SEASONAL VARIATION OF WATER QUALITY OF SELECTED HAND-DUGGED WELLS IN BIDA METROPOLIS

BY

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MEng/SIPET/2018/8992

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ABSTRACT

This study evaluates the seasonal variation of water quality from selected hand-dugged wells in Bida, Niger State, Nigeria. The water samples were collected in both dry and wet seasons and evaluated for its suitability for human consumption by subjecting the samples to physical, chemical and bacteriological analyses. Fifteen (15) parameters including pH, E-conductivity, Alkalinity, Hardness, Calcium, Magnesium, Chlorides, Bicarbonate, Total dissolve Solids, Nitrates, Phosphates, BOD, COD, Total bacterial count and Total Coli form count were evaluated. The results indicated that there are more impurities in hand–dugged wells during dry season. The work among other findings, revealed total coliform count ranges from 60 cfu/100ml to 34cfu/100ml in rainy season and 9 cfu/100ml to 72 cfu/100ml in dry season. The total bacterial count ranges from 18 cfu/ml x10^4 to 42 cfu/ml x10^4 in rainy season and 14 cfu/ml x10^4 to 66 cfu/ml x10^4 in dry season. Total dissolve solids TDS ranges from 25.9mg/l to 506mg/l and 25.36mg/l to 519.4mg/l in dry season, except for sample D (Mayaki Legbodza Area) which is above the standard limit. Nitrate ranges from 0.76 mg/l to 8.22 mg/l and 1.75 mg/l in rainy season and dry season respectively. These and other parameters explored were all within the permissible limits of World Health Organizations and Nigeria Standards for Drinking Water Quality.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

The increasing population in the world, especially developing nations has led to increasing demand for good quality water. Water is essential for life. It is a universal solvent and is the most abundant substance in plants and animals tissues, as well as, the world around us The metabolic functions within living cells occur in aqueous medium. Water carries waste out of the cells and finally out of the body (Fabio *et al.,* 2009).

Hand- dug wells also known as shallow wells are developed between one to few meters below the ground surface to explore groundwater. Groundwater is both an important direct source of water supply, which is tapped by wells, and a significant indirect source of supply, since a large portion of the flow streams is derived from subsurface water. This is formed as a result of a portion of precipitation rainfall and snowfall, which percolate into the ground. Groundwater movement is generally slow and not as much, mixing occurs in an aquifer as with the case of surface waters. Its quality changes as water percolates through natural sediments. These changes are drastic in certain sediments, while negligible in other cases (Deju *et al.,* 1990). During its movement through the surface layers of the earth, it carries some minerals as it passes through porous rocks, since the rocks are subject to mechanical and chemical weathering and leach out (Glenn and William, 1981). Near the surface of the earth, in the zone of aeration, soil pore spaces contain both air and water. These zones, which may have a zero thickness in swamp lands and several hundred feet thick in mountainous regions, contain three types of moisture. Gravity waters are in transit after a storm through small pore space by capillary action and are available for plant up-take. Hydroscopic moisture is water held in place by molecular forces during all seasons except the driest climatic conditions. Moisture from the zone of aeration cannot be tapped as a water supply source, (Xu and Usher, 2006) concluded that the quality of an aquifer is a function of the geological setting of the area and the difference between the characteristics of aquifers in the basement complex and sedimentary environments. Although it is reasonable that water may accumulate in fractured basement rocks, hand dug wells have been positioned in the weathered overburden soil because of economic implication on the individuals and the communities in general.

Groundwater provides one of the important sources of water for human (Taiwo *et al.*, 2015); However, groundwater quantity is as important as its quality. This is because the health profile of any community is dependent on quality of the water they use (Dick *et al.*, 2018). Many communities in Nigeria depend on surface and groundwater for their daily activities. Groundwater on the other hand, can be inform of hand-dugged wells or boreholes and susceptible to impurities or pollutants due to various anthropogenic and natural activities. Although, boreholes are more protected but the chemical constituents dependent on the permeable rocks that the water flow through which can influence the quality of the water (Sokpuwu, 2017). The quality of groundwater is highly related to local environmental and geological conditions, such as the quality of soil and rock types found in the area while in Nigeria, groundwater is the most common source of water in rural communities; it has proved to be the most reliable resource for meeting water demand in rural areas (Akoji, 2019). However, Groundwater can be conterminated which can arise from anthropogenic activities (Omole *et al*., 2017). Therefore, regular water quality monitoring is important to safeguard public health.

The water cycle is an obvious mode of transmission of enteric diseases. However human activities especially production and disposal of industrial wastes and sewage systems alter and pollute the natural pure state of groundwater. If contaminated groundwater is therefore supplied to a community where people live untreated, Water-related diseases include those due to micro-organisms and chemicals in water people drink; diseases like schistosomiasis which have their lifecycle in water; diseases like malaria with water-related vectors; drowning and some injuries and others such as legionellosis carried by aerosols containing certain micro-organisms (Usman *et al.,* 2014). Untreated groundwater are contaminated by different source if supply to the environment, it affect the inhabitants which results to epidermis (Agca, 2014). More people have safe drinking water, but not many have access to toilets. The world is on track to achieve the Millennium Development Goal (MDG) target on free access to potable water.

The zone of saturation offers water in a quantity that is directly available. In this zone, located below the zone of aeration, the pores are filled with water, and this is considered as groundwater (Vesilind and Pierce, 1983). Groundwater is highly valued because of certain properties that are not possessed by surface water. It is usually characterized by low contents of organic substances and as such usually preferred as a source of drinking water (Goel, 2000).

Water impurities include dissolved solid, suspended solids,Turbidity etc and Some soluble minerals impact a color and taste to the water solution. Soluble ion salt produce pale yellow solutions of ground water; some copper salts form intensely blue solutions of water.

Suspended solids are substance that are not completely soluble in water and are present as particles. These particles usually impact a visible turbidity to the water. Dissolve and suspended solids are present in most surface water. Sea water is very high in soluble sodium chloride $\left(Nacl\right)$; suspended sand and silt make it slightly cloudy.

Water occurs in all spheres of the environment- in the oceans as a vast reservoir of salt water, on land as surface water (lakes and rivers), underground as groundwater, in the atmosphere as water vapour and in polar ice caps as solid ice (Bhatia, 2002). About 97.2% of water on earth is salty and only 2.8% is present as fresh water from which about 20% constitutes ground water (Goel, 2000).

The development of water resources has often been used as a yardstick for the socio-economic and health status of many nations. However, pollution of water often negates the benefits obtained from the development of these water resources. Water is extremely abundant on the earth's surface, but access to portable water can be minimum. When safe portable water is not available at the right time or at the right place for human or ecosystem use, the well-being of the local population is at risk (Karikari and Ansa-Asare, 2009).

Water pollution and reduction in quality is a major contributor to global freshwater scarcity. Stressing the need for more integrated water management and monitoring, Dahunsi *et al*. (2014), Li and Jennings, (2017) but conducted a study on worldwide regulation of drinking water quality and pointed out that many global nations are in lack of drinking water that meet quality standards, which is also an important factor affecting the global drinking water crisis. The provision of portable water to both rural and urban population is necessary to prevent communicable diseases that might accompany the consumption of faecally contaminated water. Moreover, before water can be described as

„portable‟, it has to comply with certain physical, chemical and microbiological standards, which are designed to ensure that the water is portable and safe for drinking. Therefore, portable water is defined as water that is free from disease producing microorganisms and chemical substances that are deleterious to health (Okonko *et al*., 2007).

The assessment of groundwater quality is as important as its quantity for various purposes ranging from domestic, industrial and agricultural uses all over the globe (Subramani *et al*., 2005). The quality of groundwater in a particular region is a function of physical, chemical and biological parameters. The variation of groundwater quality in a particular area is a function of physical and chemical parameters that are greatly influenced by geological formations and anthropogenic activities. Pollution of groundwater is a major threat posed by leachate which is formed by anaerobic decomposition of waste and may infiltrate the aquifer (Tesfaye, 2007). Pit latrines are used for defecation in the rural areas including some parts of urban areas, and it has been estimated that over 1.77 billion people around the world used pit latrines. Structures like pit latrines remain a potential source of pollution to hand- dug wells when sited indiscriminately. Pit latrines and seasonal variations that is, changes from rainy to dry seasons are widely recognized as a threat to the safety and reliability of drinking water and sanitation supplies, particularly in low-income countries (WHO/UNICEF, 2006). Accordingly, the status of water quality is examined by two approaches: the water is subjected to tests by bacteriologists to ensure safety for human consumption, while physico-chemical parameters should conform to standard regulations (Adebayo and Bashire, 2002; Ahmed *et al.*, 2002; Awalla, 2002; Egbulem, 2003; Akpabio and Ebong, 2004).

As a result of the increasing usage of both pit latrine structures and indiscriminate location of hand-dug wells near pit latrines in Bida town, there is concern that the well-being of the hand-dug well users might be compromised leading to a serious public health problem. Despite the fact that groundwater is one of the major sources of water supply for majority of the Nigerians, there is no integrated ground water quality monitoring scheme in Nigeria (Adebola *et al.,* 2013). The present study is therefore carried out to examine the quality variation of some selected hand dug well parameter in Bida metropolis.

1.2 Problem statement

Solid wastes are produced everyday by residential and commercial sources as direct consequences of human activities. In an attempt to dispose off these large volume of daily wastes, man has carelessly polluted the environment especially surface and groundwater through leachate and landfill. Pollution of groundwater is a major threat posed by leachate which is formed by anaerobic decomposition of waste which infiltrate and join the aquifer (Tesfaye, 2007). Groundwater contamination has become a great problem due to rapid growth rate of population, industrialization and urbanization in the metropolitan city all over the world. The quality of groundwater is normally characterized by different physicochemical parameters level. These parameters change widely due to various types of pollution, seasonal variation and groundwater extraction (Ramakrishnaiah *et al*., 2009). Siting of open dumpsite near the residential areas can have undesirable effect on nearby water sources if the leachate emanated from decomposed solid waste penetrate and contaminate the water table, the use of polluted groundwater for drinking and consumption purposes can cause major health problem (Kenneth *et al.*, 2019). According to WHO, about

80% of all diseases in human beings are caused by water (Ramakrishnaiah et al. 2009). Therefore, a periodic assessment of groundwater quality is necessary in order to ascertain the quality for human consumption purpose as well as to provide an overall scenario about the sources of groundwater contamination, thereby open an avenue for better planning for sustainable management of groundwater.

The outbreak of cholera disease in the year 2019 in Bida metropolis was trace down to surface and ground water contamination. The major source of ground water contamination were due to the poor development of bore hole water and proximity of hand dug wells to solid waste disposal, Abattoir site and pit toilet/septic tank. The percolation of toxic chemicals contain in the waste through precipitation of rain fall into the geologic formations result to ground water contamination.

1.3 Aim and objectives of the study

To determine the Seasonal Variation of Water Quality of Selected Hand-Dugged wells in Bida Metropolis. The objectives are to;

i. Determine the physical, Chemical and biological characteristics of the hand-dug wells in Bida metropolis.

ii. Estimate the volume of water in hand-dug wells during dry and rainy season.

iii. Compare hand-dugged wells water quality in bida with World Health Organization (WHO) Standard and Nigeria Standard for Drinking Water Quality (NSDWQ).

1.4 Justification of Study

Well water is a major source of water supply to the entire populace of Bida and its environs, owing to the fact that, there is no or inadequate supply of pipe-borne water from the water works and boreholes Water development is capital intensive. Sedimentary formation of the Bida basin is hydrological attractive due to the good hydraulic characteristics of soil formation.

This research therefore, became necessary to ascertain the quality and quantity of the wells and invariably its suitability for various purposes, in order to ensure the protection of the health of common man and determine liable sources of pollution. The information will be of great importance to relevant authorities. The major hand dug wells in Bida town are relatively close to soak away, safety tank, liquid and solid waste disposal.

1.5 Scope of the study

The research study covered the analysis of water samples collected from twenty five hand dug wells in Bida town. The hand-dug wells was distributed within Bida Northwest, Northeast, North Central, Southeast, and Southwest and South Central part of Bida town. The seasonal water quality variation of hand dug wells was determined from these locations.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Water Quality

Water is one of the most indispensable resources and is the elixir of life. It constitutes about 70% of the body weight of almost all living organisms. Life is not possible on this planet without water. It acts as a media for both chemical and biochemical reactions and also serves as an internal and external medium for several organisms (Rajankar *et al.,* 2009). Additionally, basic functions of a society require water; for cleaning, for public health consumption, for industrial processes and cooling for electricity generation.

Groundwater constitutes 20% of water present as freshwater. The value of groundwater lies not only in its wide spread occurrence and availability but also in it's consistent good quality, which makes it an ideal supply for drinking water (UNESCO, 2000). However, groundwater resources are under a serious threat due to growing interest in mechanized agricultural practices, increasing population density and rapid urbanization as well as domestic and industrial usage. Groundwater provisions are sometimes unsustainable because of poor water productivity of wells, drying of wells after prolonged drought and sometimes due to poor water quality (Kortatsi, 1994; Xu and Usher, 2006).

