EFFECTS OF DEPTHS OF SOME WELLS AND PROXIMITY TO RIVERS NIGER AND BENUE ON WATER QUALITY IN LOKOJA, NIGERIA

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A DISSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY, ZARIA NIGERIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTERS DEGREE IN ANALYTICAL CHEMISTRY

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Declaration

I declare that the work in this dissertation titled **"**EFFECTS OF DEPTHS OF SOME WELLS AND PROXIMITY TO RIVERS NIGER AND BENUE ON WATER QUALITY IN LOKOJA, NIGERIA" was performed by me in the Department of Chemistry under the supervision of Dr E.D Paul and Dr K.I Omoniyi. The information derived from literature has been duly acknowledged in the text and a list of references provided. No part of this work has been presented for another degree or diploma in any other institution

____________________	____________________	____________________
SHAFIU SA`IDU	**Signature**	**Date**

Certification

This dissertation titled **"EFFECTS OF DEPTHS OF SOME WELLS AND PROXIMITY TO RIVERS NIGER AND BENUE ON WATER QUALITY IN LOKOJA, NIGERIA"** by Shafi`u Sa`idu meets the regulations governing the award of the degree of Master in Analytical Chemistry of the Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

Dr. E. D. Paul Chairman Supervisory Committee	____________________ Signature	____________ Date
Dr. K. I. Omoniyi Member, Supervisory Committee	____________________ Signature	____________ Date
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Dedication

This work is dedicated to ALLAH and my lovely family especially my elder brother Habibu Sa`idu for their prayers, patience, support and encouragement.

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Abstract

This work reports the effects of well depth on the physicochemical and microbial properties of hand dug wells water in villages close to Rivers Niger and Benue in Lokoja, Nigeria. Wells up to 2.8 m deep and 300 m away from the rivers were studied in both the dry and wet seasons. Analyses of samples of well water from the villages (Shintaku, Ganaja and Gbobe) and Lokoja metropolis showed that the total suspended solid (TSS), total dissolved solid (TDS), total solid (TS), alkalinity, total hardness (TH) and turbidity were in the ranges of 13 - 450, 57 - 905, 10 - 170, 11.5 – 18, 202 - 818 $mgdm^{-3}$ and 0.611 – 140 NTU respectively. Biochemical oxygen demand (BOD), chemical oxygen demand (COD) and dissolved oxygen (DO), were in the ranges of 0.1 - 0.45, 108 – 346 and 0.08 - 0.75 $mgdm^{-3}$ respectively. Also the ranges of electrical conductivity (EC) and pH recorded were: 53. 35 - 98.5 μScm^{-1} and 5.9 - 7.5. While those of ammonia, nitrate and phosphate in the water were in the ranges 0.01 - 0.3, 3.9 - 43 and 1.5 - 14.95 $mgdm^{-3}$**,** respectively in the dry season of 2014. TSS, TDS, TS, alkalinity, TH and turbidity of the well water samples showed the mean values of 13 - 450, 57 - 905, 10 - 170, 59 – 131, 130 - 404 $mgdm^{-3}$ and 0.611 - 140 NTU respectively. BOD, COD and DO recorded the highest concentration ranges of 0.2 to 31, 60 to 818 and 0.9 to 1.2 $mgdm^{-3}$ respectively. However, the ranges of EC and pH of the sample were: 0.611 - 140 NTU and 5.8 – 7.15, respectively. Ammonia, nitrate and phosphate were in the ranges of 3.1 - 14.5, 7.5 – 65 and 3.1-13.5 $mgdm^{-3}$, respectively in the wet season of 2014. The water samples had detectable levels of Cu, Cd, Ni, Mn, Pb and Zn, but all the samples have metal contents far below the permissible limits, except for the Cd content which was above in some of the water samples. By using the multiple tube fermentation technique, the well water from all the sites had faecal contamination with bacteria pathogens such as *Klebsiella spp*, *Escherichia coli*, *Enterobacter spp.*, *Serantia spp.* and *Citrobacter spp.* During the wet season, it was found that the amounts of nitrate, turbidity, microbial isolate and pH values of the well water were found to increase with depth of the well. And the value of TS and TDS also increases positively with the proximity of the wells to the rivers in wet season. Therefore, careful consideration and planning is needed in construction of the wells. This suggests that wells must be up to 15 m deep and 300 m distance away from the river so as to be free from pollution.

Table of Content

List of Figures

List of Tables

Appendix

ABBREVIATION

AAS	-	Atomic Absorption Spectrophotometer
ANOVA	-	Analysis of Variance
BOD	-	Biochemical Oxygen Demand
COD	-	Chemical Oxygen Demand
DO	-	Dissolved Oxygen
EC	-	Electrical Conductivity
EDTA	-	Ethylene diamine tetraacetic acid
NTU	-	Nephelometric Turbidity Unit
SON	-	Standard Organization of Nigeria
SPSS	-	Statistical Package for Social Sciences
US-EPA	-	United States Environmental Protection Agency
WHO	-	World Health Organization
FAO	-	Food and Agricultural Organization

CHAPTER ONE

1.0 INTRODUCTION

1.1 WATER

Water, after air, is the most essential commodity to the survival of life. Human life depends, to a large extent, on water. It is used for an array of activities; chief among these being drinking, food preparation, as well as for sanitation purposes. In as much as safe drinking water is essential to health, a community lacking in a good quality of this commodity will be saddled with a lot of health problems which could otherwise be avoided (Miller and Junior, 1997).

Water covers 70.9% of the earth's surface, and is vital for all known forms of life. On earth, it is found mostly in oceans and other large water bodies, with 1.6% of water below ground in aquifers and 0.001% in the air as vapour and precipitations. Oceans hold 97% of surface water, 2.4% for glaciers and polar ice caps, and, 0.6% for other land surface water such as rivers, lakes and ponds. A very small amount of the earth's water is contained within biological bodies and manufactured products (Wikipedia, 2010).

Groundwater is of major importance and is intensively exploited for private, domestic and industrial uses. According to Ajibade *et al*. (2011), 90% of the population in Nigeria depends largely on hand-dug wells and boreholes. Water is necessary for sustainable economic development in a country like Nigeria. Hand dug wells have been the sources of water for people in Nigeria for ages. Some of these wells are dug close to rivers. And literature shows that rivers are the major transporting means for different contaminants into groundwater and lakes (Sina *et al.,* 2009*).*

The preference of groundwater as a source of drinking water in rural areas is due to its relatively better quality than river water (Obiri-Danso *et al.,* 2009). Historically, rural settlement is being determined by the water source which is stream, river and spring (Okeola *et al.*, 2010). The inhabitants of these settlements rely on underground water often being within a few metres below the surface, which are exploited by well digging.

Access to safe drinking water is a basic human need and is a fundamental human right, crucial for poverty reduction and eradication. According to a report by United Nations (2003), this situation forces people to consume water directly from the rivers and ponds and this represents a high risk to the consumers' health. According to World Health Organization (WHO, 2000), in the next thirty years alone, accessible water is unlikely to increase more than ten percent (10%) but the earth's population is projected to rise by approximately one-third. Unless the efficiency of water use rises, this imbalance will reduce the quality of water services, reduce the conditions of health of people and deteriorate the environment and the world.

Rivers are the major transporting means for different contaminant into other resources like groundwater and lake (Karbassi, 2007). By passing water through the ground, its quality will change and this might be related to humans or natural phenomenon. . Generally, shallow groundwater is affected more by contamination compared to deep groundwater (Kinzelbach, 1989). Groundwater moves downwards due to the pull of gravity. It can also move up because it will flow from higher- pressure areas to lower pressure areas. The rate of groundwater flow is permeability (pore space) environmental protection agencies (EPA, 1994). The ultimate distance to which water pollution will occur in a groundwater depend on a number of complex and interlocking factors, namely wet and dry weather, (Kinzelbach, 1989). .

Heavy metals such as zinc, copper, cadmium and manganese are important in small quantities for biological processes in plants and animals. They also occur naturally in soil, water and the atmosphere. However, when they are discharged in large quantities from sewage, industrial and agricultural run-offs and ultimately find their way into water bodies including oceans and river, they constitute an increasing hazard to humans through the food chain. (Tay *et al.,* 2011). The water pollution by heavy metals has become a scientific concern in many countries because of their toxicity to human health and biological systems (Anazawa *et al.,* 2004*).* Each pollutant has its own health risk profile.

Metal concentrations in groundwater may also increase due to discharges from various anthropogenic sources. Small quantities of certain heavy metals are nutritionally essential for a healthy life. Some of these are referred to as trace elements (e.g. iron, copper, manganese and zinc). Heavy metals become toxic when they are not metabolized by the body and accumulate in the soft tissues. These metals may enter the human body through food, water and air, or absorption through the skin when they come in contact with humans in agriculture and pharmaceutical industry. Heavy metals become more hazardous when they are ingested in large quantities and these might causes public health problems *(*Anazawa *et al., 2004).*

Faecal contamination with bacteria pathogens such as *Klebsiella spp*, *Escherichia coli*, *Entrobacter spp, Serantia spp.* and *Citrobacter spp.* such contaminant are responsible for the cause of communicable enteric disease, some of the pathogenic micro-organisms that cause these diseases may be present in water. Drinking water or using it in food preparation may then result in new cases of infection (Anazawa e*t al.,* 2004). The pathogenic agents involved include bacteria, viruses, and protozoa, which may cause diseases that vary in severity from mild gastroenteritis to severe and sometimes fatal diarrhoea, dysentery, hepatitis, or typhoid fever and most of them are widely distributed throughout the world (Mara *et al.,* 1989). Faecal contamination of drinking water is only one of several faeco-oral mechanisms by which disease can be transmitted from one person to another or, in some cases, from animals to people (APHA, 1998) reported that bacteria in water are generally not present individually but as clumps or in association with particulate matter.

1.2 Justification

The quality of well water in villages close to rivers Niger and Benue in Lokoja Kogi State have become a major health concern. In addition, an inhabitant depends majorly on wells water, which have doubtful water quality especially during the wet season. The villages near rivers Niger and Benue in Lokoja are not connected to pipe water supply system causing most people to depend on other alternative sources of water such as hand dug wells constructed in many households close to the rivers with doubtful water quality. These alternative sources are, to a large extent, exposed to contaminants such as bacteria, heavy metals, nitrates and other salts which have resulted in polluting the water.

1.3 Aim of the Work

The overall aim of this work was to determine the effects of proximity and depth on the quality of water from wells of villages near river Niger and Benue on water quality in Lokoja.

1.3.1 Objectives

The above aim has been achieved by the following set of objectives:

I. To compare the effect of well depth on the water quality;

II. To determine the physicochemical and microbial properties of the well water in villages (Gbobe, Shintaku and Ganaja) near rivers Niger and Benue in Lokoja, Nigeria;

III. To compare the effect of well depths on the water quality in Lokoja metropolis;

IV. To comparing the quality of water samples collected from the wells of the villages near the flood plain with those from Lokoja metropolis;

V. To determine the effects of distance on the quality of water samples

VI. To study and compare the quality of water as a function of depth;

VII. To correlate the result of the well water quality as a function of distance to the rivers and well depths;

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Water

Water is a liquid at ambient conditions, but it often co-exists on earth with its solid state being ice, and gaseous state being water vapor or steam (Ameyibor and wiredu, 1991). The main sources of water supply in Nigeria include surface water, ground water and rain water. According to (Akumiah, 2007), rainfall, although not reliable, has a mean ranging from 2150 mm in the south-western part of Nigeria to 800 mm in the south-eastern part of Nigeria . Rainwater harvest is not so popular among urban settlers. Nevertheless, it provides a significant amount of domestic water in the southern rural areas particularly Nigeria during the humid months of May, June, July and August (Akumiah, 2007).

Sina *et al.,* (2009) determined the effects of well depth on water quality, the wells up to 4 m. depth and 100 m far away from the river were selected in Isfahan from a total of 100 samples analyzed. Results of this study showed that total coliform,

Isikwue *et al.,* (2011). Studied the effect of a well depth on the microbial pollution of shallow wells in the three floodplains of Makurdi metropolis of Benue State, Nigeria,

Ifabiyi, (2008) determined the relationships between water chemistry and depth of hand dug wells in a densely populated part of Ibadan, Nigeria.

2.1.1 Sources of Water

Surface water frequently contains substances that must be removed before it can be used as drinking water while ground water is that which is pumped from wells and boreholes that have been drilled into underground aquifers and is usually free from harmful contaminants. (Stanistski *et al.,* 2000).

2.1.2 River Niger

The Niger River is the principal river of western Africa, extending about 4,180 km. Its drainage basin is 2,117,700 km^2 in area. Its source is in the Guinea highlands in southeastern Guinea, it runs in a crescent through Mali, Niger, on the border with Benin and then through Nigeria meeting with the River Benue. It is the third-longest river in Africa, exceeded only by the Nile and the Congo rivers (Wikipedia, 2010).

2.1.3 River Benue

The Benue River previously known as Chadda River or Tchadda, is the major tributary of Niger River. The river is approximately 1,400 kilometers long and almost entirely navigable during the summer months. It rises in the Adamawa Plateau of northern Cameroon, from where it flows west, through the town of Garoua and Lagdo Reservoir, into Nigeria south of the Mandara Mountains; it processes through Jimeta, Ibi and Makurdi before meeting the Niger at Lokoja At the point of confluence. (Wikipedia, 2010).

2.2 Wells

A well is an excavation or a structure created in the ground by digging, driving, boring or drilling to access water in underground aquifers (Roger,1982).Water may be drawn by an electric submersible pump, a vertical turbine pump, a hand pump or a mechanical pump (e.g. from a water-pumping windmill). It can also be drawn up using containers, such as buckets that are raised mechanically or by hand (Obiri Danso *et al.,* 2009).

Wells can vary greatly in depth, water volume and water quality. Well water typically contains more minerals in solution than surface water and may require treatment to soften the water. There are basically three types of wells. These include: hand-dug wells, driven wells and drilled wells. Hand-dug wells are constructed by hacking at the ground with pick and shovel to dig until the water table is reached. If the ground is soft and the water table is shallow, then dug wells can work. The well is lined with stones, brick, tile, or other materials to prevent collapse, and is either covered with a cap of wood, stone, metal or concrete (Roger, 1982). In Nigeria, many of the wells we find in our homes are excavated until reaching the water table and are described as shallow well (*Obiri -Danso et al.,* 2009).

The depth of the wells depends on how far the water table could be reached. Driven wells are built by driving a small-diameter pipe into soft earth, such as sand or gravel (Roger, 1982). A screen is usually attached to the bottom of the pipe to filter off sand and other particles. They can only tap shallow water, and because the source of the water is so close to the surface, contamination from surface pollutants can occur. Drilled wells require a fairly complicated and expensive drill rig. They use rotary drill bits that chew away at the rock, percussion bits that smash the rock. Drilled wells can be drilled more than 1,000 feet deep. Often a pump is placed at the bottom to push water up to the surface (Roger, 1982).

2.2.1 Well Contamination

Shallow pumping wells can often supply drinking water at a very low cost and because impurities from the surface easily reach shallow sources, a greater risk of contamination occurs in these wells when they are compared to deeper wells. Contamination of wells increases during the rainy seasons where the aquifer is "topped up" more rapidly and both vertical and horizontal migrations of water are accelerated (Morgan, 1990). Dug and driven wells are easy to contaminate because they are relatively shallow. The quality of well water can be significantly increased by lining the well, sealing the well head, fitting a self-priming hand pump, constructing an apron, ensuring the area is kept clean and free from stagnant water and animals. Most of the bacteria, viruses, parasites and fungi that contaminate well water come from faecal material of humans and other animals.

Ground water is considered the healthiest source of drinking water, but domestic, agricultural and industrial activities have led to the degradation of ground water quality in different parts of the world. Ground water is a resource found under the earth's surface as most ground water comes from rain and melting snow soaking into the ground. Ground water qualities were affected by the depth of the well for drinking water, and chance of ground being polluted - varies from place to place. Generally, the deeper the well the better the ground water (Roger, 1982).

This was highlighted in Bangladesh where natural levels of arsenic in ground water were found to be causing harmful effects on the population (Anawara *et al., 2007*). Groundwater contamination is responsible for water related and water borne diseases in developing countries like Nigeria. The source of ground water contamination could be natural through ground water-rock interaction or through anthropogenic activities which involve human activities that can affect ground water quality. Ground water pollution which is man-made is worse than natural pollution as it eventually renders water qualities for use (Abimbola and shagodoyin, 2005).

Toxic chemicals such as arsenic and fluoride can be dissolved from the soil or rock layers into groundwater. Chemicals can enter waterways from a point source or a nonpoint source. For instance, the movement of rain or irrigation water over land picks up pollutants such as fertilizers, herbicides, and insecticides and carries them into rivers, lakes, reservoirs, coastal waters, or groundwater. Another non-point source is storm-water that collects on roads and eventually reaches rivers or lakes (Abimbola and shagodoyin, 2005).

2.3 Groundwater

Sub-surface water, or groundwater, is fresh water located in the pore space of soil and rocks. It is also water that is flowing within aquifers below the water table. Sometimes it is useful to make a distinction between sub-surface water that is closely associated with surface water and deep sub-surface water in an aquifer (sometimes called "fossil water") (Abimbola and shagodoyin, 2005).

Sub-surface water can be thought of in the same terms as surface water: inputs, outputs and storage. The critical difference is that due to its slow rate of turnover, sub-surface water storage is generally much larger compared to inputs than it is for surface water. This difference makes it easy for humans to use sub-surface water unsustainably for a long time without severe consequences. Nevertheless, over a long term the average rate of seepage above a sub-surface water source is the upper bound for average consumption of water from that source. Before 1970s, the study of life in groundwater habitats was relatively limited. In the 1970s, however, it became increasingly obvious that certain waste disposal practices were contaminating subsurface environments (Schaffter and Parriaux, 2002).

There has also been an increasing interest in demonstrating that various shallow and deep environments contain substantial numbers of viable micro-organisms to degrade potential pollutants, in bioremediation. Subsurface microbiological research to study microbial community structure, microbial activities and the geochemical properties of groundwater environments has progressed with the development of aseptic sampling techniques (Obuobie and Barry, 2010).

In a hydrogeological sense, groundwater refers to water that is easily extractable from saturated, highly permeable strata known as aquifers (Pritchard, *et al* 2008). For saturated environments, a rigorous distinction between local, intermediate, and regional flow systems, related to the topography of recharge and discharge areas has been long recognized by hydrologists. One can thus define several underground aquifers that serve as sources of potable water in the world which can be classified as shallow, intermediate and deep aquifers (Morita, 1997). Intermediate aquifers within 300 m of the surface soil are separated from shallow aquifers by confining layers; they have much slower flow rates, of the order of meters per year. Deep aquifers are also confined, but more than 300 m below the subsurface soil and they are characterized by extremely slow flow rates meters per century, (Obuobie and Barry, 2008).

Groundwater quality can be affected as a result of the mineral salts that the groundwater was in contact with the soil. Or as a result of the hydro chemical and biochemical conditions such as pH, electrical conductivity, temperature, pressure and presence of bacteria. The anthropogenic groundwater quality influenced by human activities that add components to the groundwater or change natural equilibrium in Benin, research has shown that it is obvious that anthropogenic influences, in particular contamination with pathogens play a very important role in water contamination (Sina *et al.*, 2009).

Groundwater is a key water resource in many country of the world. Many major cities and small towns in the world depend on groundwater for their water supplies, mainly because of its abundance, stable quality and also because it is inexpensive to exploit (Morris *et al.,* 2003). In developing countries, use of shallow groundwater sources for drinking and other domestic purposes is a common feature of many low-income communities (Howard *et al.,* 1999). The communities relying on such sources tend to be poor and live in polluted environments with associated high health risks (WHO and UNICEF, 2000). Such communities occur in most cities in developing countries, for example in Asia, Africa, Latin America and the Caribbean. Their occurrence is attributed to rapid urbanization where urban growth is associated with rapid expansion of small, unplanned urban centre and peril-urban settlements (Vernon, 2002; Hardroy *et al.*, 2001).

2.3.1 Groundwater Pollution

Excessive mineralization of groundwater degrades its quality producing an objectionable taste, odour and excessive hardness. Although the soil mantle through which water passes acts as an adsorbent retaining a large part of colloidal and soluble ions with its cation exchange capacity, groundwater is not completely free from the menace of chronic pollution (Bhatia, 2009). The extent of groundwater pollution depends on the following factors: (1) depth of water table; (2) rainfall pattern; (3) soil properties; (4) Distance from the sources of contamination.

2.4 Survival of Microorganisms in Groundwater

Due to the long time indigenous bacteria have had to degrade organic matter originally present, subsurface environments contain little organic matter. Furthermore, when percolating through the porous media, water containing organic matter encounters attached bacteria which remove most of this organic matter. Thus, subsurface systems are oligotrophic and the intermediate aquifer flow systems are among the most oligotrophic microbial environments that have ever been described (Morita, 1997). The average concentration of Dissolved Organic Carbon (DOC) for various types of consolidated rock aquifers ranges from 0.1 to 0.7 mg/l. Chemical analysis of the organic carbon in any environmental sample certainly does not determine what portion is available for use by the autochthonous bacteria. Humic substances have extremely complex structures, and can be divided into three major fractions defined in terms of their solubility in water: humic acid, fulvic acid and humic. In the subsurface environments, it can be supposed that the unavailable humic and fulvic acids make up more than 50% of the total organic carbon (Morita, 1997).

Microbes have evolved longer than any other living organism, so in all probability, the non-spore-forming heterotrophic bacteria must have developed mechanisms to survive long periods when no energy or nutrients were available. Thus, the concept of starvation – survival is fundamental for the evolutionary point of view. In order to provide a pragmatic approach to this concept, a definition has been provided by Morita (*op cit.*): ‘starvation - survival is a physiological state resulting from an insufficient amount of nutrients, especially energy to permit growth (cell size increase) and/or reproduction'. There are various degrees of starvation, starting with cells that just utilized the last amount of nutrients for growth, to cells that have been deprived of nutrients for long periods of time (Morita, *at el 1997.*).

2.5 Physico -chemical properties of water

2.5.1 pH

The pH is a measure of the activity of the hydrogen ion [H^+]; it is also the reciprocal of the logarithm of hydrogen ion concentration (Silberberg, 2000). The pH scale ranges from 0 to 14 (Ameyibor and Wiredu, 1991). In general, water with a pH less than 7 is considered acidic, soft and corrosive. While that with a value more than 7 is considered basic (Ameyibor and Wiredu, 1991). The pH of pure water is 7 at 25^{o}C (Silberberg, 2000), but when exposed to carbon dioxide in the atmosphere, equilibrium results in the pH of approximately 5.2. The WHO optimum limit of pH values is between 6.5 and 9.5. Because of the association of pH with atmospheric gases and temperature, it is strongly recommended that the water must be tested as soon as possible. Water with a low pH could contain elevated levels of toxic metals, cause premature damage to metal piping, and have associated aesthetic problems such as a metallic or sour taste, staining of laundry and the characteristic "blue-green" staining of sinks and drains. (Abimbola and shagodoyin, 2005).

Water with a pH more than 8.5 could indicate that the water is hard (Ameyibor and Wiredu, 1991). Hard water does not pose a health risk, but can cause anesthetics problems. These problems include formation of a "scale" or precipitate on piping and fixtures causing water pressures and interior diameter of piping to decrease, causes an alkali taste to the water and can make coffee taste bitter, formation of a scale or deposit on dishes, utensils, and laundry basins, difficulty in getting soaps and detergents to foam and formation of insoluble precipitates on clothing **(**Staniski *et al*., 2000).

a) Improving the pH of water

The primary method to treat the problem of low pH water is with the use of a neutralizer (Staniski *et al*., 2000). The neutralizer feeds a solution into the water to prevent the water from reacting with the house plumbing or contributing to electrolytic corrosion; a typical neutralizing chemical is soda ash. However, neutralizing with soda ash increases the sodium content of water **(** Staniski *et al*., 2000).

2.5.2 Total dissolved solids

Dissolved solids refer to any minerals salts metals, cations or anions dissolved in water. Total dissolved solids comprises of inorganic salts and some small amount of organic matter that are dissolved in water (Wikipedia, 2010).

TDS originate from natural sources such as, sewages, urban run-offs industrial waste water and chemicals used in the water treatment process. Total Dissolved Solids is the sum of the cations and the anions in the water **(**Nkansah *et al* 2010)**.**

An elevated TDS concentration is not a health hazard. TDS concentration is a secondary drinking standard and is therefore regulated because it is more of aesthetic rather than health hazard (Nkansah *et al., 2010*). An elevated TDS also indicates the following; (1) the concentration of the dissolved ions may cause the water to be corrosive and salty this results in scale formation. (2) Many contain elevated levels of ions that are above the primary or secondary drinking water standard such as an elevated level of nitrate, arsenic, aluminum copper and lead **(** Staniski *et al*., 2000).

The Environmental Protection Agency establishes standards for drinking water in two categories; that is primary standards and secondary standards. The primary standard is based on health consideration and the secondary is based on taste, odour, and colour, corrosively, foaming and staining properties of water. There is no primary drinking water standard for TDS but secondary standard for TDS is 500 mg/dm^{-3} (EPA, 2006).

2.5.3 Turbidity

Turbidity is an optical property where suspended and dissolved materials such as silt, clay, finely divided organic and inorganic cause light to be scattered rather than penetrate in straight lines (Wikipedia, 2010).Turbidity measures the amount of light scattered by suspended particles and can be considered as the "cloudiness" of water sample (Stanistski *et al.*, 2000). Turbidity is contributed mainly by suspended sediment and /or plankton, which are solid particles of inorganic or biological origin. Human activities, including logging, grazing and agriculture, mining road building, urbanization and commercial construction contribute to periodic pulse or chronic levels of suspended sediment in streams and other water bodies (Zoeteman, 1980). In drinking water the higher the turbidity level, the higher the risk of people develop in astrointestinal diseases. This is especially problematic for immune- compromised people, because contaminants like viruses or bacteria can become attached to the suspended solids (Stanistski et al., 2000**).**

2.5.4 Electrical conductivity

Electrical conductivity or simply conductivity is a measure of water's ability to conduct an electric current. The measurement is important because it indicates the concentration of dissolved ions in the water (Pritchard, *et al.*, 2007), which in turn reflects ground water input, catchment geology or diverse human impact. As the number of charged ions in the water increases, so does the electrical conductivity. Conductivity varies with temperature. High and low humidity result in evaporation of the water but leaves the ions behind giving the water a higher concentration of the salt and other compounds. Ground water has higher electrical conductivity than surface water because the ground water is able to react with minerals in the soil and rocks in the ground. (Staniski *et al.*, 2000).The WHO permissible limit for electrical conductivity of water is 8–10,000 μS/cm WHO, (2011).

2.5.5 Hard water

Hard water is water that has high mineral contents. Hard water has high concentration of Ca^{2+} ions and Mg^{2+} ions (Ameyibor and Wiredu, 1991). Hard water is generally not harmful to human's health but can pose serious problems in the industrial setting. It is the measure of quantity of divalent ions such as calcium, magnesium and or iron in water. These ions enter water supply or ground water by leaching (Nkansah *et al*., 2010) from minerals within an aquifer. Water hardness is measured by adding up the concentration of calcium, magnesium and converting the value to an equivalent concentrations of calcium carbonate ($CaCO_3$) in $mgdm^{-3}$ (APHA, 1998).

2.5.6 Potential health effect of hard water

Hardness does not pose a health risk and is not regulated by state agencies. In fact, calcium and magnesium in drinking water can help ensure average daily requirement for these minerals in a diet (Salami and Okafor, 2003). With hard water, soap solution forms a white precipitate instead of producing lather. The effect arises because the di cations destroy the surfactant properties of the soap by forming a solid precipitate (Ameyibor and Wiredu, 1991). It also forms deposits also called scales that cause clog to plumbing. This is scale mainly caused by $CaCO_3$, $Mg(OH)_2$ and $CaSO_4$ (Silberberg, 2000). It often causes aesthetic problems, such as an alkali taste to the water that makes coffees taste bitter (Abimbola and shagodoyin, 2005).

2.5.7 Nitrate in water

Nitrate is a colourless, odourless, and tasteless compound (Ameyibor and Wiredu, 1991) that is present in some groundwater. Nitrate can be expressed as either NO_3 (nitrate) or

NO_3-N (nitrate-nitrogen) [Silberberg, 2000]. Nitrate (NO_3) is a naturally occurring form of nitrogen found in soil. Nitrogen is essential to all life. Most crop plants require large quantities to sustain high yields. The formation of nitrates is an integral part of the nitrogen cycle in our environment. In moderate amounts, nitrate is a harmless constituent of food and water. Plants use nitrates from the soil to satisfy nutrient requirements and may accumulate nitrate in their leaves and stems. Due to its high mobility, nitrate can leach into groundwater (Self and Waskom, 2008).

Nitrates are formed when microorganisms break down fertilizers, decaying plants, manures or other organic residues. Usually plants take up these nitrates, but sometimes rain or irrigation water can leach them into groundwater **(**Ameyibor and Wiredu, 199). Although nitrate occurs naturally in some groundwater, in most cases higher levels are thought to result from human activities. Common sources of nitrate include fertilizers and manure, animal feedlots, municipal wastewater and sludge, septic systems, and N-fixation from atmosphere by legumes, bacteria and lightning. (Silberberg 2000).

a) Potential health effect of nitrate

High nitrate levels in water can cause methemoglobinemia or blue baby syndrome, a condition found especially in infants less than six months. This causes an increase in bacteria that can readily convert nitrate to nitrite (NO_2). Nitrite is absorbed in the blood, and haemoglobin (the oxygen-carrying component of blood) is converted to methemoglobin. Methemoglobin does not carry oxygen efficiently. This results in a reduced oxygen supply to vital tissues such as the brain. Methemoglobin in infant blood cannot change back to haemoglobin. (Hole, 1999), Which normally occurs in adults Severe methemoglobinemia can result in brain damage and death (Self and Waskom, 2008). Infants should not be allowed to drink water that exceeds 10 mg/l NO^{3-} N. The most obvious symptom of methemoglobinemia is a bluish colour of the skin, particularly around the eyes and mouth. Other symptoms include headache, dizziness, weakness or difficulty in breathing. If recognized in time, methemoglobinemia is treated easily with an injection of methylene blue. (Self and Waskom, 2008).

A water test for nitrate is highly recommended for households with infants, pregnant women, nursing mothers, or elderly people. These groups are the most susceptible to nitrate or nitrite contamination. Nitrate-nitrogen occurs naturally in groundwater, usually at concentrations far below a level of concern for drinking water safety **(**Ameyibor and Wiredu, 1991).

b) Standards of nitrate

Nitrate values are commonly reported as either nitrate NO_3^{--} or as nitrate-nitrogen NO_3^- N. The maximum contaminant level (MCL) in drinking water as nitrate (NO_3) is 45 mg/l (EPA, 2006). Protecting your drinking water supply from contamination is important for health and to protect property values and minimize potential liability. High nitrate levels are associated with poorly constructed or improperly located wells (Zoeteman, 1980). Although there is no enforceable drinking water standard for livestock, it is not advisable to allow animals to drink water with more than 100 mg/l NO_3^- N. This is especially true of young animals. They are affected by nitrates the same way as human babies. Older animals may tolerate higher levels **(**Ameyibor and Wiredu, 1991).

2.5.8 Alkalinity

The capacity of water to accept H^+ ions (protons) is called alkalinity (Baryla *et al.*, 2011). Alkalinity is important in water treatment and in the chemistry and biology of natural water. Frequently, the alkalinity of water must be known to calculate the quantities of the chemicals added in treating water. Highly alkaline water often has a high pH and generally contains elevated levels of dissolved solids. These characteristics may be detrimental for water to be used in boilers, food processing and municipal water systems (Baryla *et al.*, 2011). Alkalinity serves as a pH buffer and reservoir for inorganic carbon, thus helping to determine the ability of water to support algae growth and other aquatic life, so it can be used as a measure of water fertility. Generally, the basic species responsible for alkalinity in water are bicarbonate ion, carbonation and hydroxide ion (Silberberg, 2000).

$$HCO_3^- + H^+ \rightarrow CO_2 + H_2O$$

$$CO_3^{2-} + H^+ \rightarrow HCO_3^-$$

$$OH^- + H^+ \rightarrow H_2O$$

2.5.9 Chemical oxygen demand (COD)

When chemical substances which are oxygen demanding are discharged into water body, they consume the oxygen dissolved in water and lead to low oxygen concentration .This has adverse effects on the organism that require oxygen for survival in the environment (Hammer,1996).

2.5.10 Biological oxygen demand (BOD)

The biodegradable material found in water, usually the microbes and other organic matters, which require oxygen for their systems tend to compete with aquatic animals in the consumption of oxygen dissolved in water. The amount of these microbes and materials present in water are very important because they affect the available dissolved oxygen in water (Sada, 1988). The amount of oxygen dissolved in water is very essential, since it supports aquatic life in water. It is an important parameter which needs to be monitored in water (Hammer, 1996)

2.5.11 Metallic pollutants

Some metallic elements present in natural waters act as pollutants. It should be noted that many of the metals that can act as a pollutant are actually essential in human nutrition (Nkansah *et al*., 2010).

2.5.12 Effects of heavy metals

The term heavy metal refers to any metallic chemical element that has a relatively high density and is toxic or poisonous at low concentrations (Baryla *et al.,* 2011). Examples of heavy metals that are harmful to humans include mercury, lead and arsenic. Chronic exposure to these metals can have serious health consequences. Humans are exposed to heavy metals through inhalation of air pollutants, consumption of contaminated drinking water, exposure to contaminated soils or industrial wastes, or consumption of contaminated foods. Food sources such as vegetables, grains, fruits, fish and shellfish can become contaminated by accumulating metals from surrounding soil and water.

Heavy metal exposure causes serious health effects, including reduced growth and development, cancer, organ damage, nervous system damage, and in extreme cases, death (Nkansah *et al*., 2010). Exposure to some metals, such as mercury and lead, may also cause development of autoimmunity, in which a person's immune system attacks its own cells. This can lead to joint diseases such as rheumatoid arthritis, and diseases of the kidneys, circulatory system and nervous system (Baryla *et al.,* 2011)..

Metals are particularly toxic to the sensitive, rapidly developing systems of foetuses, infants, and young children. Some metals, such as lead and mercury, easily cross the placenta and damage the fetal brain. Childhood exposure to some metals can result in learning difficulties, memory impairment, damage to the nervous system, and behavioural problems such as aggressiveness and hyperactivity (Baryla *et al.,* 2011). At higher doses, heavy metals can cause irreversible brain damage. Children may receive higher doses of metals from food than adults, since they consume more food for their body weight than adults (IARC, 1990).

a) Lead

Lead is not essential in nutrition and has high toxicity level. It causes anaemia, kidney failure, mental retardation (in children) and convulsions when taken above the maximum tolerable level of 0.05 mg/l. Sources of lead to aquatic system include lead piping, lead paints and auto emissions from lead petrol as well as batteries (Nkansah *et al*.,2010).

b) Manganese

Manganese is essential in nutrition and has low level of toxicity. But it's when high concentrations are present in a human body. Maximum tolerable limit of manganese is 0.05mgdm^{-3}. However, Long-term exposure to excess manganese levels may result in iron-deficiency anemia (Nsi, 2007).

c) Copper

The major portion of copper produced in the world is used by the electrical industries with most of the remainder being combined with other metals to form alloys (Prusty, 1983). Important series of alloys in which copper is the chief constituent are brass (copper and zinc) and bronzes (copper and tin) (Morse, 1994). Copper resists the action of the atmosphere and seawater; exposure for long periods to air, however, results in the formation of a thin green protective coating (patina) that is a mixture of hydroxocarbonate, hydroxosulphate and small amounts of other compounds. Copper is a moderately noble metal, being unaffected by non-oxidizing or non-complexing dilute acids in the absence of air. It will however, dissolve readily in nitric acid and in sulphuric acid in the presence of oxygen (Frits *et al.*, 2000).

It is toxic at low concentrations in water cause brain damage in mammals (Hukabee *et al*., 2011). Toxicity of copper in plants as a result of high level in sewage treated agricultural soil has been reported. Contribution of copper to environmental burden could be by atmospheric deposition from metal industries, dumpsites and power plants that burn fuels (Baryla *et al*., 2011).

d) Zinc

The major uses of zinc metal are in galvanizing iron and steel against corrosion and in making brass and alloys for die-casting. Zinc itself forms an impervious coating of its oxide on exposure to the atmosphere and hence the metal is more resistant to ordinary atmosphere than iron and corrodes at a much lower rate (Baryla *et al*., 2011). Zinc is an essential trace element in the human body where it is found in high concentrations in the red blood cells as an essential part of the enzyme carbonic anhydrase, which promotes many reactions relating to carbon dioxide metabolism. The toxicity of zinc is low in drinking water. It can be detected by taste only when it reaches a concentration of 15 $mgdm^{-3}$ (Baryla *et al*., 2011).

Water containing 40 $mgdm^{-3}$ zinc has a definite metallic taste. Vomiting is induced when the zinc content exceeds 800 mg/kg. Cases of fatal poisoning have resulted through the ingestion of zinc chloride or sulphide, but these are rare. Both zinc and zinc salts are well tolerated by the human skin. Excessive inhalation of zinc compounds can cause such toxic manifestations as fever, excessive salivation and a cough that may cause vomiting; but the effects are not permanent (Kline *et al*., 2010).

2.5.13 Bacteriological analysis of water

Faecal contamination of drinking water is only one of several faeco-oral mechanisms by which they can be transmitted from one person to another or in some cases from animals to people. Consequently, these diseases causing organisms may be hazardous to human health if used as drinking-water or in food preparation. Faecal contamination of water is routinely detected by microbiological analysis (Mara and Cairncross, 1989).

