metals oxides. A heavy metal of concern found was nickel with a mean concentration value of 0.08mg/l. It is of concern because in small quantities nickel is essential, but when the uptake is too high it can be a danger to human health. The recommended daily intake of nickel is less than 1mg but an uptake of too large quantities of nickel has the following consequences: higher chances of development of lung cancer, nose cancer, larynx cancer and prostate cancer, sickness and dizziness after exposure to nickel gas, lung embolism, respiratory failure, birth defects, asthma and chronic bronchitis, allergic reactions such as skin rashes, mainly from jewelry and heart disorders (Lenntech, 2014).

Also, in order to establish if there is a significant difference between the heavy metals and the non-heavy metals found in the sediment from the XRF analysis, anF-ratio (ANOVA) test was conducted which results show that there is a significant difference between the two sets of elements. This therefore, implies that the composition and distributaion of compounds and elements both heavy metals and non heavy metals are independent of the factors that influences sediment generation and deposition.

5.3 RECOMMENDATION

The information gathered from the study of the dissolved sediment delivery by the Samaru stream especially from the identification of nickel in the dissolved constituent nature of the stream has confirmed earlier studies on the soil type of the study area which Wright and McCurry (1970); Kowal and Omolokun (1971) and Tokarski (1972) classified as highly leached ferruginous tropical soils which developed on weathered regolith overlain by a thin deposit of windblown silt from the Sahara desert. This suggested thepresent of a significant amount of iron (Fe) in the soil as seen also from the result of the XRF analysis where iron has a value of 1.25mg/l and was identified in all the three sediments analyzed.

Heavy metals are derived naturally or anthropogenically. In its natural form, nickel which is the heavy metal of concern identified by the XRF analysis is usually found in association with Iron. About 20% of nickel is found in this association while the remaining is believe to be derived by human activities, mostly from their released into the atmosphere by power plants and trash incinerators which then settle to the ground or fall down after reactions with raindrop while the larger part of all nickel compounds released to the environment are then been adsorbed by sediment and soil particles and become immobile as a result, but are washed down to

waterbodies during precipitation. In acidic ground however, nickel is bound to become more mobile and often rinse out to the groundwater (Lenntech, 2014)

The human factor that may be responsible for the identification of nickel in Samaru stream can be associated to the growing number of small scale animal feeds production industries along Samaru-Sokoto road where the main drainage that carries water into Kubannireservoir from Samaru stream passes. These industries operate on huge powered generators and incinerators to release smoke and dusts generated during production.Based on the findings of this research the following recommendations are made.

- That the operations of these industries be monitored because the Kubanni resevoir where the Samaru stream empties is the primary means of water supply to the ABU community, checking the operation of these industries will therefore, ease the treatment of the waterinthe ABU reservoir for human consumption.
- Effort to restore the stream embarkment from erosion in areas where it has developed over the years should commence in order to reduce erodiblity, leaching and solubility of earth materials that contributes immensely to dissolved sediment generation in the stream.
- The ABU authority should construct a sewage treatment plant and rehabilitate existing sewage channels in the campus that have collapsed and deterioted because it was observed that most of the sewages especially from Danfodio hostel, ICSA Ramat hostel, Block of 9 flats, Area 2 Quarters and Community market find their way into the stream thereby further polluting the water.

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Appendices

1. Table of Dissolved Sediment Concentration Result Obtained in the Lab.

SAMPLE NUMBER.	DATE	(W1)=WEIGHT OF EMPTY CRUCIBLE (g)	(W2)=WEIGHT OF CRUCIBLE + DISSOLVED SEDIMENT (g)	W3 (W2-W1) (g/ml)	g/ml to mg/l MULTIPLYING BY 4 and 100
1	07/04/2014	200	200.3	0.3	120
2	08/04/2014	293.6	293.9	0.3	120
3	15/04/2014	189.3	189.6	0.3	120
4	20/04/2014	176.1	176.4	0.3	120
5	26/04/2014	175.8	176.1	0.3	120
6	28/04/2014	190.3	190.0	0.3	120
7	30/04/2014	195.3	195.1	0.2	80
8	02/05/2014	204.1	204.3	0.2	80
9	03/05/2014	174.6	174.8	0.2	80
10	05/05/2014	188.5	188.3	0.2	80
11	09/05/2014	180.9	181	0.1	40
12	23/05/2014	192.7	192.5	0.2	80
13	27/05/2014	179.8	180	0.2	80
14	28/05/2014	184.5	184.7	0.2	80
15	29/05/2014	191	191.2	0.2	80
16	31/05/2014	201	201.2	0.2	80
17	03/06/2014	173.8	173.9	0.1	40
18	05/06/2014	161.7	161.8	0.1	40
19	14/06/2014	195.6	195.8	0.2	80
20	16/06/2014	195.4	195.6	0.2	80
21	18/06/2014	189.6	189.8	0.2	80
22	22/06/2014	182.8	184	0.3	120
23	28/06/2014	185.4	185.7	0.2	80
24	29/06/2014	182.9	183.1	0.2	80
25	30/06/2014	178.6	178.7	0.1	40
26	03/07/2014	174.2	174.3	0.1	40
27	06/07/2014	178.3	178.4	0.1	40
28	08/07/2014	198.7	198.9	0.2	80
29	11/07/2014	172.9	173.1	0.1	40
30	12/07/2014	175.3	175.4	0.1	40
31	16/07/2014	190.1	190.2	0.1	40
32	18/07/2014	293.7	294	0.3	120