Contaminated water resources have important implications on health and environment, The importance of water quality in human health has recently attracted a great deal of interest. In developing world, 80% of all diseases are directly related to poor drinking water and unsanitary conditions (Olajire and Imeokparia, 2001; Chung *et al.,* 2007). Groundwater quality can be affected by varied pollution sources. For example, (Hamilton and Helsel, 1995) stated that a connection between agricultural and groundwater pollution is well established. According to (Chandio, 1999), applications of Nitrogen Phosphorus Potassium fertilizer (NPK) have been increasing in Pakistan over the last few decades. As a result, high concentration of NO_3-N has been reported to be common in groundwater sources in the world (Wassenaar, 1995; Goulding, 2000). Scientists have also employed the use of principal component analysis (PCA) to study soil physicochemical properties and its geochemical constituents, identification of heavy metals pollutants in soil, analysis of heavy metals presence in dust and evaluation of influence of seasons on air pollution (Adhikari *et al*. 2003; Satyanarayanan *et al*. 2016; Gergen and Harmanescu, 2012; Iwara *et al*. 2014; Abdul Raheem *et al*. 2008).

The natural water analysis for physical, chemical, biological properties including trace elements contents are very important for public health studies. These studies are also a main part of pollution studies in the environment (Bakraji and Karajo, 1999, Ahmed et al, 2002);. According to World Health Organization (WHO/UNICEF, 2006), over 385,000 children die annually of various diseases due to drinking contaminated water. In Nigeria, the death toll from water-borne diseases is not restricted to children alone. We have had epidemic cases of cholera killing both young and old due to drinking unhygienic water in the past. Isolated cases of cholera outbreak are reported periodically in the national dailies in Nigeria. Polluted water is potentially dangerous to health because of possible outbreaks of typical dysentery or cholera, epidemics and other water-borne diseases. However, the chemistry of rocks and soils and the rock geological condition in any area has a great influence on the quality of water, which determines the concentration of introduced cations and anions in the water, making it unsuitable for the consumption.

A lot of studies abound in the literature on water quality assessment and development and also on heavy metal pollution on water sources. Such works include (Akpabio and Ebong 2004). They concluded that there was the need to monitor water quality on regular basis. This is because the increase in concentration of trace elements in potable water, microbial contamination from faecal *coliform* and E-coli and influence of filths, unguided wastes and sewage disposal will increase the threat to man's health and life. Cases of diarrhea affecting both children and adults are commonly reported in our hospitals especially in the rural area where potable water is not available and untreated ground well water serves as one of the major sources of domestic water supply.

All over the world there is an increasing demand of potable water in industries or in variety of other uses. And surface water resources cannot adequately satisfy this astronomical increasing demand for potable water in both developing and industrialized world. Groundwater resources have a major role to play in the provision of potable water for the world populace and industries now and in the future (Addo *et al*, 2009). Consequently, healthy living is a function of accessible potable water supply potable pipe borne water is a rare but essential commodity. Less than 5% inhabitants in Bida local government area have access to the intermittently supplied pipe borne water. Most homes in the area depend on groundwater wells and boreholes for their survival. However, since these wells sunk to tap the groundwater are situated in towns and villages where human beings dispose wastes, and animals like chicken, dogs and goats stray about and defecates arbitrarily, bacteria contents of the well water, were also investigated. There is no evidence that the groundwater wells in Bida town have been assessed scientifically.

Okunye and Odeleye, (2015), Conducted an assessment of bacteriological investigation of well water samples from selected market location in Ibadan Nigeria. They make use of colony counter to carry out bacteriological analysis of well water samples. Six well water samples were collected and the analysed. The results revealed that all samples investigated were found to be heavily ladened with coliforms and other isolates; pseudomonas and Klebsiela were obtained in varying percentage. The P^H of the 2A well water samples were progressively acidic with the exception of two well water with P^H 7.0 though the regressive analysis to determine the significant of the extrinsic and intrinsic values of the sampled water extend beyond the P^H- values less than or equal the total viable count obtained from six well water elicited the water as grossly contaminated therefore, it is unsafe for drinking to avoid water –borne infection.

Oladipo and Adeboye, (2015) conducted physico- chemical and bacteriological analysis of well water used for drinking and domestic purposes in Ogbomosho, Nigerians make use of reagents to carryout physico- chemical and bacteriological from five different locations in Ogbomosho. The results reveals that total viable count was between 1.0×10^3 and 2.2×10^3 cf/ml, the P^H ranges from 5.9 to 6.9 while the turbidity of the well water samples ranges from 0.67 to 1.00. the chemical oxygen demand of the samples was of the samples within the range of 1.10 to 3.33 while the chloride content of the samples was within the range 7.43- 18.47; none of the sample met the Chloride content standard set by Environmental protection agency, Environmental Protection Agency (EPA).The total bacterial counts for the water samples were generally high exceeding the limit of 1.0×10^2 cfu/ml which is the standard limited of heterotrophic count for drinking water. The isolated organism were identified to be Bacillus polymxa Bacillus alvei, Pseudomonas fluorents, Bacillus megaterium and Bacillus lichesniformis.

Conclusively, proper well location and construction control of human activities to prevent sewage from entering water body is the key to the avoiding bacterial contamination of drinking water household treatment such as boiling should be encouraged before water from these wells is used for drinking and domestic purposes.

Olajubu and Ogunika, (2014) carried out the assessment of physico-chemical and microbiological properties of bore hole water samples from Akungba- Akoko Ondo state, Nigeria. They make use of chemical reagents and colony counter to carry out the experiments. In the physico- chemical analysis of the borehole water sample, the lowest P^H (6.54) was recorded 1BK1 sample AKA water sample gave highest calcium concentration (86.97)gm/l). The total hardness ranged between 171.76 and 327.33mg/l elements such as manganese, zinc, copper, cadmium were detectable levels in the water samples. Seven bacteria species, Bacillus cereus, Bacillus subtilis, pseudomonas aeruginosa, klebsiella pneumonine, staphylococcus aureus, salmonella paratyphi and proteus vulgaris were isolated. AKA sample gave the highest bacterial count of 1.6 x 10^5 cfu/ml. Staphylocossus aureus was the most frequently isolated among the bacteria having been isolated in three out of the seven samples examined. The antibiotics susceptibility test showed that proteus vulgaris and klebsiella pneumonaie were susceptible to most antibiotics.

Woke & Umesi,(2018); Conducted physiochemical and bacteriological analysis of well water in Zango-abattoir, Kaduna, Nigeria, A total of twelve samples were collected from B open wells. The mean $P^{H,}$ electrical conductivity, turbidity dissolve oxygen (DO) and Biochemical Oxygen Demand (BOD) were 5.98, 228Us/cm 18.1 NTU, 0.4mg/l and

0.23mg/l respectively, The result indicated very high concentration of sodium and 132.5 to 222.5mg/l for potassium. The concentration of lead and Cadmium were also significant ranging from 0.3972 to 0.652mg/l and 0.0062 to 0.0193 mg/l respectively. The bacterial analysis bacterial also revealed that nine (9) of the samples had total coliform bacterial and for had fecal bacteria. Though the overall physio-chemical and bacteriological quality of water samples within the maximum permissible limit of established standards the high metal concentration make the water unsuitable for drinking.

(Agbaire and Oyibo, 2009). Investigated seasonal variability of physico-chemical elements in boreholes in Abraka town. The result show total dissolved solids were lower in the dry season. (Ocheri and obeta 2010) assessed seasonal variation in nitrate level in Makurdi metropolis and found 80% of the wells had nitrate concentrations above the WHO allowable limit for drinking water for wet season. Other parameters whose concentrations were higher in the wet season are p^H, turbidity, electrical conductivity, chloride, iron, calcium, chromium, biochemical oxygen demand and faecal coliform bacteria. (Nwafor *et al;* 2013). anlysed the seasonal influence on the physico-chemical concentrations in hand dug wells in Akure town noted, of the parameters studied, pH, total dissolved solids, total alkalinity, potassium, iron, sulphate have higher concentrations in the wet season. Whereas, temperature, turbidity, total hardness, chloride, magnesium, electrical conductivity, sodium, nitrate have higher concentrations in the dry season.

2.2 Water Pollution

Water pollution on surface and ground water may be considered as a naturally induced change in water quality or conditions induced directly by man's numerous activities which renders it unsuitable for food, human health, industry, agriculture or leisure per suit With exploiting population and increasing industrialization and urbanization, water pollution by agriculture, municipal and industrial sources has become a major concern for the welfare of mankind. The menace of water borne diseases and epidemics still threatens the well-being of population, particularly in under developed and developing countries. Thus, the quality as well as the quantity of clean water supply is of vital significance for the welfare of mankind. (Agbaire and Oyibo, 2009)

2.2.1 Types of water pollution

Water pollution may be divided into the following five major categories on the basis of sources and storage of water: 1. Groundwater pollution 2. Surface water pollution

a. Lake water pollution

b. River water pollution

c. Sea water pollution (Agbaire and Oyibo, 2009)

Groundwater pollution

Groundwater contamination is generally irreversible, i.e. it is difficult to restore the original water quality of the water of the aquifer once contaminated. Excessive mineralization of groundwater degrades water 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, but groundwater is not completely free from the menace of chronic pollution (Bhatia, 2009). The extent of groundwater pollution depends on the factors: (a) depth of water table; (b) dainfall pattern; (c) soil properties; (d) distance from the sources of contamination.

Pollutant of groundwater can be classified broadly into five categories as follows:

1. **Organic Pollutants**: The organic pollutants may be further categorized as follows:

a. **Oxygen - Demanding Wastes**: These include domestic and animal's sewage, biodegradable organic compounds and industrial wastes from food processing plants, meat-packing plants, slaughter-houses, paper and pulp mills, tanneries, etc., as well as agricultural runoff. All these wastes undergo degradation and decomposition by bacterial activity in presence of dissolved oxygen (DO) and this result in rapid depletion of DO from the water, which is harmful to aquatic organisms. The optimum DO in natural waters is 4-6 mg/L, which is essential for supporting aquatic life. Any decrease in this value is an index of pollution by the above mentioned oxygen-demanding wastes (Bhatia, 2009).

b. **Disease-Causing Wastes:** These include pathogenic microorganisms which may enter the water along with sewage and other wastes and may cause tremendous damage to public health. These microbes, comprising mainly of viruses and bacteria, can cause dangerous water-borne diseases such as cholera, typhoid, dysentery, polio and infectious hepatitis in humans (Bhatia, 2009).

c. **Synthetic Organic Compounds:** These are the man-made materials such as synthetic pesticides, synthetic detergents (syndents), food additives, pharmaceuticals, insecticides, paints, synthetic fibres, elastomers, solvents, plasticizers, plastics and others industrial chemicals. These chemicals may enter the hydrosphere either by spillage during transport and use or by intentional or accidental release of wastes from their manufacturing establishments. Most of these chemicals are potentially toxic to plants, animals and humans. Some bio-refractory lie, resistant to microbial degradation. Organics such as aromatic chlorinated hydrocarbons may causes offensive colours, odors and tastes in water, even when present in traces and makes the water unacceptable from aesthetic point of view. Non-degradable chemicals such as alkyl benzene sulphonate from synthetic detergents often lead to persistent foams.

d. **Sewage and Agricultural Runoff:** Raw sewage dumped into shallow soak pits and seepage from polluted lake, pond or stream pollutes water. Fertilizers, pesticides, insecticides, processing wastes and animal waste etc. are added to the water. Leachate from agricultural lands containing nitrates, phosphates and potash, moves downward with percolating water and join the aquifers below posing danger to the groundwater. It also supplies plant nutrients, which may stimulate the growth of algae and other aquatic weeds in the receiving water body.

e. **Oil:** Oil pollution may take place because of oil spills from cargo oil tankers on the seas, losses during off-shore exploration and production of oil, accidental fires in ship and oil tankers and leakage from oil pipe lines, crossing waterways and reservoirs. This pollution reduces the DO in water.

2. **Inorganic Pollutants:** Inorganic pollutants comprise of mineral acids, inorganic salts, finely divided metals or metal compounds, trace elements, cyanides, sulphates, nitrates, organometallic compounds and complexes of metal with organics present in natural water. The metal-organic interactions involve natural organic species such as fulvic acids and synthetic organic species such as EDTA.

Various metals and metallic compounds release from anthropogenic activities add up to their natural background levels in water. Some of these trace metals play essential roles in biological processes, but at higher concentrations they may be toxic to biota. (NWRI 2001) The most toxic among the trace elements are the heavy metals such as Hg, Cd and Pb and metalloids, such as As, Sb and Se. Water pollution by heavy metals occurs mostly due to street dust, domestic sewage and industrial effluent. Polyphosphates from detergents serve as algal nutrients and thus are significant as water pollutants.

3. Suspended Solids and Sediments

Sediments are mostly contributed by soil erosion, natural processes, agricultural development, strip mining and construction activities. Suspended solids in water mainly comprise of silt, sand and minerals eroded from the land. Soil may get removed from agricultural land to areas where it is not at all required, such as water reservoirs. This reduces the water storage capacity of the reservoirs and thus shortens their life. Suspended solids present in water bodies, may also block the sunlight required for photosynthesis (Bhatia, 2009).

The organic matter content in sediments is generally higher than that in soils. Sediments and suspended particles exchange cations with the surrounding aquatic medium and act as repositories for trace metals such as Cu, Co, Ni, Mn, Cr and Mo.

4. Radioactive Materials

The radioactive water pollutants may originate from the following anthropogenic activities:

a. Mining and processing of ores, e.g. uranium tailings.

b. Increasing use of radioactive isotopes in research, agricultural, industrial and medical/diagnostic, as well as, therapeutic applications e.g.

I^{131}, P^{22}, Co^{60}, Ca^{45}, S^{35}, C^{14}, Rb^{86}, Ir^{132} and Cs^{137}.

c. Radioactive materials from nuclear power plants and nuclear reactors, e.g.

Sr^{90}, Cs^{127} Pu^{248}, Am^{241}.

d. Radioactive materials from testing and use of nuclear weaponry, e.g. Sr^{90},Cs^{137}.