It is impractical to attempt the routine isolation of pathogens because they are present in relatively small numbers compared with other types of micro-organisms. Moreover, there are many types of pathogen and each requires a unique microbiological isolation technique (Baryla *et al*., 2011). The approach that has been adopted is to analyse for indicator organisms that inhabit the gut in large numbers and are excreted in human faeces. According WHO (1989), the presence of these indicator organisms in water is evidence of faecal contamination and, therefore people are at risk of infection. If indicator organisms are present in large numbers, the contamination is considered to be recent or severe (Schaffter and Parriaux, 2002).

Bacteria in water are, in general, not present individually, but as clumps or in association with particulate matter. When enumerating bacteria in water it is not the number of individual bacteria present which are counted, but the number of clumps of bacteria or the particles and their associated bacteria. Each clump or particle may have many bacteria associated with it (Mara and Cairncross, 1989).

Ideally, all samples taken from the distribution system of the river including consumers' premises should be free from coliforms organisms. This is always attainable to control purity of water, the following microbiological parameters for water collected in distribution system is therefore recommended as Indian standard, IS (1981).

a. Throughout any year, 95% of samples should not contain any coliform organisms in 100 cm^{-3}.

b. No sample should contain *Escherichia Coli* in 100 cm^{-3}.

c. No sample should contain more than 10 coliform organisms per 100 cm^{-3}.

d. Coliform organisms should not be detectable in 100 cm^{-3} of any two consecutive samples.

a) Total coliforms

The term "total coliforms" refers to a large group of Gram-negative, rod-shaped bacteria that share several characteristics. The group includes thermotolerant coliforms and bacteria of faecal origin, as well as some bacteria that may be isolated from environmental sources (Mackie and McCartney, 1989). Thus the presence of total coliforms may indicate faecal contamination. In extreme cases, a high count for the total coliform group may be associated with a low, or even zero count for thermotolerant coliforms. Such a result would not necessarily indicate the presence of faecal contamination. It might be caused by the entry of soil or organic matter into the water or by conditions suitable for the growth of other types of coliform. In the laboratory total coliforms are grown in or on a medium containing lactose, at a temperature of 35 or 37 °C. They are provisionally identified by the production of acid and gas from the fermentation of lactose. ISO (1981)

b) Escherichia coli

Escherichia coli is a Gram-negative, non-spore forming, rod-shaped bacterium which can be either motile or nonmotile (motile cells are peritrichous); growth is aerobic or facultatively anaerobic. Metabolism is both respiratory and fermentative; acid is produced by the fermentation of glucose and lactose. *Escherichia coli* is found in large numbers in the faeces of humans and of nearly all warm blooded animals; as such it serves as a reliable index of recent faecal contamination of water (Mackie and McCartney, 1989). *Escherichia coli* in fresh faeces might attain concentrations of 109 per gram. It is found in sewage, treated effluents, and all natural waters and soils subject to recent faecal contamination either from human wild animals, and agricultural activity.

Escherichia coli may be present or even multiply in tropical waters not subject to human faecal pollution. However, even in the remotest regions, faecal contamination by wild animals, including birds, can never be excluded, because animals can transmit pathogens that are infectious in humans; however the presence of *Escherichia coli* must not be ignored (Mackie and McCartney, 1989)

2.6 Mode of Operation of AAS

Solution containing a metal is aspirated in the form of an aerosol into a hot flame, the solvent is evaporated from the droplets and the metal vapourized mainly as atoms. Alternatively, an atomic vapour could be produced by rapid electrothermal heating of graphite rod or tube on which a drop of the sample has been placed. A beam of electromagnetic radiation characteristic of a particular element can be passed through the atomic vapor and monitored by a photomultiplier detector. If the sample contains that particular element, its atom will selectively absorb some of the radiation thereby attenuating the beam and causing the detector signal to fall. This absorbance, is proportional to the concentration of that element in the vapor and hence in the original sample. The advantages of the atomic absorption spectrophotometer method of analysis are the high degree of sensitivity, accuracy and its relative freedom. (EPA, 1990)

2.6.1 Principles of the operation of Hi 83200, photometer

HI 83200 is a multi-parameter bench photometer dedicated for laboratory analysis. It measures using specific liquid or powder reagents. The amount is precisely dosed to ensure maximum reproducibility. The principle behind its operation is also based on Beer-Lambert law: $-\log I/I_o = \varepsilon_\lambda c d$ or $A = \varepsilon_\lambda c d$

Where:

$-\log I/I_o$ = Absorbance (A)

I_o = intensity of incident light beam

I = intensity of light beam after absorption

$E\lambda$ = molar extinction coefficient at wave length λ

c = molar concentration of the substance

d = optical path through the substance

Therefore, the concentration of the analyte can be calculated from the absorbance of the substance as other factors are known. Photochemical analysis is based on the possibility to develop an absorbing compound from a specific chemical reaction between sample and reagents.

The optical system of HI 83200 is based on special subminiature tungsten lamps and narrow- band interference filters to guarantee both high performance and reliable results. Five measuring channels allow a wide range of tests. A microprocessor controlled special tungsten lamp emits radiation which is first optically conditioned and beamed through the sample contained in the cuvette. The optical path is fixed by the diameter of the cuvette. Then the light is spectrally filtered to a narrow spectral bandwidth, to obtain a light beam of intensity Io or I. the photoelectric cell collects the radiation I that is not absorbed by the sample and converts it into an electric current, producing a potential in the mV range. The microprocessor then uses this potential to convert the incoming value into the desired measuring unit and to display it on the Liquid Crystal Display (LCD).

2.7 Principle for Multiple Tube Fermentation Technique

Separate analyses are usually conducted on five portions of each of three serial dilutions of a water sample. The individual portions are used to inoculate tubes of culture medium that are then incubated at a standard temperature for a standard period of time. The presence of coliforms is indicated by the production of gas formation. The MPN index is determined by comparing the pattern of positive results (the number of tubes showing growth at each dilution) with statistical tables. The tabulated value is reported as MPN per 100 cm^3 of sample WHO (1985).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the Study Area

Kogi State is located in the North Central region of Nigeria. It occupies 29,833 square kilometers of river Niger and Benue, it lies on $7^0$30N and $6^0$42E, it has 21 of Nigeria's 774 local government areas and shares common borders with Federal Capital Territory (FCT) to the north, Benue State to the East, Anambra State to the South and Niger State to the north. It is popularly called the confluence state because the confluence of Rivers Niger and Benue is at its capital, Lokoja, the first administrative capital of modern-day Nigeria.

Like many states in Nigeria, Kogi State faced the problem of flooding in 2012, In that year, the river extended its territory beyond its banks, thus sacking residents from their humble abodes. The disaster brought back the memories of 1998, when the river covered and threatened some of the buildings at the river bank,

Consequently, the level of pollutant in the region washed away a large amount of farm lands; hence the levels of heavy metals Physico-chemical and bacteriological of wells water in close proximity to the River are expected to be above the threshold levels.

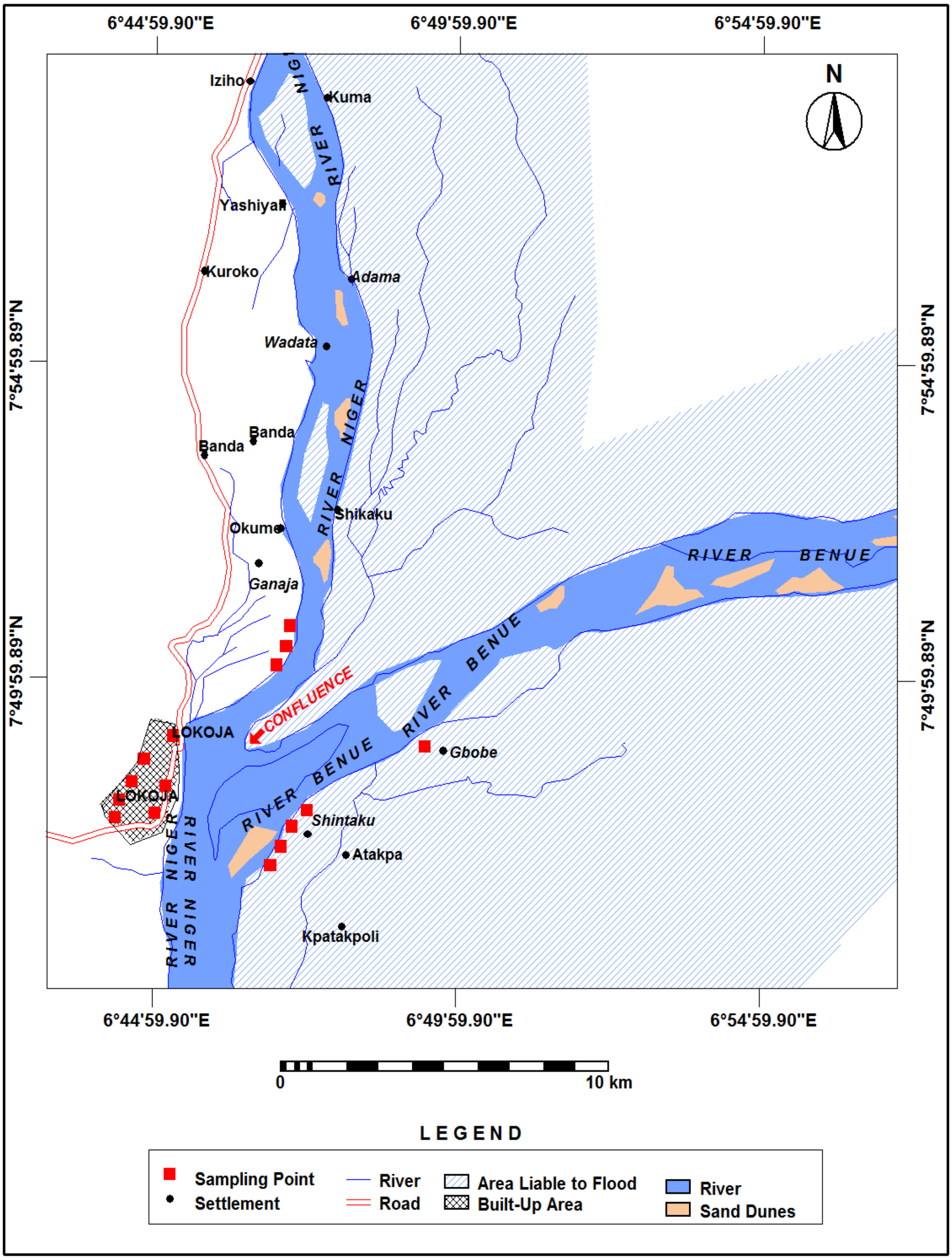

Fig 3.1: The map of Lokoja and environs indicating the sampling points.

3.1.1. Sampling site

Water samples from eight wells were collected in the villages (Shitaku, Ganaja and Gbobe) near Rivers Niger and Benue and seven (7) wells located at the margin of Lokoja metropolis which were 300 m away from the rivers. Those wells chosen were of different distance from the river. The study area Included three villages (Gbobe (B),Shintaku (S) and Ganaja (G)) near the rivers Niger and Benue floodplain located in Lokoja, Kogi State. The south bank has two villages and one village at the east. These areas are flooded in the rainy season. Other sites are located within Lokoja metropolis were distances away from the rivers. And the depth of the studied wells differs.

3.1.2 Sample collection

The sample bottles to be used for collection were washed thoroughly with 2% $HNO_{3(aq)}$ and sterilized to avoid contamination by any physical, chemical or microbial means. The well water samples from Lokoja metropolis and villages near Rivers Niger and Benue were collected in one liter bottles that had been sterilized. Weights were attached to the bottles so that they were vertically sank into the well (this is to avoid collecting water samples at the surface only). The water samples were collected in triplicates. The samples were aseptically transferred into sterile one liter screw capped containers and labeled accordingly. These samples were then taken to the laboratory within twenty four hours of collection.

Collection of the well water samples was done in 2014, (wet season May 2014) and (dry season October 2014). A total of 90 samples were collected for the physico-chemical, heavy metal and microbial analyses. Samples for heavy metals determination was preserved by treatment to a pH of 2, using analytical grade concentrated nitric acid.

Those samples for bacteriological analysis were preserved in well sterilised sample bottles and stored in ice box at 4 to $10^{o}C$ (APHA, 2000). The bacteriological analysis was done within twenty four hours of collecting the samples at the Nigerian Institute of Leather Research Science and Technology Samaru, Zaria. The samples were given treatment at the field according to the standard method of American Public Health Association (APHA 2000). Physico- chemical analyses of the water samples was carried out using the Standard method of American Public Health Association (APHA2000).

Parameters with extremely low stability such as pH and temperature were measured on the field using pH meter and thermometer respectively. Thereafter, other parameters were measured in the laboratory using standard procedures as specified by American Public Health Association (APHA, 2000) and all the parameters were measured in triplicate.

3.2 Preparation of Aqueous Stock Solutions

All chemicals used were of analytical grade. All solutions used for the analyses were prepared by dissolving appropriate amount of the solute in distilled water. Distilled water were used for solution preparations.

3.2.1 Sodium nitrite solution (1%):

This was prepared by dissolving 1g of sodium nitrite in 100 cm^3 distilled water in a volumetric flask. This solution was kept in a brown bottle in order to be stable for at least, one week.

3.2.2 Alizarin solution:

A 0.7 g alizarin red weighed into a volumetric flask was dissolved in about 700 cm^3 distilled water. The solution obtained was shaken and made up to the mark of the 1000 cm^3 thus giving a 1000 ppm Standard solution.

3.2.3 Zirconyl Acid:

A 0.354 g zirconyl acid was weighed into a 1000 cm³ volumetric flask containing 800 cm³ distilled water, 33.3 cm³ conc. H_2SO_4 was added slowly with stirring and made up to the mark with distilled water (thus giving a 1000 ppm standard solution).

3.2.4 Copper solution

The solution was prepared by dissolving 3.803 g of $Cu(NO_3)_2.3H_2O$ in 5.00 cm³ concentrated HNO_3 and made up to 1000.00 cm³ with distilled water giving a1000 ppm copper solution.

3.2.5 Lead solution (1000 ppm)

The solution was prepared by dissolving 1.599 g of $Pb(NO_3)_2$ in distilled water and made up to 1000 cm³ in a volumetric.

3.2.6 Zinc solution

This solution was prepared by dissolving 1.244 g of ZnO in 5.00 cm³ of water then 25.00 cm³ concentrated HNO_3 was added and made up to 1000 cm³ with distilled water, giving 1000 ppm zinc solution.

2.2.7 Manganese solution

The solution was prepared by dissolving 4.058 g $MnSO_44H_2O$ in 5.00 cm³ of water, 1.00 cm³ concentrated H_2SO_4 was then added and the solution made up to 1000 cm³ with distilled water giving 1000 ppm manganese solution.

3.2.8 Calibration Curves

Five working standards solutions were prepared in triplicates for each metal by serial dilution of stock solutions. These standard solutions and the blank were aspirated in a Varian AA240FS atomic absorption spectrophotometer. Then the calibration curves of absorbance versus concentrations of the samples were plotted.

3.3 Determination of Physico-chemical Parameters of the Well Water

The standard methods as recommended by World Health Organization (WHO), and United State Environmental Protection Agency (US- EPA), were employed for the preparation of reagents used for the determination of water quality parameters.

3.3.1 **Determination of temperature**

The temperatures values were determined *in situ* with a Hg filled glass thermometer. It was ensure that the thermometer was brought to room temperature (30^0C) before each reading was taken and held upright to avoid parallex error (US-EPA, 1983; APHA-AWWA-WPCF, 1985; Trivedy and Goel, 1986).

3.3.2 Determination of pH

The pH value of the water samples were determined using a portable pH meter after being standardized with buffers of pH 4.0 and pH 9.2 (Ademoroti, 1996).

3.3.3 Determination of conductivity

Conductivity value of the well water samples were determined using the standard procedure approved by (AOAC 1998). The conductivity metre (Hach model CO150) was used. The power key and the conductivity key of the conductivity metre was switched on, and the temperature of the meter adjusted; the instrument was calibrated with 0.001 M KCl to give a value of 14.7 (µS/cm) at 25^0C. The probe was dipped below the surface of both samples. Time was allowed for the reading to be stabilized and the reading was recorded (APHA, 2000).

3.3.4 Determination of turbidity

A turbidity meter was used in determining the turbidity of the samples. The turbidity metre was first set to zero with distilled water. Some samples of the water was thoroughly shaken and a portion of it poured into the sample tube, making sure that no air bubbles were trapped. The sample tube was shaken vigorously and then thoroughly wiped dry and inserted into the instrument and the reading noted. Calibration curve was prepared from standard turbidity suspension (Formazin Polymer which is a product of hydrazine sulphate and Hexamethylenetetramine). Standard solutions of the suspension of concentrations of 5, 10, 15, 20, 25 and 30 cm^3 were prepared and used to determine the turbidities of the samples and to calibrate the instrument. The unit of measurements is called Formazin Turbidity Units (FTU) (APHA, 2000).

3.3.5 Determination of total hardness

This was determined by EDTA titration using Eriochrome black T indicator as described by Hydrology Project Government of India and Netherland, (1999). The samples were shaken thoroughly; 25 cm^3 was taken in each case and diluted to 50 cm^3 with distilled water. 2 cm^3 of buffer solution was added then 2 drops of Eriochrome black T indicator. Immediately after this was titrated with EDTA within 5 minutes intervals, a blue coloration indicated the end point (APHA, 2000).

$$\text{Total hardness (mg CaCO}_3\text{/L)} = \frac{A \times B \times 1000}{ml\ \ sample}$$

Where A = cm^3 EDTA titrated for sample

B = mg $CaCO_3$ equivalent to 1.00 cm^3 EDTA titrant

3.3.6 Determination of total dissolved solids

A 100 cm^3 of the sample was quantitatively transferred into an evaporating dish that had been previously weighed and dried in an oven for one hour and cooled in a desiccator. The content of the dish was evaporated to dryness on a water-bath to a constant weight. The residue was then dried in an oven between 103 and 105^oC for two hours cooled in a desiccator and the difference in weight calculated (US-EPA, 1983; APHA-AWWA-WPCF, 1985; Trivedy and Goel, 1986; NWRI, 2001).

Calculation.

$$\text{TDS } (mg/dm^3) = \frac{\text{difference in weight x 1000}}{\text{ml of sample}}$$

3.3.7 Determination of chemical oxygen demand (COD)

The COD value of the water samples collected were determined using the standard method described by (Ademoroti, 1996). 0.4 cm^3 of H_2SO_4 was placed in a refluxing flask. About 20 cm^3 of the samples in each case was diluted with 20 cm^3 of distilled water. 10 cm^3 standard solution of $K_2Cr_2O_7$ was then added to glass already heated to 600 ^oC for 1 hour. The flask was then attached to the reflux condenser and about 30 cm^3 of concentrated H_2SO_4 containing Ag_2SO_4 was added through the open end of the condenser. The resulting solution was thoroughly mixed by switching. The mixture was refluxed for 1 hour, cooled and the condenser washed with about 25 cm^3 of distilled water. The mixture was diluted with 150 cm^3 of distilled water and cooled to room temperature. About 3 drops of (0.10 - 0.15 cm^3) ferroin indicator was added. The mixture was then titrated with $Fe(NH_4)_2(SO_4)_2$ taking as the end point, the sharp colour change from blue-green to reddish brown. In the same manner blank containing 20 cm^3 distilled water was refluxed together with the reagent. This was carried out for the well water sample collected in May and October 2014.

Calculation

$$\text{COD } mg/dm^3 = \frac{(a-b) \times M \times 8000}{ml\ of\ sample}$$

Where: COD=COD from potassium dichromate

a= cm^3 Fe $(NH_4)_2$ $(SO_4)_2$ used as blank

b= cm^3 Fe $(NH_4)_2(SO_4)_2$ used for sample.

M= morality of Fe $(NH_4)_2$ $(SO_4)_2$ (APHA, AWWA, 2000).

3.3.8 Determination of biochemical oxygen demand (BOD)

Fresh well water samples collected for the study were incubated at 20^{o} C for five days and the above procedure for the determination of dissolved oxygen was then repeated. The differences between DO for incubated water samples and DO not incubated water samples were determined (US-EPA, 1983; APHA – AWWA 2010).

Calculation:

$$BOD_{5\ mg/L} = \frac{\mathbf{DO(0) - DO(5)}}{\mathbf{dilution\ factor}} \quad \text{……………………..…………………...3.1}$$

$$\text{Dilution factor} = \frac{\mathbf{No\ of\ days}}{\mathbf{ml\ of\ sample}} \quad \text{…………………….............................3.2}$$

Where DO (5) = Demand Oxygen at day five and DO (0) = Dissolved Oxygen before incubation.

3.3.9 Determination of nitrate and phosphate

The HANNA multi parameter logging spectrophotometer (HI83200) was used to digitally determine the nitrate and phosphate level in the surface and underground water samples. The concentrations of nitrate and phosphate were determined using standard procedure. Phosphate was determined using direct reading from HI 83200 HANNA multi parameter. (Greenberg *et al*., 1992)

3.3.10 Determination of dissolved oxygen

The dissolved oxygen (DO) content of the well water samples were measured using the Jenway Model 9070 water proof metre according to the standard Method described by (APHA, 1998).

3.3.11 Determination of total alkalinity

In each case to 100 cm³ of the well water sample was transferred into a conical flask, two drops of phenolphthalein indicator were added and the solution titrated with standard H_2SO_4 to the end point. Again, two drops of methyl orange was added to the titrated mixture and the titration continued to methyl orange end point (US-EPA, 1983; APHA-AWWA, 2010; Trivedy and Goel, 1986; NWRT, 2001).

Calculation: Total Alkalinity, mg $CaCO_3$

$$= \frac{\mathbf{A \times B \times 1000}}{\mathbf{ml\ of\ sample}}$$

Where,

A=Vol of standard H_2SO_4

B=Titer of standard acid

3.4 Sample Digestion.

A portion of each of the samples of water for heavy metal determination was preserved by treatment with drops of analytical grade concentrated HNO_3 to a pH of 2. Acid digestion of the water was carried out by using a 2:1 of concentrated HNO_3 and concentrated HCl (APHA, 2000). Was added and heated on a hot plate making sure the sample did not boil, (at the point of boiling hot(80^{o}C) distilled water was added in drops) until the volume was reduced to about 15 cm^3. The samples were then allowed to cool, filtered and quantitatively transferred into a 100 cm^3 standard volumetric flask in each case and made up to mark with distilled water in each case the concentrations of Cd, Cu, Ni, Mn, Pb, Zn in the samples were then determined by using an atomic absorption spectrophotometer (model TAS990, Intec Co. Ltd., Rome). Absorbance measurements of both the standards and sample solutions were read at appropriate wavelengths using a single element hollow cathode lamp on the spectrometer, equipped with automatic background correction ((Ekwumemgbo *et al*., 2011). The result of each sample was the average of triplicate sequential readings.

3.5 Sample Analysis

The digested well water samples were subjected to analysis using atomic absorption spectrophotometer. (Cu, Cd, Mn, Ni and Pb) were assayed using a Varian AA240FS

Atomic Absorption Spectrophotometer at the Multipurpose Science Research Laboratory, Ahmadu Bello University, Zaria.

3.6 Bacteriological Analysis (EPA, 1994.)

3.6.1 Presumptive coliform test

The modified multiple tube fermentation technique of Collins and Lynne (1998), Mackie and McCartney (1989) as reported by Asbolt (2004) was used in this study. In this method, varying amounts of well water samples were added to the double and single strength Mac Conkey broth in bottles containing inverted sterile Durham tubes as follows: 1 x 50 cm^3 well water to 50 ml double strength medium, 5 x 10 cm^3 well water to 10 ml double strength medium, 5 x 1 cm^3 well water to 5 cm^3 single strength medium.

The bottles were incubated aerobically at 37^oC for 18 - 24 h after which they were examined for production of acid and gas. Sterile distilled water was used as a control for each test batch. Presumptive coliform count was obtained by the most probable number (MPN) of coliform per 100 cm^3 of well water samples by making reference to the Mc Crady's probability table after combination of various positive and negative results.

3.6.2 Identification of isolates

Positive tubes of the presumptive test were sub-cultured on Mc Conkey agar for the enumeration of *Escherichia coli* and other enteric coliforms enumeration. All the inoculated media were incubated aerobically at 37^oC for 24 h, after which the isolates were further characterized by a combination of colonial and morphological characteristic on solid media as well as standard biochemical tests (Cowan, 1993).

CHAPTER FOUR

4.0 RESULTS

Table 4.1: Indicates the properties of the well water samples from the villages near rivers Niger and Benue. The depth of the wells ranged from 1.85 m (G1) to 9.6 m (L4). The proximity of the wells to river Niger and Benue is 350 m to greater than 1000 m. Table 4.2: shows the physicochemical parameters of the well water samples during the dry season (October, 2014). The highest mean values of temperature, pH, electrical conductivity and nitrate were 33^{o}C, 7.43, 985(µS/cm) and 43.35 mg/dm^3 respectively. The biological oxygen demand, dissolved oxygen, chemical oxygen demand manganese and nickel content were 0.405, 0.85, 345, 0.009 and 0.008 mg/dm^{3}respectively during the dry season of 2014.

Table 4.3: represents the physicochemical parameters of the wells water samples during the wet season (May, 2014). The highest mean values of temperature, pH, nitrate and electrical conductivity were 32^{o}C at station (S1), 7.15 at station (L4), 28.8 mg/dm^3 at station (B1) and 1398 µS/cm at station (G3) respectively. The biological oxygen demand, dissolved oxygen, chemical oxygen demand manganese and nickel content ranged from 0.2 - 0.6 at station (S3) 0.9 - 1.1 at station (S3), 110 - 550 at station (L2),0.001 - 0.013 at station (L4) and 0.009 - 0.045 mg/dm^3 at station (G1) respectively. The total suspended solid, total solid, total dissolved solid, phosphate, ammonia and cadmium content ranged from 13 – 450 at station (BI), 105 – 750 at station (L1),57.5 – 310 at station (L1), 3.2 – 13.5 at station (S1), 3.1 – 12 at station (G3) and 0.001 – 0.004 mg/ dm^3 at station (B1) respectively during the wet season of 2014.

Table 4.1: Properties of the well water samples sourced from the villages near Rivers Niger and Benue

S/n	Sample ID	Source	Proximity to the river (m)	Depth of well (m)
1	L1	Lokoja	>1000	9.20
2	L2	Lokoja	>1000	8.80
3	L3	Lokoja	>1000	6.80
4	L4	Lokoja	>1000	9.60
5	L5	Lokoja	>1000	4.90
6	L6	Lokoja	>1000	5.30
7	L7	Lokoja	>1000	6.00
8	S1	Shintaku	350	2.40
9	S2	Shintaku	850	5.20
10	S3	Shintaku	1000	5.40
11	S4	Shintaku	800	3.60
12	G1	Ganaja	650	1.85
13	G2	Ganaja	520	4.20
14	G3	Ganaja	300	8.40
15	B1	Gbobe	700	2.70

Table 4.2: Physicochemical parameters of the wells water samples during the dry season (October, 2014)

	L1	L3	L5	L6	L2	L4	L7	S1	S2	S3	S4	G1	G2	G3	B1
pH	6.90	6.38	7.00	7.50	7.40	6.70	7.40	5.90	6.20	6.70	6.90	6.30	6.80	6.40	7.43
T ^oC	30.00	31.00	29.00	29.00	29.50	33.00	28.70	29.60	33.00	29.50	32.00	27.40	31.00	28.30	33.00
EC uS/cm	676.00	185.10	167.70	185.10	725.00	231.95	985.00	985.00	957.00	343.00	347.00	941.00	320.00	53.50	216.00
Alk (mgdm$^{-3)}$	32.50	13.50	11.50	13.50	55.50	20.00	41.50	31.00	24.00	18.00	33.00	41.50	23.50	23.50	59.00
Turbidity NTU	0.13	0.17	53.46	0.17	0.06	0.09	24.45	6.46	9.51	6.58	5.03	6.05	5.05	7.64	130.45
TH (mgdm$^{-3)}$	515.10	217.15	202.01	217.15	479.75	252.50	621.10	817.25	430.25	362.85	815.30	346.25	232.80	474.60	817.85
Phos (mgdm^{-3})	8.60	3.05	3.15	3.05	4.30	4.15	3.75	14.95	6.95	9.90	11.85	1.50	1.50	3.60	3.35
NO_3^-(mgdm^{-3})	13.35	12.60	11.80	12.60	9.40	9.70	8.50	24.35	9.55	12.30	15.00	8.90	21.95	3.90	43.35
NH_3 (mgdm^{-3})	0.02	0.03	0.04	0.03	0.02	0.02	0.30	0.02	0.02	0.02	0.03	0.04	0.03	0.25	0.07
TSS (mgdm^{-3})	445.00	45.00	115.00	45.00	75.00	60.00	20.00	13.00	76.00	28.00	47.50	78.00	75.00	20.00	450.00
TDS (mgdm$^{-3)}$	310.00	105.00	135.00	105.00	65.00	265.00	195.00	213.50	76.00	105.00	57.50	73.00	84.00	905.00	125.00
TS (mgdm$^{-3)}$	755.00	150.00	250.00	150.00	140.00	325.00	215.00	226.50	152.00	133.00	105.00	151.00	159.00	925.00	575.00
DO (mgdm$^{-3)}$	0.45	0.45	0.40	0.45	0.45	0.25	0.75	0.35	0.55	0.55	0.75	0.55	0.09	0.40	0.12
BOD (mgdm$^{-3)}$	0.10	0.25	0.15	0.25	0.20	0.15	0.15	0.35	0.25	0.33	0.41	0.39	0.04	0.25	0.03
COD (mgdm$^{-3)}$	250.00	105.00	290.00	105.00	260.00	295.00	330.00	208.50	345.50	185.50	190.00	240.00	265.00	225.00	315.00
Cu (mgdm$^{-3)}$	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.01	0.01	BDL	BDL	0.01	0.00
Ni (mgdm$^{-3)}$	0.01	BDL	BDL	0.01	0.02	BDL	0.01	0.01	0.01	0.04	0.04	0.04	0.03	0.03	0.04
Zn (mgdm$^{-3)}$	BDL	BDL	BDL	0.01	BDL	BDL	0.01	0.01	0.02	0.02	0.03	0.04	0.01	0.01	BDL
Mn (mgdm$^{-3)}$	BDL	BDL	BDL	BDL	0.01	0.01	0.01	0.01	0.01	BDL	0.01	0.01	0.01	0.01	0.01
Pb (mgdm$^{-3)}$	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.01	0.01	BDL	0.01	0.01	BDL	BDL
Cd (mgdm$^{-3)}$	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
TC MPN/100cm^3	2.00	3.00	4.50	2.00	12.00	6.00	7.00	33.50	12.50	13.00	21.50	64.00	26.50	3.00	31.00

BDL: below the detection limit. ALK : alkalinity, TBD : Turbidity. TH : total hardness. PO_4^{3-}P : phosphate. NO_3^- :nitrate. NH_3: ammonia.

Table 4.3: Physicochemical parameters of the wells water samples during the wet season (May, 2014)

	L1	L3	L5	L6	L2	L4	L7	S1	S2	S3	S4	G1	G2	G3	B1
pH	5.90	5.70	5.80	6.65	6.55	7.15	5.45	6.40	6.20	7.00	6.25	6.95	5.80	6.40	5.75
T ^{o}C	30.00	29.00	30.00	29.00	30.00	27.00	29.00	32.00	29.00	29.00	28.50	29.00	29.00	30.00	30.60
EC uS/cm	896.00	920.00	94.30	644.00	650.00	47.40	75.10	425.00	428.00	289.60	300.00	97.30	78.90	1398.00	1206.00
ALK(mg dm^{-3})	115.00	131.00	18.00	82.00	44.00	21.00	22.00	41.00	32.00	39.00	3 2.00	28.00	21.00	84.00	111.00
TBD(NTU)	0.61	0.71	0.71	0.62	0.62	53.50	0.81	100.00	111.00	4.11	4.18	140.00	1.38	1.04	2.83
TH(mg dm^{-3})	343.30	232.30	151.50	333.30	292.90	141.40	141.40	303.00	313.10	22.20	242.40	151.50	151.50	404.00	373.70
PO_4^{3-}P (dm^{-3})	10.50	3.50	3.20	4.60	4.50	9.50	3.50	13.50	13.20	10.40	10.50	3.50	3.10	12.00	12.50
Nitrate mg dm^{-3}	12.50	65.00	13.50	10.50	7.50	18.00	11.20	20.50	25.00	19.50	18.50	10.90	10.50	28.50	28.80
NH^{3-} mg dm^{-3}	10.50	3.50	3.20	4.60	4.50	9.50	3.50	13.50	13.20	10.40	10.50	3.50	3.10	12.00	12.50
TSS mgdm^{-3}	240.00	280.00	230.00	240.00	230.00	260.00	70.00	370.00	300.00	280.00	260.00	0.90	130.00	240.00	270.00
TDS mgdm^{-3}	850.00	870.00	100.00	750.00	560.00	140.00	130.00	470.00	470.00	390.00	380.00	170.00	100.00	1560.00	1550.00
TS mgdm^{-3}	1090.00	1150.00	330.00	990.00	790.00	400.00	200.00	840.00	770.00	670.00	640.00	170.90	230.00	1800.00	1820.00
DO mgdm^{-3}	0.90	1.20	1.20	1.20	1.00	1.10	1.00	1.20	1.10	1.10	1.10	0.90	1.10	0.90	1.10
BOD mgdm^{-3}	0.40	0.40	0.40	0.40	0.20	0.40	0.30	0.30	0.30	0.60	0.50	0.30	0.30	0.30	0.20
COD mgdm^{-3}	490.00	320.00	380.00	360.00	550.00	260.00	210.00	290.00	220.00	230.00	270.00	240.00	110.00	60.00	290.00
Cu m dm^{-3}	0.01	0.00	0.01	0.01	BDL	BDL	0.00	BDL	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Ni mgdm^{-3}	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.03	0.05	0.04	0.05	0.04	0.08	0.05
Zn mgdm^{-3}	BDL	BDL	BDL	BDL	BDL	BDL	0.05	0.07	0.02	0.03	0.02	0.02	0.01	0.01	BDL
Mn mgdm^{-3}	BDL	BDL	BDL	BDL	0.01	0.01	0.01	0.01	0.01	BDL	0.01	0.01	0.01	0.01	0.01
Pb mgdm^{-3}	BDL	0.01	BDL	BDL	BDL	BDL	0.01	0.01	0.01	0.01	BDL	0.01	0.01	0.01	BDL
Cd mgdm^{-3}	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
TC (MPN/100cm$^{-3)}$	8.00	13.00	14.00	5.00	14.50	25.00	21.50	40.50	17.00	22.00	39.50	74.00	36.00	5.50	40.00

BDL: below the detection limit. ALK : alkalinity, TBD : Turbidity. TH : total hardness. PO_4^{3-}P : phosphate. NO_3^- :nitrate. NH_3: ammonia.

From Tables 4.2 and 4.3 the electrical conductivity values of the well water samples collected from each of the eight (8) wells located in the villages (Shitaku, Ganaja and Gbobe) near rivers Niger and Benue and also from seven (7) wells that are on the margin of Lokoja metropolis at distances up to 300 m away from the rivers during the dry season of 2004 were ranged between 53.5 and 985 µS/cm and 47.4 to 1398 µS/cm during the wet season of 2014 respectively (Figure 4.1).

Tables 4,2 and 4.3 showed the mean values of alkalinity of the well water samples collected from each of the eight (8) wells located in the villages (Shitaku, Ganaja and Gbobe) near rivers Niger and Benue and also from seven (7) wells that are on the margin of Lokoja metropolis at distances up to 300 m away from the rivers during the dry season of 2004 were in the ranged of 11.5 to 18 $mgdm^{-3}$ during the dry season and 59 to 131 $mgdm^{-3}$ during the wet season of 2014 respectively (Figure 4.2).

Tables 4,2 and 4.3 showed the result for the level of turbidity of the well water samples collected from each of the eight (8) wells located in the villages (Shitaku, Ganaja and Gbobe) near rivers Niger and Benue and also from seven (7) wells that are on the margin of Lokoja metropolis at distances up to 300 m away from the rivers during the dry season of 2004 were in the ranged of 0.063 to 130.45 NTU during the dry season and 0.611 to 140 NTU during the wet season of 2014 respectively (figure 4.3).

From tables 4, 2 and 4.3 the total hardness values of the well water samples collected from each of the eight (8) wells located in the villages (Shitaku, Ganaja and Gbobe) near rivers Niger and Benue and also from seven (7) wells that are on the margin of Lokoja metropolis at distances up to 300 m away from the rivers during the dry season of 2004 were in the ranged of 202 to 818 $mgdm^{-3}$ during the dry season and 130 to 404 $mgdm^{-3}$ in the wet season of 2014 respectively (figure 4.4).