33	21/07/2014	175.2	175.3	0.1	40
34	28/07/2014	175.7	175.9	0.2	80
35	31/07/2014	189.5	189.6	0.1	40
36	01/08/2014	180.8	180.9	0.1	40
37	02/08/2014	174.2	174.3	0.1	40
38	03/08/2014	182.9	183.	0.1	40
39	05/08/2014	200.1	200.3	0.2	80
40	09/08/2014	204.2	204.5	0.2	80
41	11/08/2014	189.6	189.8	0.2	80
42	12/08/2014	191.1	191.2	0.1	40
43	13/08/2014	179.9	180	0.1	40
44	14/08/2014	161.5	161.6	0.1	40
45	16/08/2014	176.2	176.3	0.1	40
46	17/08/2014	174.6	174.7	0.1	40
47	18/08/2014	201	201.1	0.1	40
48	20/08/2014	190.1	190.2	0.1	40
49	21/08/2014	185.4	185.5	0.1	40
50	22/08/2014	211	211.1	0.1	40
51	25/08/2014	186.5	186.6	0.1	40
52	29/08/2014	193.3	193.4	0.1	40
53	31/08/2014	177.3	177.4	0.1	40
54	01/09/2014	178.3	178.4	0.1	40
55	02/09/2014	187.4	187.6	0.2	80
56	04/09/2014	184.7	184.8	0.1	40
57	05/09/2014	173.2	173.3	0.1	40
58	08/09/2014	178.7	178.8	0.1	40
59	09/09/2014	195.5	195.6	0.1	40
60	11/09/2014	291.6	291.65	0.05	20
61	12/09/2014	187.3	187.35	0.05	20
62	15/09/2014	197.5	197.6	0.1	40
63	16/09/2014	199.6	199.7	0.1	40
64	17/09/2014	185.5	185.6	0.1	40
65	19/09/2014	203.4	203.45	0.05	20
66	25/09/2014	200.2	200.3	0.1	40
67	29/09/2014	185.8	185.9	0.1	40
68	30/09/2014	199.3	199.4	0.1	40
69	01/10/2014	195.9	195.95	0.05	20
70	04/10/2014	188.8	188.85	0.05	20
71	10/10/2014	199.9	200	0.1	40

2: Mean Daily Rainfall Values of Samaru (mm) for 2014.

DAYS	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1								34.0	0.7	2.0		
2			TR		9.8	2.9		94.9	22.5			
3					51.5		21.4		6.3			
4									TR	0.7		
5					26.7	30.0		97.8	31.0			
6							9.0					
7				1.3					TR			
8				12.8			17.0		1.0			
9					6.3			TR	32.4			
10										5.3		
11							4.8		11.8			
12							4.2		TR			
13					TR	4.3		4.4				
14						28.7						
15				28.0				13.8	13.8			
16						16.1	10.3		11.9			
17						3.1			1.3			
18					TR		12.3	10.0				
19				8.4				15.4	9.1			
20								0.4	1.2			
21							3.3	2.3	3.2			
22						9.4	TR	46.2				
23				3.3	2.3		TR	6.6				
24												
25				22.0								
26					4.1				7.6			
27					9.9	TR		18.8				
28					8.7	3.3	20.4					
29					6.3	16.4			16.6			
30	0.4			5.4		4.9		1.0	16.1			
31					3.9		13.0	28.7				
TOTAL	**0.4**			**81.2**	**127.2**	**119.1**	**115.7**	**374.3**	**186.5**	**8.0**		

Total=1016mm; 70 rain days

Adopted from Soil Science Department Meteorological Station, A.B.U Zaria

3: Summary Statistics of Rainfall from 2008-2014

NO:	YEAR	DAYS	RAINFALL (mm)
1	2014	70	1044.2
2	2913	65	1059.1
3	2012	78	1358.1
4	2011	72	916.2
5	2010	84	1128.5
6	2009	76	1278.0
7	2008	74	1171.1
TOTAL	**……**	**519**	**7955.2**
MEAN	**…….**	**74**	**1136.5**

4: Sediment Calculation and Conversion from Residue to Actual Concentration

- Vol. of H_2O used to generate 1gram residue sample are: Sediment 1= 3.5 litres; Sediment 2= 5 litres; Sediment 3= 7.5 litres

- Wt of Residue generated from sediment = 1g

Example

Sediment 1

Ni concentration in residue of Sediment 1 = 0.417%

$$\text{Wt of Ni} = \frac{0.417\% \times 1g}{100} = 0.00417g$$

$$\text{Therefore, Concentration of Ni in } H_2O = \frac{0.00417g \times 3.5 \text{ litres}}{3.5 \text{ litres} \times 3.5 \text{ litres}} = 0.0011914g/l$$