The radioactive isotopes found in water include Sr^{90}, I^{131}, Cs^{37}, Co^{60}, Mn^{54}, Fe^{55}, Pu^{239}, Ba^{140}, K^{40}, Ra^{226}. These radioactive isotopes are toxic to life forms (karanth, 2010).

5. Heat

Waste heat is produced in all processes in which heat is converted into mechanical work. Thus, considerable thermal pollution results from thermal power plants, particularly the nuclear-power-based electricity generating plants. In such industries, where the water is used as a coolant, the waste hot water is returned to the original water bodies. Hence, the temperature of the water body increases. This rise in temperature decreases the DO content of waters (karanth, 2010).

Surface water Pollution

Surface water pollution is a type of pollution that occurs above ground, such as Ocean, Stream, Lakes and river. These water becomes polluted due to contaminated rainwater runoff that gets transported to nearby water sources, surface water pollution is not only detrimental to the health of humans but it also affect all living creatures, when surface water resources become polluted, any source of life that depends on water to survive will begins to deteriorate and worse case die. This affect the whole food chain (Nsi, 2007).

2.3 Water Quality Assessment

Water quality is the physical, chemical and biological characteristics of water. It is the measure of the condition of water relative to the requirements of one or more biotic species and to any human need or purpose. Water quality is determined by the concentration of physical, chemical and biological contaminants. If fresh and pure, water has no taste, Odour, Colour or turbidity. But water is never 100% pure as it carries traces of other substances, which bestow physical, chemical and biological characteristics (Nsi, 2007).

2.3.1 Physico-chemical characteristics

Most common physical contaminants of water are suspended sediments. These are properties which are often apparent to casual observer such as colour, odour, taste and turbidity. Chemicals are the major sources of water contamination. Some chemicals are introduced during movement through geological materials or by manufactured chemicals.

a. **Taste and Odour**

The odour in potable water may be defined as the sensation due to the presence of substances having an appreciable vapor pressure and stimulates the human sensory organs in the nasal and sinus cavities (Nsi, 2007). Odour in water may have natural origins, such as earthly, fishy, rotten hydrogen sulphide, aromatic swampy, clayey or artificial flavors, for instance, of chlorine, camphor, pharmaceuticals (Nikoladze and Mints, 1989).

Water may have a salty, bitter, sweet or acidic taste. This may be due to dissolved inorganic and organic substances in nature, phenols and chlorophenols. Both taste and odour are subjective properties, which are difficult to measure (Nsi, 2007)..

b. **Colour**

Colour is the sensation produced in the eyes by the rays of a decomposed light. Even pure water is not colourless: it has a pale green-blue tint in large volumes. It is necessary to differentiate between true colour due to material in solution and apparent colour due to suspended matter. Natural yellow colour in water from upland catchments is due to organic acids which are not in any way harmful, being similar to tannic acid from tea, Colour in water may be due to the presence of colouring matter such as humic and tanning substances leached into water and suspended in it. Colour of water, aesthetically affects its portability and may not be necessarily harmful (Nikoladze and Mints, 1989; Nsi, 2007).

c. **Turbidity**

Turbidity may be defined as the measure of clarity of water. It is caused by the presence of suspended insoluble materials such as clay and silt particles, discharges of sewage or industrial wastes, or the presence of large numbers of micro-organisms mainly occurring in surface water, which makes them objectionable for almost all uses.

Excessive turbidity protects microorganisms from effects of disinfectants, stimulates the growth of bacteria in water. There is no constant linear relationship between turbidity and concentration of suspended matters, since the former is affected by shapes, sizes and refractive index of the particulates (Vesilind and Pierce, 1983; Nsi, 2007).

d. **Total Dissolved Solids**

This is given as a number expressing the concentration of filterable solids present in water. Water with high concentration of dissolved solid present has poor taste and may induce unfavorable psychological reaction in the consumer. For this reason, a limit of 500mg/l of dissolved solids is desirable for potable waters. This includes settleable and non- settleable solids (Nsi, 2007).

e. **Electrical Conductivity**

Conductivity is a quantitative measure of the ability of water to pass electric current. This ability depends largely on the quantity of dissolved salts present in any water sample. In dilute form conductivity is approximately proportional to dissolved solids (DS) content. Monitoring of conductivity can thus usefully indicate variations in salt concentration in water, but for water quality control, various limitations abound. Thus, organic compounds do not ionize greatly in aqueous solutions; therefore organic pollutant would not be monitored by conductivity measurement (Nsi, 2007).

f. **pH**

The degree of acidity or alkalinity of any water is determined by its hydrogen ion concentration, pH. This is defined by $pH = -\log_{10} [H^+]$

$[H^+]$ is the concentration of hydrogen ions in solutions moles/liter. The pH is measured using pH meter. Most natured water usually has pH between 6.0 and 9.0. However, pH can be said to have indirect effect on health since it affects the removal of viruses, bacteria and other harmful organisms. For potable water, the recommended value of the pH is 6.5 to 8.5 (Nsi, 2007).

g. **Alkalinity**

The capacity of water to accept H^+ ions is called alkalinity. 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. 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 (Nikoladze and Mints, 1993). Generally, the basic species responsible for alkalinity in water are bicarbonate ion, carbonation, and hydroxide ion.

$$HCO_3^- + H^+ \rightarrow CO_2 + H_2O \qquad (2.1)$$

$$CO_3 + H^+ \rightarrow HCO_3^- \qquad (2.2)$$

$$OH^- + H^+ \rightarrow H_2O \qquad (2.3)$$

h. **Hardness of Water**

Hardness may be defined as the concentration of all multivalent metallic cations in solution. The principal ions causing hardness in natural water are calcium and magnesium. Others, which may be present though in much smaller quantities, are iron, manganese, strontium and aluminum. Ground water is much prone to hardness due to high concentration of calcium and magnesium ions (Nsi, 2007). Hardness of natural water is not harmful to the health of man, on the contrary, calcium promotes removal of cadmium; an element that can adversely affect the cardiovascular system (Nikoladze and Mints, 1993). An elevated hardness, however, makes water unsuitable for domestic and industrial use.

Hardness can be determined by various methods such as Ethylenediamine tetracetic acid (EDTA), tritrimetric method (Vesilind and Pierce, 1983).

2.3.2 Metallic pollutants

Some metallic elements present in natural waters act as pollutants. Typical chemical form or oxidation state for each element is also present. In any particular situation, the element might be present in some other form, depending on the source. It should be noted that, many of the metals that can act as a pollutant are actually essential in human nutrition. For example copper has a relatively low toxicity. An absence of copper in the diet produces an anemic or iron deficient condition, because copper is used in the body along with iron in some metabolic processes. The minimum dietary requirement is in the order of 2mg of copper daily. However, a much higher intake, say about 55mg daily cause diarrhea, vomiting and other miserable symptoms (Vesilind and Pierce, 1983).

Metals vary a great deal in their toxicity and in the toxic effects they bring about. This is so because they differ in the kind of chemical reactions they undergo with biochemical systems. Cadmium, for instance owes its high toxicity to the fact that, it is chemically similar to zinc, a metallic element that is essential in many biochemical reactions. For example, zinc is an essential part of carbonic anhydrase, the enzyme that catalyzes the reaction of carbondioxide and water. When cadmium takes the sites of zinc, it fails to perform precisely as zinc would and this brings about serious problem (Vesilind and Pierce, 1983).

a. **Cadmium** - Cadmium is not essential in nutrition but has high toxicity. Its' toxicity effect are felt in the form of high blood pressure, kidney damage and red blood cells loss. The limit per liter is 0.01mg (Bhatia, 2009).

b. **Chromium** - This is present in aquatic system as CrO_4^{2-}. It is essential in nutrition. It has medium level toxicity. Chromium is expected to be carcinogenic. Its major source is electroplating. The maximum tolerable level is 0.5mg/l (Bhatia, 2009).

c. **Lead** - Lead is not essential in nutrition and has high toxicity level. It causes anemia, kidney failure, mental retardation (in children) and convulsions when taken above the maximum tolerable level of 0.05mg/l (NSDWQ, 2007), Sources of lead to aquatic system include lead piping, lead paints and auto emissions from lead petrol as well as batteries.

d. **Manganese -** Manganese is essential in nutrition and low level of toxicity. Its toxicity effect is not well characterized. Maximum tolerable limit is 0.05mg/l (NSDWQ,2007). However, this limit is not determined by its toxicity, but because they stain clothing and ceramic plumbing fixtures (Nsi, 2007).

2.3.3 Biological Characteristics

Biological contaminants are primarily from animal and human wastes. The presence of organic matter and bacteria are measured by Biological Oxygen Demand (BOD) and coliform count. BOD is a measure of oxygen required to oxidize the organic matter present in a sample, through the action of microorganisms contained in a sample of wastewater. It is the most widely used parameter of organic pollution applied, to wastewater, as well as, surface and groundwater (Bhatia, 2009). To evaluate BOD, the total volume of oxygen gas taken up by microorganisms in a given quantity of water in a period of 5 days at $20^{o}C$ is measured. Microorganisms use the oxygen to decompose complex organic molecules present in the water in their aerobic metabolic processes. The BOD test thus, provides a measure of the total quantity of microorganisms in the sample, and of the nutrient available to them. The determination of DO is the basis of BOD test, which is commonly used to evaluate the pollution strength of waste waters. BOD represents the quantity of oxygen required by bacteria and other microorganisms during the biochemical degradation and transformation of organic matter present in water under aerobic conditions (karanth, 2010).

The coliform count is used to determine the presence of harmful bacteria in the water. This is done by looking for the presence of a common bacterium, *Escherichia coli*, which is present in excrement. The idea is that, if the water is contaminated with this common bacterium, there is a possibility of contamination by pathogenic or harmful bacteria as well (karanth, 2010).

2.4 Brief Geology of the Study Area

The geology of the study area consists of Cretaceous to recent sedimentary rocks sandstone, silt and clay of Bida basin which overlie the Precambrian basement unconformably. The Cretaceous sediment was dipping to the southwest reaching a thickness of 1.72 km and 3.24 km. The Cretaceous to recent sediment of the study area consist of Sakpe iron stone formation, Enagi silt stone, Batati iron stone and Bida formation. The Bida formation consists of Doko sand stone and zhima silt stone. These formations influence the potential of ground water in terms of porosity, permeability and chemical composition of ground water (Nwafor *et al;* 2013).

CHAPER THREE

3.0 MATERIALS AND METHODS

3.1 Study area

Bida is a local government area in Niger state, Nigeria, located at latitude $9^{0}\,9^{'}\,25^{''}$N to $9^{0}\,1^{'}\,15^{''}$N and longitude 6^{0} 4’ 45$^{''}$ E to $5^{0}\,58^{'}\,35^{''}$ E with total area of 1698km^{2} (656sqm). Bida is the second largest city in Niger state, it is located South west of Minna capital of Niger state and is a dry arid town, the town is known for its production of traditional crafts notably glass bronze art crafts and brass wares. Bida is also known for its Durbar festival and Nupe day festival. It is also the home of Federal Polytechnic, Bida, Federal Medical Centre, Bida and College of Nursing Sciences Bida.

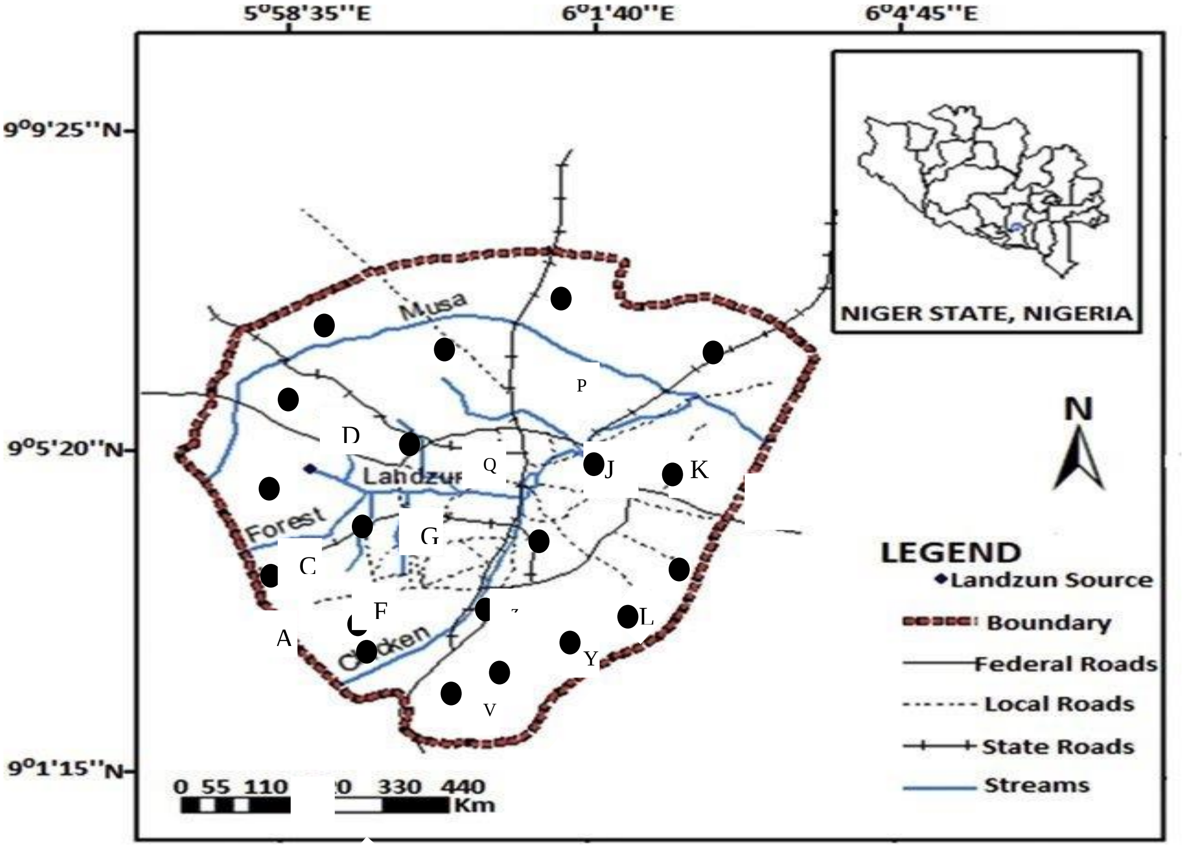


Figure 3.1: Study location in Bida, Niger State (Abdullahi and Busari, 2021)