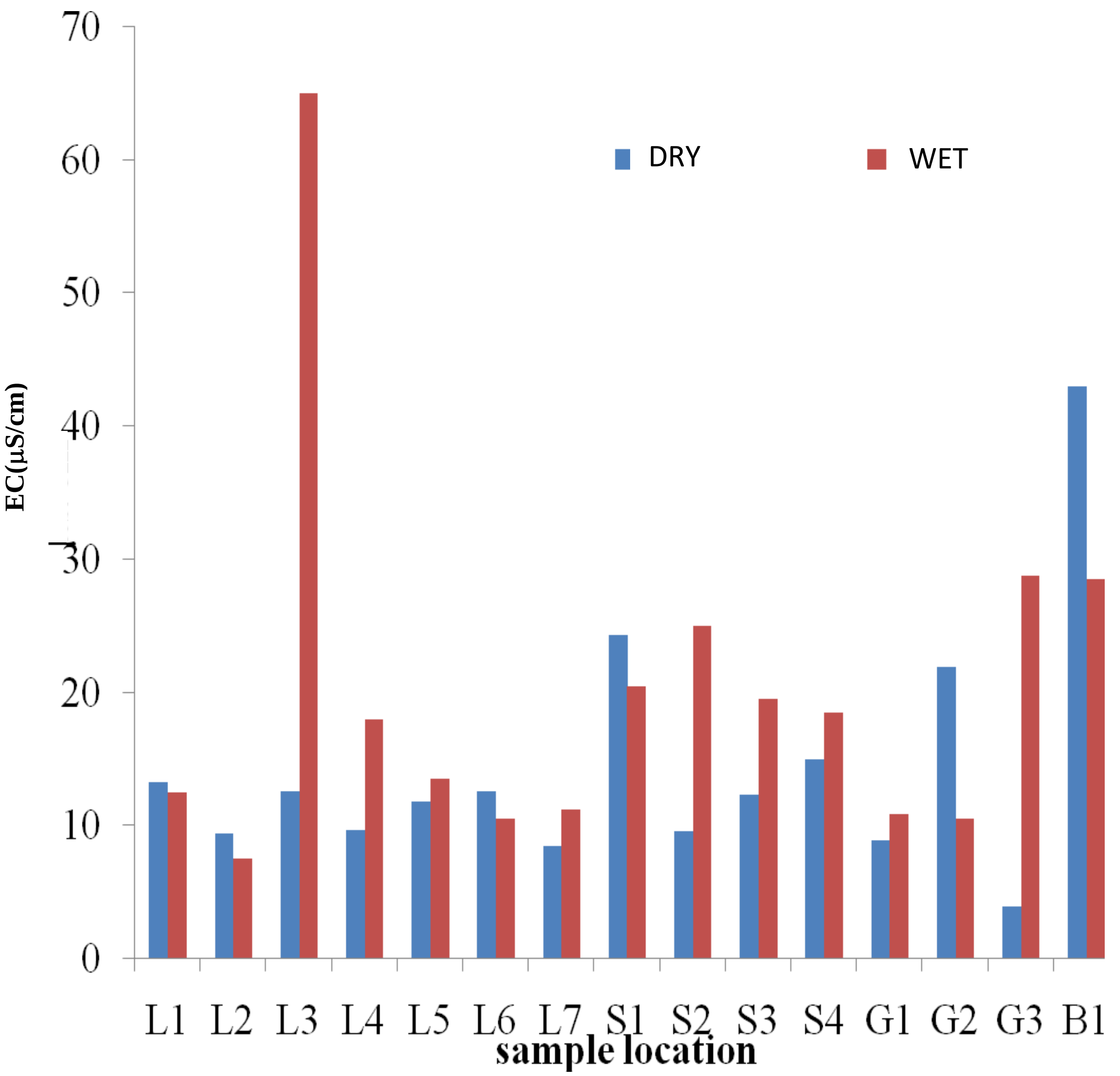

Figure 4.1: The effects of seasonal variation on the electrical conductivity of well water samples near River Niger and Benue in Lokoja.

Key: DWS: Drinking water standard

Dry: Dry season

Wet: Wet season

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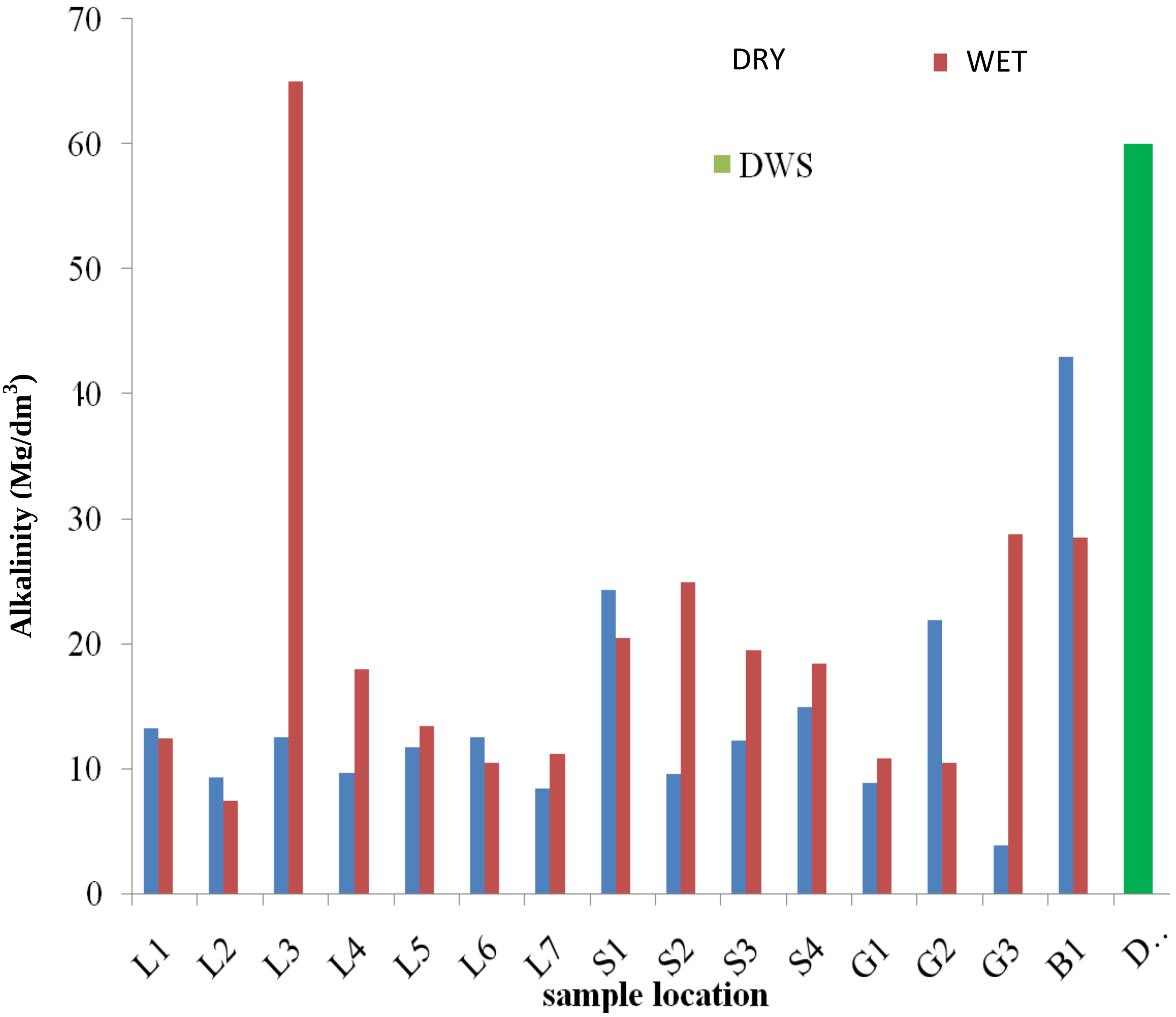

Figure 4.2: The effects of seasonal variation on the alkalinity values of the well water samples near Rivers Niger and Benue in Lokoja with WHO standards.

Key: DWS: Drinking water standard

Dry: Dry season

Wet: Wet season

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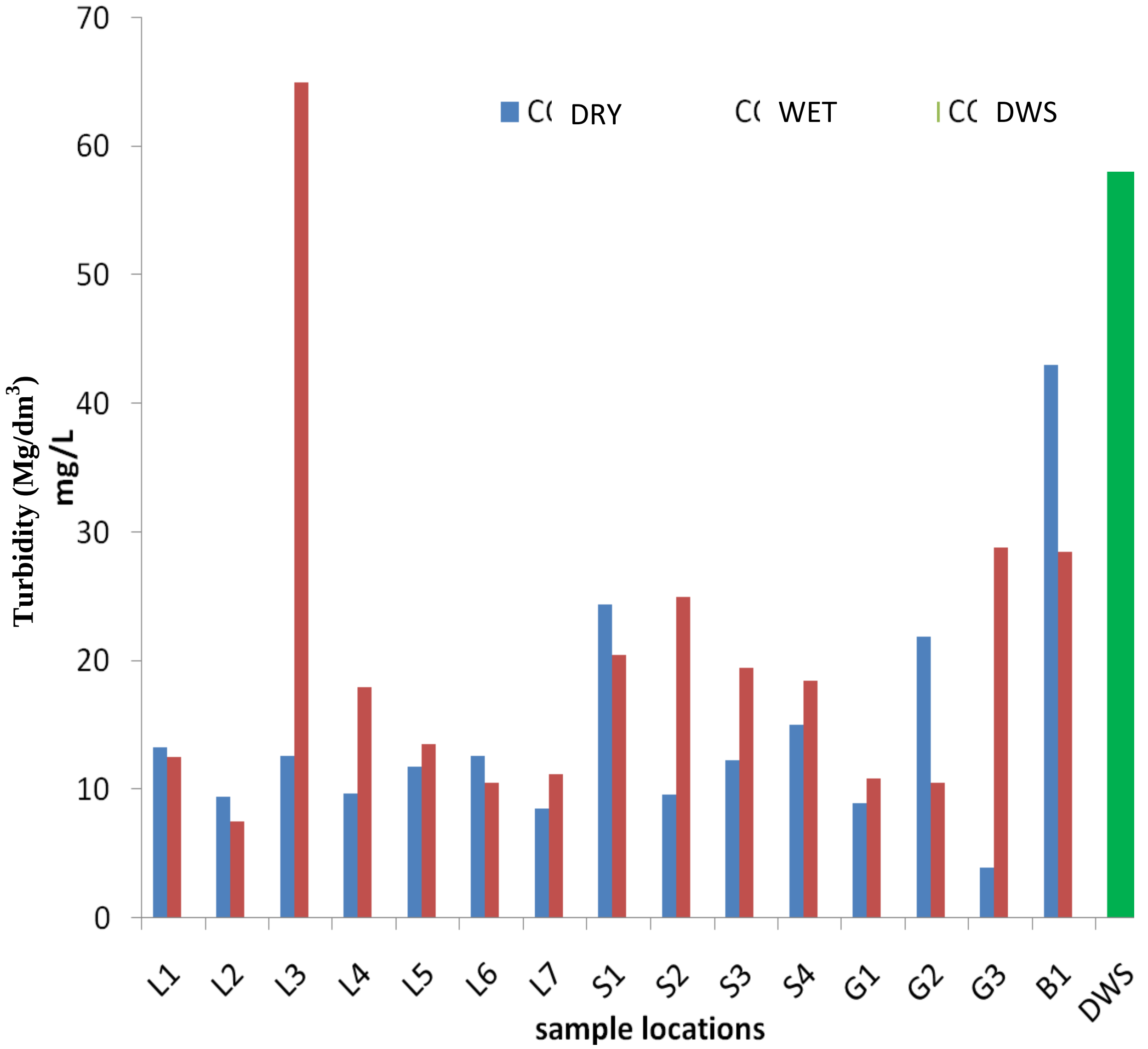

Figure 4.3: The effects of seasonal variation on the Turbidity of well water samples near Rivers Niger and Benue in Lokoja.

Key: DWS: Drinking water standard

Dry: Dry season

Wet: Wet season

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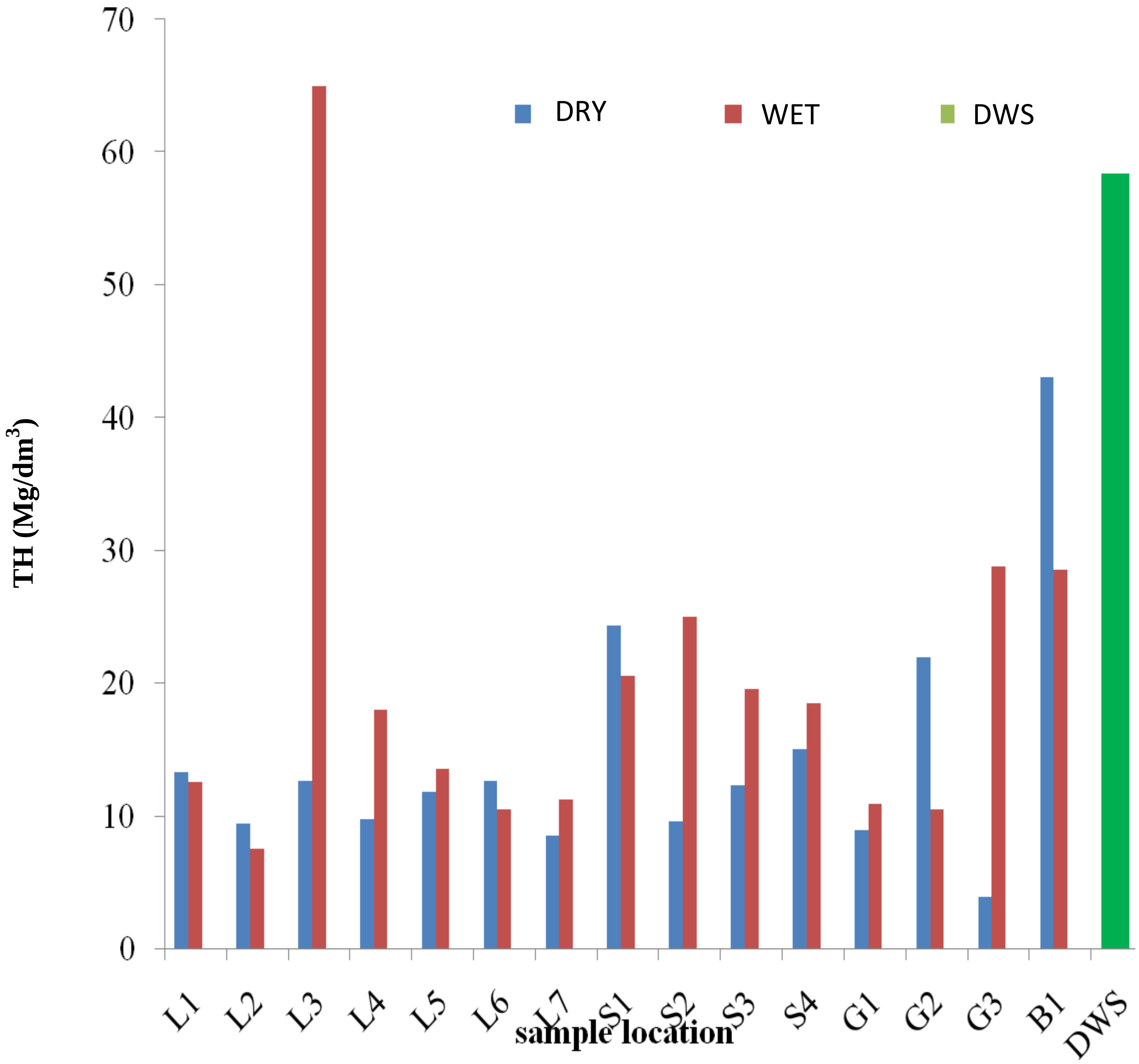

Figure 4.4: The effects of seasonal variation on the Total Hardness of well water samples near River Niger and Benue in Lokoja.

Key: DWS: Drinking water standard

Dry: Dry season

Wet: Wet season

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From Tables 4.2 and 4.3 the observed COD values of the well water samples collected from each of the eight (8) wells located in the villages (Shitaku, Ganaja and Gbobe) near rivers Niger and Benue and also from seven (7) wells that are on the margin of Lokoja metropolis at distances up to 300 m away from the rivers are varied from 108 to 346 mgdm^{-3} during the dry season and 60 to 818 mgdm^{-3} during the wet season of 2014 (Figure 4.5).

From Tables 4.2 and 4.3 the observed BOD values of the well water samples collected from each of the eight (8) wells located in the villages (Shitaku, Ganaja and Gbobe) near rivers Niger and Benue and also from seven (7) wells that are on the margin of Lokoja metropolis at distances up to 300 m away from the river were found in the range of 0.1 to 0.45 mgdm^{-3} with the exception of sample G2 which was 0.035 mgdm^{-3} during the dry season and 0.2 to 0.6 mgdm^{-3} with the exception of sample B1 which was 31 mgdm^{-3} during the wet season of 2014 (figure 4.6).

From Tables 4.2 and 4.3 the observed TSS values of the well water samples collected from each of the eight (8) wells located in the villages (Shitaku, Ganaja and Gbobe) near rivers Niger and Benue and also from seven (7) wells that are on the margin of Lokoja metropolis at distances up to 300 m away from the rivers were in the ranged of 13 – 450 mgdm^{-3} during the dry season and 70 - 370 mgdm^{-3} of the wet season of 2014 (Figure 4.7).

From Tables 4.2 and 4.3 the observed TDS values of the well water samples collected from each of the eight (8) wells located in the villages (Shitaku, Ganaja and Gbobe) near rivers Niger and Benue and also from seven (7) wells that are on the margin of Lokoja metropolis at distances up to 300 m away from the rivers were in the ranged of 57.5 – 310 mgdm^{-3} during the dry season and 102 – 1550 mgdm^{-3}during the wet season of 2014 (Figure 4.8).

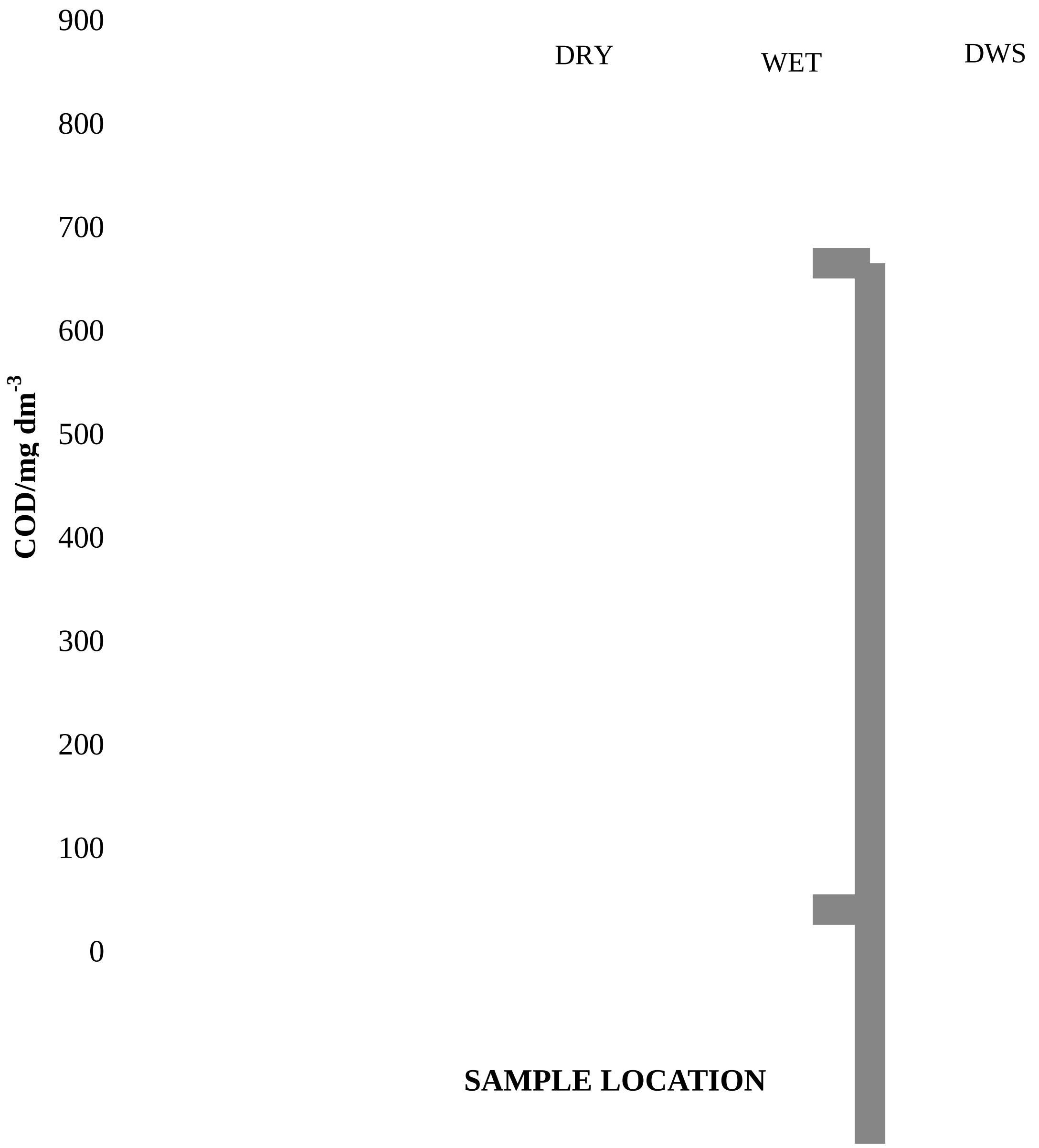

Figure 4.5: The effects of seasonal variation of the chemical oxygen demand values of the well water samples near River Niger and Benue in Lokoja.

Key: DWS: Drinking water standard

Dry: Dry season

Wet: Wet season

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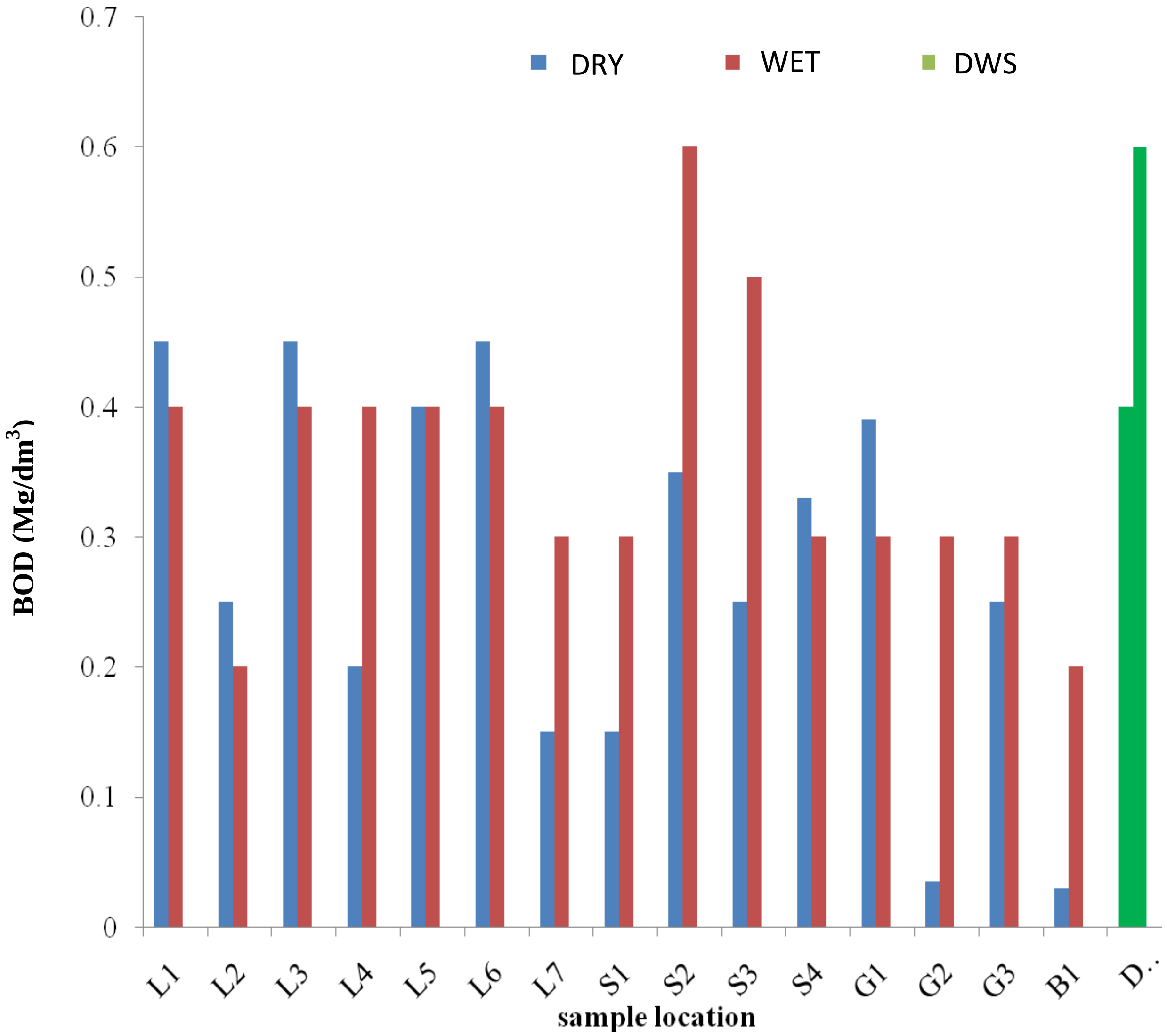

Figure 4.6: The effects of seasonal changes on the biological oxygen demand values of the well water samples near Rivers Niger and Benue in Lokoja.

Key: DWS: Drinking water standard

Dry: Dry season

Wet: Wet season

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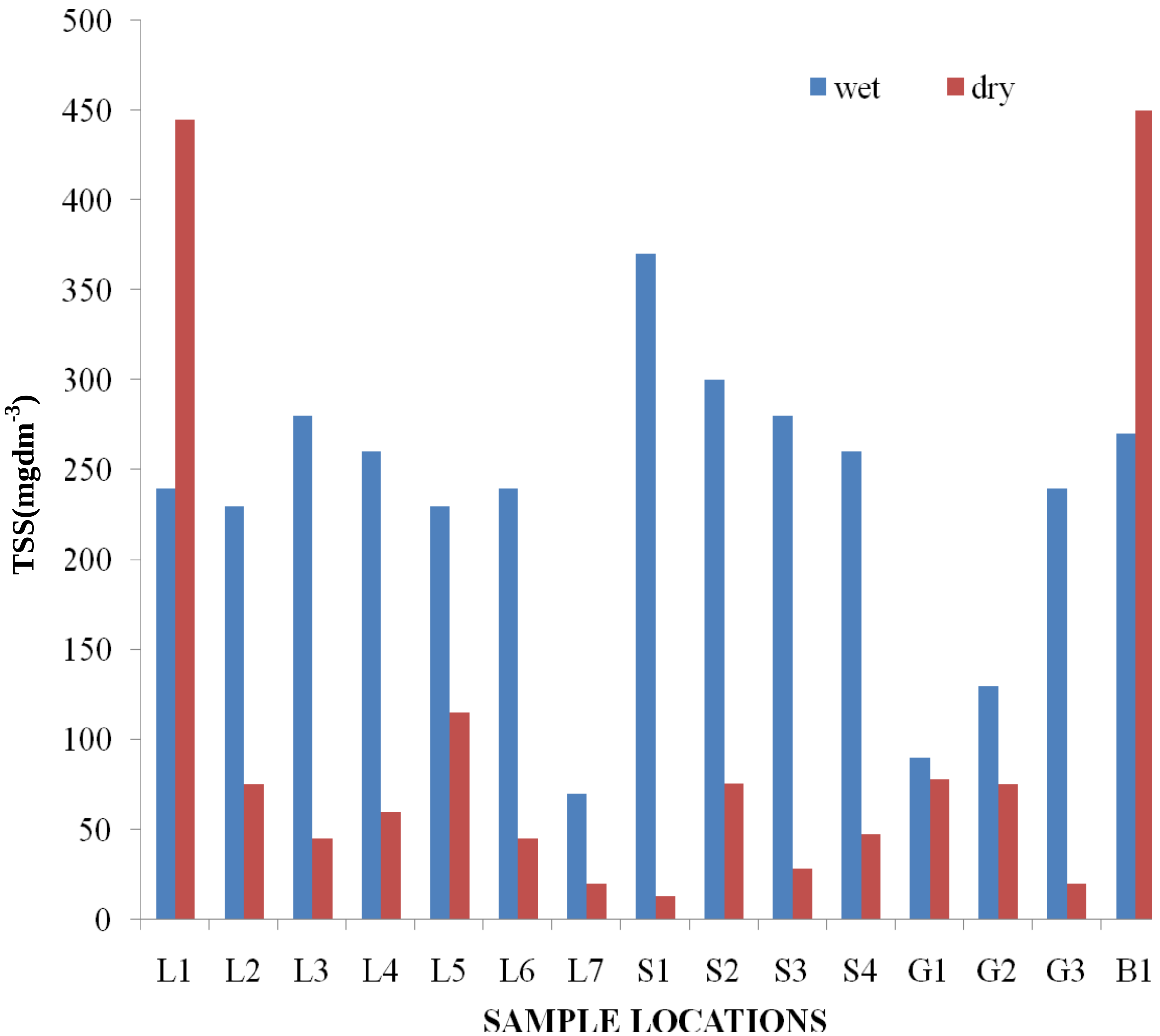

Figure 4.7: The effects of seasonal variation on the total suspended solid values of the well water samples near Rivers Niger and Benue in Lokoja.

Key: DWS: Drinking water standard

Dry: Dry season

Wet: Wet season

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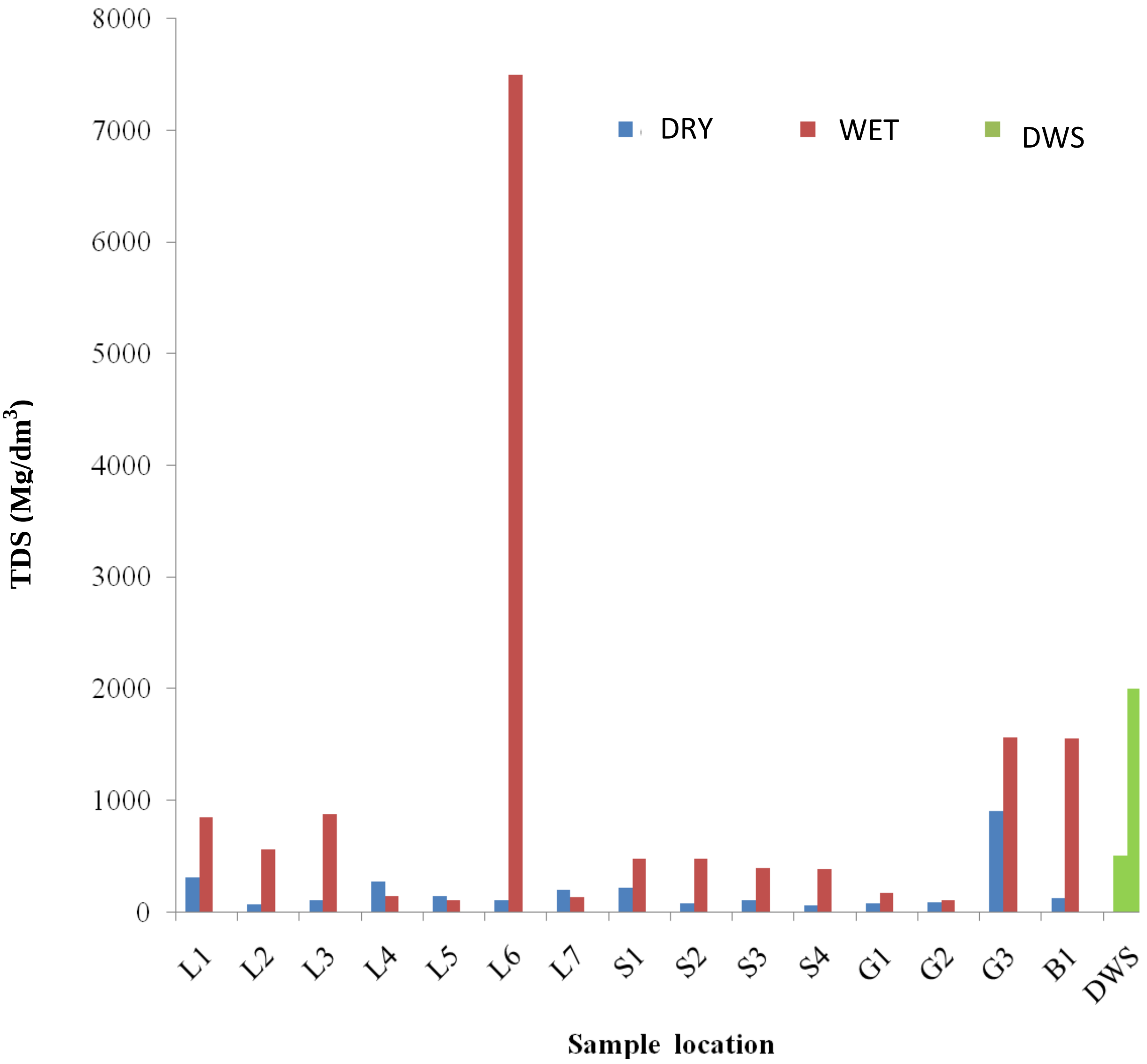

Figure 4. 8: The effects of seasonal variation of total dissolved solid values of the well water samples Near Rivers Niger and Benue in Lokoja.

Key: DWS: Drinking water standard
Dry: Dry season
Wet: Wet season

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From Tables 4.2 and 4.3 the dissolved oxygen values of the well water samples collected from each of the eight (8) wells located in the villages (Shitaku, Ganaja and Gbobe) near rivers Niger and Benue and also from seven (7) wells that are on the margin of Lokoja metropolis at distances up to 300 m away from the rivers were in the ranged of 0.08 - 0.75 $mgdm^{-3}$ during the dry season and 0.9 - 1.2 $mgdm^{-3}$ during the wet season of 2014 (Figure 4.9).

From Tables 4.2 and 4.3 the observed total solid values of the well water samples collected from each of the eight (8) wells located in the villages (Shitaku, Ganaja and Gbobe) near rivers Niger and Benue and also from seven (7) wells that are on the margin of Lokoja metropolis at distances up to 300 m away from the rivers were in the ranged of 105 - 925 $mgdm^{-3}$during the dry season and 170 – 1820 $mgdm^{-3}$ during the wet season of 2014 (Figure 4.10).

From Tables 4.2 and 4.3 the mean phosphate contents of the well water samples collected from each of the eight (8) wells located in the villages (Shitaku, Ganaja and Gbobe) near rivers Niger and Benue and also from seven (7) wells that are on the margin of Lokoja metropolis at distances up to 300 m away from the rivers were in the ranged of 1.5 - 14.95 $mgdm^{-3}$ during the dry season and 3.1 - 13.5 $mgdm^{-3}$ during the wet season of 2014 (Figure 4.11).

From Tables 4.2 and 4.3 the mean nitrate contents of the well water samples collected from each of the eight (8) wells located in the villages (Shitaku, Ganaja and Gbobe) near rivers Niger and Benue and also from seven (7) wells that are on the margin of Lokoja metropolis at distances up to 300 m away from the rivers were in the ranged of 3.9 - 43.4 $mgdm^{-3}$ during the dry season and 7.5 - 65 $mgdm^{-3}$ during the wet season of 2014 (Figure 4.12).

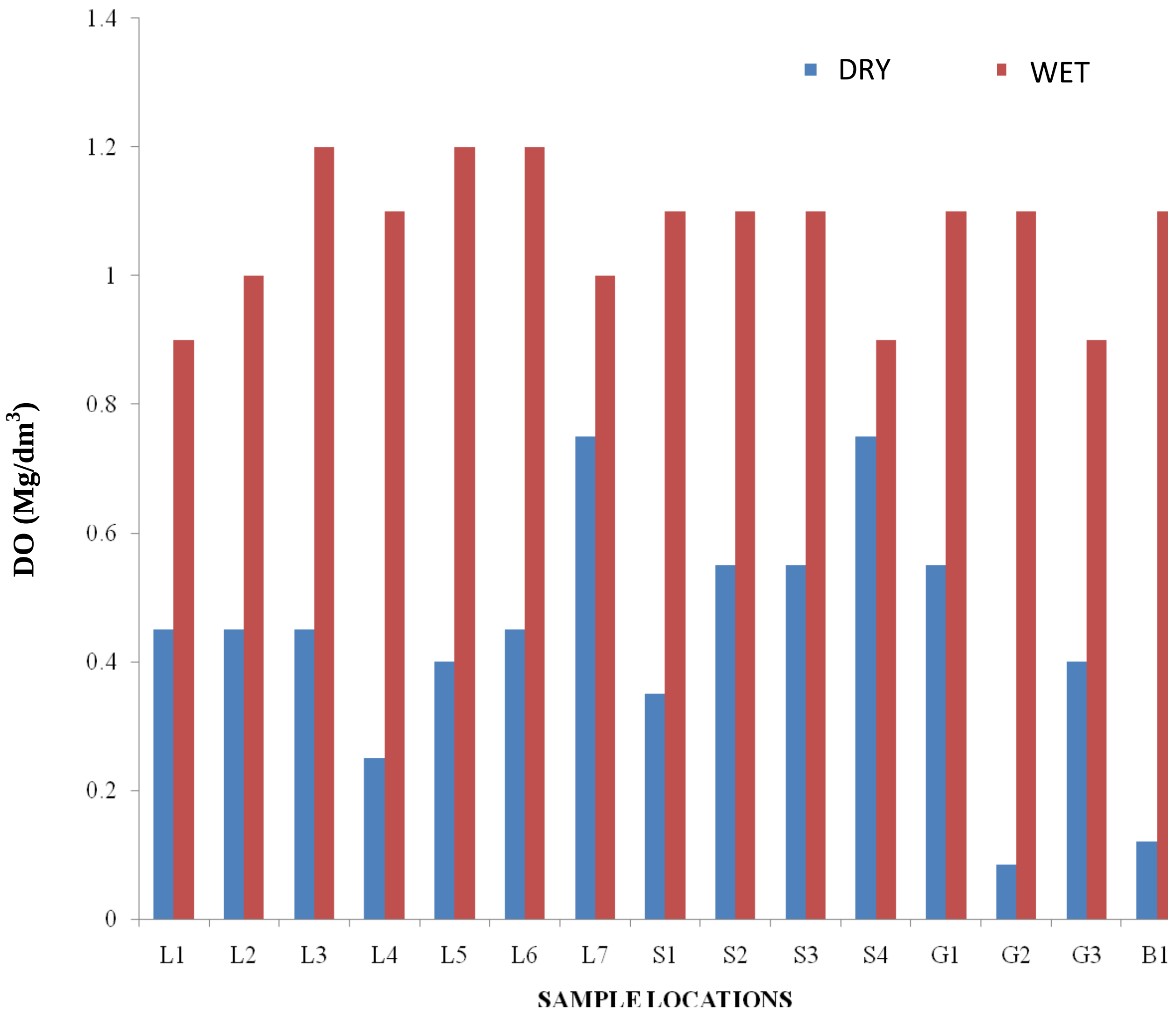

Figure 4.9: The effects of seasonal variation on the dissolved oxygen values of the well water sample near Rivers Niger and Benue in Lokoja.