Concentration of Ni in mg/l = 0.0011914g/l x 100 = 0.12mg/l

Sediment 2

$$\text{Wt of Ni} = \frac{0.457\% \times 1g}{100} = 0.00457g$$

$$\text{Concentration of Ni in } H_2O = \frac{0.00457g \times 5 \text{ litres}}{5 \text{ litres} \times 5 \text{ litres}} = 0.000914g/l$$

Concentration of Ni in mg/l = 0.000914g/l x 100 = 0.09mg/l

Sediment 3

$$\text{Wt of Ni} = \frac{0.20\% \times 1g}{100} = 0.002g$$

$$\text{Concentration of Ni in } H_2O = \frac{0.002g \times 7.5 \text{ litres}}{7.5 \text{ litres} \times 7.5 \text{ litres}} = 0.0002667g/l$$

Concentration of Ni in mg/l = 0.0002667g/l x 100 = 0.03mg/l

Average concentration of Ni = 0.12+0.09+0.03= **0.08mg/l**

01-Dec-2014 11:01:11

Sample results

Sample ident
SEDIMENT 1

Application	<Standardless>
Sequence	1 of 1
Measurement time	01-Dec-2014 10:44:52
Position	1

Compound	SiO2	SO3	Cl	K2O	CaO	TiO2	V2O5	MnO	Fe2O3	NiO	ZnO	Y2O3
Conc	10.5	11.9	25.3	8.09	42.49	0.10	0.004	0.063	0.522	0.341	0.040	0.45
Unit	%	%	%	%	%	%	%	%	%	%	%	%

Compound	BaO	Re2O7
Conc	0.12	0.08
Unit	%	%

01-Dec-2014 11:01:16

Sample results

Sample ident
SEDIMENT 2

Application	<Standardless>
Sequence	1 of 1
Measurement time	01-Dec-2014 10:47:53
Position	2

Compound	Al2O3	SiO2	SO3	Cl	K2O	CaO	TiO2	MnO	Fe2O3	NiO	ZnO	Y2O3
Conc	1.9	6.74	9.61	22.0	13.4	44.61	0.071	0.03	0.560	0.349	0.02	0.29
Unit	%	%	%	%	%	%	%	%	%	%	%	%

Compound	BaO	Eu2O3	Re2O7
Conc	0.14	0.11	0.15
Unit	%	%	%

01-Dec-2014 11:01:20

Sample results

Page 1

Sample ident
SEDIMENT 3

Application	<Standardless>
Sequence	1 of 1
Measurement time	01-Dec-2014 10:50:55
Position	3

Compound	SiO2	SO3	Cl	K2O	CaO	TiO2	V2O5	MnO	Fe2O3	NiO	ZnO	Y2O3
Conc	9.62	13.0	24.6	9.36	41.95	0.11	0.004	0.029	0.512	0.15	0.038	0.3
Unit	%	%	%	%	%	%	%	%	%	%	%	%

Compound	BaO	Eu2O3	Yb2O3	Re2O7
Conc	0.13	0.11	0.01	0.15
Unit	%	%	%	%

01-Dec-2014 11:01:23

Sample results

Page 1

Sample ident
SEDIMENT 1

Application	<Standardless>
Sequence	1 of 1
Measurement time	01-Dec-2014 10:53:58
Position	1

Compound	Si	S	Cl	K	Ca	Ti	V	Mn	Fe	Ni	Zn	Y	Ba	Re
Conc	4.74	5.41	33.1	9.57	45.24	0.10	0.007	0.071	0.561	0.417	0.033	0.41	0.17	0.16
Unit	%	%	%	%	%	%	%	%	%	%	%	%	%	%

01-Dec-2014 11:02:10

Sample results

Sample ident
SEDIMENT 2

Application	<Standardless>
Sequence	1 of 1
Measurement time	01-Dec-2014 10:56:59
Position	2

Compound	Al	Si	S	Cl	K	Ca	Ti	Mn	Fe	Ni	Zn	Y	Ba	Eu
Conc	0.81	2.92	4.32	27.0	15.5	47.31	0.069	0.03	0.670	0.457	0.04	0.25	0.21	0.21
Unit	%	%	%	%	%	%	%	%	%	%	%	%	%	%

Compound	Re
Conc	0.2
Unit	%

01-Dec-2014 11:03:09

Sample results

Sample ident
SEDIMENT 3

Application	<Standardless>
Sequence	1 of 1
Measurement time	01-Dec-2014 11:00:01
Position	3

Compound	Si	S	Cl	K	Ca	Ti	Mn	Fe	Ni	Zn	Y	Ba	Eu	Yb
Conc	4.22	6.03	31.1	11.1	45.73	0.097	0.03	0.614	0.20	0.061	0.2	0.21	0.17	0.0
Unit	%	%	%	%	%	%	%	%	%	%	%	%	%	%

Compound	Re
Conc	0.2
Unit	%