Table 3.1: Sampling site and their designated Names

Sample	Locations	Latitude	Longitude
A	Ram market	9.088N	5.998E
B	Area One (1)	9.086N	5.992E
C	Mayaki Legbodza	9.089N	5.998E
D	Kabaligulu	9.096N	6.009E
E	Alh. Kabaraini	9.090N	6.020E
F	Gomina Saurayi	9.092N	6.008E
G	Majin Kimpa	9.081N	5.996E
H	Tswanku Gana	9.081N	5.996E
I	Sarkin Bora	9.088N	6.002E
J	EmiLabozhi Masaba	9.089N	6.002E
K	Emi Yagba	9.067N	6.013E
L	Emi Nda Ilorin	9.063N	6.012E
M	Umaru Sanda	9.063N	6.013E
N	Yalukuku	9.063N	6.013E
O	Karazumata	9.064N	6.017E
P	Emi Jibo	9.064N	6.017E
Q	Emi Antu	9.076N	5.992E
R	Gogotasala	9.077N	5.996E
S	Dan Galadima	9.074N	5.996E
T	Emi Sakpe	9.081N	5.996E
U	Old market	9.085N	6.010E
V	Lafarma Lonchita	9.082N	6.003E
W	Wakili Gabas	9.074N	6.001E
X	Man dzwakwa	9.073N	6.002E
Y	Emi Kangiwa	9.076N	6.007E

3.2 Materials

The following materials were used in conducting the investigations and analysis of the research work;

i. Global Positioning System (GPS) Garmin Emese Legend, it was used for establishment of samples points and wells locations. See in Appendix D
ii. Water level indicator was used for the determination of groundwater levels from wells.
iii. C100 multi- parameter ion specific meter was used for determination of p^H.
iv. Conductivity meter was use for the determination of electrical conductivity.
v. Chemical reagents for determination of chemical parameters.
vi. Turbidimeter was used for determination of total colloidal particles in water sample colony counter was used for total coliform count

3.3. Sample Collection and Treatment

Water from the study area which comprised twenty five (25) sampling wells was collected from Bida Northwest, Northeast, North central, Southwest, southeast and south central, between August 2020 and September 2020 (20th August to 5th September). See in Appendix A. The peak of raining season and another twenty five sampling well water was collected from same Bida Northwest, Northeast, North central, Southwest, Southeast and south central between February 2021 And march 2021 (25th February to 10th march 2021) the peak of Dry season. And the wells earmarked for sampling were picked from each zone to give a good representation of the entire study area. All the samples were picked from private residence.

Samples from the wells were collected by lowering a clean plastic container tied to a synthetic rope down the well. Five liters of samples collected were transferred into washed and labeled containers and labeled appropriately.

Samples for heavy metals determination was preserved by adding analytical grade HNO_3 acid, causing it to attain a p^H of 2. Those for bacteriological analysis were preserved in well sterilized glass bottles and stored in ice box at 4^0C to 10^0C.

3.4 Water Sample Analysis

3.4.1 Determination of physico-chemical parameters

Standard methods as recommended by relevant authorities such as World Health Organization (WHO), United State Environmental Protection Agency (USEPA), etc were employed for the preparation of reagents and determination of all water quality parameters.

3.4.2 Preparation of pH 9 buffer solution

30g of MgCl was weighed and mixed with 5g of sodium acetate in a beaker and 1g of potassium nitrate was added, then 20cm3 of acetic acid was introduced and the mixture was diluted with $500cm^3$ of distilled water and was then transferred into a volumetric flask and made up to 1litre.

3.4.3 Preparation of 0.01m ethylene diamine tetracetic acid (EDTA)

60g of EDTA was dissolved with distilled water and mixed in $60cm^3$ of NH_4OH in a beaker.

3.4.4 Preparation of 0.04m potassium dichromate

12.259g of $K_2Cr_2O_7$ was weighed and dissolved in a litre of distilled water in a volumetric Flask.

3.4.5 Preparation of 0.8M alkali-iodide azide reagent

100g of NaOH was dissolved in 125cm^3 of distilled water in a beaker and cooled slightly to produce Solution A. Then 225g of Sodium iodide was dissolved in solution A to produce solution B. 2g of Sodium azide was weighed and dissolved in 10cm^3 of distilled water and mixed separately, it was then added to the mixture of solution A and B and made up to mark in a 1litre volumetric flask.

3.4.6 Preparation of starch solution

2g of soluble starch and 0.2g of Salicylic acid was weighed and dissolved in 100cm^3 of distilled water in a conical flask.

3.4.7 Preparation of 0.21m ammonium molybdate

25g of Ammonium molybdate crystal was dissolved in 175cm^3 of distilled water in a beaker. H_2SO_4 (with specific gravity of 1.84) was diluted with 400cm^3 of distilled water in a beaker and allowed to cool, and then the molybdate solution was added to it and transferred into a volumetric flask and made up to 1 litre.

3.4.8 Preparation of 0.11m stannous chloride

2.5g of $SnCl_2.2H_2O$ was weighed and added into 100cm^3 of glycerol in a beaker. It was then heated in a water bath while been stirred with a glass rod to produce stannous chloride solution**.**

3.4.9 Preparation of 2.13m manganous sulphate

90g of $MnSO_4$ was weighed and dissolved in 250cm^3 of distilled water in a beaker.

3.4.10 Determination of temperature

The temperature was determined in situ with Hg filled glass thermometer. The thermometer was dipped into each sample and observed to movement of the Hg thread, reading was taken at point when there no more development. It was ensured that the thermometer was brought to room temperature (30^0C) before each reading was taken and held upright to avoid parallax error (USEPA, 1983; Trivedy and Goel, 1986).

3.4.11 Determination of pH

The pH meter was standardized using buffer solutions of pH 4 and 9, the response of the pH meter corresponded with the manual temperature of the buffer solution at both instances. Before each sample was measured, the electrode was placed in distilled water. In measuring the pH of sample, the meter was placed inside the sample and the electrode response taken. This was repeated thrice for accuracy for all samples measured (USEPA, 1983;

3.4.12 Determination of conductivity

A conductivity meter was used .The conductivity cell was calibrated with the standard KCl solution. The sample was brought to room temperature. The conductivity cell was washed with portion of the sample and then filled completely with the sample ensuring there was no air bubble adhered to the electrode and reading taken. The results were expressed as micro Siemens per centimeter (μS/cm) (USEPA, 1983; Trivedy and Goel, 1986).

3.4.13 Determination of turbidity

A nephelometer was used in determining turbidity of the samples. The turbidimeter was first set to zero with distilled water. Sample 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 then 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 were prepared and this was used to determine the turbidities of the samples and to calibrate the instrument. The unit of measurements is called Formazin Turbidity Units (FTU) .

3.4.14 Determination of total hardness

The EDTA titration method was used in determining the total hardness of the samples. The sample was shaken thoroughly. $25cm^3$ of the sample was taken and diluted with $50cm^3$ of distilled water and transferred quantitatively into a clean $250cm^3$ Elemeyer flask. 2cm3 of buffer solution (NH_4CL – NH_4OH) was added, followed by two drops of Eriochrome Black indicator and the sample titrated with standard EDTA solution that has been standardized using the standard calcium solution. The formation of blue colour indicated the end point, titer value was recorded. (USEPA, 1983; Trivedy and Goel, 1986)

Calculation

Hardness (EDTA) as mg $CaCO_3$T

$$= \frac{A \times B \times 100}{Ml\ of\ samples} \qquad (3.1)$$

Where A = Titre for sample and B = mg $CaCO_3$ equivalent to 1.00ml EDTA titrant

3.4.15 Determination of total dissolved solids

100ml of the sample was quantitatively transferred into an evaporating dish that has been previously weighed and dried in an oven for one hour and cooled in desiccators. The content of the dish was evaporated to dryness on a water –bath to a constant weight. The residue was dried in an oven between 103-1050C for two hours, cooled in a desiccators and the difference in weight calaculated (USEPA, 1983; Trivedy and Goel, 1986).

$$DS_{mg/l} = \frac{Difference\ in\ weight \times 100}{Ml\ \ of\ sample} \qquad (3.2)$$

3.4.16 Determination of suspended solids

A $20cm^3$ of well-mixed water sample was filtered through Gooch funnel under slight suction ensuring all solids were transferred; the residue was washed three times with about $5\text{-}10cm^3$ of water allowing to drain free from water after each wash. The residue was placed on a watch glass and dried in an oven at 105^0C for one hour. It was then allowed to cool in a dessicator and its constant weight was taken. Weight of the filter was subtracted to obtain the weight of the suspended solids (Nsi, 2007).

Calculation

$$SS_{(mg/l)} = \frac{SS_{mg/l} \times 100}{ml\, of\, samples} \tag{3.3}$$

3.4.17 Determination of chemical oxygen demand (COD)

$20cm^3$ of sample was placed in a $500cm^3$ refluxing flask. $10cm^3$ of standard $K_2Cr_2O_7$ with several glass beads already heated for 1 hour was added and 30cm3 of sulphuric acid containing 0.4g of Ag_2SO_4 was added slowly and mixed to dissolve Ag_2SO_4. It was then refluxed for 1hour.It was cooled and diluted with $150cm^3$ of distilled water, the mixture was titrated against standard ferrous ammonium sulphate (FAS) using $0.15cm^3$ ferrion indicator. Reflux of blank containing the reagents was also titrated as above (Nsi, 2007).

Calculation

$$COD_{(mg/l)} = \frac{(A \times B) \times M \times 8000}{ml\, of\, samples} \tag{3.4}$$

where A = ml Ferrous Ammonium Sulphate used for blank, B = ml Ferrous Ammonium Sulphate used for sample and M = Molarity of Ferrous Ammonium Sulphate

3.4.18 Determination of dissolved oxygen and biochemical oxygen demand

The Azide modification of the Winkler's method was used to determine DO and BOD. 250cm^3 of the sample was introduced into a stopped dark bottle and 2cm^3 of manganese sulphate solution and 2cm^3 alkali-iodide-azide reagent was added and mixed by inverting the bottle several times. Then 5cm^3 of H_2SO_4 was added immediately precipitate settled. The bottle was then shaken to ensure distribution of iodine. 25cm^3 of the mixture was taken into a conical flask and titrated against 0.01M sodium thiosulphate, until titrand changed to pale-straw colour. 5cm^3 of starch indicator was then added to it and the titration continued until first disappearance of the blue colour. The titration was carried out three times and average titer value was noted as dissolved oxygen (DO).

A fresh sample was incubated at 20^{0}C for 5 days and the above procedure repeated with it. The difference between DO for incubated sample and DO not incubated was determined (USEPA, 1983)

Calculation

$$BOD_{(5)} \quad = \quad \frac{DO_0 - DO_5}{ml\ of\ samples} \qquad (3.5)$$

where dilution factor $= \dfrac{\text{No. of days}}{\text{Ml of samples}}$

3.4.19 Determination of nitrate.

100cm^3 of the sample was evaporated to dryness on a boiling water bath. The residue left in the dish was treated with phenoldisulphonic acid until it was completely dissolved. The dissolved residue was diluted slightly with distilled water and quantitatively filtered into a 50cm^3 volumetric flask. Concentrated ammonia solution (6-7cm^3) was added to the solution to produce a permanent yellow phenoldisulphonic acids reagent nitrate colour. The flask was made to mark with distilled water, allowed to cool and measurement made at 500nm.

Blank: Blanks was used to calibrate the instrument. Nitrate standard of 0.5mg/l, 1.0mg/l, 2.0mg/l, 3.0mg/l, 4.0mg/l and 5.0mg/l was prepared from anhydrous KNO_3. Nitrate congregation in the sample was determined from the calibration curve (Tewas, 1950; USEPA, 1983; Trivedy and Goel, 1986).

Calculation

$$NO_{3(mg/l)} = \frac{(A \times B) \times M \times 8000}{ml\ of\ samples} \tag{3.6}$$

mg/l NO_3 = mg/l NO_3 ml of sample

3.4.20 Determination of phosphate.

Reagents 'A': This was prepared by dissolving 12g of ammonia molybdate in 250cm^3 of distilled water and 0.2908g potassium antimony tartate in one liter of distilled water. Both solutions was added to a standard solution of H_2SO_4 (2.5M), mixed thoroughly and made up to two liters.

Reagent 'B': This reagent was prepared by dissolving. 1.05g of ascorbic acid in 200cm^3 of reagent A and mixed thoroughly.

10cm^3 of the sample was transferred into 50cm^3 volumetric flask, 2cm^3 of reagent B was then added and the solution made to mark with distilled water. Measurement was made at 912nm wavelength after fifteen minutes. Sample blanks and phosphate standard solutions prepared from KH_2PO_4 was also determined. Concentration of phosphorus in sample was estimated from calibration curve (Murphy and Riley, 1952; USEPA 1983; Trivedy and Goel, 1986).