Key: DWS: Drinking water standard

Dry: Dry season

Wet: Wet season

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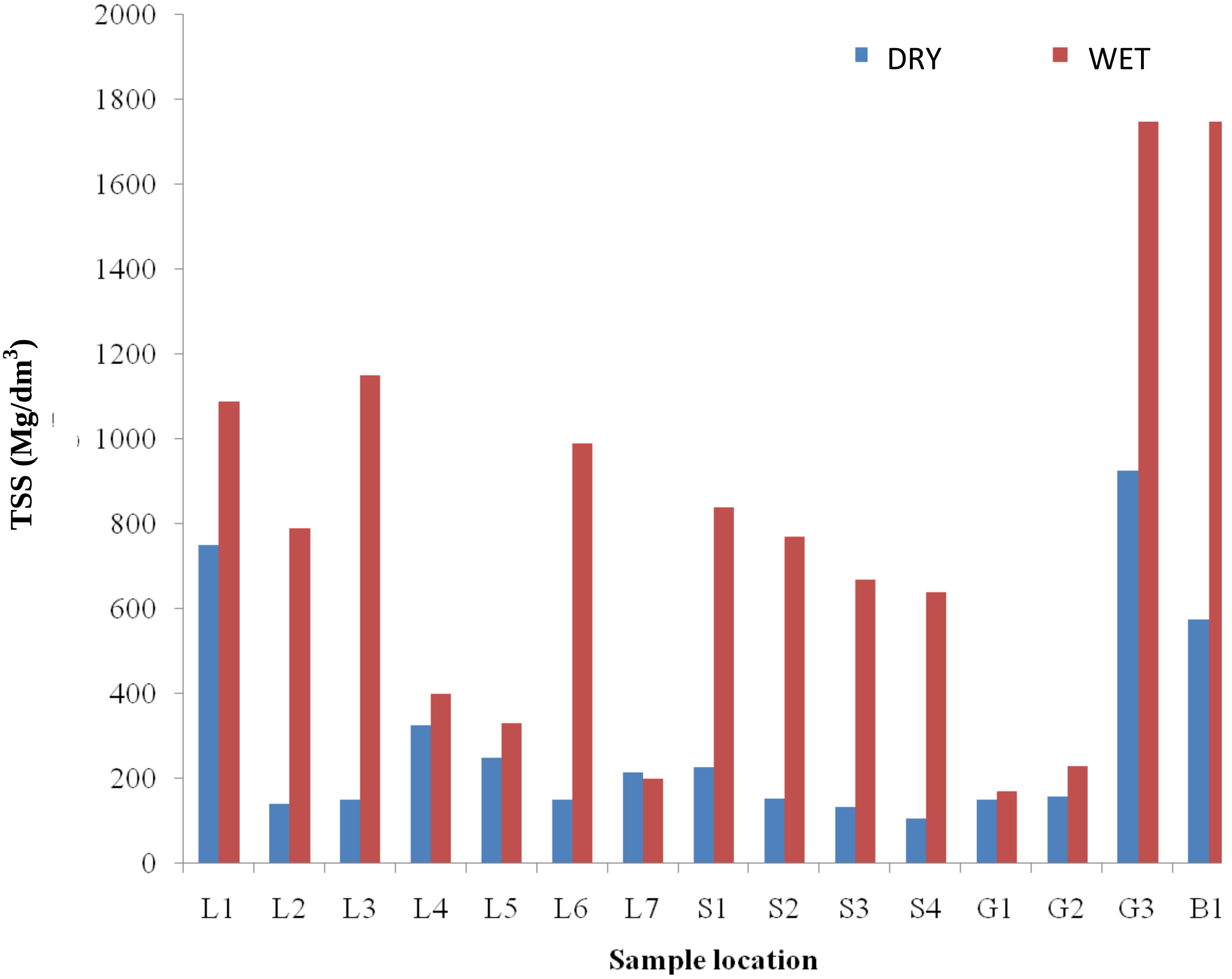

Figure 4.10: The effects of seasonal variation of the total solid values of the well water samples near Rivers Niger and Benue in Lokoja.

Key: DWS: Drinking water standard

Dry: Dry season

Wet: Wet season

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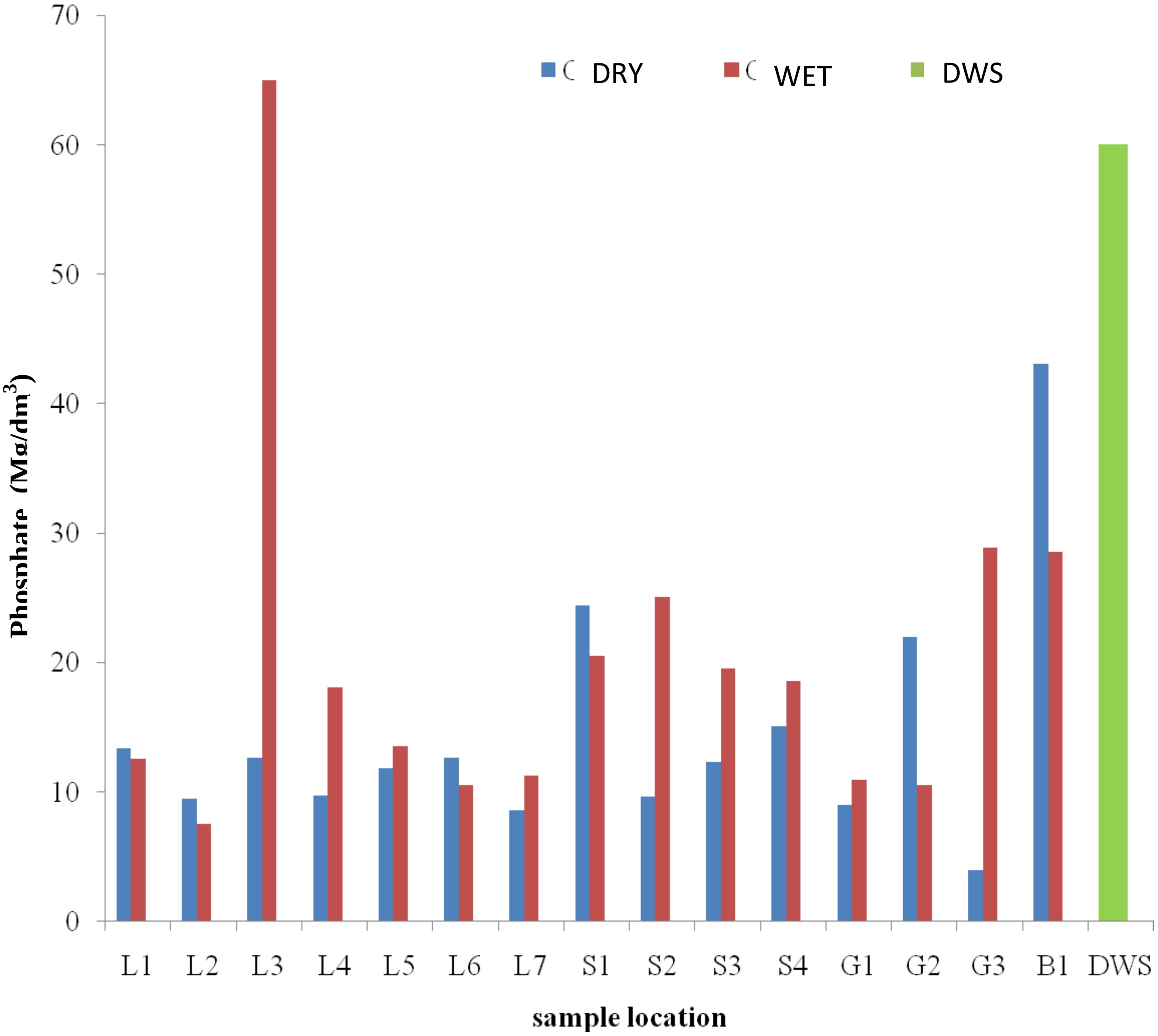

Figure 4.11: the effects of seasonal variation on the Phosphate values of the well water samples near Rivers Niger and Benue in Lokoja with WHO Standards.

Key: DWS: Drinking water standard

Dry: Dry season

Wet: Wet season

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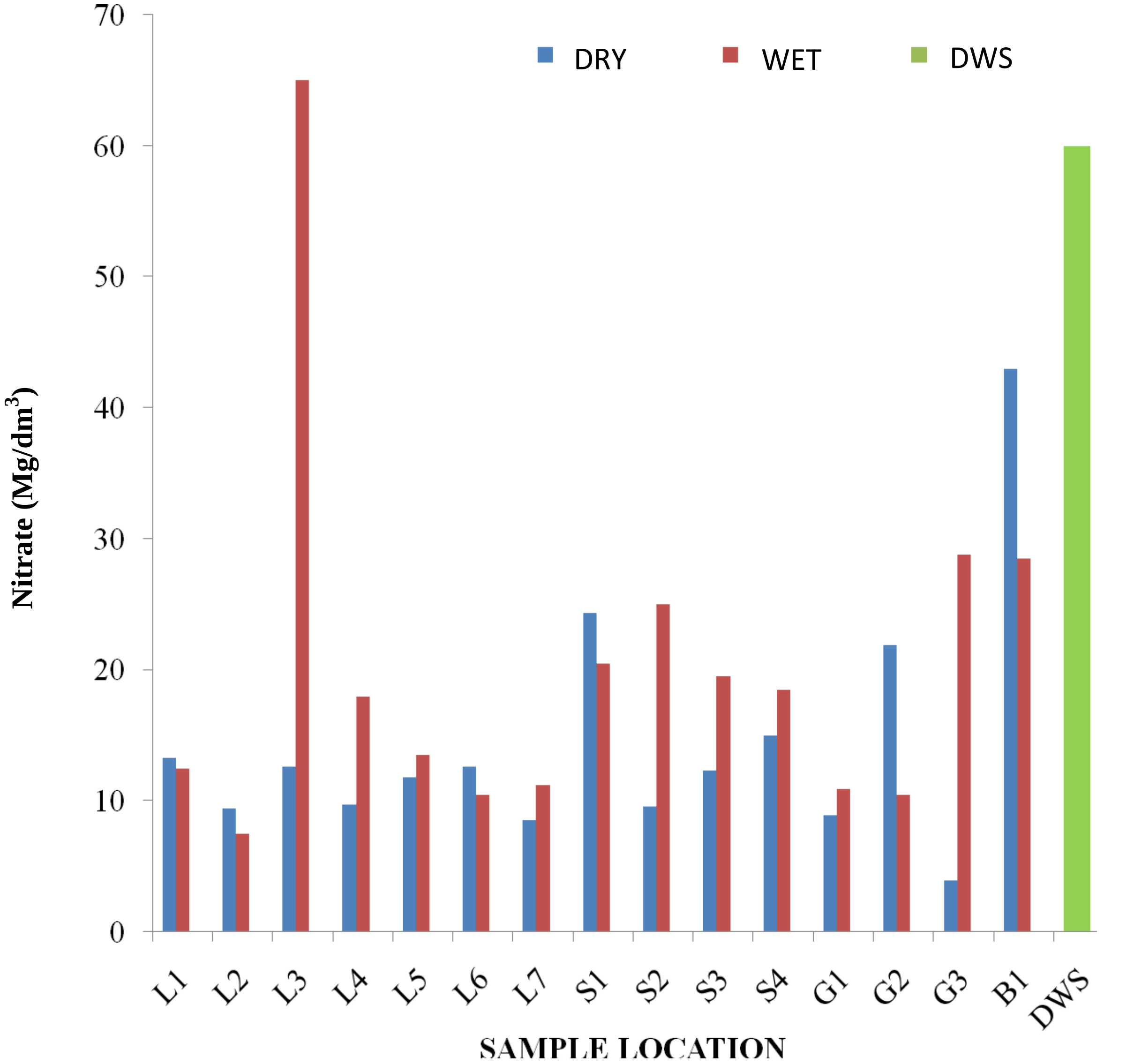

Figure 4.12: The effects of seasonal variation on the Nitrate values of the well water samples near Rivers Niger and Benue in Lokoja with WHO Standards.

Key: DWS: Drinking water standard

Dry: Dry season

Wet: Wet season

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From Tables 4.2 and 4.3 the ammonia concentration of the well water samples collected from each of the eight (8) wells located in the villages (Shitaku, Ganaja and Gbobe) near rivers Niger and Benue and also from seven (7) wells that are on the margin of Lokoja metropolis at distances up to 300 m away from the rivers were in the ranged of 0.01 - 0.3 $mgdm^{-3}$ during the dry season and 3.1 - 13.5 $mgdm^{-3}$ during the wet season of 2014 (Figure 4.13).

From Tables 4.2 and 4.3 the copper contents of the well water samples collected from each of the eight (8) wells located in the villages (Shitaku, Ganaja and Gbobe) near rivers Niger and Benue and also from seven (7) wells that are on the margin of Lokoja metropolis at distances up to 300 m away from the rivers were in the ranged of 0.001 – 0006 $mgdm^{-3}$ during the dry season and 0.001 – 0.008 $mgdm^{-3}$ during the wet season of 2014 (Figure 4.14).

From Tables 4.2 and 4.3 the nickel contents of the well water samples collected from each of the eight (8) wells located in the villages (Shitaku, Ganaja and Gbobe) near rivers Niger and Benue and also from seven (7) wells that are on the margin of Lokoja metropolis at distances up to 300 m away from the rivers were in the ranged of 0.002 - 0.044 $mgdm^{-3}$ during the dry season and 0.006 - 0.080 $mgdm^{-3}$ during the wet season of 2014 (Figure 4.15).

From Tables 4.2 and 4.3 the zinc contents of the well water samples collected from each of the eight (8) wells located in the villages (Shitaku, Ganaja and Gbobe) near rivers Niger and Benue and also from seven (7) wells that are on the margin of Lokoja metropolis at distances up to 300 m away from the rivers were in the ranged of 0.001 - 0.022 $mgdm^{-3}$ during the dry season and 0.02 – 0.024 $mgdm^{-3}$ during the wet season of 2014 (Figure 4.16).

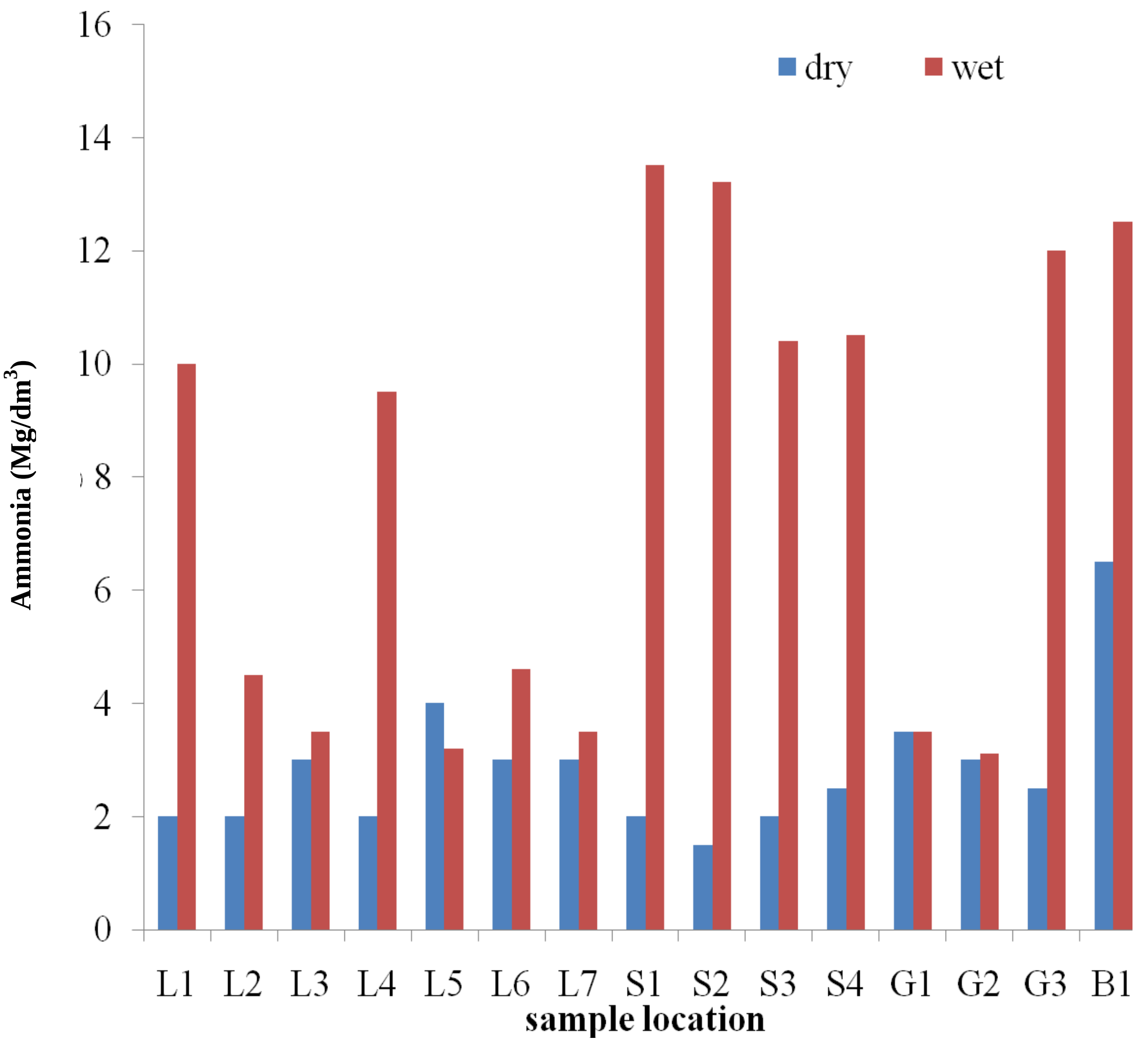

Figure 4. 13: The effects of seasonal variation on the ammonia values of the well water samples near Rivers Niger and Benue in Lokoja.

Key: DWS: Drinking water standard

Dry: Dry season

Wet: Wet season

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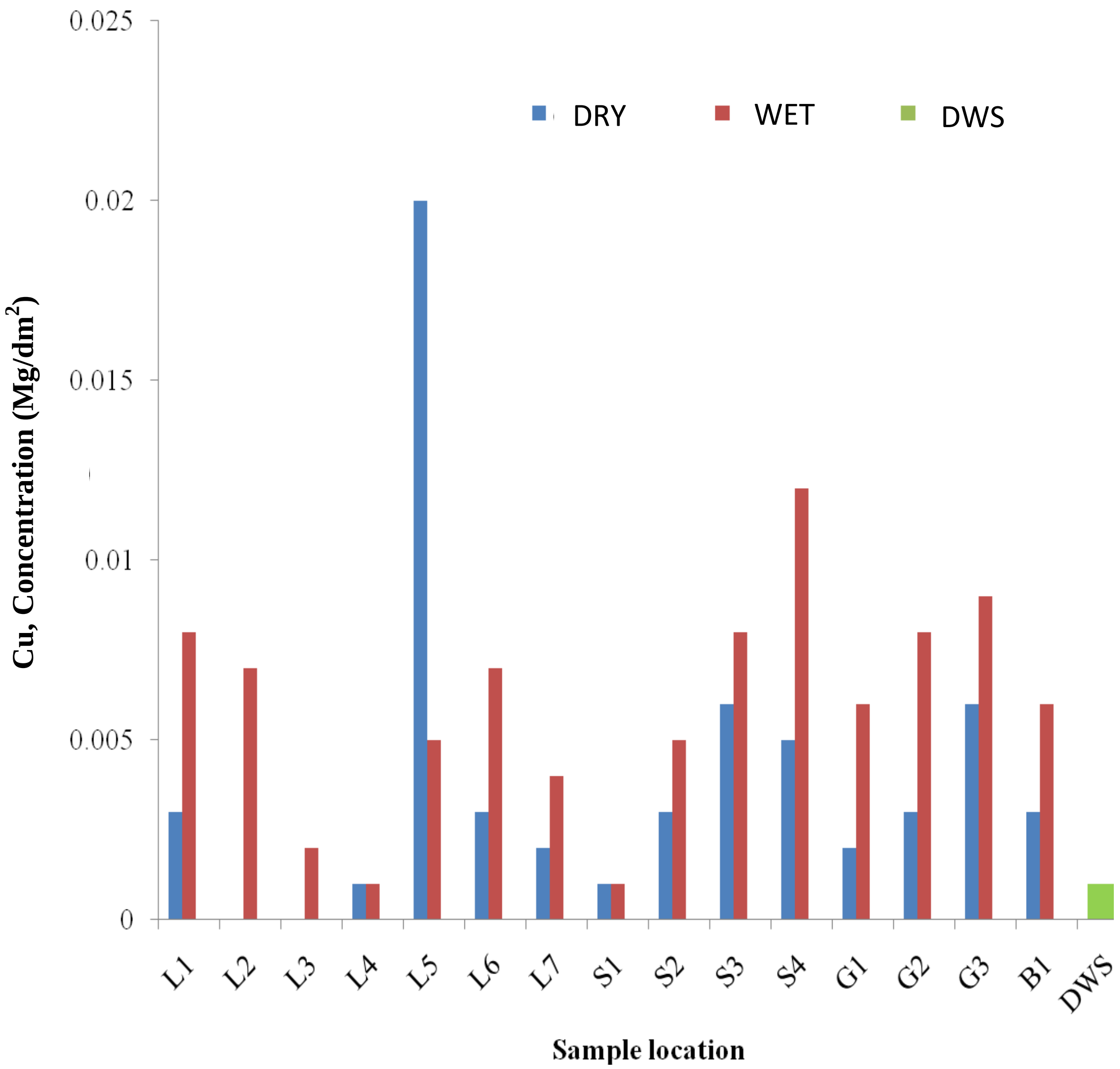

Figure 4 .14: The effects of seasonal changes on the Cu content of the well water samples near Rivers Niger and Benue in Lokoja.

Key: DWS: Drinking water standard

Dry: Dry season

Wet: Wet season

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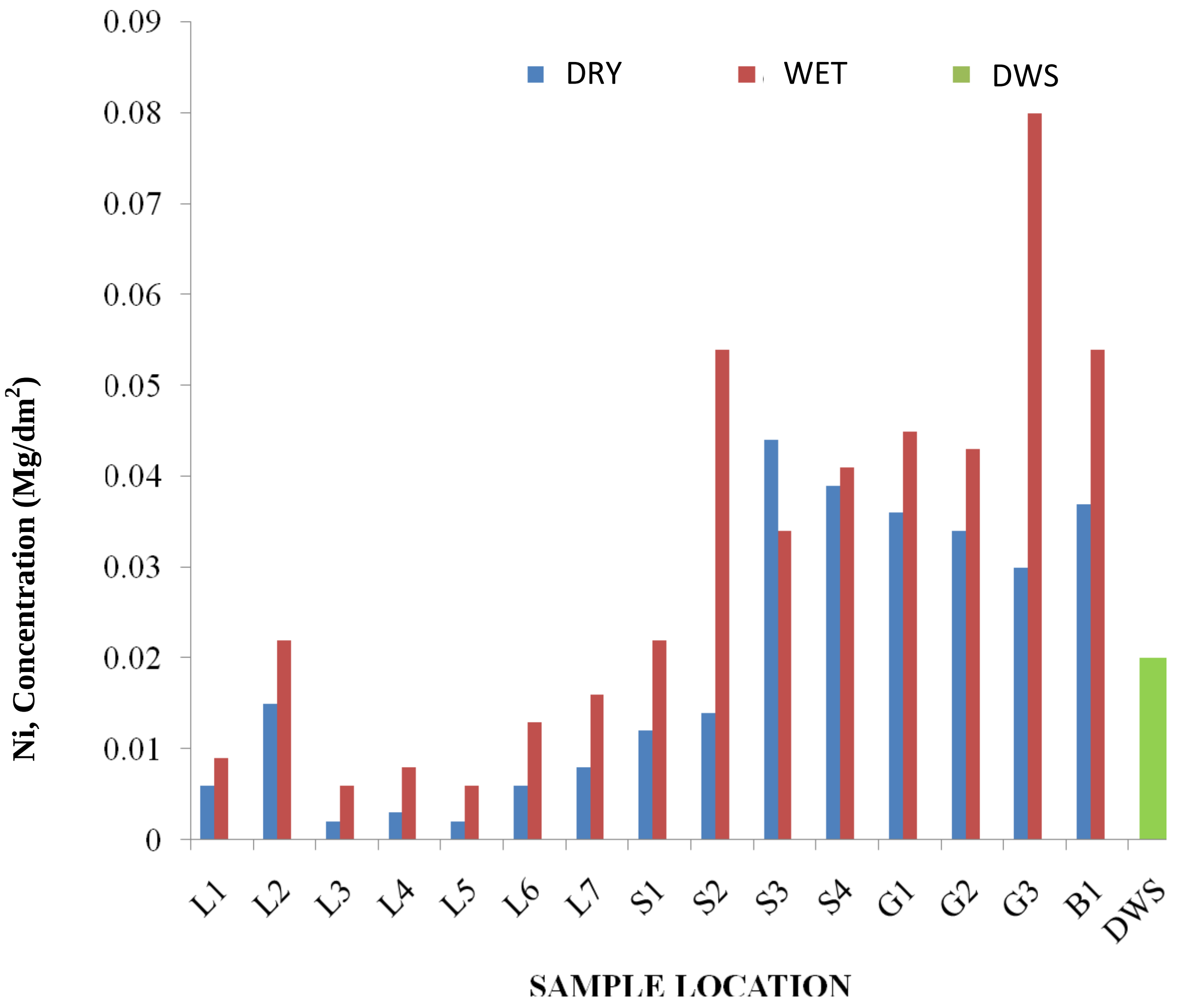

Figure 4.15: The effects of seasonal changes on the nickel content of the well water samples near Rivers Niger and Benue in Lokoja.

Key: DWS: Drinking water standard
Dry: Dry season
Wet: Wet season

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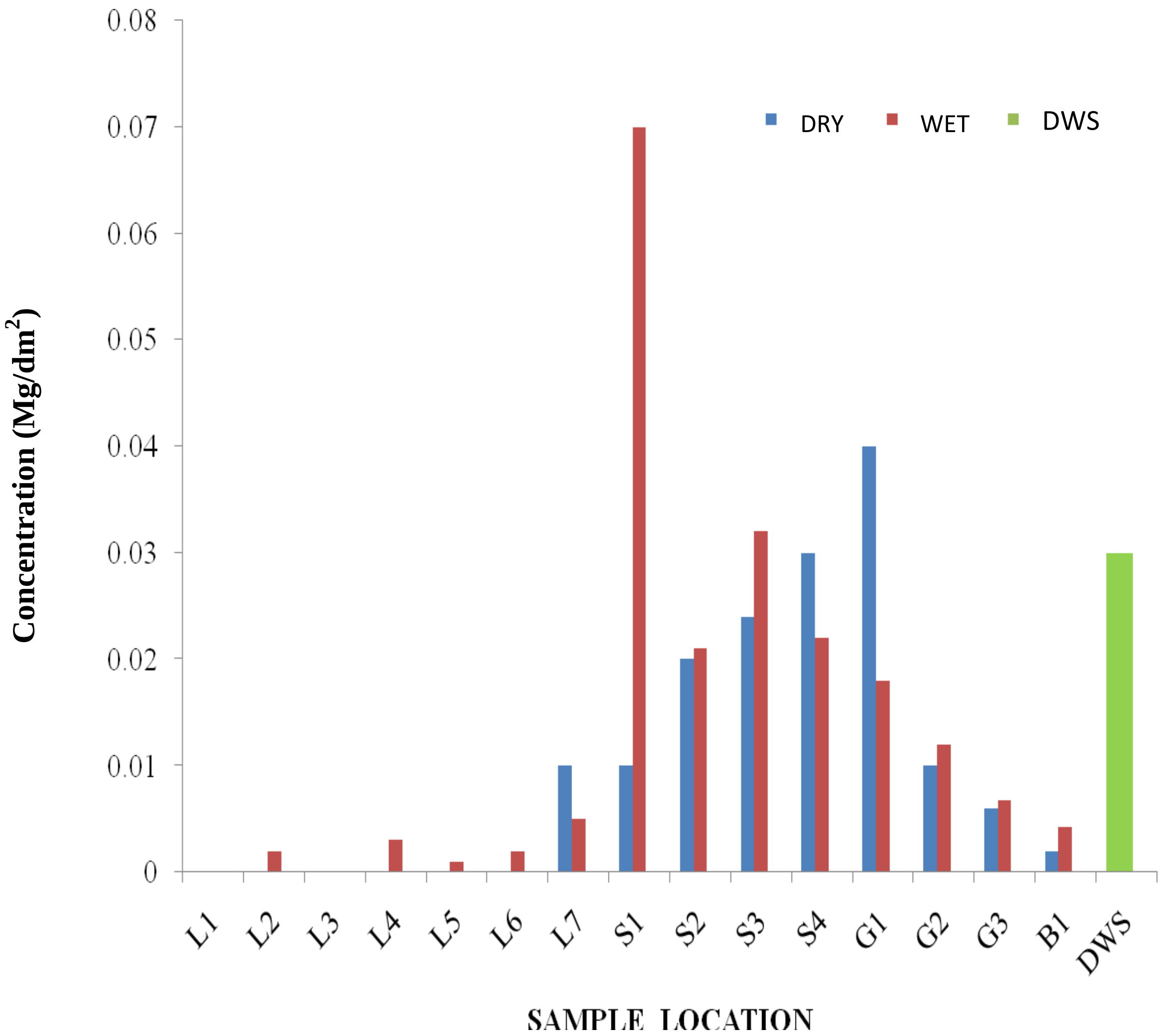

Figure 4.16: The effects of seasonal changes on the zinc content of the well water samples near Rivers Niger and Benue in Lokoja.

Key: DWS: Drinking water standard

Dry: Dry season

Wet: Wet season

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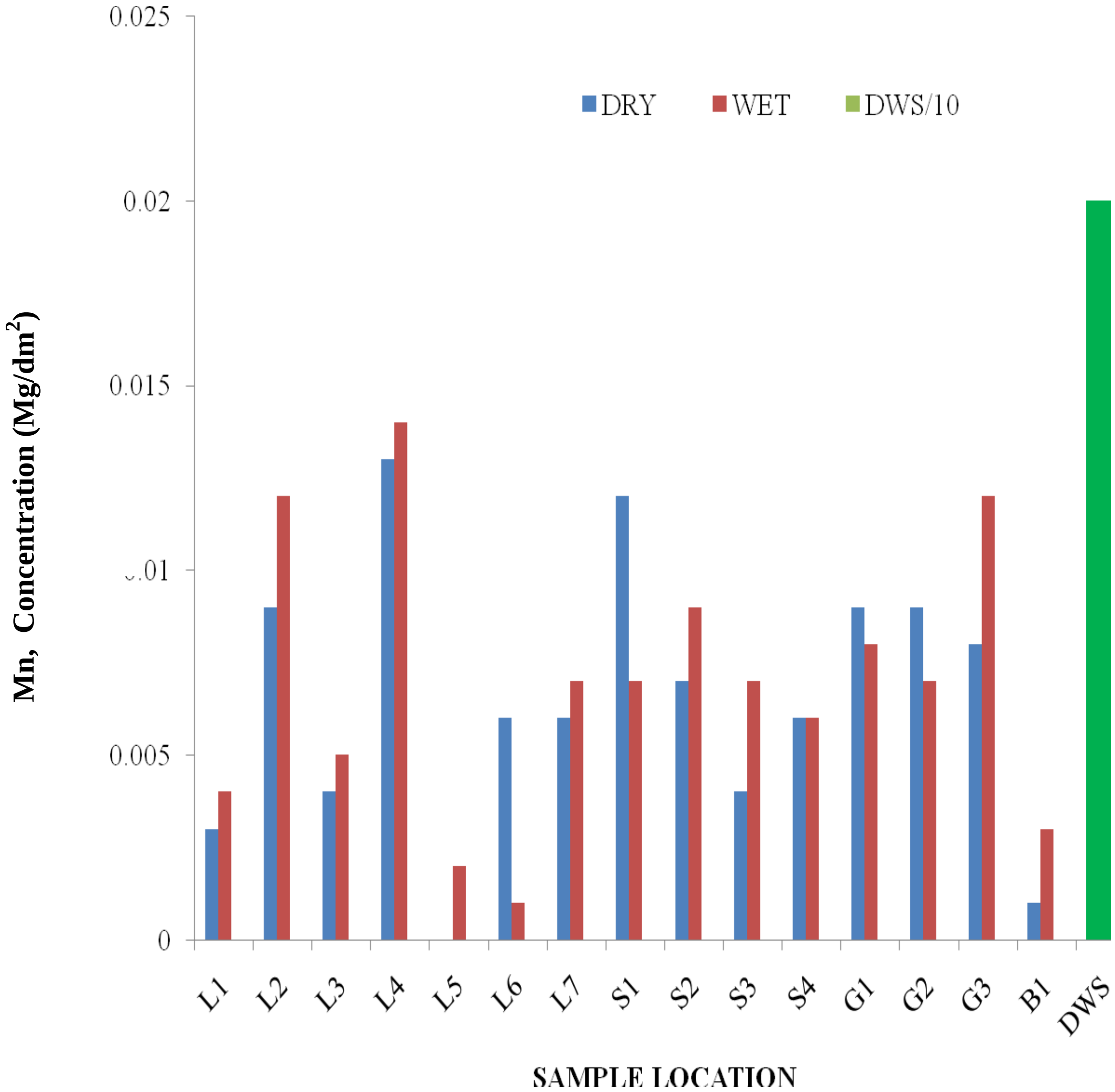

Figure 4.17: The effects of seasonal changes on the manganese content of the well water samples near Rivers Niger and Benue in Lokoja.

Key: DWS: Drinking water standard

Dry: Dry season

Wet: Wet season

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From Tables 4.2 and 4.3 the manganese contents of the well water samples collected from each of the eight (8) wells located in the villages (Shitaku, Ganaja and Gbobe) near rivers Niger and Benue and also from seven (7) wells that are on the margin of Lokoja metropolis at distances up to 300 m away from the rivers were in the ranged of 0.001 - 0.013 $mgdm^{-3}$ during the dry season and 0.01 – 0.01 $mgdm^{-3}$ during the wet season of 2014 (Figure 4.17).

From Tables 4.2 and 4.3 the lead contents of the well water samples collected from each of the eight (8) wells located in the villages (Shitaku, Ganaja and Gbobe) near rivers Niger and Benue and also from seven (7) wells that are on the margin of Lokoja metropolis at distances up to 300 m away from the rivers were in the ranged of 0.001 – 0009 $mgdm^{-3}$ during the dry season and 0.001 – 0.013 $mgdm^{-3}$ during the wet season of 2014 (Figure 4.18).

From Tables 4.2 and 4.3 the cadmium contents of the well water samples collected from each of the eight (8) wells located in the villages (Shitaku, Ganaja and Gbobe) near rivers Niger and Benue and also from seven (7) wells that are on the margin of Lokoja metropolis at distances up to 300 m away from the rivers were in the ranged of 0.001 - 0.004 $mgdm^{-3}$ during the wet season and were not detected during the dry season of 2014 (Figure 4.19).

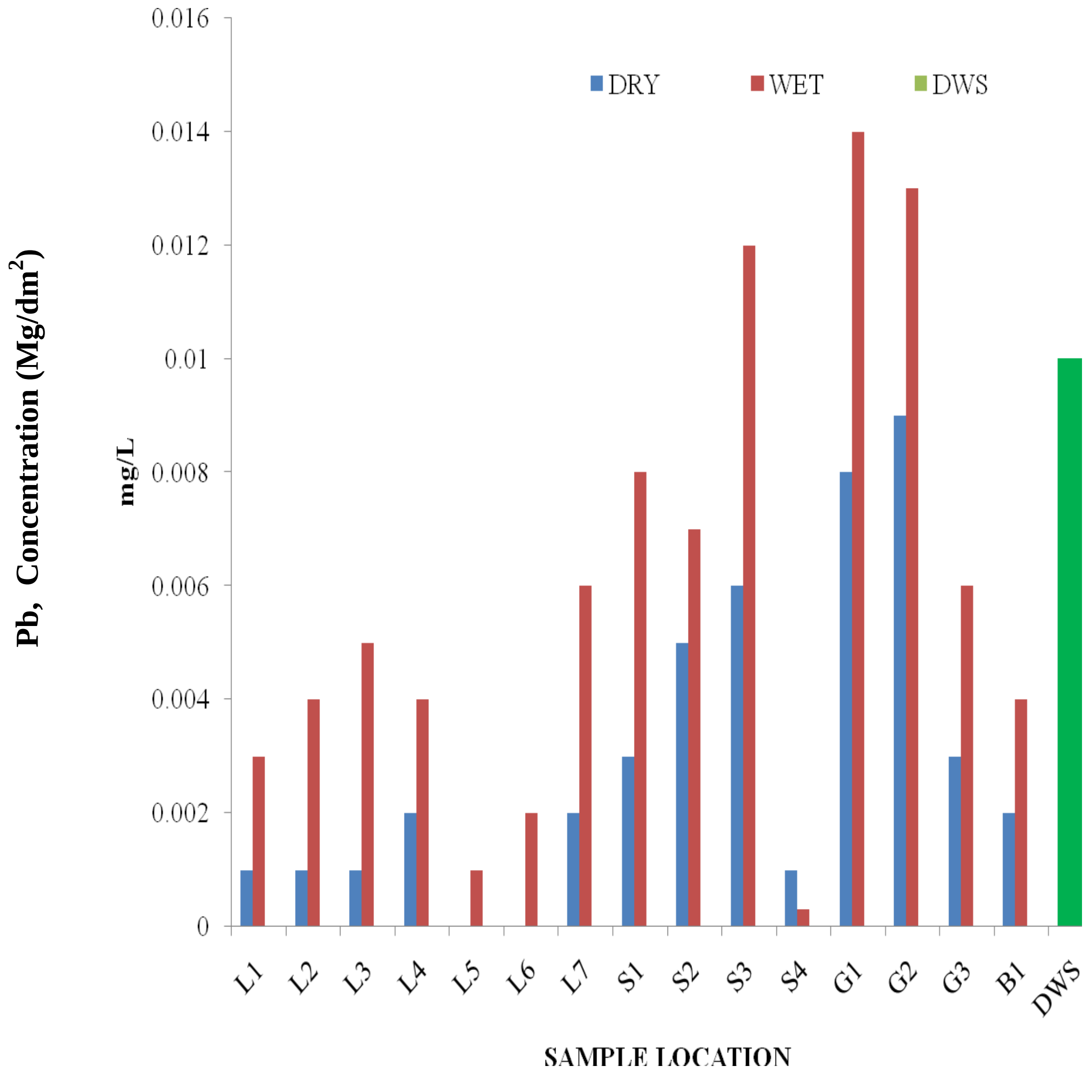

Figure 4.18: The effects of seasonal changes on the lead content of the well water samples near Rivers Niger and Benue in Lokoja.