3.4.21 Determination of chloride

Highly colored samples was treated with $Al(OH)_3$ suspension, allowed to settle and then filtered. 50ml of the sample was placed in 250cm3 flask. $1.0cm^3$ of K_2CrO_4 indicator solution was added and sample titrated with standard $AgNO_3$ (0.14M) to a reddish brown color. Blank and standard titrations were carried out. (USEPA 1983; Trivedy and Goel 1986; Nsi, 2007)

3.4.22 Determination of total alkalinity

$100cm^3$ of the sample was transferred into a conical flask, two drops of phenolphthalein indicator was 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 titration continued to methyl orange end point (USEPA 1983; Trivedy and Goel, 1986).

Calculation

Total Alkalinity, mg $CaCO_{3\ (mg/l)}$

$$= \quad \mathrm{CaCO}_{3(mg/l)} = \frac{A \times B \times 1000}{ml\ of\ samples} \tag{3.7}$$

where A = Vol. of standard H_2SO_4 and B = Titre of standard acid

3.4.23 Determination of heavy metals

Heavy/trace metals were determined using Atomic Absorption Spectrophotometer.

a. Sample preparation: $50cm^3$ of the sample was transferred quantitatively into a beaker, $5cm^3$ conc. HCl and $3cm^3$ conc. HNO_3 acid was added and heated in a boiling water bath until the volume was reduced to about $15cm^3$. The sample was then allowed to cool, filtered and transferred into a $50cm^3$ standard flask and made to mark with distilled water.

b. Measurement: The atomic absorption spectrophotometer was operated in the air-acetylene flame mode and lamps operated at the following wavelengths according to the manufacturer's instruction (Cd, 228.2nm; Pb, 283nm; Cr, 302.2nm; Mn, 205.1nm; Ca, 435; Na, 589nm. Blanks readings were obtained from those of standards and samples before calibration curves were prepared from where each metal concentration was determined (USEPA 1983; Trivedy and Goel 1986).

3.4.24 Determination of coliform organism

a. **Presumption Phase Fermentation**

A single strength broth (McKonkey Broth Purple) was prepared by dissolving 40g of the Broth in 500cm3 distilled water in a beaker. 10cm3 of the solution was transferred into five specimen bottles, filled with Durham tubes. These were sterilized by autoclaving at 120^0C for fifteen minutes. The medium (Broth) was then inoculated with $10cm^3$ of the various water samples, mixed thoroughly and incubated at 35oC for 48 hours. After wards, the tubes were shaken gently and then examined for gas production. The result was recorded.

b. **Confirmed Phase**

The tube showing positive test (gas production) was shaken gently and a sterile metal loop 3mm in diameter was used to transfer one loop-full of culture to the fermentation tubes containing brilliant lactose bile broth. The metal loop was removed and discarded.

The inoculated green brilliant green lactose bile broth tube was inoculated for 48 hours at 35°C. The tube was then examined for gas production after this period. The result was then recorded. (Trivedy and Goel 1986; Nsil 2007; APHA 1998; Awalla 2002).

3.5 Principal Component Analysis

PCA is the most widely used, straight forward and quantitatively involved method for transforming a given set of interrelated variables into a new set of variables called the principal components corresponding to factors in factor analysis. The set of principal components generated presents uncorrelated linear combinations of the original variables and accounts for the total variance of the original data. In this method, all the principal components are generated in such a way that they are orthogonal to each other; hence, correlation between them is zero. The principal components are generated in a sequentially ordered manner with decreasing contributions to the variance, i.e. the first principal component explains most of the variations present in the original data, and successive principal components account for decreasing proportions of the variance. This property means that the data points can be rigorously separated into distinct clusters when projected into a space spanned by the first few principal components, which are called factors.

This achieves the dimensionality reduction objective of factor analysis. PCA can be broadly classified into two categories, viz., R-mode and Q-mode, based on application. If PCA is used to develop a structure among variables, it is referred to as an R-mode PCA. When PCA analysis is used to group cases, it is called a Q-mode PCA. It is customary to use rotation methods to transform the factors to simpler and more interpretable constructs.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

This chapter involves the presentation of the results and its results discussion. It included observations made on site, the physical parameters, chemical parameters, bacteriological parameters, the variation in the volume of hand dug well during rainy and dry season, correlation matrix and principal component analysis of both rainy and dry season The results of wet and dry seasons were compared. Data were been presented in the form of Tables and Figures.

4.1 Variation of Parameter from Dry and Rainy Season

4.1.1 Physical parameters

(a) Power of hydrogen (P^H): is a vital parameter which determines the suitability of water for diverse purposes. In this current study pH average value is 8.06 in dry season which is within maximum limit of WHO and NSDWQ and 7.3 in rainy season. There is slight increase in p^H during the dry season compared to the rainy season. p^H is most important in determining the corrosive nature of water. The Lower the pH value, the higher the corrosive nature of water. The p^H value is positively correlated with electrical conductance and total alkalinity (Gupta, 2009). The reduced rate of photosynthetic activity the assimilation of carbon dioxide and bicarbonates which are ultimately responsible for increase in pH, the low oxygen values coincided with high temperature during the dry month. Various factors bring about changes the p^H of water. The higher p^H values observed suggests that carbon dioxide, carbonate-bicarbonate equilibrium is affected more due to change in physico-chemical condition (Karanth, 2010).

(b) **Electrical conductivity:** The average value of electrical conductivity analysed is 590.84 μS/cm during dry season and 473.52 μS/cm in rainy season for hand dug wells water samples which are within standard permissible limit. (Nkansah *et al*; 2010) suggested that the underground drinking water quality of study area can be checked effectively by controlling conductivity of water and this may also be applied to water quality management of other study areas. Though sample D has higher value during both season also M During dry season only It is measured with the help of EC meter which measures the resistance offered by the water between two platinized electrodes. The instrument is standardized with known values of conductance observed with standard KCl solution.

(c) Total dissolve Solid: The current study indicated that the concentration of dissolved solid is slightly higher in rainy season than in dry season which is 186.32mg/l and 151.52mg/l in dry season. This is because when rain falls, debris, silt and other solid fall in to hand dug wells thereby increasing it dissolves solids. Total dissolved solids (TDS) are a measure of the total amount of dissolved minerals in water. Essentially, TDS represents the sum of concentrations of all dissolved constituents in water. Water in contact with highly soluble minerals will probably contain higher TDS levels than water in contact with less soluble minerals. TDS content is usually the main factor, which limits or determines the use of groundwater for any purpose.

4.1.2 Chemical parameters

(a) Nitrate: The concentrations of nitrate in water depend on the activity of nitrifying bacteria which are influenced by presence of dissolved oxygen. The nitrate average mean values obtained in this study during the rainy season is 4.159mg/l and 5.44 mg/l during dry season which are both within permissible limit of both WHO and NSDWQ.

Contaminants such as heavy metals, nitrates and salt have the potential of polluting water supplies as a result of inadequate treatment and disposal of waste from humans and livestock, industrial discharges, and over-use of limited water resources (Nkansah *et al;* 2010). The maximum contaminant level (MCL) for nitrate in drinking water is 10 milligrams per liter (mg/l), often expressed as 10 parts per million (ppm) - measured on the basis of the nitrogen content of nitrate (WHO/UNICEF, 2006). High concentrations of nitrate and nitrite ions may give rise to potential health risks such as methmoglobinemia or "blue – baby syndrome" particularly in pregnant women and bottle-fed infants respectively.

(b) Chloride: Is one of the essential parameters in assessing the water quality. The higher concentrations of chlorides may indicate higher degree of organic pollution. In the current study the mean average concentration of chloride in dry season is 91.97mg/l and 77.498mg/l in rainy season which within stipulated WHO and NSDWQ. Chlorides are widely distributed in nature as salts of sodium, calcium, and potassium. Chloride concentration in excess of 250mg/l or (250ppm) gives rise to taste in water (Farwell, 2010) chloride in groundwater are from both natural and anthropogenic sources such as run-off containing road de- icing salts, the use of inorganic fertilizers, landfill leachates, septic tank effluents, animal feeds, industrial effluents.

(c) Calcium: Average mean value in rainy season is 27.514 and 30.47 mg/l in dry season; both are within the standard limit of WHO and NSDWQ, There is low calcium during rainy season because the water table is high there by diluting the impurities and becomes settle in dry season while water table is low.

(d) Magnesium: Average mean value is 11.26mg/l in dry season and 8.712mg/L in rainy season, the water sample is quite consumable as the result is within the stipulated limit of WHO as well as NSDWQ.

(e) Total alkalinity: The average mean value of total alkalinity in dry season is 67.6mg/l and 29.136mg/l was recorded during rainy season, there is more total alkalinity in dry season while compare with that of rainy season because in the dry season there is less water in the well and hence the concentration of alkaline nature become more

(f) Total hardness: The Average mean value during dry season is 110.8mg/l and 104.84mg/l was also recorded during rainy season, this revealed that there more concentration of total hardness during dry season compare to rainy season this is because when rain falls it dilute the chemical concentration . This total hardness gives palatability to water. It has been suggested that moderately hard water containing sufficient calcium is essential for normal growth and health. However, high values of hardness arising from high level of magnesium phosphate are undesirable.

(g) Biocarbonate: The average mean value of HCO_3 recorded during dry season is 32.26mg/l in dry season and 12.433mg/l during rainy season, both also fall within the standard limit of WHO and NSDWQ , The excess presence of HCO3 in the body may result in to health complication such as headech, nauses and vomiting.

(h) Biochemical oxygen demand: (BOD) is the amount of dissolved oxygen required by aerobic organisms to breakdown organic materials present in the water, the mean average value of BOD from the water sample analysed during rainy season was 12.488mg/l and 20.04mg/l in dry season, BOD is a measure of organic material contamination in water, specified in mg/L. BOD is the amount of dissolved oxygen required for the biochemical decomposition of organic compounds and the oxidation of certain inorganic materials

(Such as iron, sulfites). Typically the test for BOD is conducted over a five-day period (Milacron Marketing Co.).

(i) Phosphate: The Average mean value of phosphate in dry season was 0.4624mg/l during rainy season and 0.61mg/l during dry season, which is quite desirable for consumption as it fall within permissible limit of WHO and NSDWQ except sample D which is above the permisble limits Though the concentration of phosphate is more during dry season compare to rainy season.

(j) Chemical Oxygen Demand (COD): The study revealed that the mean average COD obtained from twenty five water sample during dry season was 40.67mg/l and 31.28mg/l for rainy season. COD is another measure of organic material contamination in water specified in mg/L. COD is the amount of dissolved oxygen required to cause chemical oxidation of the organic material in water. Both BOD and COD are key indicators of the environmental health of a surface water supply. They are commonly used in waste water treatment but rarely in general water treatment (Milacron Marketing Co.).

4.1.3 Bacteriological parameters

(a) Total coliform count: The average value of total coliform count during dry season is 24.88cfu/100ml and 17.32cfu/100ml was recorded in rainy season which were both within WHO and NSDWQ standard of <=1cfu/ml. The finding shows the possibility of the absence of pathogens in the analyzed samples. The cause of acute intestinal illness, which are generally considered discomfort to health and could become fatal for some susceptible groups such as infants, elderly and those who are sick (Addo *et al.*, 2009; NSDWQ, 2007), may not be linked to this selected water sample.

Generally, underground water is often considered as the purest form of water (Sokpowu 2017), although it’s vulnerability to contamination could be due to improper construction, animal waste, proximity to toilet facilities, sewage, refuse dump site and various human activities surrounding it (Bilton, 1994).

(b) Total bacterial count: Average mean value of TBC in dry season is 40.2cfu/ml(x10^4) and 29.36cfu/ml(x10^4) the result shows that the sample is safe for drinking as its within the WHO However, no *E. coli* were detected in all the water samples, which indicate that all the water samples are free from recent faecal contamination. The ability to detect faecal contamination in drinking water is necessary, as pathogenic microorganisms from human and animal faeces in drinking water pose the greatest danger to public health.

The results of this study indicated that the values of the parameters including pH, TA, TH, HCO_3, Cl, NO_3, PO_4, Ca and Mg, were higher during dry season and that of EC And TDS Were slightly higher during rainy season that means when rain falls water infiltrate in to the ground there by increasing water table and hence dilute the ground water and reduces the concentration of heavy metals and other parameters as well. Figure 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9, 4.10, 4.11, 4.12, 4.13, 4.14 shows seasonal changes in water quality characteristics.

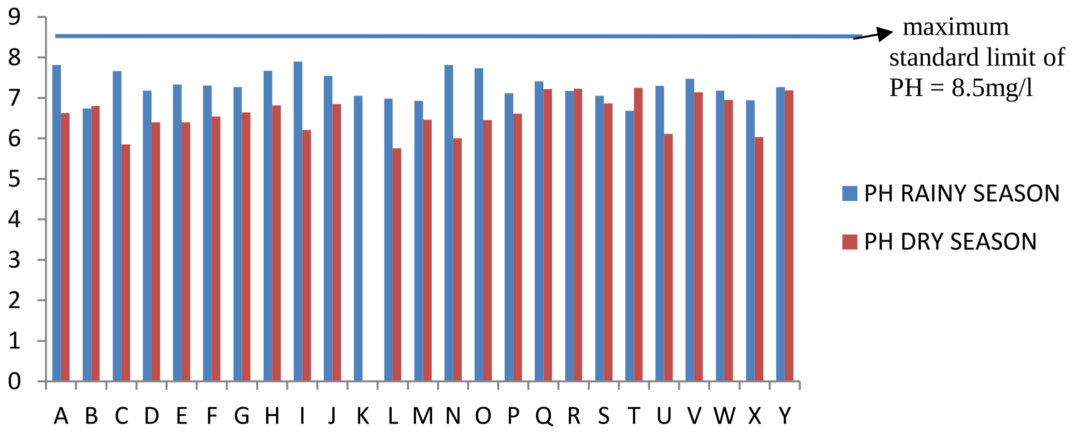


Figure 4.1: Variation in P^H of Dry and Rainy season

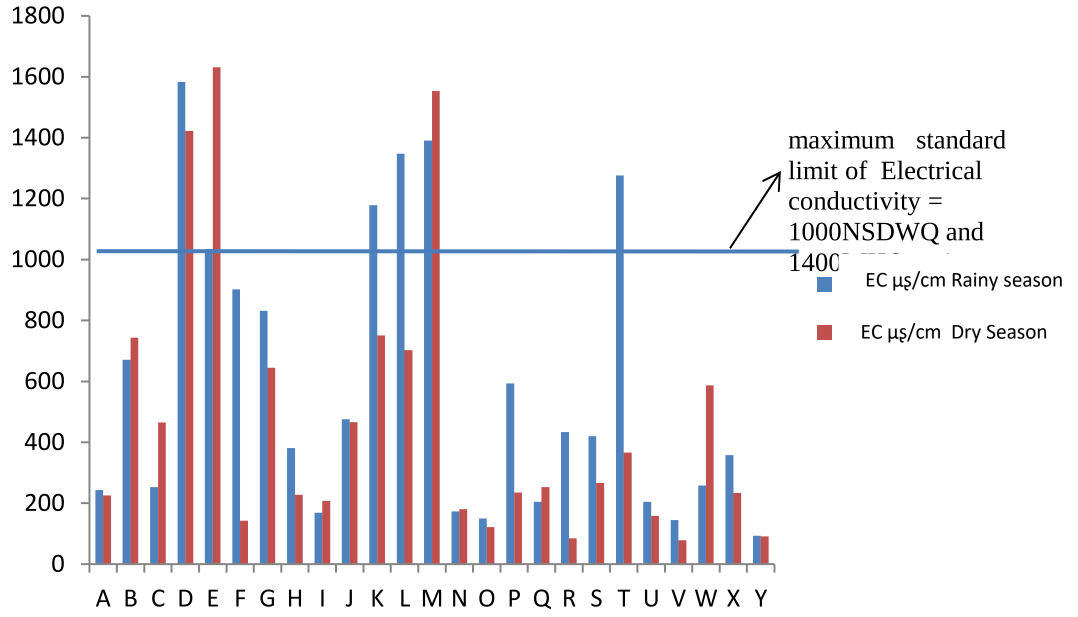


Figure 4.2: Variation in Electrical Conductivity of Dry and Rainy season

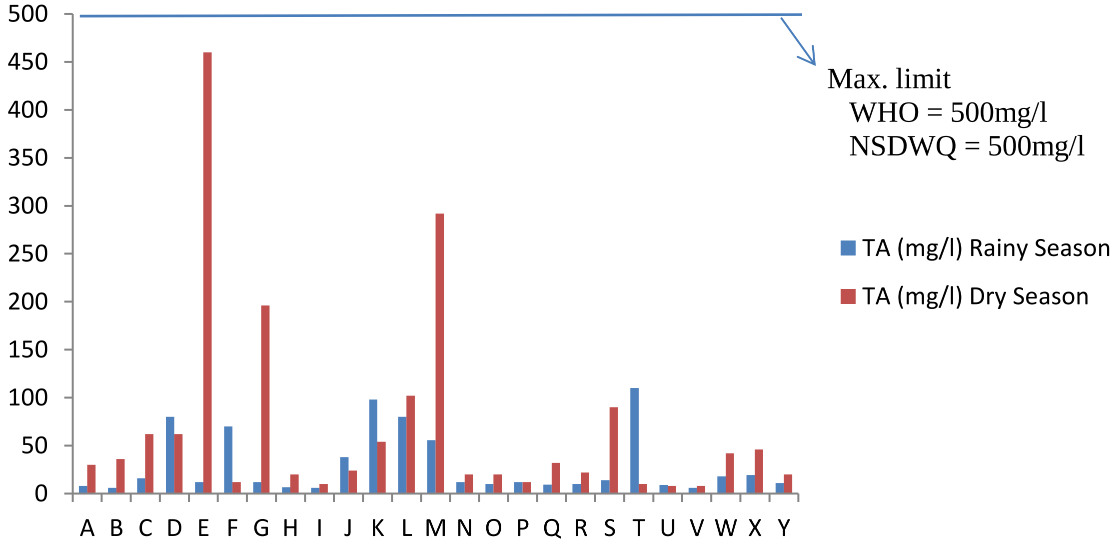
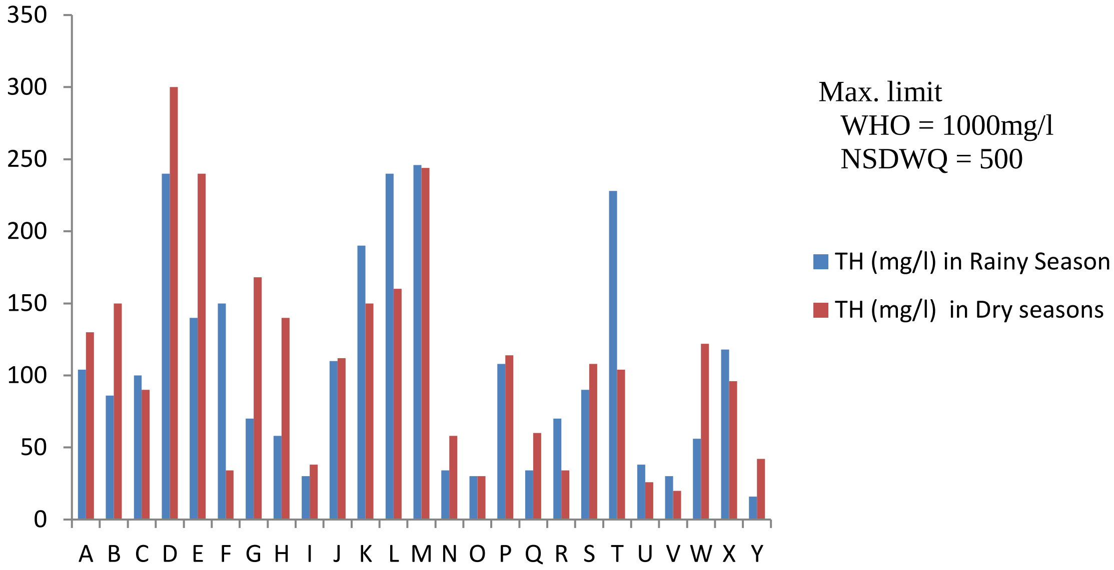
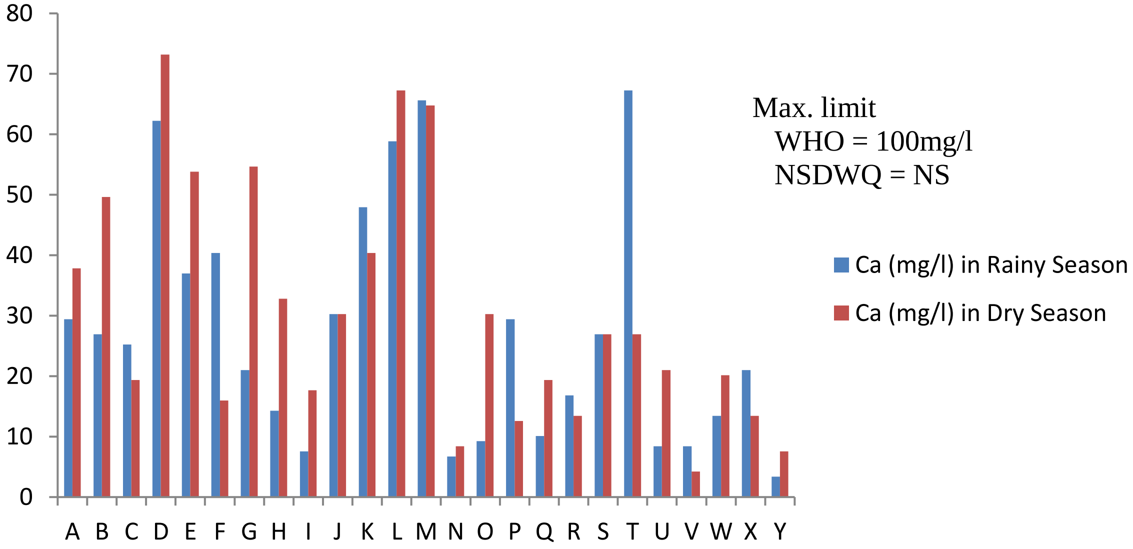