Key: DWS: Drinking water standard

Dry: Dry season

Wet: Wet season

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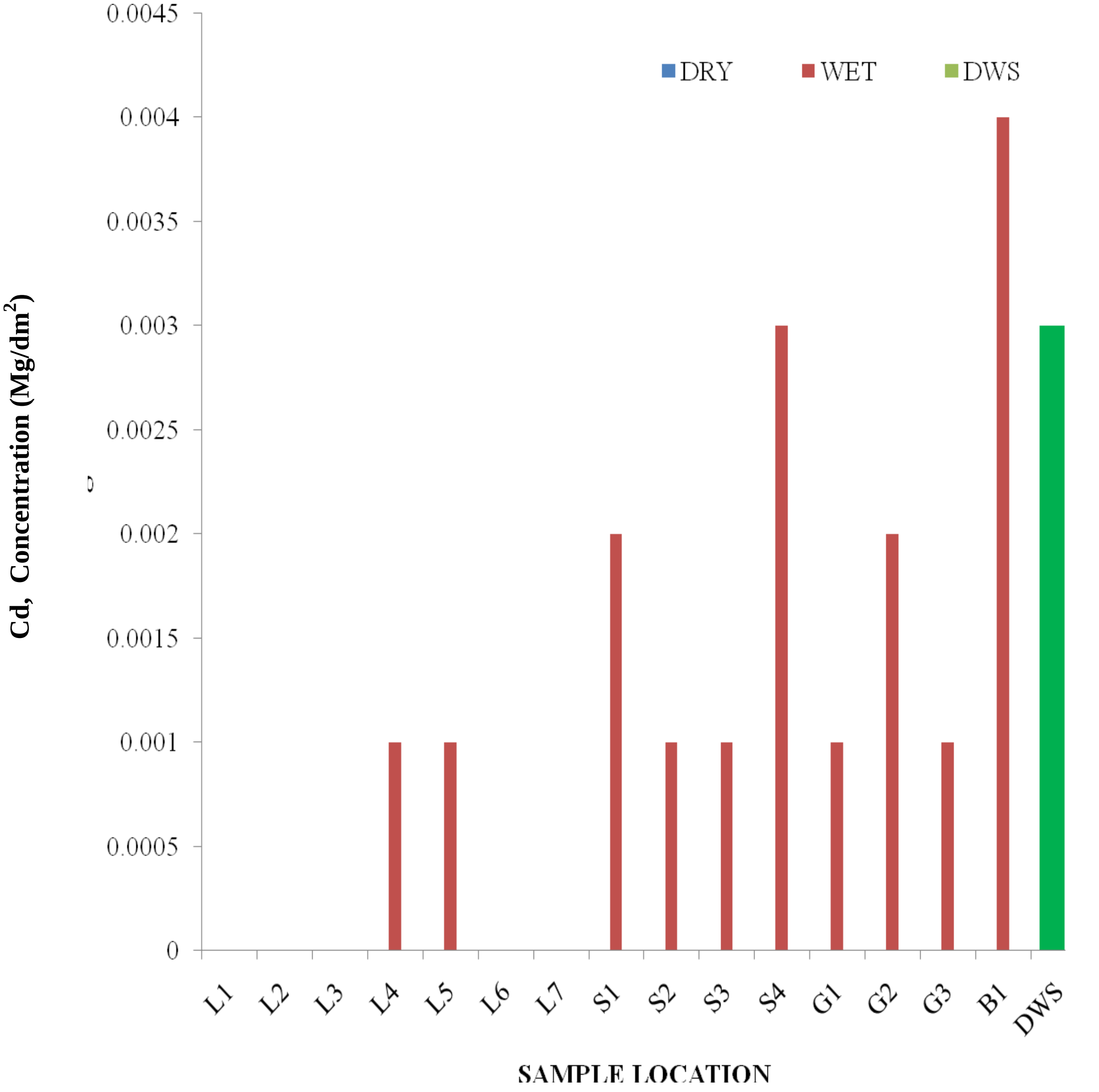

Figure 4.19: The effects of seasonal changes on the cadmium content of the well water samples near Rivers Niger and Benue in Lokoja.

Key: DWS: Drinking water standard

Dry: Dry season

Wet: Wet season

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Microbial Analysis

Table 4.3: Microscopic examination of isolate of the well water samples in dry and wet season of 2014.

S/N	Sample ID	Gram reaction	Wet	Suspected organism	
				Dry	Wet
1	K1	Negative	Rods	*E. coli*, *Enterobacter* spp	*E. coli*, *Escherichia* spp, *Enterobacter* spp
2	K2	Negative	Rods	*E. coli*, *Klebsiella* spp	*E. coli*, *Klebsiella* spp
3	K3	Negative	Rods	*E coli*, *Klebsiella* spp	*E. coli Escherichia* spp, *Klebsiella* spp
4	K4	Negative	Rods	*E coli*, *Enterobacter* spp	*E. coli*, *Enterobacter* spp
5	K5	Negative	Rods	*Serantia* spp, *Enterobacter* spp	*Serantia* spp, *Enetrobacter* spp
6	K6	Negative	Rods	*Klebsiellasp, E. coli, Enterobacter* spp	*Klebsiella* spp, *E. coli*, *Enetrobacter* spp
7	K7	Negative	Rods	*E. coli*, *Serantia* spp	*Serantia* spp, *Escherichia* spp, *E. coli*
8	S1	Negative	Rods	*E. coli*, *serantia* spp	*E. coli*, *Escherichia* spp, *Serantia* spp,
9	S2	Negative	Rods	*Klebsiella* spp, *Enterobacter* spp, *E. coli*	*Enterobacter* spp, *Klebsiella* spp, *E. coli*
10	S3	Negative	Rods	*Serantia* spp ,*E. coli Enterobacter* spp	*E. coli*,*Enterobacter* spp, *Serantia* spp
11	S4	Negative	Rods	*Serantia* spp, *klebsiella* spp	*Klebsiella* spp, *Sarantia* spp, *Escherichia* spp
12	G1	Negative	Rods	*E coli*,*Enterobacter* spp	*Entrobacter* spp, *Escherichia* spp, *Citrbacter* spp, *E. coli*
13	G2	Negative	Rods	*E coli*,*Enterobacter* spp	*Enterobacter* spp, *Escherichia* spp, *E. coli*
14	G3	Negative	Rods	*E coli*, *Entrobacter* spp	*Enterobacter* spp, *Escherichia* spp, *E coli*
15	B1	Negative	Rods	*Klebsiella* spp, *serantia* spp, *E. coli*	*Serantia* spp, *Klebsiella* spp, *E. coli*

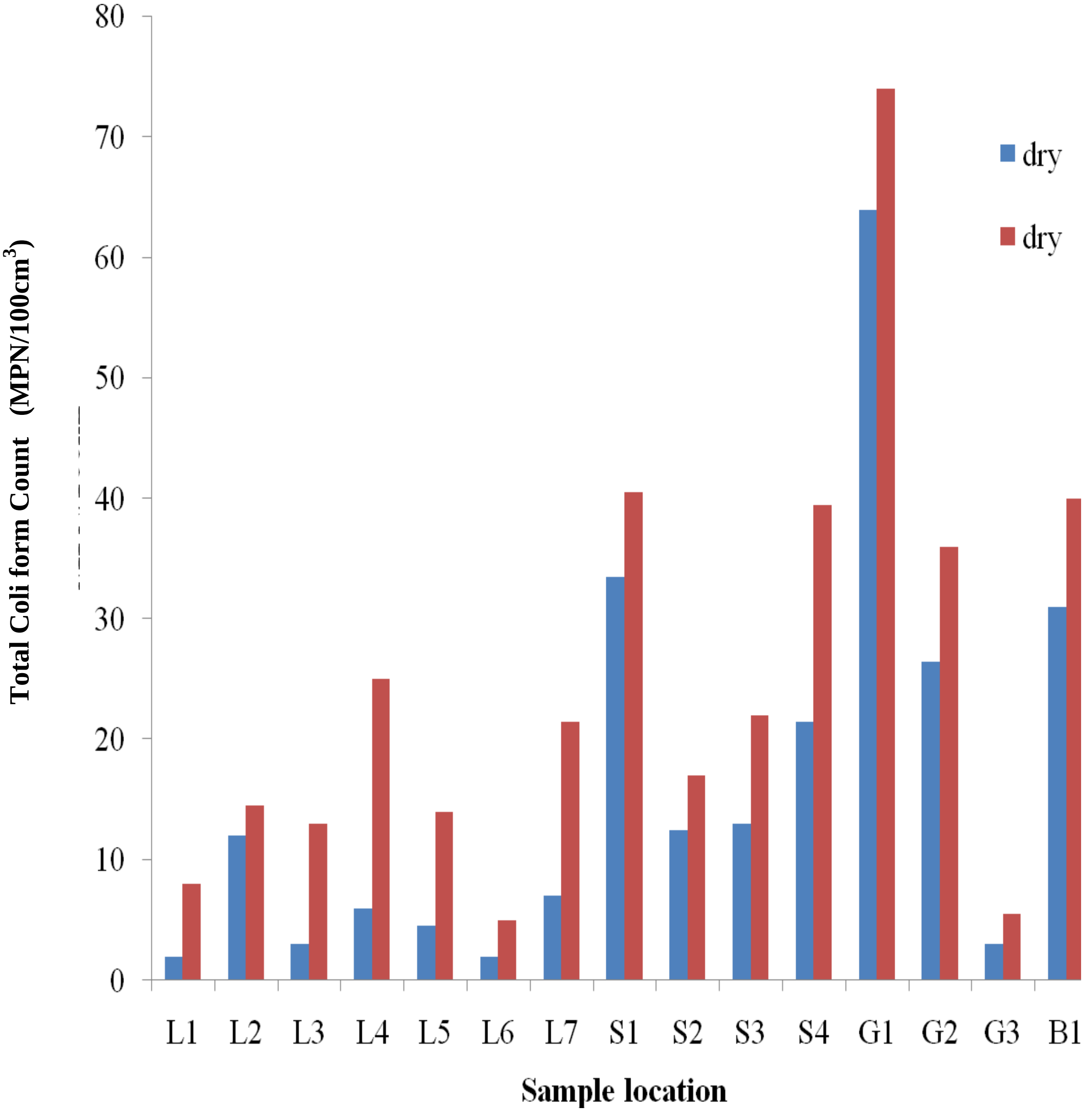

Figure 4.20: Effects of seasonal variation on the microbial qualities of the well water samples near the rivers Niger and Benue in Lokoja.

Key: MPN: most probable number

Effect of well Depth (X100 m) and distance from the river bank (m) on water quality

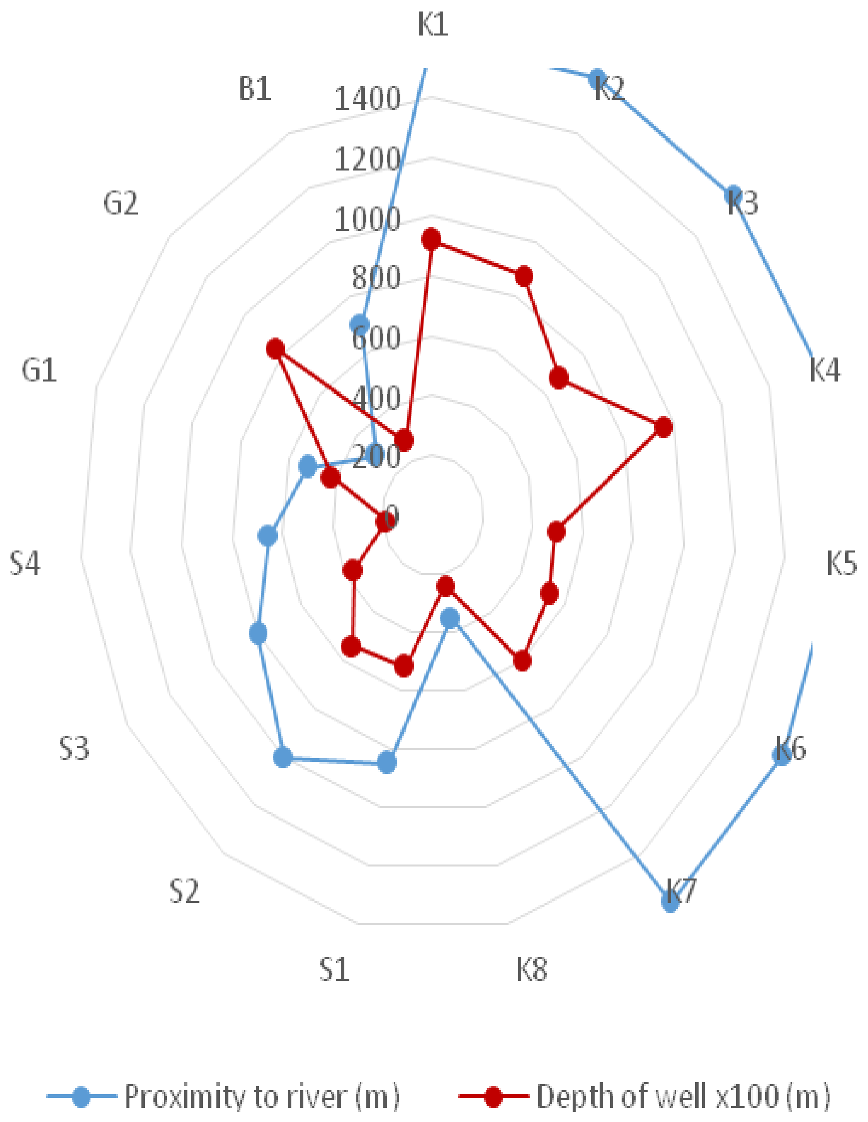

Figure 4.21: Mean depth and distance of the well water samples studied from Rivers Niger and Benue in Lokoja

Table 4.4: Correlation coefficients of the effect of depth and distance of the wells to the rivers on the water quality

Parameter	Depth				Distance			
	R^2		Slope		R^2		Slope	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
TSS	0.2133	0.0468	-6.4370	2.0741	0.1179	0.0033	0.0371	0.0157
TDS	0.0037	0.5414	2.8616	133.4600	0.3714	0.7631	-0.1490	0.7476
TS	0.0875	0.5187	-33.1280	144.8900	0.3714	0.7361	-0.1490	0.7479
BOD	0.0731	0.4088	0.4088	0.1707	0.0228	0.3457	0.0001	0.0003
DO	0.3110	0.0484	0.0218	0.0265	0.2060	0.0460	4.0000	0.0001
COD	0.0544	0.4786	-34.9440	37.3800	0.0100	0.1935	0.1526	0.0238
T Hardness	0.3102	0.0959	24.0580	22.4200	0.0006	0.2687	-0.2748	-0.0239
Turbidity	0.8868	0.1314	-0.0196	-0.0150	0.4173	0.1802	-0.0039	-0.1047
EC	0.1183	0.4283	-59.3950	131.5700	0.1905	0.0027	-0.6747	0.0907
Phosphate	0.8114	0.0072	-0.2681	0.0279	0.4601	0.0003	0.0122	0.0003
Nitrate	0.8019	0.0074	0.8724	-0.1510	0.0290	0.0169	-0.0047	-0.0033
Ammonia	0.0668	0.0072	-0.0137	0.0279	0.3371	0.0003	-0.0002	0.0003
Cu	0.2735	0.9058	0.0003	0.0012	0.0848	0.0307	0.0000	0.0000
Ni	0.1714	0.1975	-0.0010	0.0014	0.6371	0.3358	0.0000	0.0000
Zn	0.0000	0.0000	-0.3907	-0.0004	0.0760	0.9454	0.0000	0.0000
Pb	0.2850	0.0987	-0.0002	-0.0003	0.0056	0.0019	0.0000	0.0000
Cd	0.0000	0.0000	0.1705	0.0001	0.0000	0.0000	0.0046	0.0000
Mn	0.6292	0.0017	-0.6292	-0.0017	0.5469	0.0000	-0.5469	-0.0000
Microbial	0.7751	0.6556	-1.6061	-2.9076	0.7369	0.4563	-0.0326	-0.0296

R^2 : coefficient of correlation

Statistical Analysis

Table 4.6: Correlation matrix for the water quality parameters in dry season of 2014

	pH	T	EC	Alk	NTU	TH	PO_4^{3-}	N03	NH4+	TSS	TDS	TS	DO	BOD	COD	Cu	Ni	Zn	Mn	Pb	TC
pH	1																				
T	0.17	1																			
EC	-0.26	-0.25	1																		
Alk	0.34	0.04	0.43	1																	
NTU	0.38	0.26	-0.22	0.44	1																
TH	0.02	0.05	0.35	0.66	0.37	1															
PO_4^{3-}	-0.37	0.02	0.31	-0.01	-0.20	0.61	1														
$N0_3$	0.19	0.59	-0.12	0.42	0.75	0.49	0.12	1													
NH_4^+	0.18	-0.23	0.04	0.16	0.12	0.20	-0.25	-0.25	1												
TSS	0.33	0.38	-0.07	0.44	0.60	0.29	-0.05	0.58	-0.17	1											
TDS	-0.22	-0.23	-0.28	-0.13	-0.09	0.06	-0.04	-0.29	0.60	-0.03	1										
TS	0.00	0.01	-0.28	0.14	0.26	0.21	-0.07	0.08	0.41	0.54	0.83	1									
DO	0.00	-0.46	0.41	-0.01	-0.38	0.19	0.31	-0.58	0.27	-0.36	-0.11	-0.29	1								
BOD	-0.50	-0.48	0.25	-0.16	-0.48	0.15	0.49	-0.39	-0.14	-0.58	-0.06	-0.37	0.63	1							
COD	0.10	-0.22	0.38	0.43	0.42	0.22	-0.15	0.13	0.25	0.30	0.02	0.18	-0.14	-0.49	1						
Cu	-0.01	-0.15	-0.32	-0.17	0.04	0.17	0.22	-0.05	0.24	0.01	0.40	0.34	0.19	0.20	-0.08	1					
Ni	-0.06	0.01	-0.09	0.33	0.21	0.33	0.11	0.30	0.00	0.03	0.00	0.02	-0.02	0.24	0.00	0.66	1				
Zn	-0.39	-0.44	0.40	0.12	-0.19	0.20	0.24	-0.15	-0.08	-0.29	-0.24	-0.37	0.49	0.67	0.01	0.39	0.66	1			
Mn	-0.33	-0.16	0.25	0.46	0.10	0.35	0.08	0.29	0.01	-0.06	0.12	0.07	-0.41	-0.04	0.42	-0.25	0.22	0.11	1		
Pb	-0.44	-0.04	0.27	0.03	-0.16	-0.17	-0.13	0.03	-0.08	-0.19	-0.10	-0.19	-0.19	0.09	0.19	0.24	0.60	0.62	0.35	1	
TC	-0.31	-0.16	0.42	0.46	0.17	0.28	0.03	0.35	-0.22	0.03	-0.31	-0.24	-0.09	0.32	0.12	-0.06	0.56	0.68	0.49	0.62	1

Table 4.7: Correlation matrix for the water quality parameters in wet season of 2014

	pH	T	EC	Alk	NTU	TH	PO_4^{3-}	$N0_3$	NH^{4+}	TSS	TDS	TS	DO	BOD	COD	Cu	Ni	Zn	Mn	Pb	Cd	TC
pH	1																					
T	0.05	1																				
EC	-0.20	0.13	1																			
Alk	-0.29	-0.03	0.86	1																		
NTU	0.42	0.33	-0.33	-0.36	1																	
TH	-0.21	0.37	0.80	0.60	-0.05	1																
PO43-	0.20	0.72	0.40	0.17	0.23	0.44	1															
N03	-0.26	0.11	0.48	0.61	-0.08	0.17	0.13	1														
NH4+	0.20	0.72	0.40	0.17	0.23	0.44	1	0.13	1													
TSS	0.07	0.52	0.39	0.32	-0.11	0.38	0.66	0.39	0.66	1												
TDS	-0.16	0.21	0.98	0.81	-0.30	0.77	0.46	0.45	0.46	0.37	1											
TS	-0.14	0.29	0.97	0.81	-0.29	0.78	0.54	0.48	0.54	0.52	0.99	1										
DO	-0.11	0.19	-0.21	-0.05	-0.09	-0.15	-0.06	0.31	-0.06	0.53	-0.19	-0.08	1									
BOD	0.29	-0.24	-0.28	-0.08	-0.21	-0.51	0.06	0.09	0.06	0.21	-0.28	-0.22	0.25	1								
COD	-0.01	-0.03	0.08	0.25	-0.17	0.18	-0.17	-0.16	-0.17	0.21	-0.02	0.01	0.08	-0.04	1							
Cu	0.01	-0.08	0.09	0.03	-0.28	0.03	0.19	-0.20	0.19	-0.15	0.16	0.12	-0.28	0.44	-0.37	1						
Ni	0.19	0.08	0.35	0.00	0.03	0.15	0.40	0.00	0.40	-0.09	0.44	0.39	-0.41	-0.09	-0.63	0.54	1					
Zn	0.00	0.06	-0.35	-0.41	0.39	-0.22	0.27	-0.15	0.27	0.05	-0.32	-0.28	0.12	0.03	-0.29	-0.19	0.08	1				
Mn	0.28	0.51	-0.08	-0.29	0.47	0.05	0.34	-0.06	0.34	0.02	-0.02	-0.02	-0.15	-0.51	-0.29	-0.34	0.27	0.29	1			
Pb	0.27	-0.28	-0.33	-0.33	0.47	-0.46	-0.07	-0.09	-0.07	-0.43	-0.29	-0.35	-0.25	0.00	-0.54	0.07	0.48	0.39	0.33	1		
Cd	-0.09	0.60	0.07	-0.07	0.07	0.13	0.47	0.03	0.47	0.20	0.21	0.23	0.19	-0.12	-0.33	0.34	0.50	0.15	0.44	0.10	1	
TC	0.21	0.14	-0.40	-0.36	0.60	-0.29	-0.03	-0.17	-0.03	-0.44	-0.30	-0.36	-0.14	-0.16	-0.25	0.05	0.28	0.35	0.52	0.60	0.54	1

Table 4.9: Pairwise Comparisons of means of trace metals in ANOVA

(I) Trace Metals	(J) Trace Metals	Mean Difference (I-J)	Std. Error	Sig.[b]
	Ni	-.020*	.003	
	Zn	-.008	.003	.233
Cu	Pb	-.003	.001	.094
	Mn	.000	.001	1.000
	Cd	.004*	.000	.000
	Cu	.020*	.003	.000
	Zn	.013	.004	.066
Ni	Pb	.018*	.003	.000
	Mn	.020*	.003	.000
	Cd	.024*	.003	.000
	Cu	.008	.003	.233
	Ni	-.013	.004	.066
Zn	Pb	.005	.003	1.000
	Mn	.007	.003	.204
	Cd	.011*	.003	.009
	Cu	.003	.001	.094
	Ni	-.018*	.003	.000
Pb	Zn	-.005	.003	1.000
	Mn	.002	.001	.058
	Cd	.006*	.001	.000
	Cu	.000	.001	1.000
	Ni	-.020*	.003	.000
Mn	Zn	-.007	.003	.204
	Pb	-.002	.001	.058
	Cd	.004*	.001	.000
	Cu	-.004*	.000	.000
	Ni	-.024*	.003	.000
Cd	Zn	-.011*	.003	.009
	Pb	-.006*	.001	.000
	Mn	-.004*	.001	.000

Based on estimated marginal means *. The mean difference is significant at the .05 level .b. Adjustment for multiple comparisons: Bonferroni.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Characterization of well water samples

The properties of the wells from which the water samples were sourced are presented in Table 4.1. The distances of the wells from the main river bank and the corresponding well depths are presented in the table. The physicochemical properties of the well water samples and their corresponding mean values for the wet season and dry seasons are listed in Tables 4.2 and 4.3 respectively. The results were also used to compare the quality of the well water as a function of season.

5.1.1 pH of the Well Water Samples

The mean values for all the physicochemical properties of the well water in wet and dry seasons are presented in Tables 4.2 and 4.3 respectively. The pH values of the water is between 5.9 to 7.5.The maximum permissible limit of pH value for drinking water as specified by the Nigerian drinking water standards is from 6.5 to 8.5. The pH values of the water reported in this work is within the range recommended by WH O of 6.5 - 8.5. Excepts sample S1 with mean value 5.9. pH values lower than 6.5 are considered too acidic for human consumption and can cause health problems such as acidosis which could have adverse effects on the digestive and lymphatic systems of human (Nkansah *et al*, 2010). Generally, pH of water is influenced by geology of catchments area and buffering capacity of the water (Nkansah *et al*, 2010). pH affects the dissolved oxygen level in the water, photosynthesis of aquatic plants, metabolic rates of aquatic organisms and the sensitivity of these organisms to pollution, parasites and disease (FWPCA, 1968).

5.1.2 Temperature of the Well Water Samples

The most common physical assessment of water quality is the measurement of temperature. The temperature values reported in this work are within the range recommended by WHO of (30^{o}C) except sample L4, S2, S4 and B1 which were above the permissible limit during the dry season with a mean value of 33, 31, 32 and 33.2^{O}C respectively were obtained. The higher value of water temperature observed in the results obtained during the period of investigation in the present study is attributed to the relatively warmer ambient day temperature in the dry season, while the lower temperatures were obtained during the wet season. Temperature is one of the factors that govern the assimilative capacity of an aquatic system (Yisa *et al* 2009).

5.1.3 Electrical Conductivity (EC) of the Well Water Samples

Figure 4.2 shows the values of electrical conductivity of the well water samples collected from the villages near rivers Niger and Benue in Lokoja during the wet and dry season of 2014. From the results the electrical conductivity values are within the (WHO 2004) recommended limit of 750 µs/cm except for samples L7, S1, S2 and G1 with the respective means values of 985, 984, 957 and 941 µS/cm, which were found to be above the recommended limit during the dry season. These high values may be due to the soluble ions present in the water at the locations analyzed. Samples L1, L2, G3 and B1 with respective mean values of 895, 920, 1398 and 1206 µs/cm during the wet season, were also found above the (WHO, 2004) recommended limit. Generally from the result obtained the electrical conductivity values showed that the more the well depth the higher the TDS and EC values because TDS load of an aquifer is a function of various factors including aquifer mineralogy, residence time (i.e. how long the water has been in contact with aquifer materials) and how fast the groundwater is moving in a given aquifer (Harry 1991). This confirms the fact that pollution could result due to the depth of the wells as earlier pointed out by Bolaji and Martins (2008) and Abimbola and Sangodoyin (1991). This showed that the quality of the wells studied depend on the season of the year. All the wells studied in the three villages were least polluted in dry season and more polluted in wet season irrespective of the depth. This is because during the wet season most of the wells were flooded and in some cases collapsed (Harry, 1991) this observation is in agreement with the finding of Harry (1991).

5.1.4 Total Alkalinity of the Well Water Samples

The results show that the alkalinity values in both the dry and wet seasons of 2014 were within the normal and in permissible limits of 120 $mgdm^{-3}$. Except for samples L3 with a mean value of 131 $mgdm^{-3}$ during the wet season that was found to be above the desirable limit but within the maximum permissible limit of 600 $mgdm^{-3}$. Water samples with a high alkalinity value are concluded to be well buffered and resist a decrease in pH, However if water has a low alkalinity value it is poorly buffered and pH sensitive. This could be harmful to the plant and animal that live in the water. (WHO 2011) The alkalinity value of water provides an idea of natural salts present in water (Escher et al, 2011).The major cause of alkalinity are the minerals which dissolve in water from the soil (Shyamala *et al.*, 2008).A comparison of the alkalinity results for the wet and dry seasons is shown in Figure 4.2. An increase in the values of the alkalinity was observed in 10 samples this was in agreement with the findings of (Ezeribe *et.a.*,, 2012). Increased alkalinity is characteristic of the source of water and natural processes taking place at any given time (Sharma, 2004). The alkalinity varies in accordance with the fluctuation in the pollution load (Parashar *et* *al.,* 2006). Anthropogenic activities from small scale dyeing units, mechanic workshops, fertilized farm, restaurants present in Lokoja are constantly increasing in the absence of proper drainage systems. The waste waters are discharged into the soil and this may lead to increase in alkalinity of ground water in these areas (Shyamala *et al.,* 2008).

5.1.5 Turbidity of the Well Water Samples

Following the results of Figure 4.3, in few of the wells studied, the values of turbidity in dry season of (May,2014) were below the permissible limits except samples L5 and L7 with respective mean values of 53.38 and 25.45 NTU which were found to be above the maximum permissible limit of 25 NTU as given by WHO, (2004). This may be due to the scarcity of water in the villages as a result the silts; clay and sediments of the ground water are suspended in the water making it to be more turbid. The more turbid the water is the higher the chances of water borne diseases. This is because contaminants like bacteria and viruses can become attached to the suspended solids (USEPA 1986). The values of turbidity recorded during the wet season were found to be within the WHO recommended permissible limit except samples L4, S1, S4 and G1 with respective mean value of 53.8, 100, 111 and 140 NTU. This might be due to the suspended particles and other contaminant from the surface water runoff as a result of flooding from the rivers, since most of the wells have no cover. As a result, contaminants can easily enter in to them from the surface. Figure 4.3 illustrates the effect of seasonal changes on the turbidity of the water samples. suggests that seasonal changes may not play a direct role in influencing turbidity change.

5.1.6 Total Hardness (TH) of the Well Water Samples

In the present study, the values of total hardness of the well water samples from the different locations near River Niger and Benue in Lokoja are presented in Tables 4.2 and

4.3 respectively. NIS (1996) has specified the maximum permissible limits of total hardness to be within 150 $mgdm^{-3}$ of $CaCO_3$ while the USEPA (1983) guidelines are within 500 $mgdm^{-3}$ of $CaCO_3$. During the dry season, samples S1 had the highest Total Hardness values of 817 $mgdm^{-3}$ while sample G3 was found with the highest value of 404 $mgdm^{-3}$ during the wet season. During the wet season of 2014 all samples had TH above the recommended limit of 150 $mgdm^{-3}$ but were well within the USEPA (1983) limits of 600 $mgdm^{-3}$. Samples S1, S4, L7 and sample L1 with respective mean values of 818 $mgdm^{-3}$, 815, 621 and 515 $mgdm^{-3}$ are above the recommended limits of 150 mg/L during the dry season.

Higher value of total hardness in the water samples might be due to the dissolution of minerals made up of carbonate and bicarbonate. The values of the dry season (October 2014) were comparatively higher than the wet seasons (May 2014). Though the hardness of water is not a pollution parameter and has no adverse effect on human health, it indicates water quality and water with hardness above 200 mg/L may cause scale deposition in the water distribution system and more soap consumption (Kumar et al., 2010; Yadav and Kumar, 2011).

5.1.7 Chemical Oxygen Demand (COD)

As presented in Tables 4.2 and 4.3, all the samples in the dry seasons had chemical oxygen demand value that were below the WHO 2004 maximum permissible limit of 200 $mgdm^{-3}$ except samples L2, L4, L5, L7,S2, G2 and B1 with respective mean values of 260, 295, 290, 330, 345.5, 265 and 315 $mgdm^{-3}$. Also all the samples in the wet season had values above the permissible limit of 200 $mgdm^{-3}$ except sample L7, S2, S3, G1, G2,G3 and B1 with respective mean values of 210, 220, 230, 240,310, 260 and 818 $mgdm^{-3}$. The maximum permissible limit of chemical oxygen demand for drinking water is 255 mgdm^{-3} (Escher *et al*, 2011). Most applications of COD determine the amount of organic pollutants found in surface water, making COD a useful measure of water quality (clair *et al.,* 2011). And is helpful in indicating toxic conditions and the presence of biologically resistant organic substances (Kumar *et al.,* 2010; Yadav and Kumar, 2011) The maximum COD values recorded were 818 mgdm^{-3} at B1 and 345 mg/L during the wet and dry seasons respectively, while the minimum values were recorded as 60 mgdm^{-3} at G3 and 105mgdm^{-3} at L4 for wet and dry seasons respectively. The high values of COD in the study areas could be due to high levels of pollutants present in the water samples (Yadav and Kumar, 2011), Resulting from anthropogenic activities at the course of the two rivers.

5.1.8 Biochemical Oxygen Demand (BOD)

As presented in Tables 4.2 and 4.3. All the water samples obtained during the dry and wet seasons of 2014 were below the recommended permissible limit. The desirable limit for BOD is 4.0 mgdm^{-3} and permissible limit is 6.0 mgdm^{-3} (WHO, 2000). The BOD represents the amount of oxygen needed by microbes to stabilize biologically oxidizable matter (Baryla *et al.,* 2001). Comparisons of the dry and wet season results show that there is an increase in BOD values across water samples from the dry to the wet season which indicates that seasonal changes may influence biological pollution and in turn affect the water quality (Yadav and Kumar, 2011). Also the observed BOD value of all the samples during the dry seasons was lower than the observed BOD values obtained during the wet season, this might be attributed to the surface water run off by rain water (Yadav and Kumar, 2011).

5.1.9 Dissolved Oxygen (DO) of the Well Water Samples

From the result obtained in Tables 4.2 and 4.3 during the dry and wet seasons it was observed that all the samples were far below the recommended limit of 5.0 mgdm$^{=3.}$ Dissolved oxygen DO of ground water samples is an indication of the capacity of the water to hold oxygen (Pushpendra *et al.*, 2012). The recommended permissible value of dissolved oxygen is 5.0 mgdm$^{=3}$. The low values of dissolved oxygen observed in the samples might be an indication of high rate of oxygen consumption by oxidisable matter (Yadav and Kumar, 2011). Very low DO may result in anaerobic conditions that can cause bad odour in water. The low DO levels situation may result through the decomposing organic matter, dissolved gases, industrial waste, mineral waste and landfill leachate (Pushpendra *et al.*, 2012).

However, high levels of total dissolved solids and electrical conductivity recorded in this study could have an influence on the level of dissolved oxygen since the presence of other solutes in the solution affect the solubility of gases in a solvent. It was observed that the samples had more dissolved oxygen during the wet seasons. This might be due to the rain water that has more dissolved oxygen that percolate through the soil during wet season there by adding more dissolved oxygen to ground water (Sawyer *et al., 2013*). Generally, there was an increase in dissolved oxygen values from dry to wet season except for the values of sample B1 which indicated a decrease from 0.12 mgdm$^{=3}$ to 0.03 mgdm$^{=3}$

Total Dissolved Solids (TDS) of the Well Water Samples

From the result obtained in Tables 4.2 and 4.3 during the dry and wet seasons it was observed that the total dissolved solid in the well water samples studied in the three villages and Lokoja near Rivers Niger and Benue during the dry season were in the range of 57 to

310 mgdm$^{-3,}$ except for sample S1 which was 905 mgdm^{-3}, the desirable limit of total dissolved solid is 500 mgdm^{-3}. The maximum permissible levels are 2000 mgdm^{-3} (Escher *et al., 2011*). The TDS values observed in the 14 sites during the dry season of 2014 were well within the desirable limit. During the wet season of 2014, the average values of TDS in the well water samples were in the range of 100 to 1560 mgdm^{-3}. The TDS values were found to be below the permissible limit of 500 mg/L though some of the samples were above the desired limit of 500 mgdm^{-3}. The high values of TDS in the well water may be due to ground water pollution by the leaching of various pollutants when waste waters from both residential and industrial units are discharged into pits, ponds and lagoons enabling the waste migrate down to the water table (Rani and Robison, 2003, Pushpendra *et al.*, 2012). This decreases the portability and may cause gastrointestinal irritation in human and may also have laxative effect particularly upon transits (WHO, 2004). Figure 4.8 shows the effect of seasonal changes on the TDS values of the well water samples. The TDS levels in the well samples, L1, B1 and G1, increased from the dry season to the wet season. This may be due to the increased migration of ground water in the water table which promotes the transport of pollutants (Pushpendra *et al.*, 2012).

Total Suspended Solids (TSS) of the Well Water Samples

Tables 4.2 and 4.3 indicate that the minimum total suspended solids value in the well water samples was recorded as 13 mgdm^{-3} at site S1 and maximum value as 450 mgdm $^{-3}$ from site B1 during the dry season of 2014. Also during the wet season the total suspended solids values were found in the range r of 70 - 370 mgdm^{-3}. The total suspended solids are composed of carbonates, bicarbonates, chlorides, phosphates and organic matter, salts and may also include mud, algae and faecal material (Kumar *et al*., 2010; Pushpendra *et al.*, 2012).When the concentration of suspended solids is high it may be aesthetically unsatisfactory for bathing (Pushpendra *et al*., 2012). The effect of seasonal changes on the total suspended solids is illustrated in Figure 4.7. All values increased during the wet season except sample L1 and B1 which increased during the dry season.

Total Solids (TS) of the Well Water Samples

From Tables 4.2 and 4.3 the values of total solid in the dry season (October , 2014) were recorded at a minimum of 105 mg/L in site S4 and a maximum of 925 mg/L in site G3. The values in the wet season were higher with a minimum of 170 mg/L at site G1 and a maximum of 1820 mg/L at site B1.The effect of seasonal changes, as illustrated in Figure 4.10 shows that there is an increase in total solid values from the dry to the wet season. The exception being L7 is attributed to the relatively smaller value of the total suspended solid results of chemical properties of the well water samples, near the River Niger and Benue in Lokoja, Nigeria.

5.2 Chemical Properties of the Well Water Samples Near River Niger And Benue In Lokoja, Nigeria

5.2.1 Nitrate of the Well Water Samples

As presented in Figure 4.7, the mean nitrate contents of the well water samples were determined in both dry and wet seasons of 2014. The highest nitrate values recorded in sample B1 with respective mean value of 43.4 mgdm^{-3} during the dry season and 65 mgdm^{-3} in sample L2 for the wet season. While the minimum amount of nitrates value were recorded at station S1 with respective mean value of 3.9 mgdm^{-3} for the dry season, and sample S2 with mean values of 7.5 mgdm^{-3} for the wet seasons. The nitrate content values fall within the World Health Organization 2004 and NIS accepted limits of drinking water standards of 50 mgdm^{-3}, except for sample L2 whose value was 65 mgdm^{-3} during the wet season of 2014. This implies that the well water samples analysed in this study contained high level of oxidized organic matter which appears in the form of soluble anions such as nitrate.(baryla *et al*., 2001). Nitrate (NO3-N) is a contaminant that is regulated as it has significant health risks associated with excess nitrate consumption in the human diet. Nitrites are veritable indication of biological pollution in natural waters (Addo *et al,* 2011). Some ground water might also have nitrate concentration as a result of leaching from natural vegetation and dumpsites (Emmanuel, 2012). The observation is also in agreement with the findings of other workers in similar studies (Abulhakeen *et al*., 2011 and Ezeribe *et al.*, 2012).

5.1.2 Phosphates of the Well Water Samples

As shown in Tables 4.2 and 4.3 respectively, none of the water samples had phosphate values within the acceptable limits for both the dry and wet seasons of 2014. The recommended limit for phosphates in drinking water is 0.1 $mgdm^{-3}$. The high levels of phosphate might be due to agricultural runoff containing phosphate fertilizer as well as the waste water containing detergent (McCutcheon *et al*., 1989). This observation is also not in agreement with the findings of other workers in similar studies (Abulhakeen *et al*., 2011: McCutcheon *et al*., 1989 and Ezeribe *et al.,* 2012).

Low levels of phosphate have no adverse effects on human health. However, extremely high levels of phosphate in water can cause digestive problems (Sheila, 2005). Seasonal changes were observed from dry to wet season, the values of phosphate in the well water samples increased during the wet seasons except sample S1 and S4 whose values are 20.5 $mgdm^{-3}$ and S4 (19.0 $mgdm^{-3}$ which showed a slight decrease in phosphate concentration during the wet seasons of 2014 as shows in Figure 4.12.

Ammonia of the Well Water Samples

As presented in Table 4.2 and 4.3 respectively, the study indicate that none of the samples had values of ammonia above the acceptable limit of 5 $mgdm^{-3}$ during the dry and wet seasons of 2014 except samples at stations L1, S1, S2, S3, S4 and B1 with respective mean values of 10.5, 13.5. 13.2, 10.4, 10.5 and 12.5 $mgdm^{-3}$, during the wet season. A comparison of the wet and dry season ammonia contents suggests that the effect of seasonal changes from dry to wet season has a direct influence on the ammonia concentration in the well water samples with the ammonia contents of samples in the wet season being higher than those of the dry season.

5.3 Heavy Metals in the Well Water Samples

The heavy metal composition of the well samples as seen in Tables 4.2 and 4.3. The Nigerian standards for drinking water has the standard limits for Cu, Cd, Mn, Ni, Pb and Zn as 1.00 $mgdm^{-3}$, 0.02 $mgdm^{-3}$, 0.001 $mgdm^{-3}$, 0.20 $mgdm^{-3}$, 0.01 $mgdm^{-3}$, and 0.003 $mgdm^{-3}$ and 3.00 $mgdm^{-3}$ respectively. All samples have heavy metal contents far below the permissible limits for the heavy metals. In the wet season, except for the Cd contents at stations S3, S4 , G1 and G3 respectively with respective mean values of 0.044 mg/L, 0.049 mg/L, 0.036 $mgdm^{-3}$, 0.034 $mgdm^{-3}$, 0.030 $mgdm^{-3}$. However, during the dry season all the well water samples had the heavy metal contents below the permissible limits for Cu, Zn Mn and Cd except sample B1, with mean values of 0.004 mg/L which was slightly above the permissible limit for Cd (WHO, 2004).

High levels of cadmium in the samples were observed. Cadmium might be released to water by natural weathering processes as a result of discharge from industrial facilities or sewage treatment plants, atmospheric deposits by leaching from landfill, soil, and phosphate fertilizer from agricultural deposit (EPA 1981).

The Ni content of the water samples indicated that Ni values were within the permissible limit, except samples S3, S4, G1, G2 and B1 with respective mean values of 0.044 $mgdm^{-3}$, 0.039 $mgdm^{-3}$, 0.036 $mgdm^{-3}$, 0.034 $mgdm^{-3}$ and 0.037 $mgdm^{-3}$ during the dry season. Also other hand, samples L2, S2, S3,S4,G1,G2 and B1 with respective mean values of 0.022 $mgdm^{-3}$, 0.022 $mgdm^{-3}$, 0.032 $mgdm^{-3}$, 0.054 $mgdm^{-3}$, 0.041 $mgdm^{-3}$, 0.045 $mgdm^{-3}$, 0.043, 0.054 $mgdm^{-3}$ recorded in the wet seasons of 2014 were found slightly above the permissible limits of 0.02 $mgdm^{-3}$ in drinking water. Nickel is regarded as an essential trace metal but high amount of nickel in water is toxic to human and it is considered as carcinogenic. Although its toxicity of is enhanced in the presence of some metals in drinking water (Mandour and Azab 2010).

The Pb contents of the water samples indicated that samples S3, G1 and G2 with respective mean values of 0.012, 0.013 and 0.014 $mgdm^{-3}$ were found above the permissible limit of 0.003 $mgdm^{-3}$. Inadequate head of the well allowing water to enter the well from surface water runoff and also infiltration of rain water through the soil increase the heavy metals concentrations (Musa *et al* 2004). An exposure to lead causes a variety of health effects which affect various system of the body including the nervous and reproductive system and the kidney. At very high levels, lead can cause convulsion coma and death (WHO, 2011). Improper cover head for wells may allow water to enter the well from surface water runoff and also infiltration of rain water through the soil (Adepelumi *et al*., 2001).

According to (Adekunle et al., 2007), higher trace metal concentrations in the wet season implies increased soil metal burden from atmospheric deposit of air-borne particulates by wet precipitation and subsequent rainwater run-off of waste materials. There were no changes in the values of Mn as the season changed. Metal levels could also be traced to dissociation from bedrocks through which the well water flows (Adepelumi *et al*., 2001).

5.4 Microbiological Characterization of the Well Water Samples

The results of the bacteriological analysis of the well water samples are shown in Tables 4.2, 4.3 and 4.4. Table 4.3 is the result of the examination of microbial isolates in the well water during wet season and reveals six microbes in the well water samples. All samples, excluding samples L5 and S4, had *Escherichia coli* which is an indicator of faecal pollution. Escherichia coli causes urinary tract infection and diarrhoea. *Enterobacter* spp was found in nine samples (L1, L4, L5, L6, S2, S3, G1, G2 and G3*). Sarantia spp* was present in six samples (L5, L7, S1, S3, S4 and B1). *Citrbacter spp* was found in sample G3. While *Klebsiella spp* was found in five samples viz. L2, L3, L6, S2, S4 and B1. *Escherichia coli* was the most widely adopted indicator of faecal pollution, and was also isolated and identified only in the wet season. This study is also in agreement with the findings of Agbede and Akpen (2008): Isikwue et al, (2011) and Iorver (2011) that the main coliform bacterial contaminant of the wells within the Makurdi floodplains is of faecal origin. The shallowest well was 0.87 m deep and had an average pollution level of 128 cfu/cm^{-3} which has exceeded WHO, (2004) limit of 0 cfu/ cm^{-3} and NAFDAC's (2004) limit of 10 cfu/cm^{-3} for potable water, This study is also in agreement with the findings of Sina et al (2009) that faecal coliform had a range of 3 - 460 and 0 - 29 MPN/100 ml.

A comparison of the dry and wet season results show that the same microbes present in the dry season were present in the wet season for each sample but with the presence of *Escherichia coli* in samples L1, L3, L7, S1, S4, G1, G2 and G3. Sample G1 had the highest microbial count in both the wet and dry season of 2014. However, lower concentrations of bacteria were detected during the dry than wet season. This agrees with the increase in the level of total coliform. Coliform populations are indicators of pathogenic organisms which should not be found in drinking water but are usually present in surface water, soil and faeces of humans and animals (Adekunle *et al*., 2008). High coliform populations in all the water samples may be an indicator of poor sanitary conditions in the region. Inadequate and unhygienic handling of solid-wastes in the rural area could have generated high concentration of microbial organisms (Adekunle *et al*., 2008).

High coliform counts appear to be characteristic of rural ground water quality in Nigeria, the present study is consistence with the work of other investigators who worked on bacteriological and chemical characteristics of rural water supplies in other parts of the country (Aremu *et al*., 2002; Ugboaja, 2004; Adekunle *et al*., 2008). faecal coliform had a range of 3 - 460 and 0 - 29 MPN/100 ml. This also showed that COD, NO_3, total dissolved solid and electrical conductivity increased with increasing well depth and Total Coliform, Fecal Coliform decreased with increasing well depth.

5.5 The Effects of Distance and Depth on Water Quality

The distance and depth of each well sample site are presented in Table 4.1 and graphically illustrated in Figure 4.21, showing the spread of the well water sites about the river bank. To study the fate and extent of pollution, the relationship of depth (samples L1 to L7) and of distance (S1 to S4, G1 to G3 and B1) against the tested parameters was undertaken. The effect of distance and depth on the physical, chemical and bacteriological properties of all water samples are presented in Table 4. 4. The Figures show the change in the mean values of the tested parameters as distance and depth change and further explains the results of the effect of seasonal changes on the tested parameters. Mathematical expressions that define the patterns shown in these figures are presented on the Table and the coefficients of correlation are also presented in the Table 4.4.

The linear expression and coefficient of regression (R^2) on the figures were used to predict the fate of chemic als/pollutants present and the extent of pollution in remote wells. In the dry season there was a negative correlation between the values of physicochemical parameters total suspended solid (TSS), total solid (TS), chemical oxygen demand (COD), electrical conductivity (EC) and total coliform count (TBC) with the increase in well depth. This implies that as the well depths increased, these values decreased. This trend is also seen in the chemical compositions of the well water samples. Phosphate and metal compositions also decreased as well depth increased. The Nitrate composition, showed a positive correlation but has a relatively very poor rate as show in Table 4.4 Also, This study is also in agreement with the findings of Sina, et al (2009): Ifabiyi et al, (2008) which showed that COD, NO_3, total dissolved solid and electrical conductivity increased with increasing well depth and Total Coliform, Fecal Coliform decreased with increasing well proximity to the river.

The proximity of the well water to Rivers Niger and Benue in Lokoja showed a negatively correlations with total dissolved solid (TDS), total hardness (TH), turbidity, electrical conductivity (EC), nitrates, ammonia, manganese (Mn), cadmium (Cd) and the total coliform counts (TBC). The values of the change and coefficient of correlation (R^2) for these parameters as functions of distance and depths of the well show that during the wet season, there was a change in pattern of the rate of change with depth of well to total suspended solid (TSS), total solid (TS), chemical oxygen demand (COD), electrical conductivity (EC) and nitrate contents of the well water samples near Rivers Niger and Benue in Lokoja.

5.6 Statistical Data Analysis

As presented in Tables 4.6 and 4.7 the data obtained for the physico-chemical parameters of the well water were subjected to statistical analysis. The mean values of the investigated parameters were correlated using the Pearson's correlation equation and the correlation co-efficient (r) among the various water quality parameters as presented in Tables 4.5 and 4.6 for the dry and wet seasons of 2014 respectively. Positive and negative Pearson correlation coefficients were obtained among the water quality parameters. The results show that most of these parameters, especially in the dry season, were not strongly correlated (> 0.8 or < -0.8). The data were further treated by subjecting them to Analysis of Variance (ANOVA) to find if there were differences in the mean values of the metal content in the well water sites. The results of the ANOVA are presented in Table 4.8. The within-subject factors were the mean results of each trace metals tested while the subject factors were the wet and dry season. Customarily, a difference is not regarded as proven unless the probability (P) obtained with F ratio tables is less than 0.05 (Ton, 2000). Table 4.7 shows that there is a significant difference ($P = 0.00$) within the means of the trace metals detected but no significant difference or no interaction ($P = 0.21$) between the mean metal load in each season. In the test of between season effects, the significance value is 0.021 ($P < 0.05$), which implies that there is a significant difference in the metal loads of the dry and wet season. Therefore, there is a significant increase in the trace metal content of the well waters in the wet season. This means that the differences lie between the metal content values. To find out exactly where the difference lies in the ANOVA results a pairwise comparison has been carried out and is presented in Table 4.8. The results in the Table show that there are no significant differences in the relationship between the mean values of Cu, Ni, Pb and Mn but there is a difference between Ni content and all the tested metals, and between Cd and all the tested metals. This implies that the Ni contents of the well waters in dry and wet seasons are significantly higher than those of other metals and the Cd content is significantly lower than the rest.

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMENDATION

6.1 Summary

The effects of proximity of the wells of Rivers Niger and Benue and depth of the well water on the water quality in some villages.(Gbobe, Shintaku Ganaja village) and Lokoja metropolis, Kogi State, Nigeria. Showed that most of the physicochemical parameters such as total alkalinity, total hardness, turbidity, dissolved oxygen, biochemical oxygen demand, copper, and manganese were respectively within the acceptable limits as recommended by WHO 2004. However, electrical conductivity, Lead, nitrate, nickel, cadmium, phosphate, ammonia and microbial count were mostly found to exceed the maximum permissible limit as recomme nded by WHO at some study sites. However, since some of the results indicate high levels above the Standard set by W.H.O safe limits, there is the tendency of high potential health hazards to the inhabitants of the areas that uses these water sources for drinking and other domestic purposes without further treatment.

6.2 Conclusion

The results of the study showed that all the well water samples had *E. coli* but sample G1 contained more microbial pollutants during the wet season. This is evident in the fact that well G1 had the least depth and hence could be easily polluted from surface run-off. The nitrate, turbidity and pH values of the wells were found to increase with depth in dry season, since their R^2 values were between 0.7 - 0.8. Zn content was found to increase with the well proximity to the rivers. However, all the samples had metal contents far below the permissible limits in the wet season, except for the Cd content which were found to be above the permissible limit in some of the water samples. Cu, Zn and Mn were found to be below the permissible limits in drinking water. Since the physico-chemical and microbial qualities of the well water in villages close to the rivers Niger and Benue in Lokoja, Nigeria were found above the standards for potable water therefore the Level of heavy metal pollution is very critical as it posses' significant health hazard to any form of life and causing global problem and warrant ultimate remediation measurement. Our study shows that the sustainable development goal should be step up to meet the provision of adequately safe drinking water for the increasing urban and rural populace.

6.3 Recommendations

a) Continuous water quality monitoring in the study area should be f carried out. This will act as a whistle blowing activity should safe limits of heavy metals be exceeded due to increasing activities.

b) It is advised that underground waters from these villages should not be used as drinking water without prior treatment due to some heavy metals content.

c) In addition to metal studies, frequent research on arsenic, chromium and iron which are water contaminants of concern must be evaluated in the wells. The overall implication of this observation calls for an urgent water resources management strategy (including treatment of the water) in the area in order to circumvent the fast deteriorating water resources quality, which may pose associated health risk and environmental hazards

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APPENDICES

Appendix I: T test results for physicochemical parameter of well waters in dry and wet season of 2014

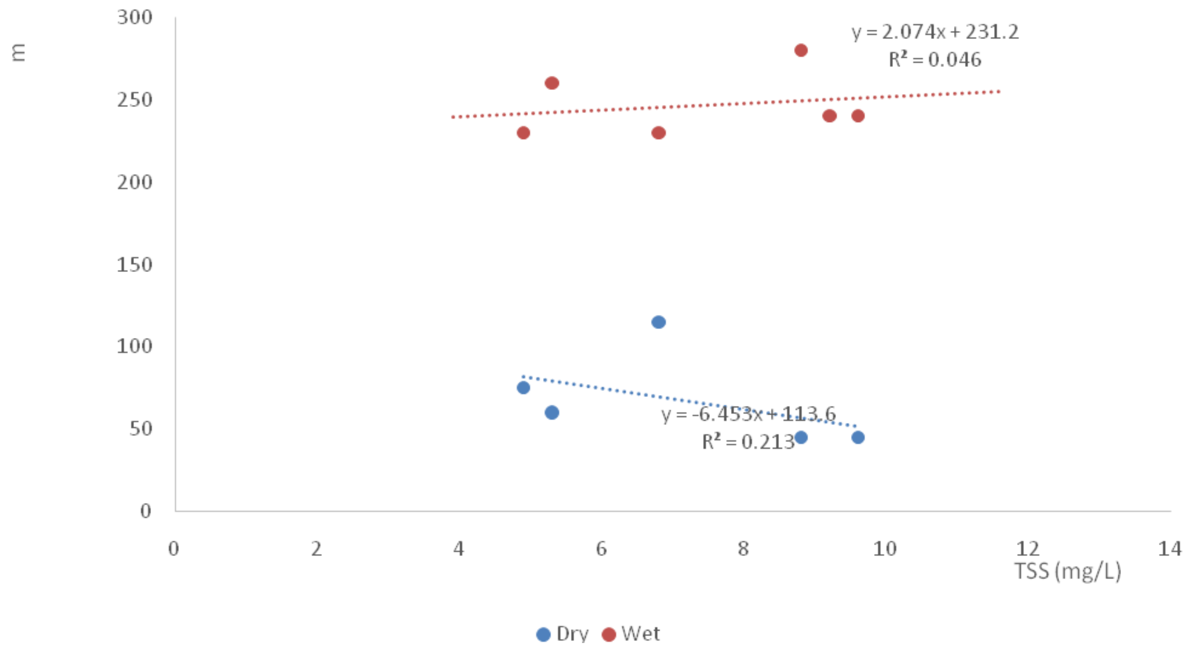
Test	Paired Differences					t	Df	Sig. (2t)	Corr	Sig.
	Mean	SD	Std. EM	95% CI						
				Lower	Upper					
EC	-15.42	505.25	130.45	-295.21	264.38	-0.12	14.00	0.91[a]	0.19	0.51[a]
TBD	-11.12	64.19	16.57	-46.67	24.42	-0.67	14.00	0.51[a]	-0.18	0.53[a]
TA	-25.30	40.90	10.56	-47.95	-2.65	-2.40	14.00	0.03	0.05	0.86[a]
Pair 1	-44.70	153.38	39.60	-129.64	40.24	-1.13	14.00	0.28[a]	-0.11	0.69[a]
BOD	-0.13	0.12	0.03	-0.20	-0.07	-4.24	14.00	0.00	0.41	0.13[a]
DO	-0.64	0.24	0.06	-0.77	-0.50	-10.35	14.00	0.00	-0.21	0.46[a]
TH	213.63	208.37	53.80	98.24	329.02	3.97	14.00	0.00	0.40	0.15[a]
TDS	-378.07	404.48	104.44	-602.06	-154.07	-3.62	14.00	0.00	0.55	0.04
TSS	-143.81	141.29	37.76	-225.39	-62.24	-3.81	13.00	0.00	0.07	0.83[a]
TS	-498.63	394.35	101.82	-717.01	-280.24	-4.90	14.00	0.00	0.68	0.01
NIT	-5.54	16.13	4.16	-14.48	3.39	-1.33	14.00	0.20[a]	0.11	0.69[a]
PHO	-2.29	3.38	0.87	-4.16	-0.42	-2.62	14.00	0.02	0.66	0.01
AM	-7.81	4.19	1.08	-10.13	-5.48	-7.21	14.00	0.00	-0.07	0.81[a]

95% Confidence Interval of the Difference

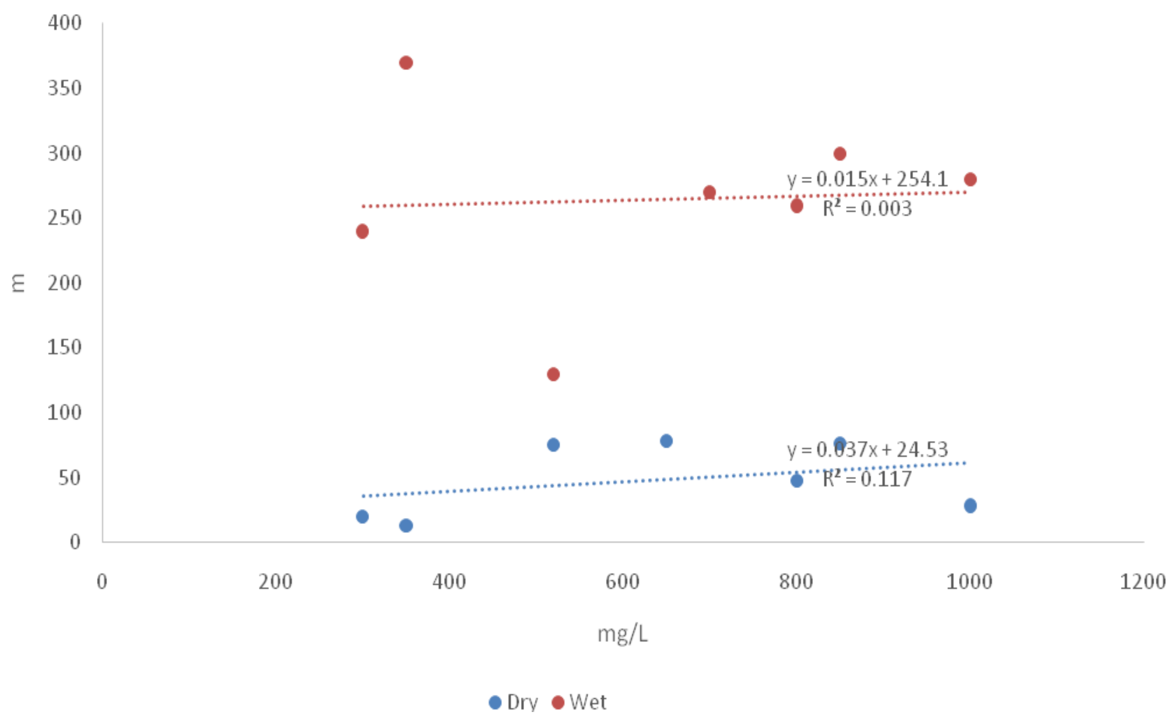
There was no significant difference in the mean values of the parameters tested in different seasons

Appendix II: ANOVA results for trace metals of well waters in dry and wet season of 2014

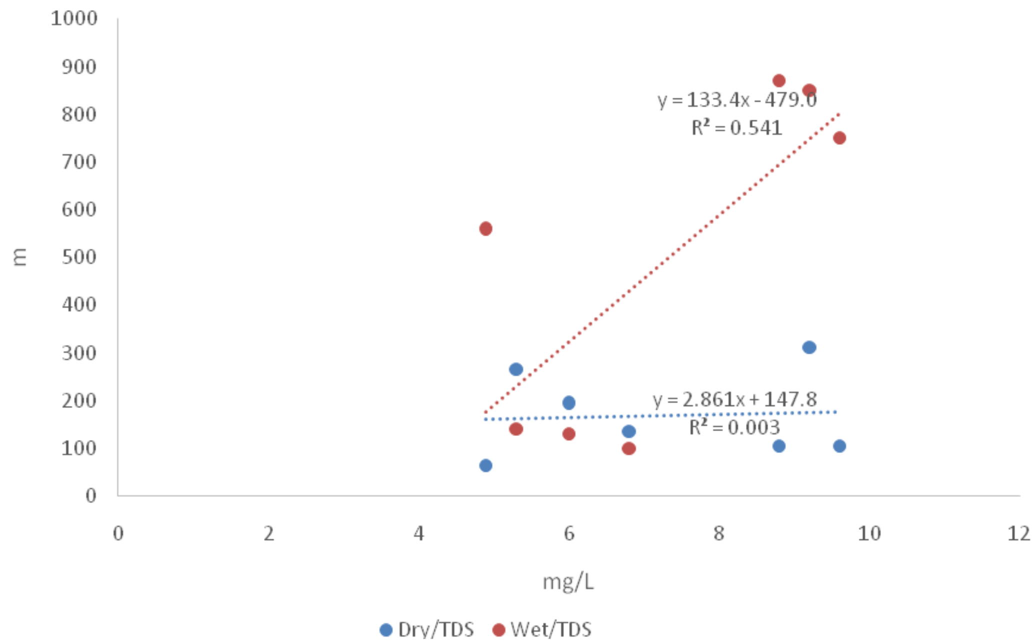
Source	Sum of Squares	df	Mean Square	F	Sig.
Tests Within-Subjects Effects					
Trace metals	.011	5	.002	22.809	.000
Trace metals * Season (interaction)	.001	5	.000	1.450	.210
Tests Between-Subjects Effects					
Season	.001	1	.001	5.352	.028



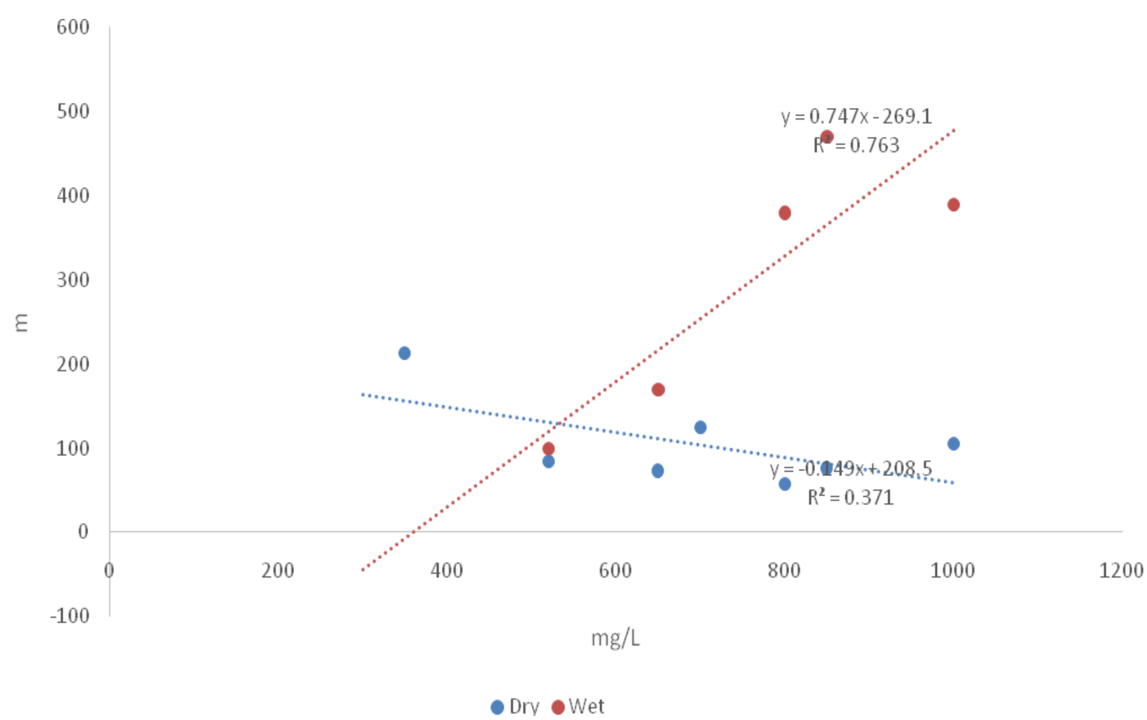
Appendix III: Change in Total Dissolved Solids as depth increases



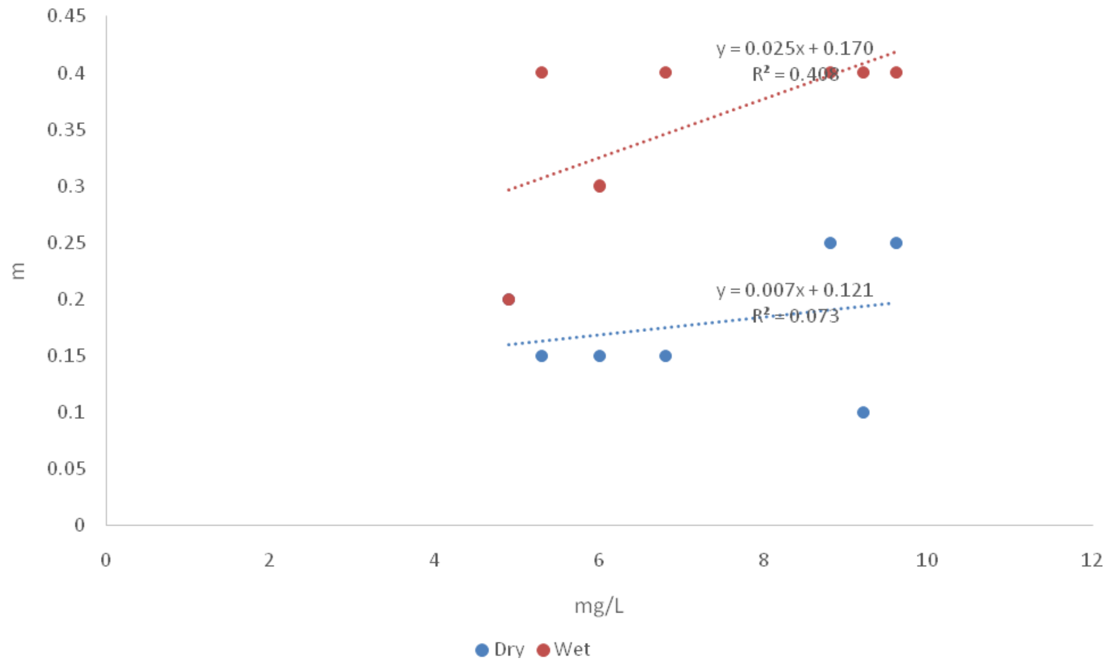
Appendix IV: Effect of proximity of well on Total Suspended Solid content



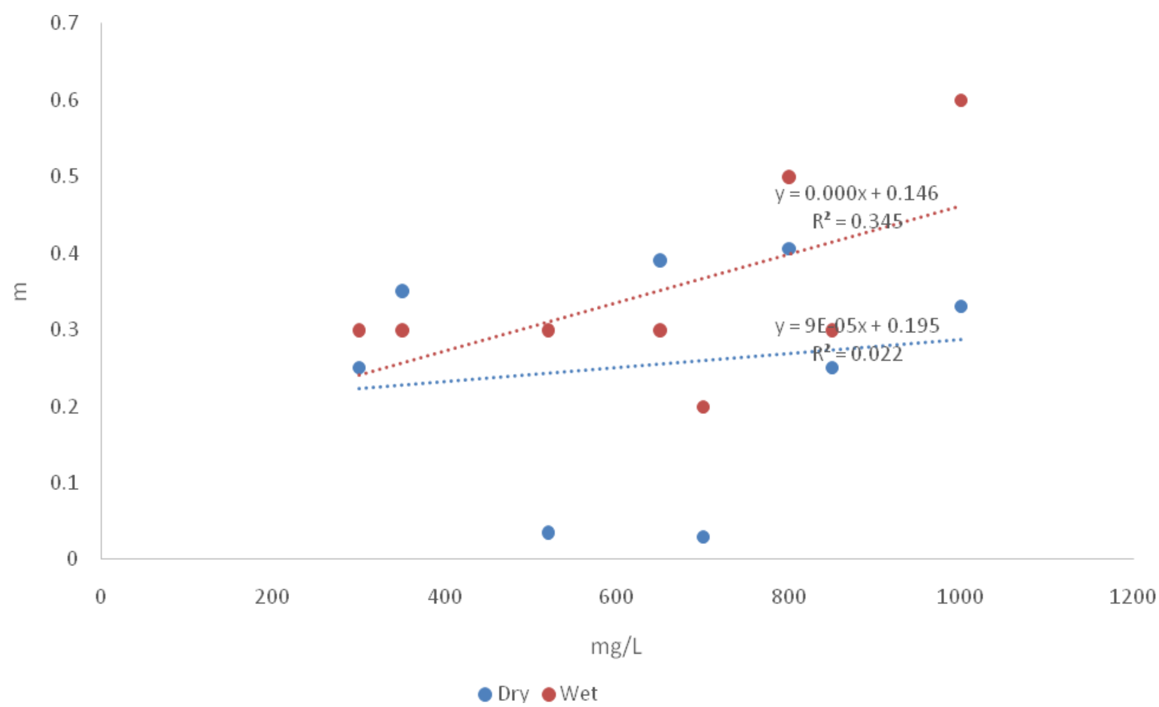
Appendix V: Change in Total Dissolved Solids as depth increases



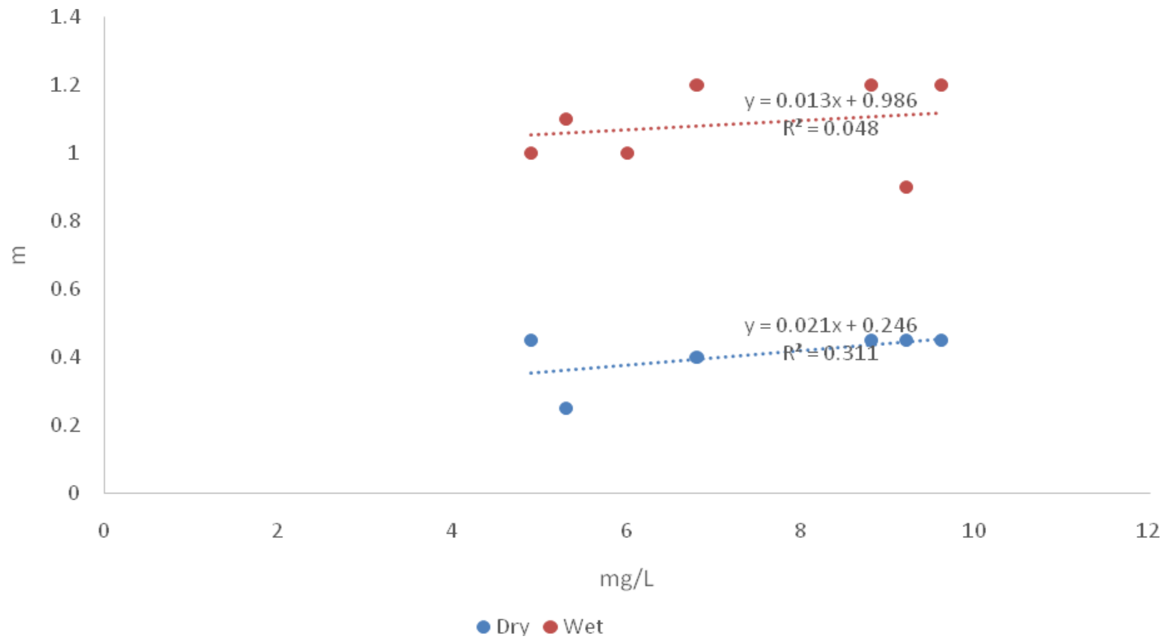
Appendix VI: Effect of proximity of well on Total Suspended Solid content



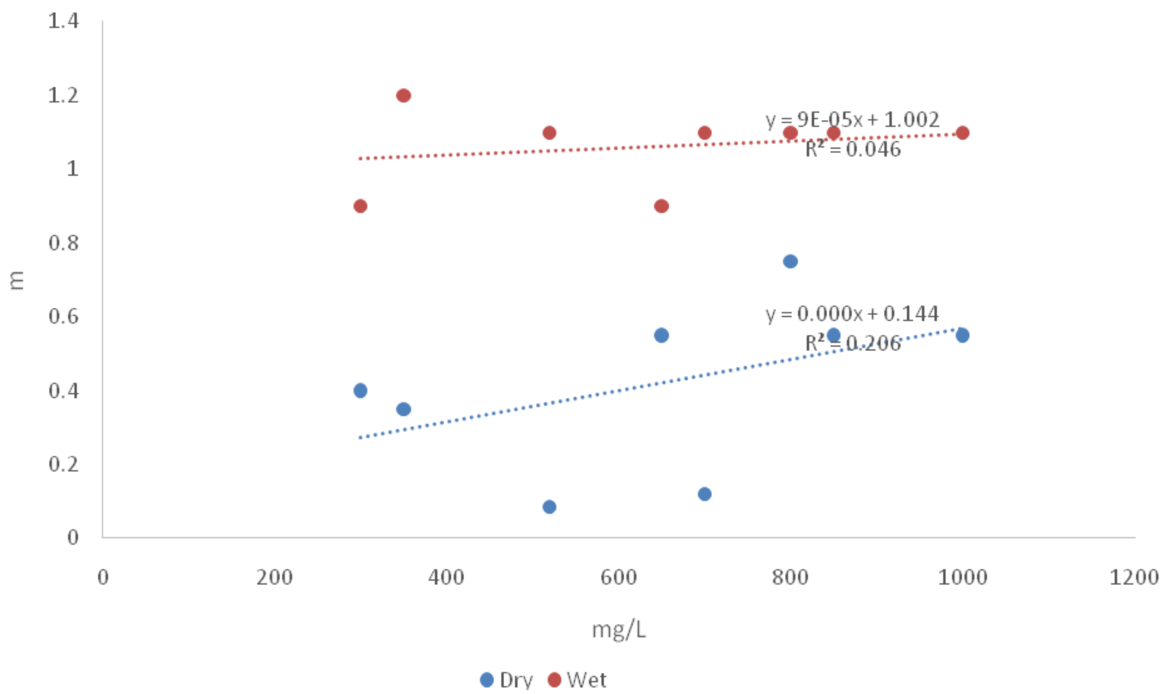
Appendix VII: Change in Total Solid content as distance increases