Figure 4.3: Variation in Total Alkalinity of Dry and Rainy season



Max. limit
WHO = 1000mg/l
NSDWQ = 500

Figure 4.4: Variation in Total hardness of Dry and Rainy season



Max. limit
WHO = 100mg/l
NSDWQ = NS

Figure 4.5: Variation in Calcium of Dry and Rainy season

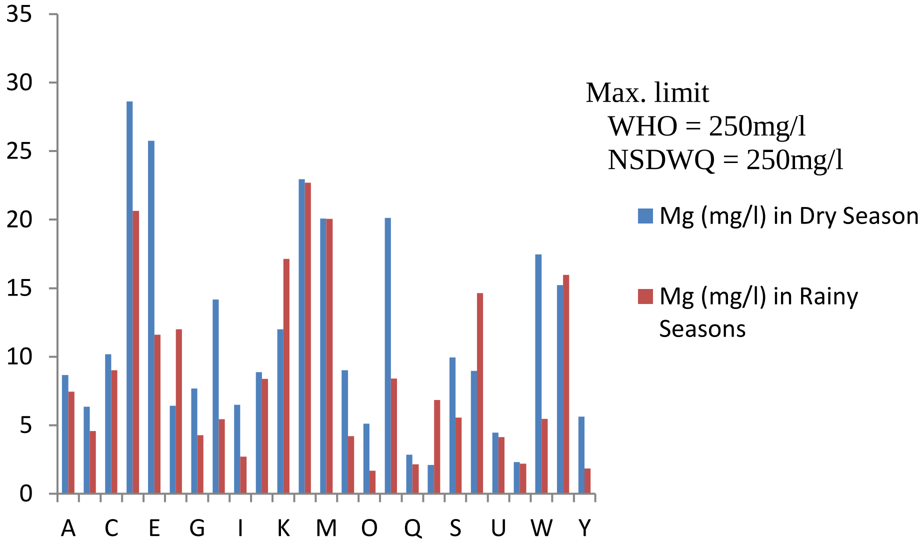


Figure 4.6: Variation in magnesium of Dry and Rainy season

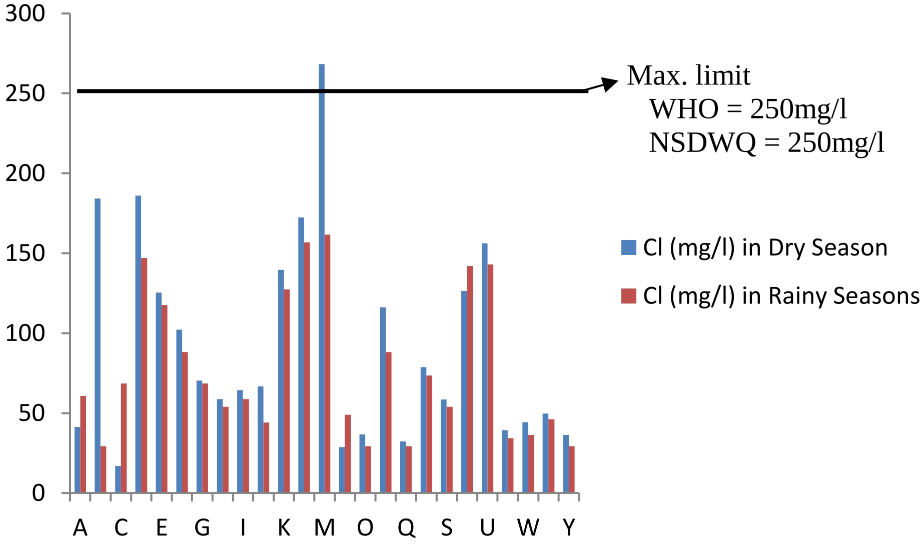


Figure 4.7: Variation in Chloride of Dry and Rainy season

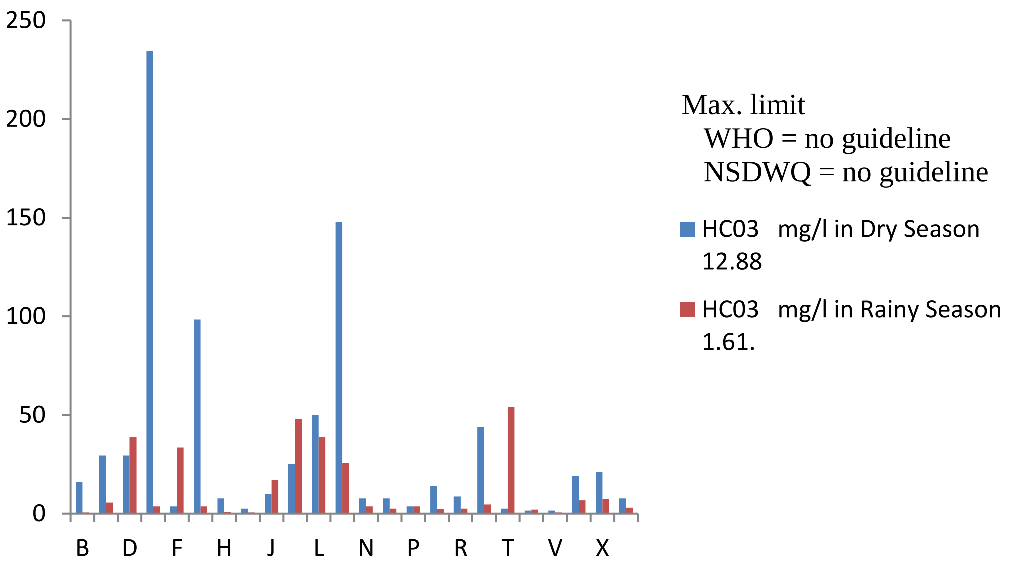


Figure 4.8: Variation in Biocarbonate of Dry and Rainy season

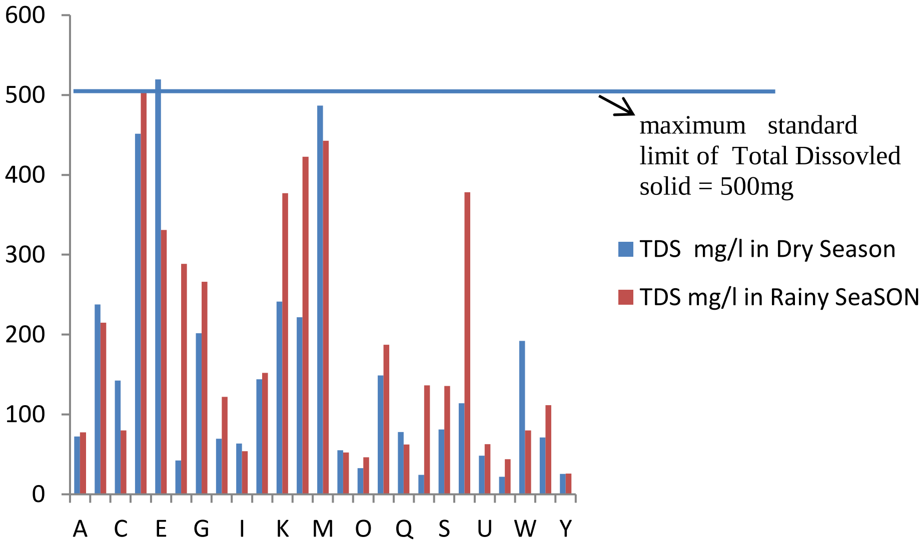


Figure 4.9: Variation in TDS (mg) of Dry and Rainy season

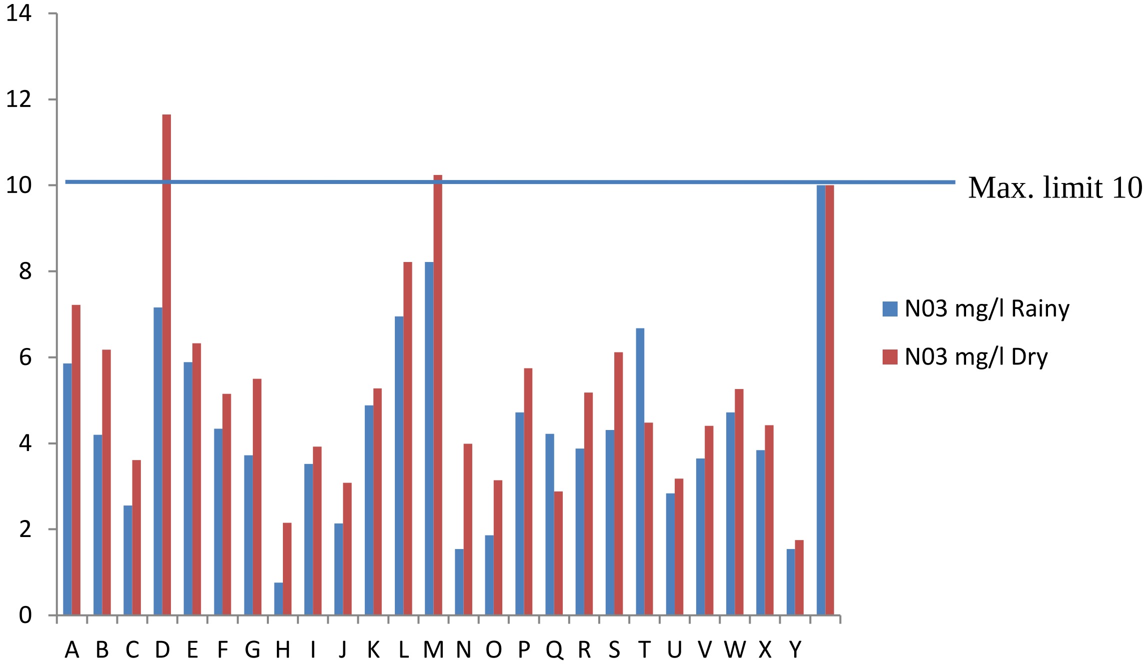


Figure 4.10: Variation in NO3 of Dry and Rainy season

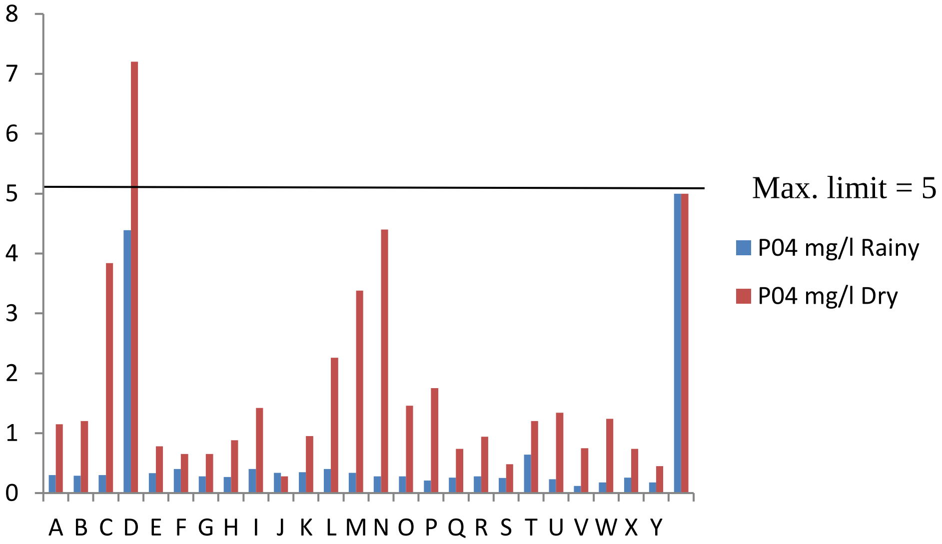


Figure 4.11: Variation in PO4 of Dry and Rainy season

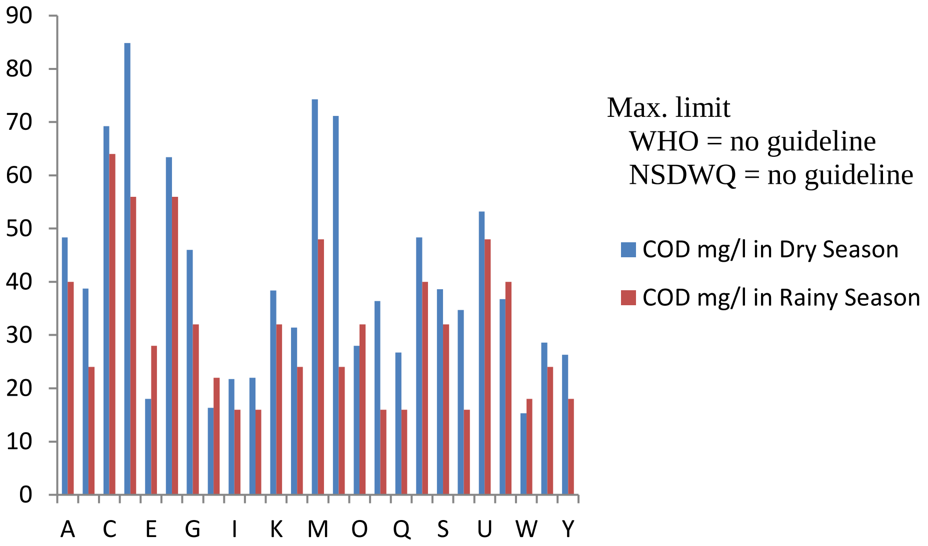


Figure 4.12: Variation in COD (mg) of Dry and Rainy season

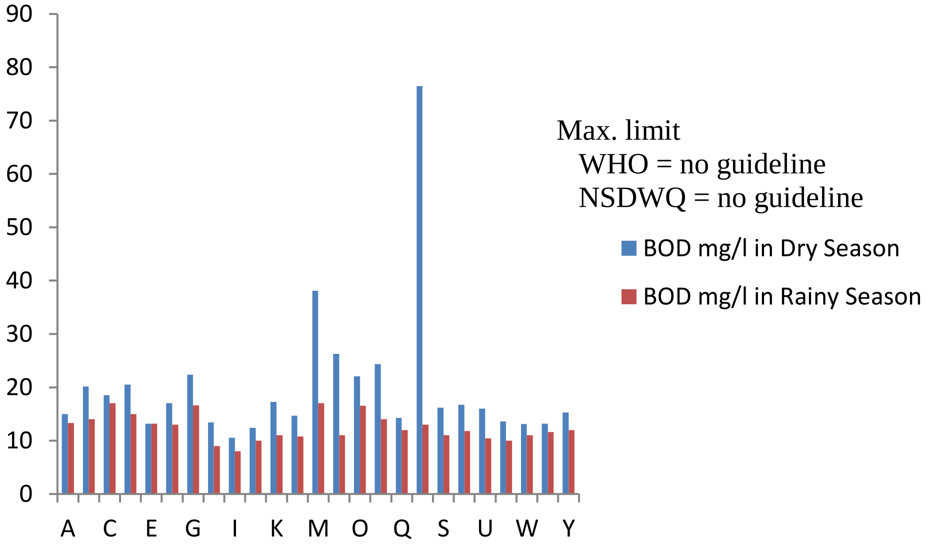


Figure 4.13: Variation in BOD (mg) of Dry and Rainy season

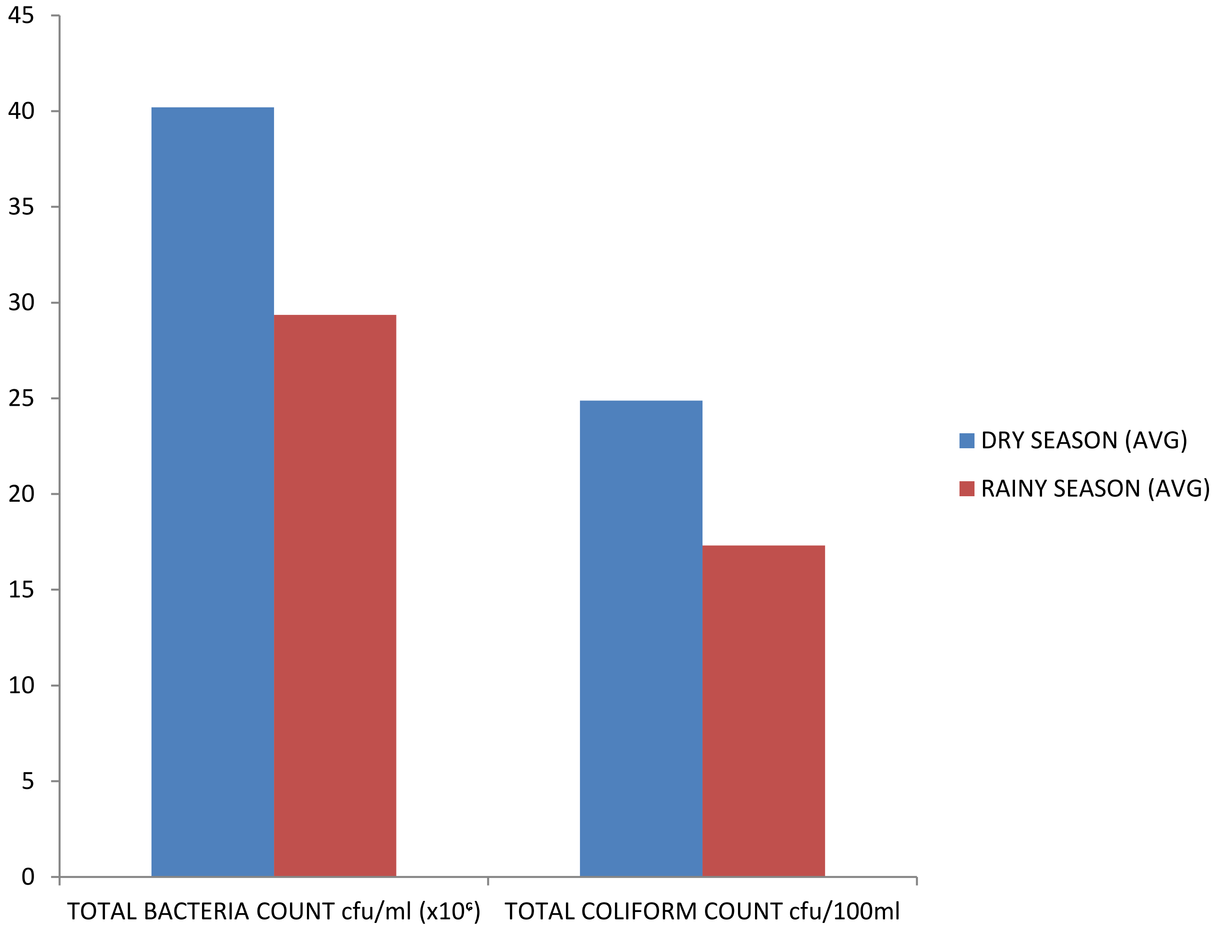


Figure 4.14: Variation in bacteria count and coliform count of dry and rainy season