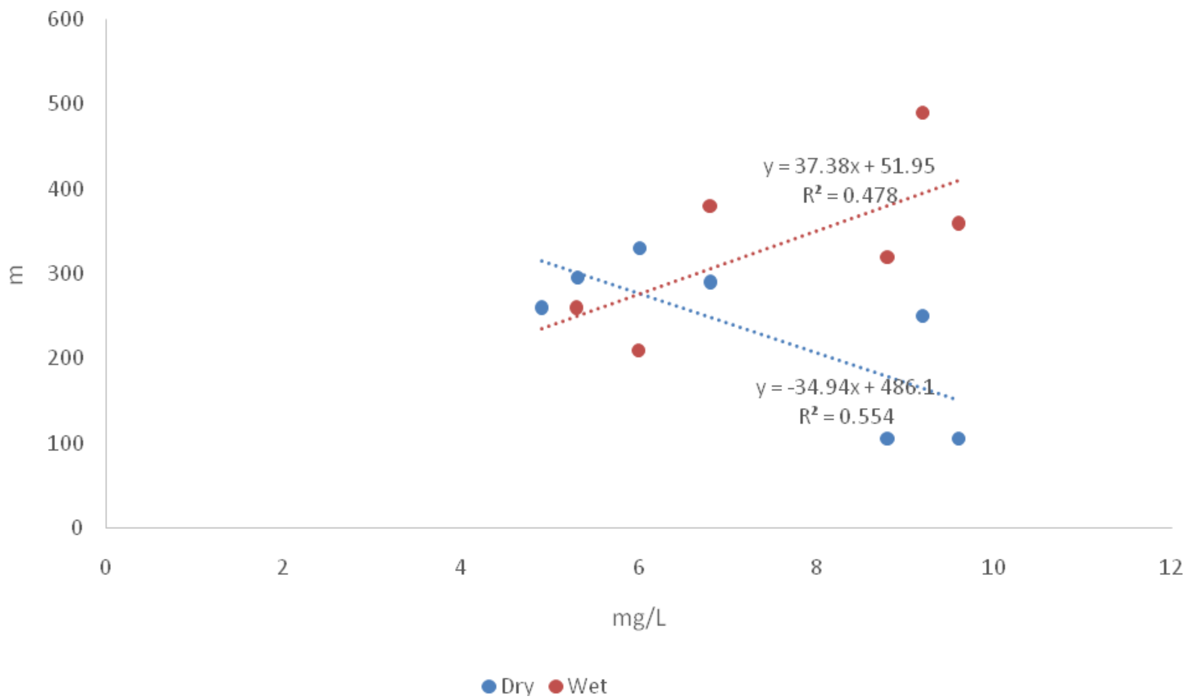
Appendix VIII: Change in Biological Oxygen Demand as well depth increases



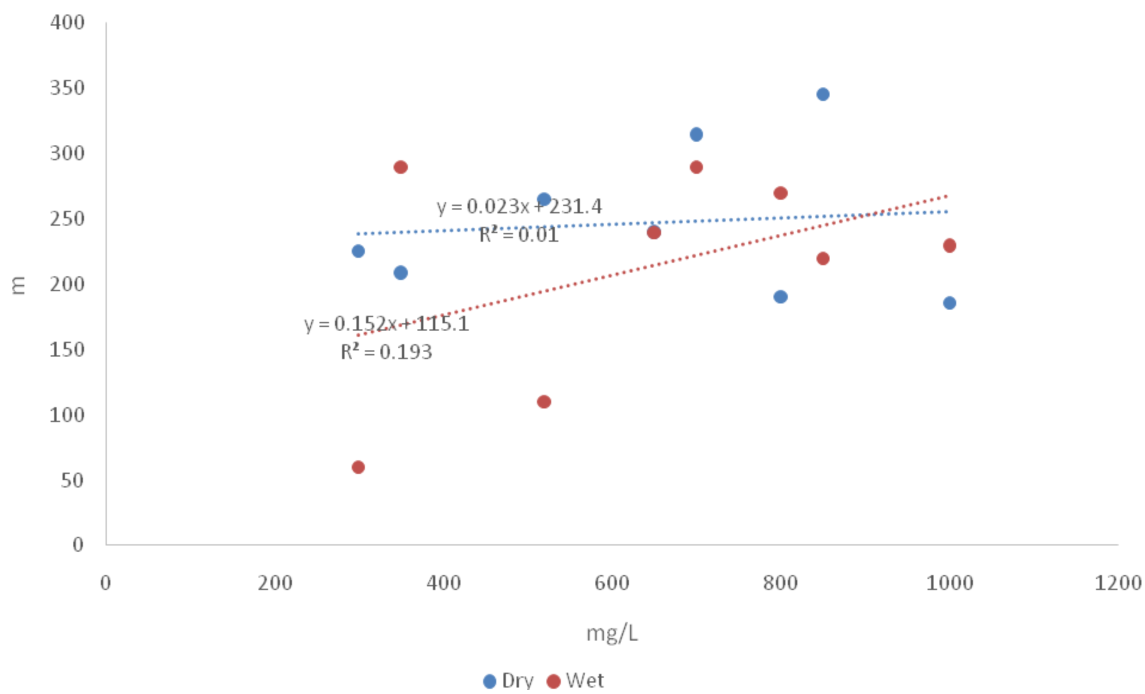
Appendix X: Effect of proximity of well on the value Biological Oxygen Demand



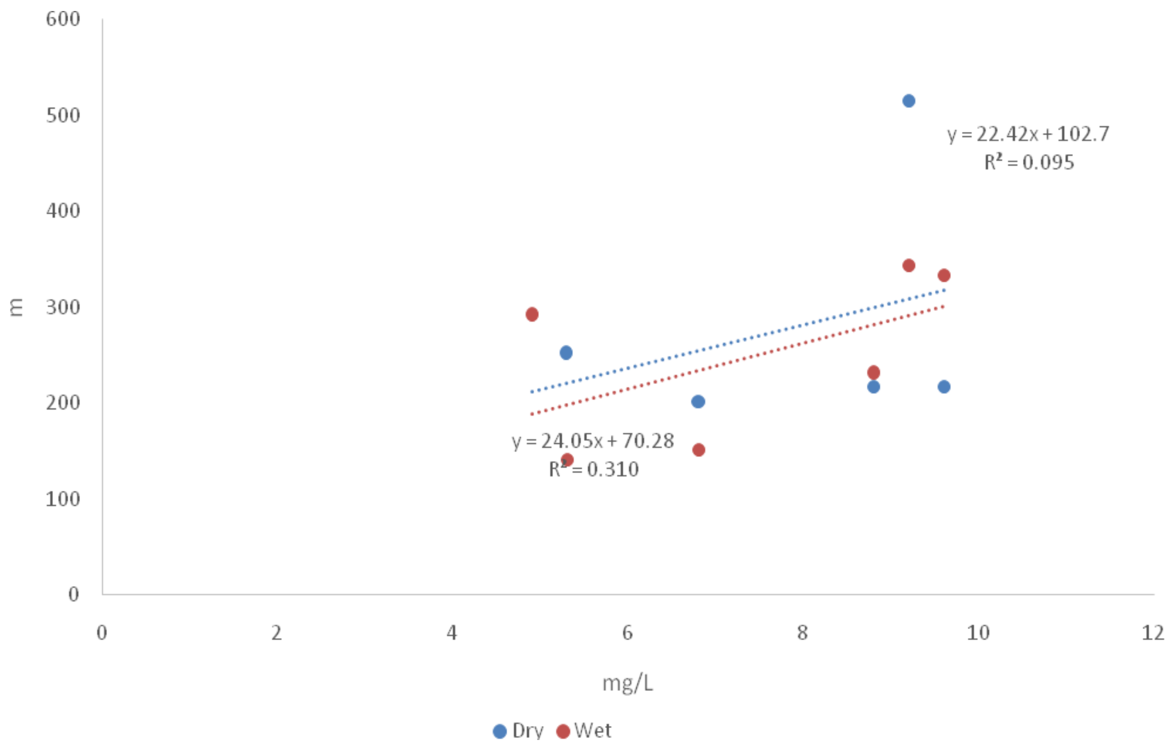
Appendix XI: Effect of proximity of well on the Dissolved Oxygen of the water sample



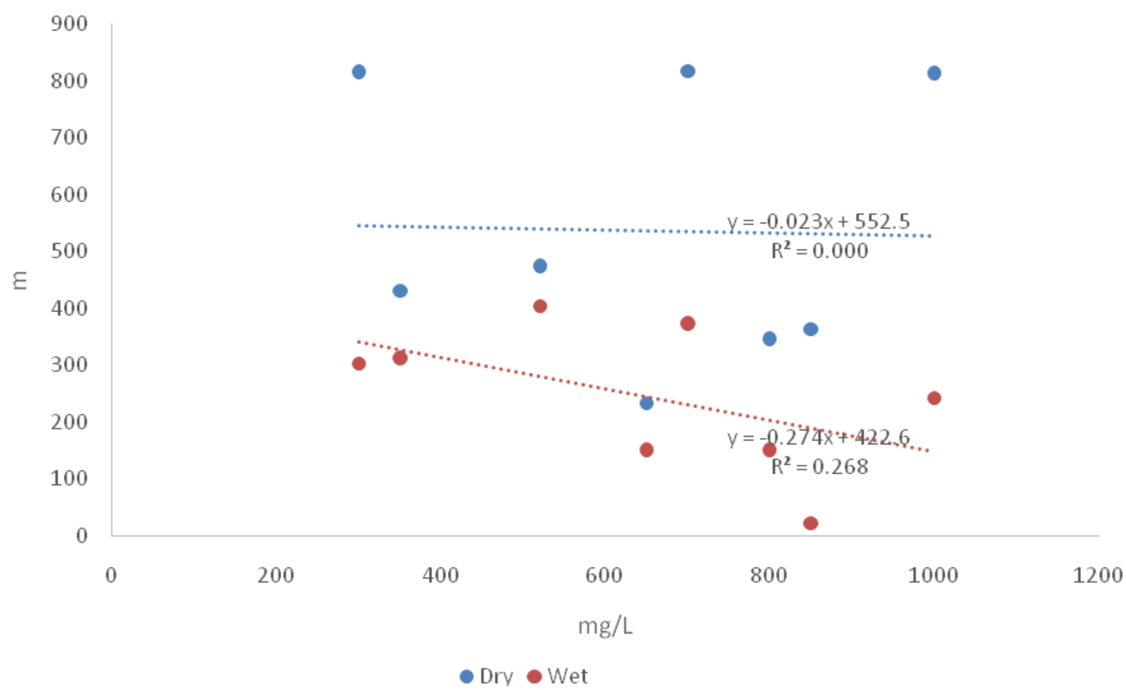
Appendix XII: Change in Chemical Oxygen demand as well depth increases



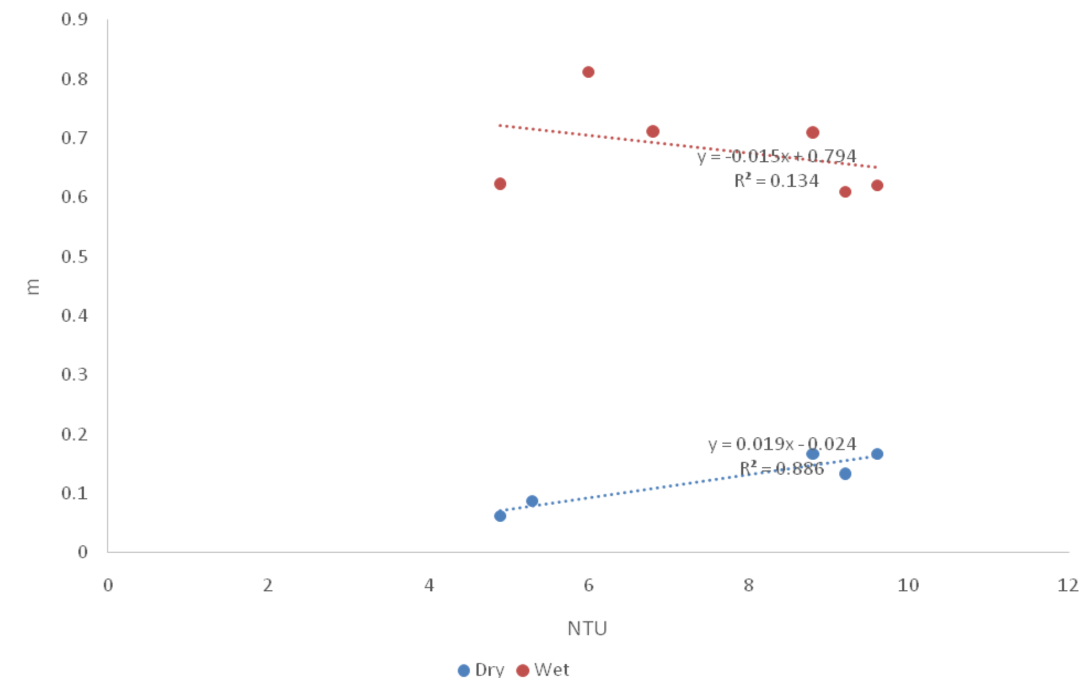
Appendix XIII: Effect of proximity of well on the Chemical Oxygen Demand of the water sample



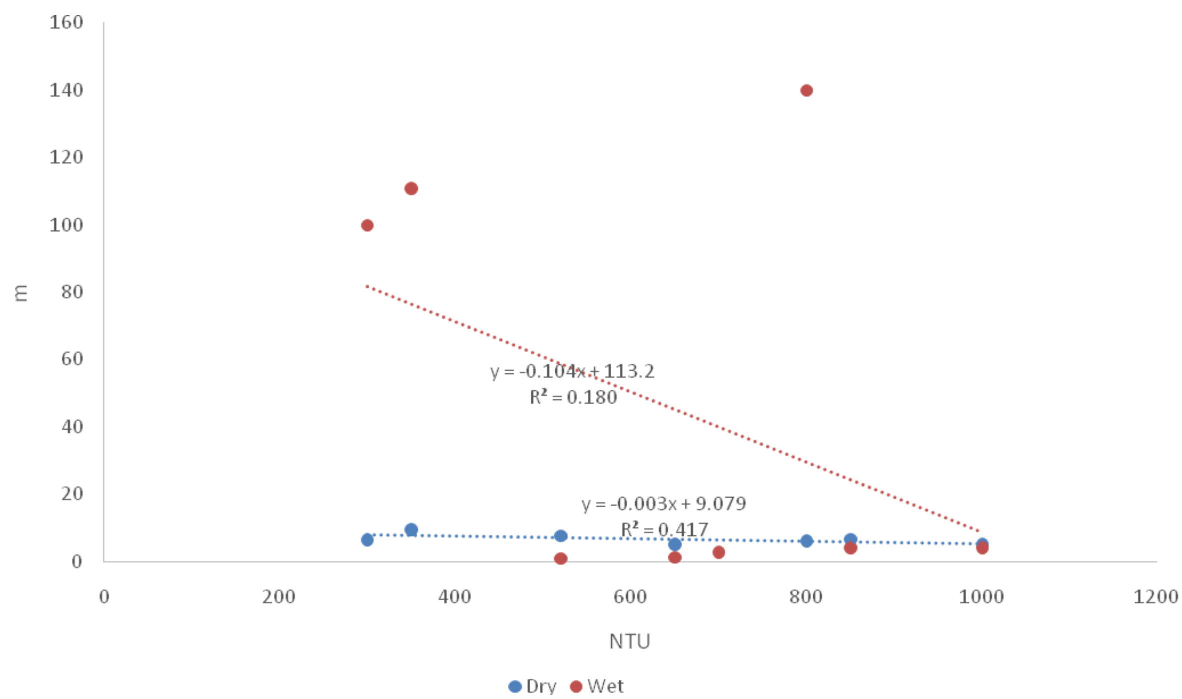
Appendix XV: Change in Total Hardness as well depth increases



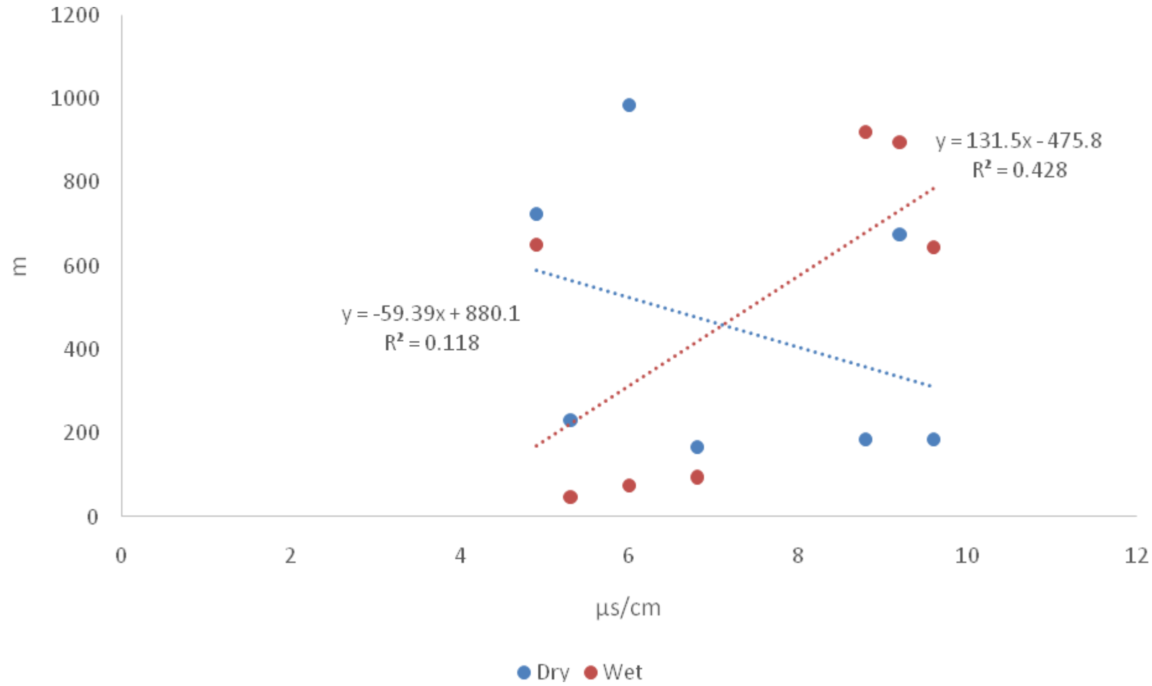
Appendix XIV: Effect of proximity of well on the Total Hardness of the water sample



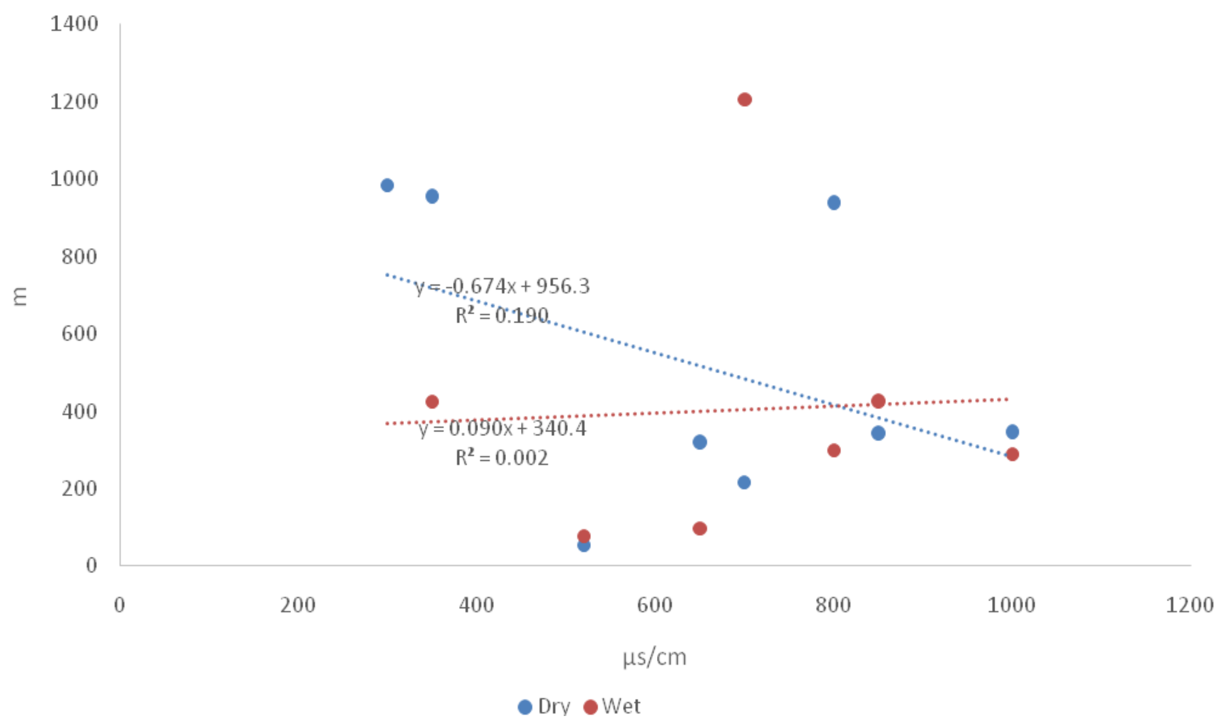
Appendix XVI: Change in turbidity as well depth increases



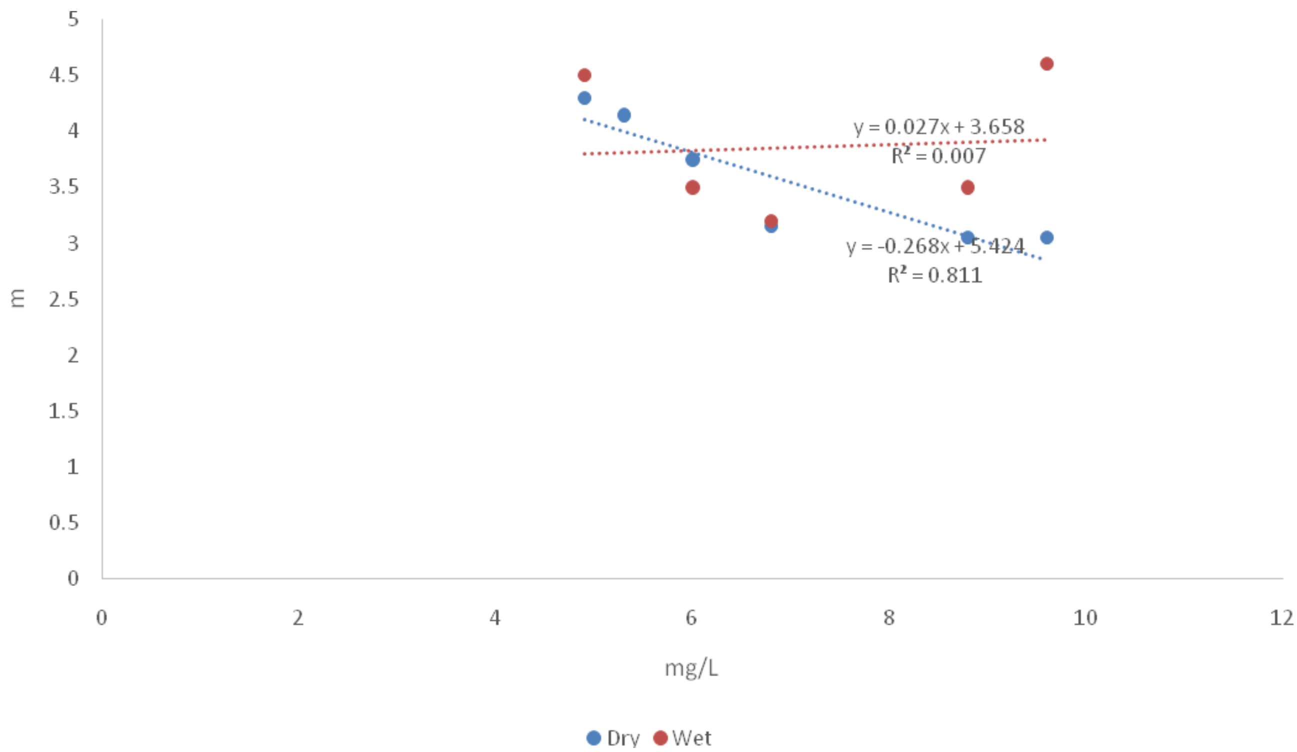
Appendix XVII: Effect of proximity of well on the Turbidity of the water sample



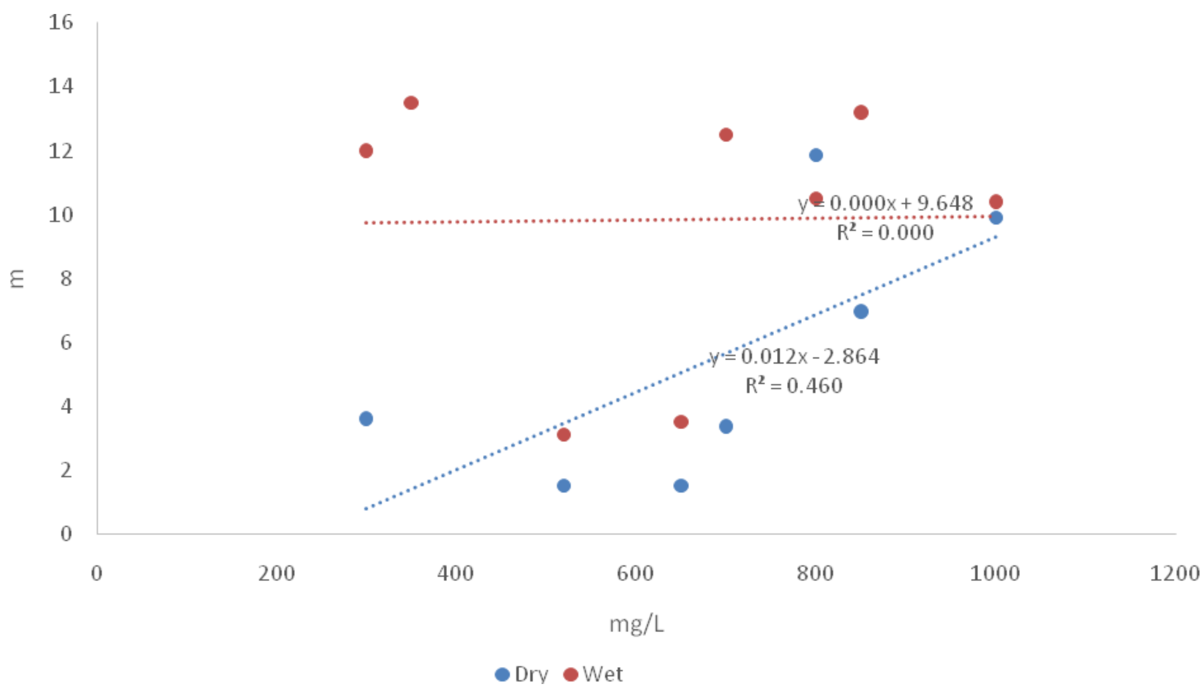
Appendix XVIII: Change in the electrical conductivity as well depth increases



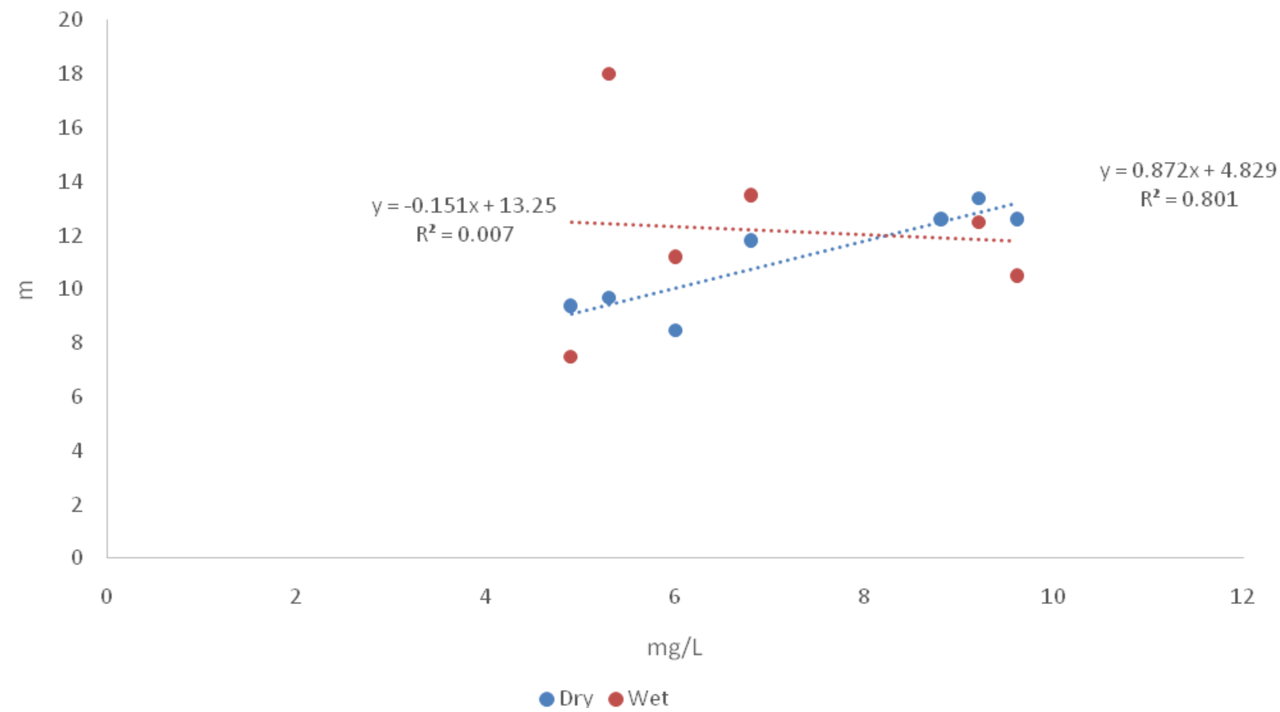
Appendix XVIII: Effect of proximity of well on Electrical conductivity of the water sample



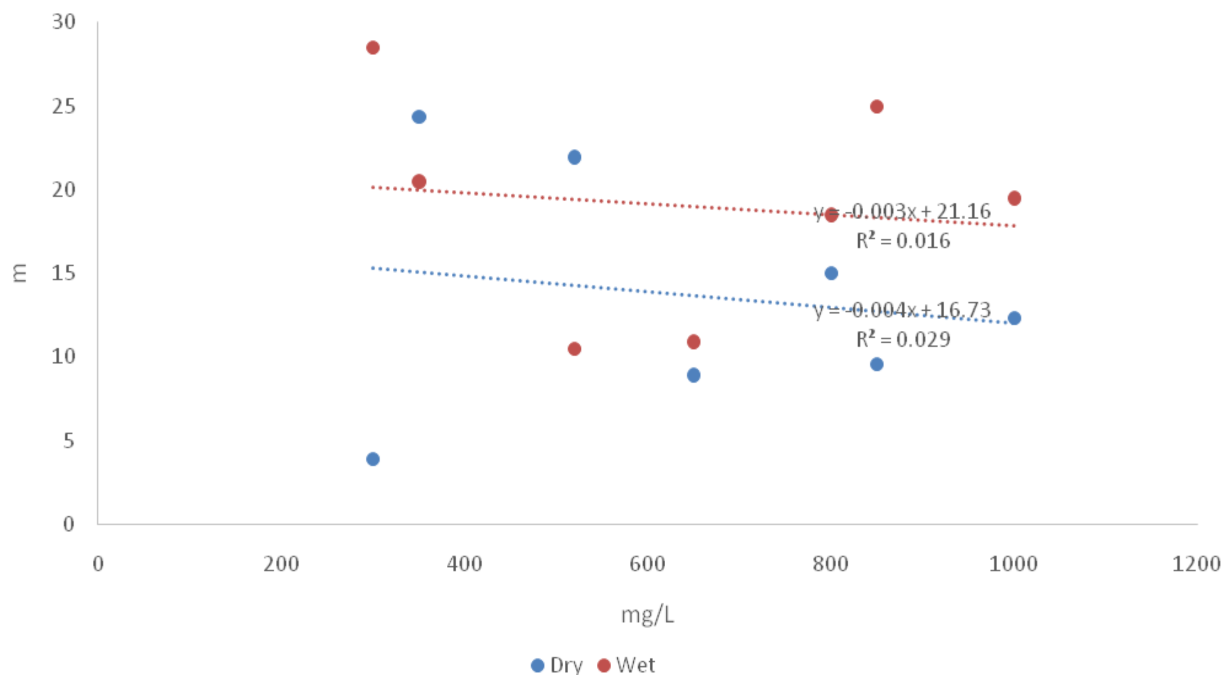
Appendix XIX: Change in phosphate content as well depth increases



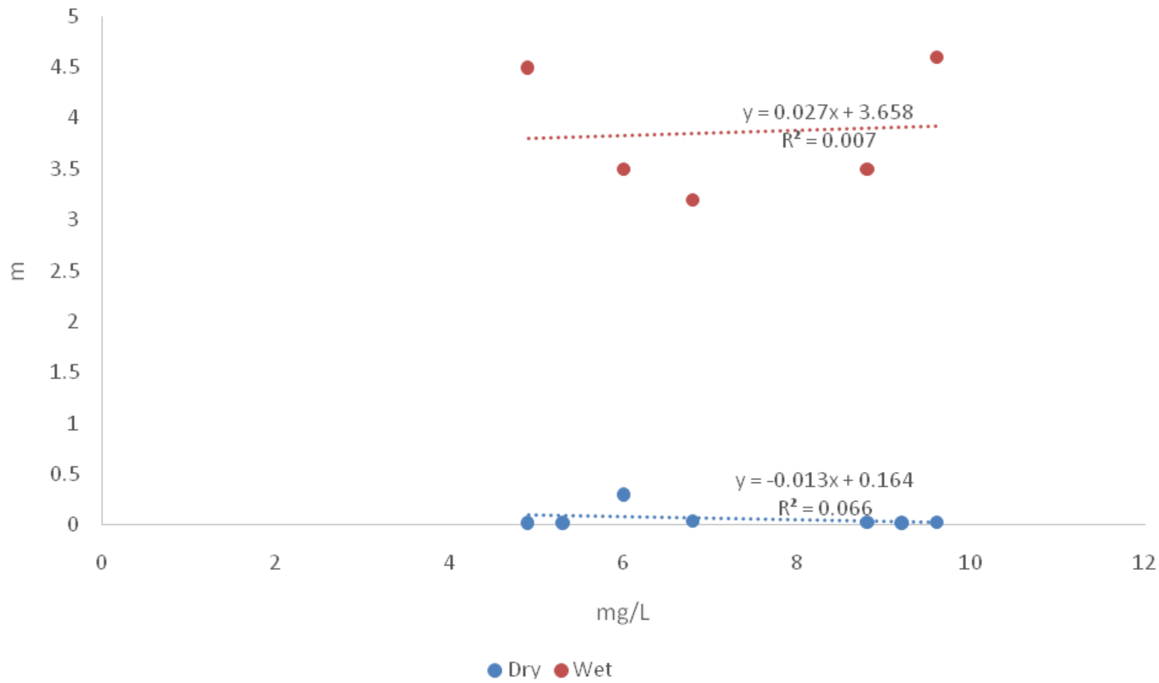
Appendix XX: Effect of proximity of well on the phosphate content of the water sample



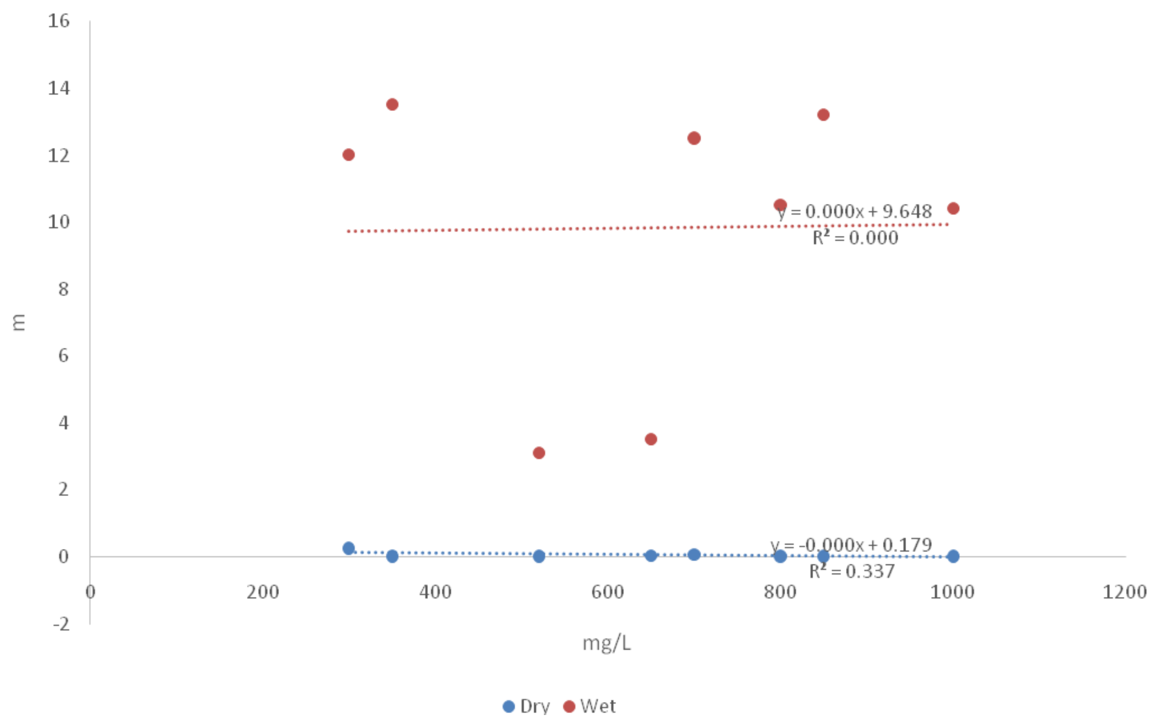
Appendix XXI: Change in Nitrate as well depth increases



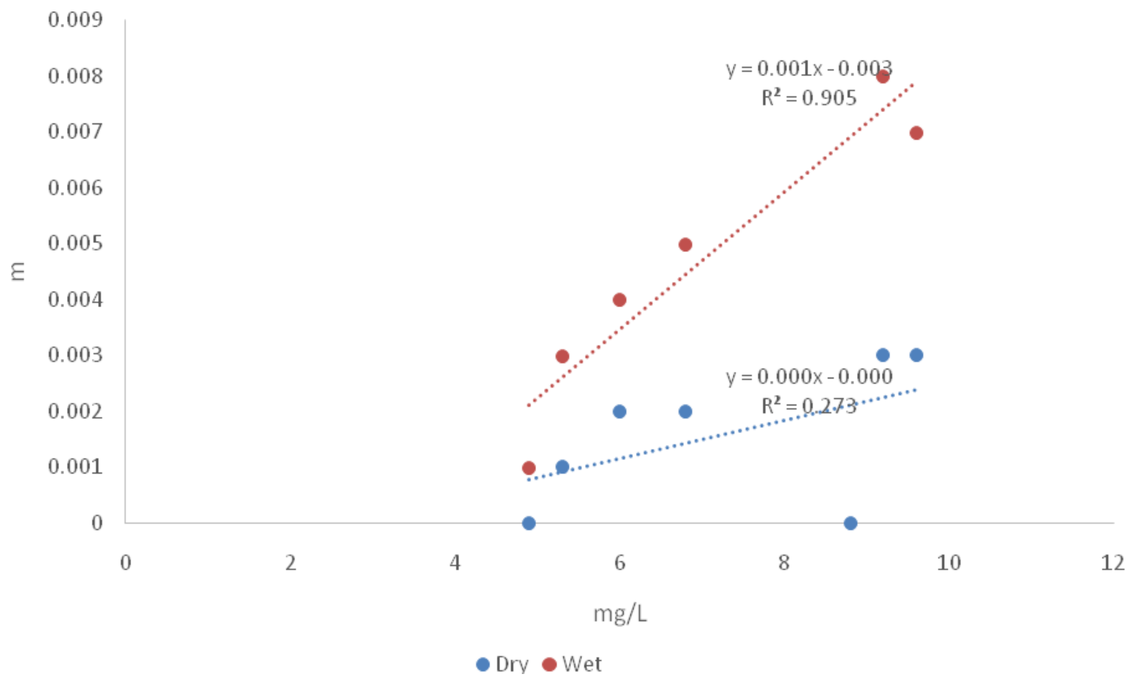
Appendix XXII: Effect of proximity of well on the nitrate content of the water sample



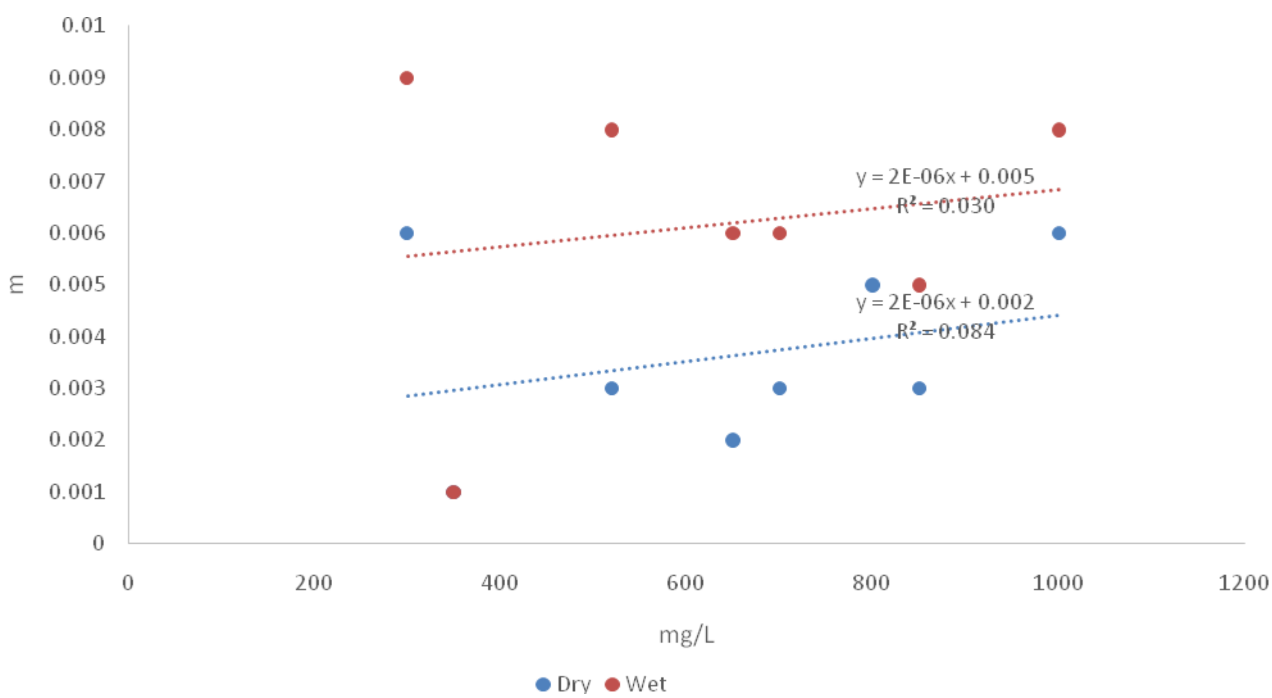
Appendix XXIII: Change in ammonia content as well depth increases



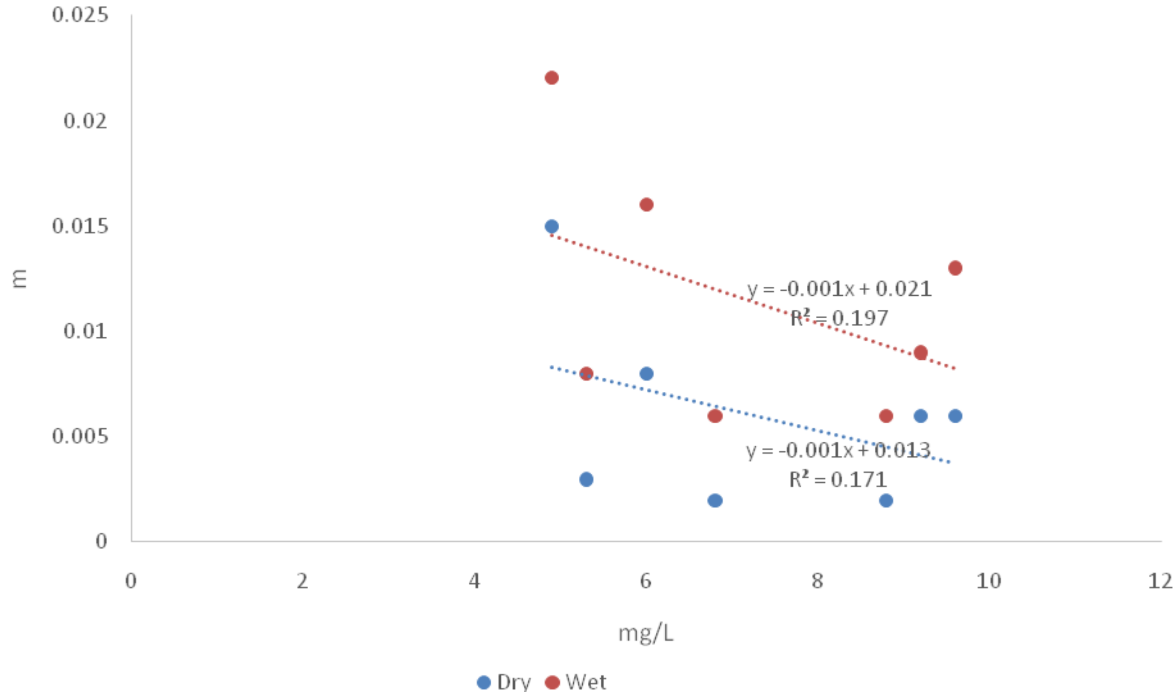
Appendix XXIV: Effect of proximity of well on ammonia content of the water sample



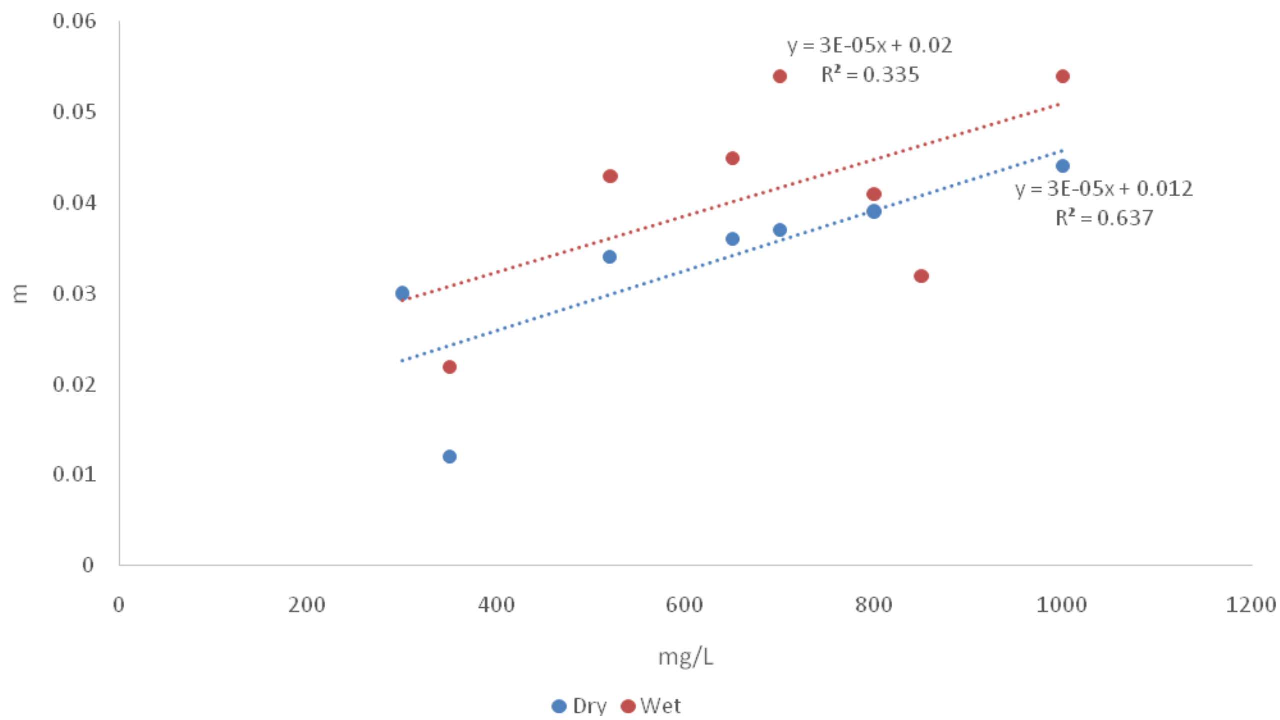
Appendix XXV: Change in copper content as well depth increases



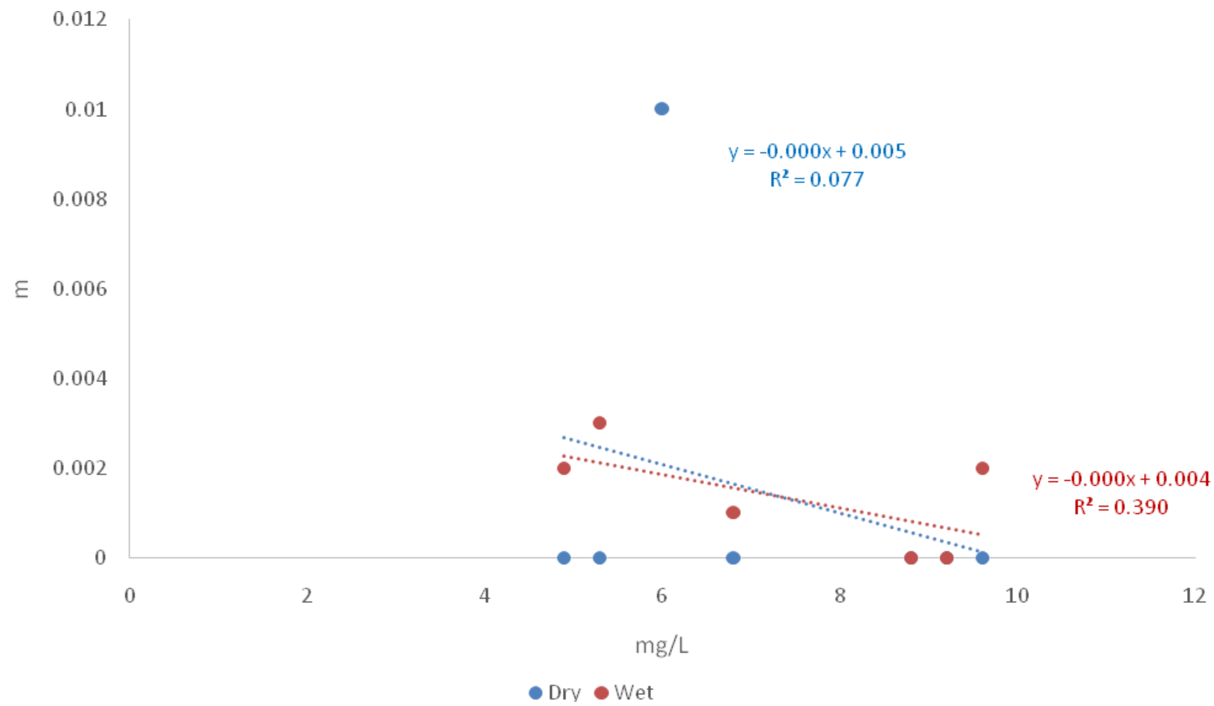
Appendix XXVI: Effect of proximity of well on the copper content of the water sample



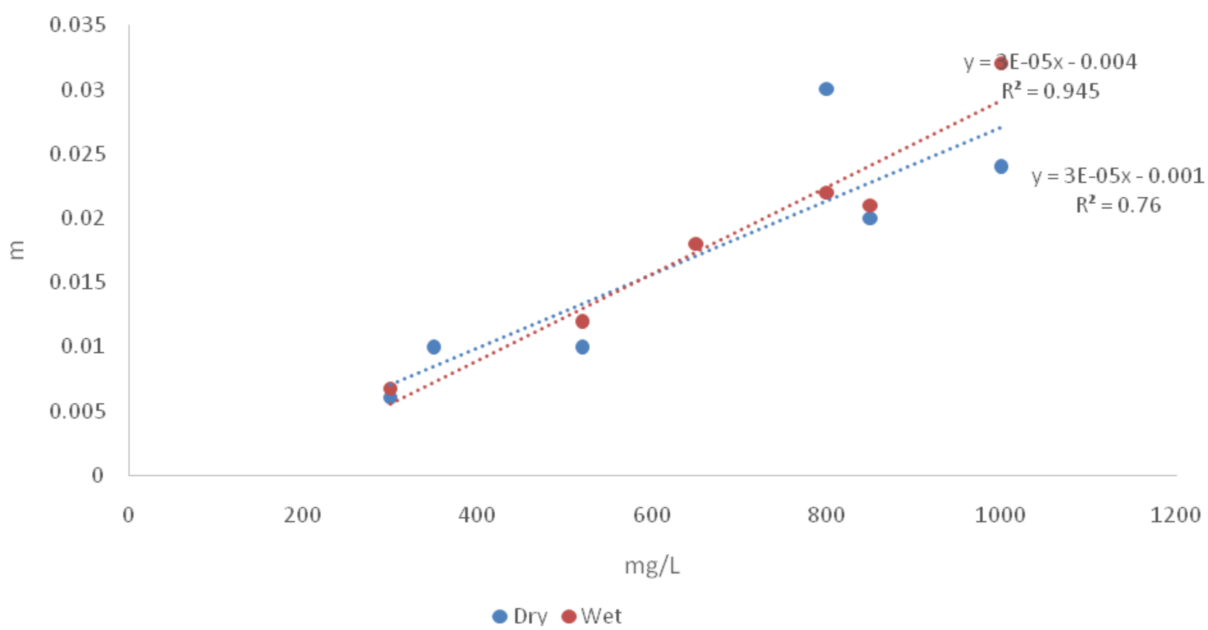
Appendix XXVII: Change in nickel content as well depth increases



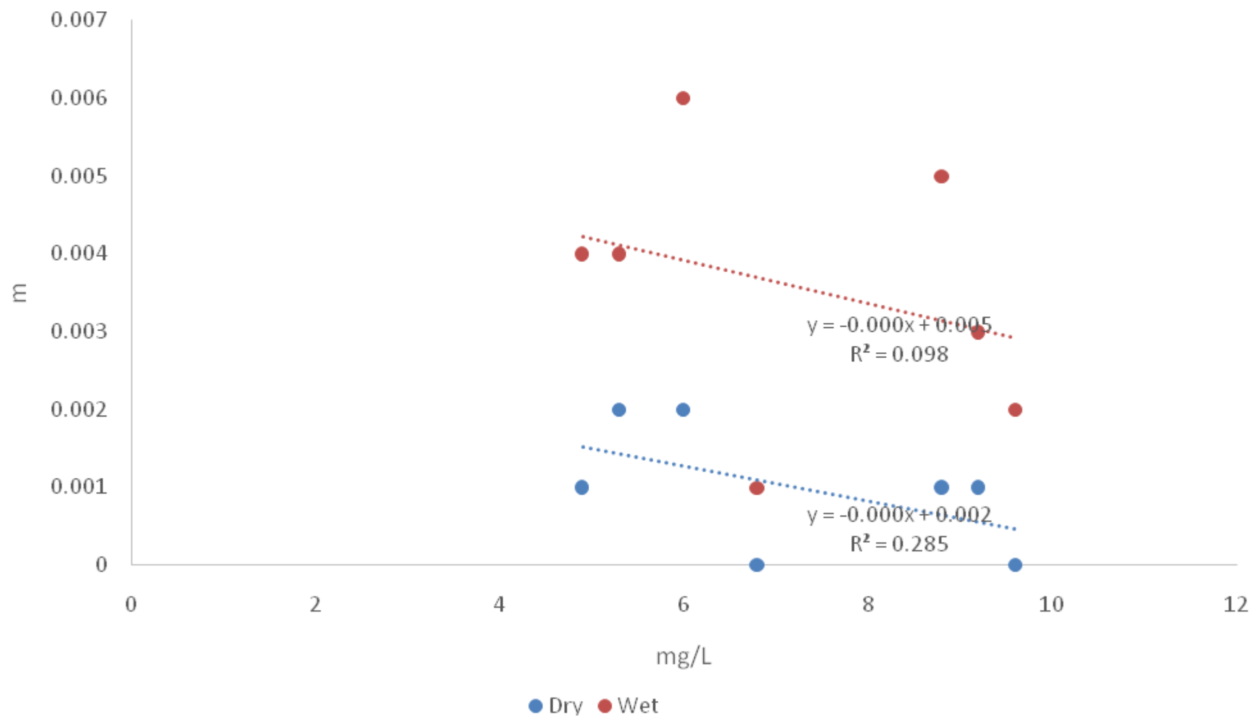
Appendix XXVIII: Effect of proximity of well on nickel content of the water sample



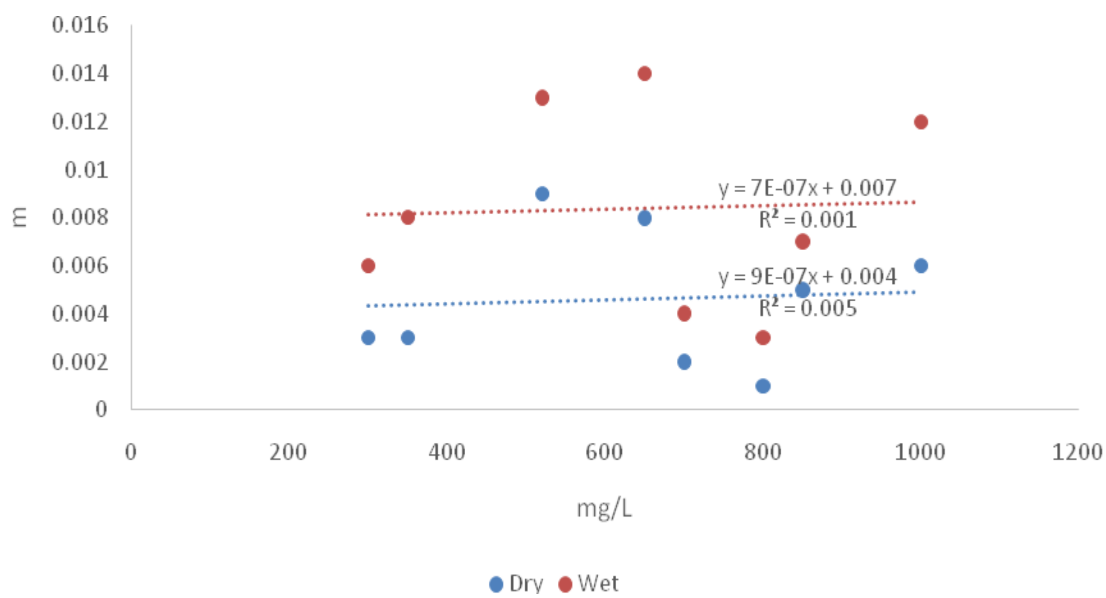
Appendix XXIX: Change in zinc content as well depth increases



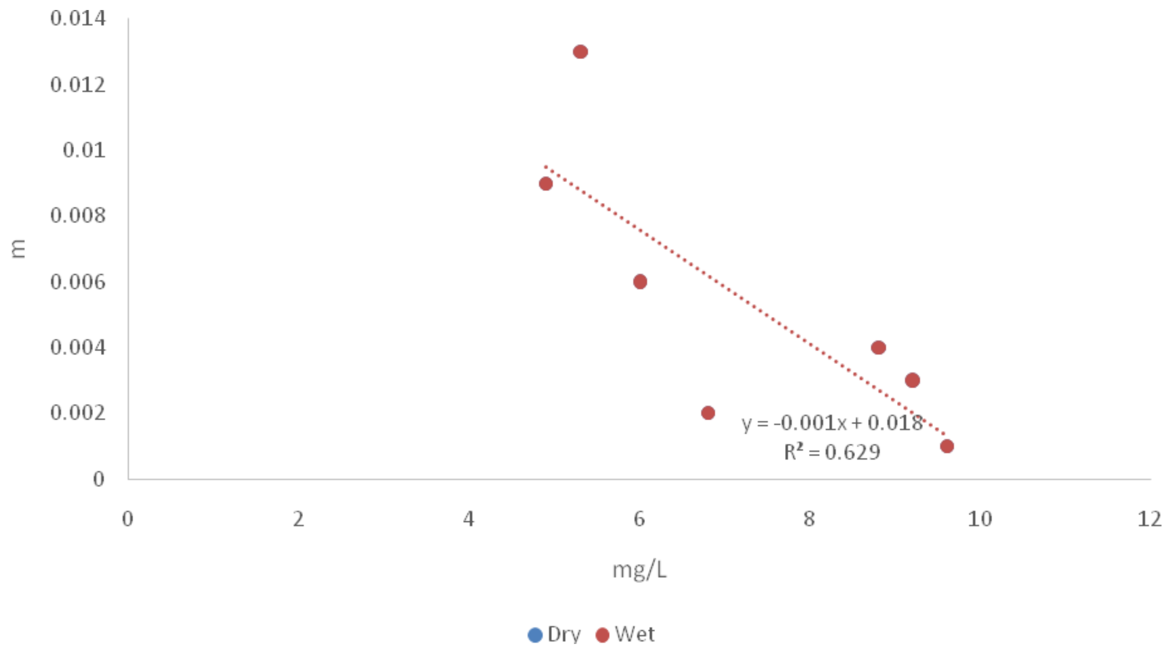
Appendix XXX: Effect of proximity of well on zinc content of the water sample



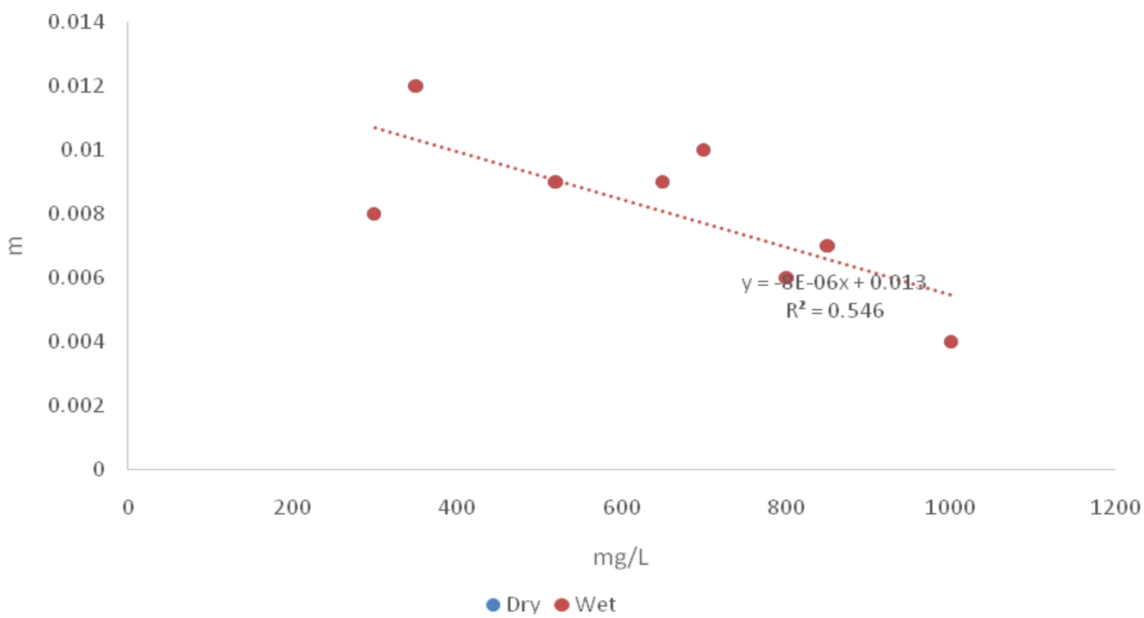
Appendix XXXI: Change in Lead content as well depth increases



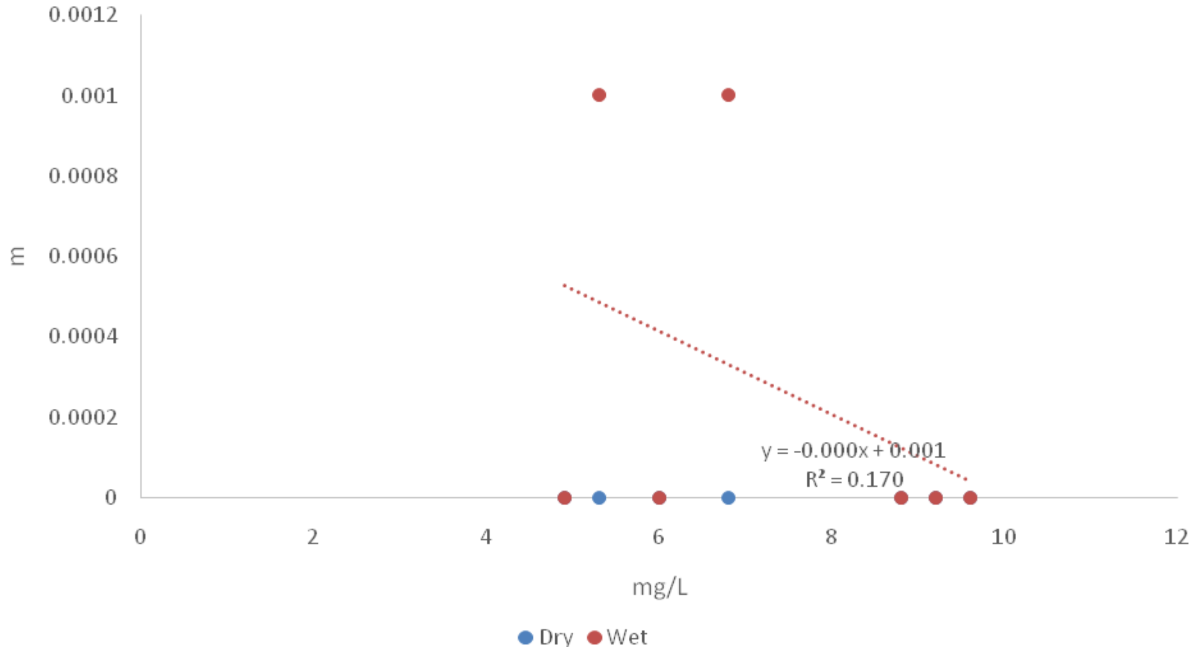
Appendix XXXII: Effect of proximity of well on lead content of the water sample



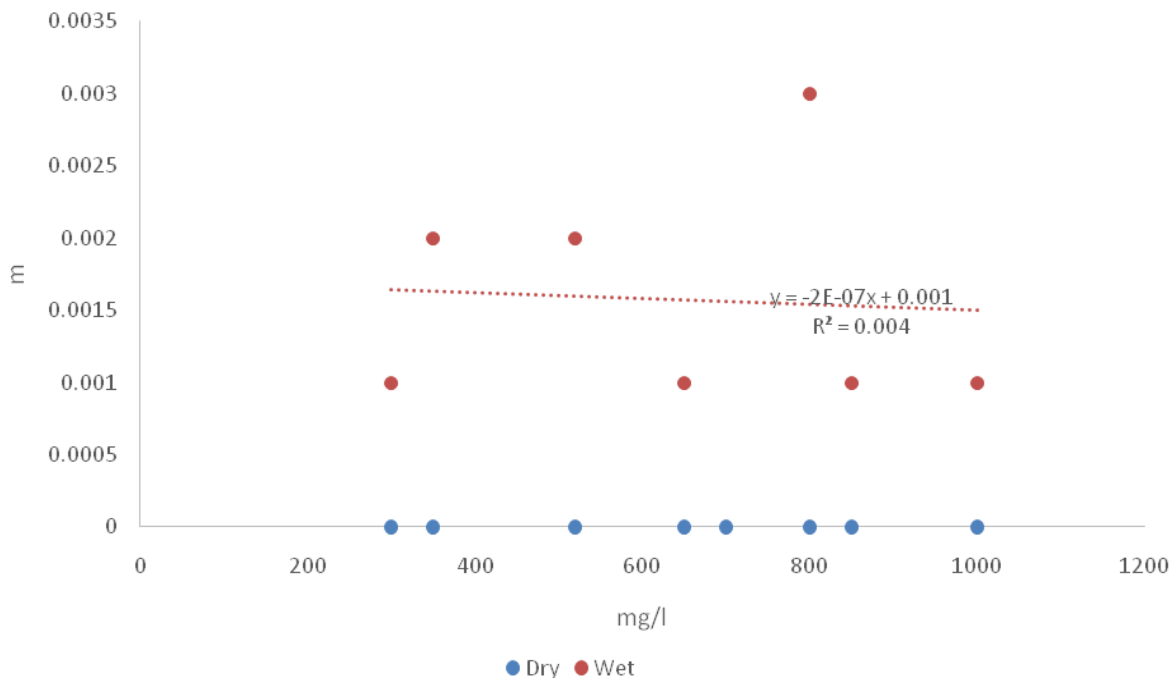
Appendix XXXIII: Change in manganese content as well depth increases



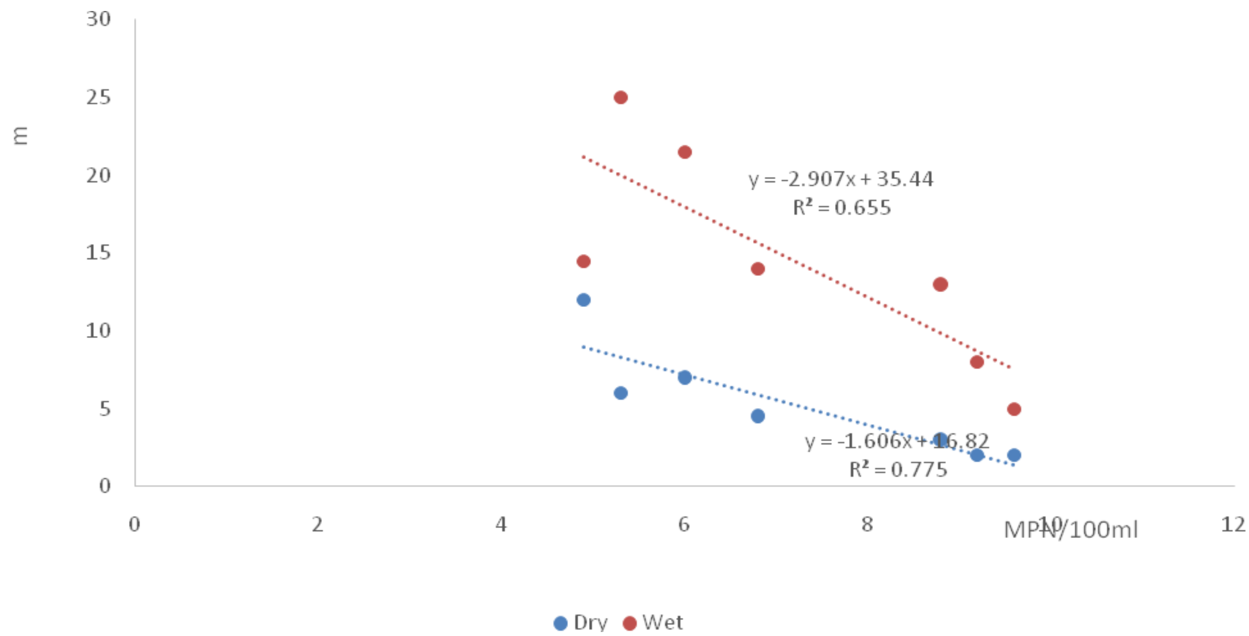
Appendix XXXIV: Effect of proximity of well on manganese content of the water sample



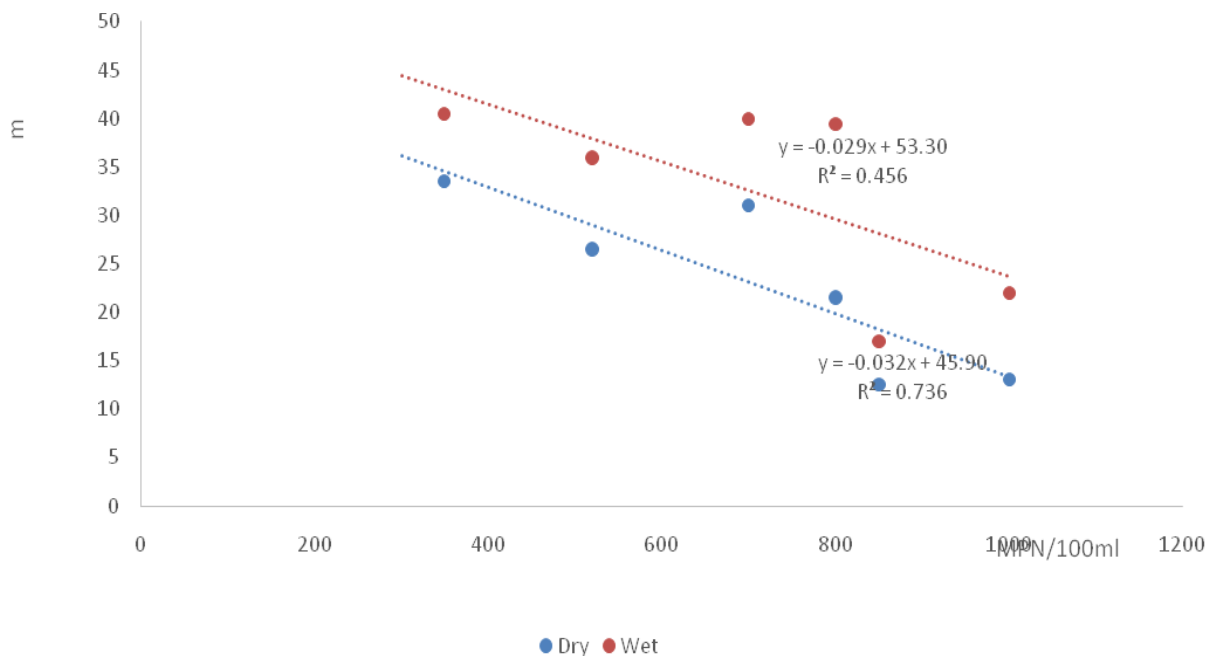
Appendix XXXV: Change in cadmium content as well depth increases



Appendix XXXVI: Effect of proximity of well on cadmium content of the water sample



Appendix XXXVII: Change in total coliform count as well depth increases



Appendix XXXVIII: Effect of proximity of well on the total coliform count of the water sampleb