Table 4.1: Volume of water in hand dug well during Rainy and Dry season

Sample ID	Well depth (m)	Depth of Water (m)		Diameter of well (m)	Volume of water well (m^3)	
		Rainy	Dry		Rainy	Dry
A	11	6.9	0.91	1.2	31.22	4.12
B	10	3.3	1.41	1.1	20.15	5.36
C	10.5	4.9	1.01	1.0	15.40	3.17
D	9	5.4	1.31	0.8	10.86	2.63
E	12	6.0	2.11	1.1	22.81	8.02
F	11	7.3	2.40	1.1	27.75	9.12
G	10	6.4	2.20	1.0	20.11	6.91
H	11	5.9	1.30	1.0	18.54	4.08
I	10	4.0	0.80	1.0	12.57	2.51
J	12	7.4	1.60	1.3	39.29	8.50
K	8.5	4.0	0.80	1.1	15.21	6.84
L	10	4.7	1.10	1.3	24.96	5.84
M	9.5	4.3	0.83	1.0	13.51	2.61
N	9.5	4.4	1.22	0.9	11.26	3.10
O	11.5	6.8	1.41	1.0	21.36	4.43
P	10.8	5.2	2.94	1.2	23.53	13.30
Q	12	5.9	1.30	1.2	26.69	5.88
R	12	5.0	0.63	1.0	15.71	1.98
S	12	6.0	0.34	1.2	27.15	1.58
T	12	6.3	0.90	1.2	28.50	4.07
U	12.5	6.2	1.00	1.1	23.57	3.80
V	12	6.0	1.20	1.0	18.85	3.77
W	10	4.3	0.60	1.0	13.51	1.88
X	11	5.4	2.1	1.0	16.97	6.60
Y	12	6.0	1.20	1.0	18.85	3.77

Table 4.1 above , its well observed that the water table becomes low in the dry season, hence the volume of water in the well become small which lead to difficulties for the users

during the season. Sometimes the water is dried off leading to change in colour of water to mudy. In this season, the concentration of heavy metals is higher compare to rainy season. While in rainy season, its observed that the water volume is appreciated due to rise in water table during rainy season. The concentration of water quality parameters becomes lower because if when rain falls it particulate into the ground thereby diluting the water impurities. Figure 4.16 below shows variation in volume of water during dry and raining seasons

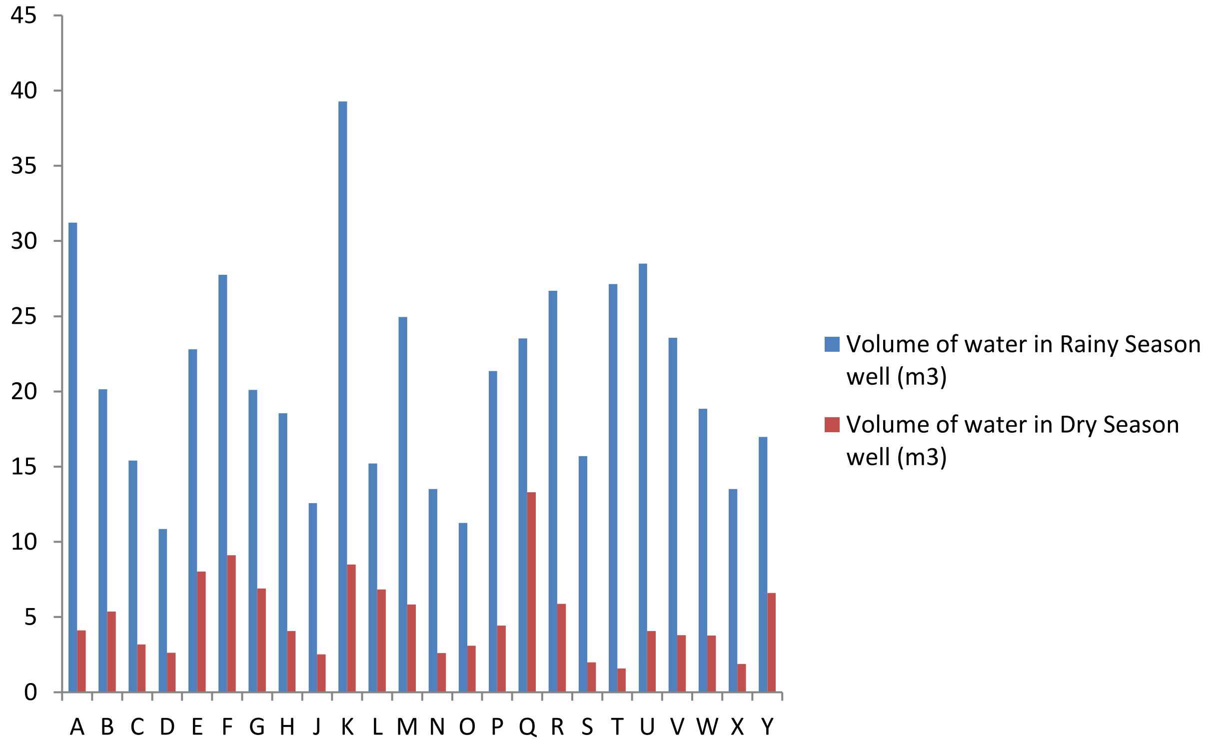


Figure 4.15: Variation of Volume Water Samples During Dry And Rainy Season

Table 4.2: Correlation Matrix between the fifteen parameters for Rainy Season. Highly correlated values (>0.5) are indicated in bold.

Correlation Matrix

		PH	EC	TA	TH	Ca	Mg	Cl	HC03	TDS	NO3	PO4	COD	BOD	TBC	TCC
Correlation	PH	1.000	-.042	-.064	-.004	-.027	-.217	.110	-.091	-.043	.123	.054	.391	**.582**	.377	.332
	EC	-.042	1.000	**.817**	**.935**	**.940**	**.836**	**.822**	**.813**	**.999**	**.787**	**.519**	.287	.378	.292	.072
	TA	-.064	**.817**	1.000	**.854**	**.855**	**.785**	**.711**	1.000	**.806**	**.598**	.420	.201	.150	.132	.005
	TH	-.004	**.935**	**.854**	1.000	**.988**	**.924**	**.823**	**.849**	**.931**	**.822**	.466	.337	.373	.299	.081
	Ca	-.027	**.940**	**.855**	**.988**	1.000	**.870**	**.805**	**.850**	**.934**	**.826**	.455	.316	.378	.312	.104
	Mg	-.217	**.836**	**.785**	**.924**	**.870**	1.000	**.746**	**.788**	**.836**	**.679**	.444	.255	.150	.105	-.107
	Cl	.110	**.822**	**.711**	**.823**	**.805**	**.746**	1.000	**.704**	**.816**	**.731**	.394	.438	.336	.256	.059
	HC03	-.091	**.813**	1.000	**.849**	**.850**	**.788**	**.704**	1.000	**.801**	**.588**	.419	.189	.129	.114	-.011
	TDS	-.043	**.999**	**.806**	**.931**	**.934**	**.836**	**.816**	**.801**	1.000	**.782**	**.525**	.297	.379	.294	.070
	NO3	.123	**.787**	**.598**	**.822**	**.826**	**.679**	**.731**	**.588**	**.782**	1.000	.387	.322	.464	.369	.130
	PO4	.054	**.519**	.420	.466	.455	.444	.394	.419	**.525**	.387	1.000	.364	.225	-.162	-.285
	COD	.391	.287	.201	.337	.316	.255	.438	.189	.297	.322	.364	1.000	.611	.115	-.117
	BOD	.582	.378	.150	.373	.378	.150	.336	.129	.379	.464	.225	**.611**	1.000	**.600**	.373
	TBC	.377	.292	.132	.299	.312	.105	.256	.114	.294	.369	-.162	.115	**.600**	1.000	**.842**
	TCC	.332	.072	.005	.081	.104	-.107	.059	-.011	.070	.130	-.285	-.117	.373	**.842**	1.000

Table 4.3 and 4.5 below shows variations of principal component analysis for dry and raining seasons.

Table 4.3: Principal Component Analysis for Rainy Season Data

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	8.237	54.910	54.910	8.237	54.910	54.910
2	2.667	17.779	72.689	2.667	17.779	72.689
3	1.586	10.571	83.260	1.586	10.571	83.260
4	.593	3.951	87.210			
5	.573	3.821	91.031			
6	.406	2.707	93.738			
7	.295	1.965	95.703			
8	.206	1.371	97.075			
9	.188	1.253	98.327			
10	.104	.693	99.021			
11	.100	.669	99.690			
12	.046	.306	99.996			
13	.001	.004	99.999			
14	.000	.001	100.000			
15	2.200E-6	1.467E-5	100.000			

Extraction Method: Principal Component Analysis.

Table 4.4: Correlation Matrix between the fifteen parameters for Dry Season. Highly correlated values (>0.5) are indicated in bold.

		PH	EC	TA	TH	Ca	Mg	Cl	HCO3	TDS	NO3	PO4	COD	BOD	TBC	TCC
Correlation	PH	1.000	-.213	-.188	-.172	-.256	-.394	-.175	-.188	-.210	-.176	-.467	-.343	.194	-.012	-.069
	EC	-.213	1.000	.792	**.908**	**.820**	**.751**	**.688**	**.792**	**.994**	**.743**	.443	.247	.002	.436	.379
	TA	-.188	**.792**	1.000	**.645**	**.578**	**.536**	.396	1.000	**.782**	**.510**	.051	.023	.041	.428	.403
	TH	-.172	**.908**	**.645**	1.000	**.867**	**.829**	**.619**	**.645**	**.915**	**.725**	.464	.228	-.051	**.523**	**.501**
	Ca	-.256	**.820**	**.578**	**.867**	1.000	**.628**	**.700**	**.578**	**.804**	**.707**	.383	.226	-.022	.354	.325
	Mg	-.394	**.751**	**.536**	**.829**	**.628**	1.000	**.502**	**.536**	**.784**	**.593**	**.503**	.110	-.143	.463	.492
	Cl	-.175	**.688**	.396	**.619**	**.700**	**.502**	1.000	.395	**.699**	**.764**	.329	.354	.178	.268	.135
	HCO3	-.188	**.792**	1.000	**.645**	**.578**	**.536**	.395	1.000	**.782**	**.509**	.051	.023	.041	.428	.403
	TDS	-.210	**.994**	**.782**	**.915**	**.804**	**.784**	**.699**	**.782**	1.000	**.746**	.445	.238	.006	.480	.423
	NO3	-.176	**.743**	**.510**	**.725**	**.707**	**.593**	**.764**	**.509**	**.746**	1.000	.491	**.511**	.263	.213	.076
	PO4	-.467	.443	.051	.464	.383	**.503**	.329	.051	.445	.491	1.000	**.736**	.134	.292	.237
	COD	-.343	.247	.023	.228	.226	.110	.354	.023	.238	**.511**	**.736**	1.000	.356	.108	-.003
	BOD	.194	.002	.041	-.051	-.022	-.143	.178	.041	.006	.263	.134	.356	1.000	.039	-.071
	TBC	-.012	.436	.428	.523	.354	.463	.268	.428	.480	.213	.292	.108	.039	1.000	**.953**
	TCC	-.069	.379	.403	.501	.325	.492	.135	.403	.423	.076	.237	-.003	-.071	**.953**	1.000

Table 4.5: Principal Component Analysis for Dry season Data

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	7.547	50.313	50.313	7.547	50.313	50.313
2	2.152	14.346	64.660	2.152	14.346	64.660
3	1.545	10.300	74.960	1.545	10.300	74.960
4	1.331	8.875	83.835	1.331	8.875	83.835
5	.880	5.869	89.704			
6	.466	3.107	92.810			
7	.418	2.784	95.595			
8	.283	1.886	97.481			
9	.196	1.306	98.787			
10	.097	.647	99.433			
11	.049	.324	99.758			
12	.020	.135	99.892			
13	.014	.094	99.987			
14	.002	.013	100.000			
15	2.422E-10	1.615E-9	100.000			

Extraction Method: Principal Component Analysis.

$-1 \leq r \leq 1$

If r = -1, that means there is perfect negative relationship between two variables.

r = 1, that means there is perfect positive relationship between two variables.

If r = 0.5 meaning there is average relationship

If r = 0.6, 0.7, 0.8, 0.9 its means there is strong positive relationship

If r = 0.1, 0.2, 0.3, 0.4 that means there is weak positive relationship between the two variables.

Table 4.6: Eigen values for each principal components for both season

	Eigen (Dry)	Eigen (Rainy)
PCA1	7.547	8.237
PCA2	2.152	2.667
PCA3	1.545	1.586
PCA4	1.331	.593
PCA5	.880	.573
PCA6	.466	.406
PCA7	.418	.295
PCA8	.283	.206
PCA9	.196	.188
PCA10	.097	.104
PCA11	.049	.100
PCA12	.020	.046
PCA13	.014	.001
PCA14	.002	.000
	2.422E-10	2.200E-6

From Table 4.3 and 4.5, in Rainy season, the first principal component account for 54.91% of the total variation of water quality while in Dry season, the first principal components account for 50.313% of the total variation of water quality analysed, second principal component analysed account for 72.669 of the total variation of water quality in Rainy season while the second component account for 64.660% of the total variation of water quality in dry season, also in Rainy season the third principal component account for 83.260% of the total variation of water quality and statistically 80% of the total variation is the acceptable percentage explained in the components, the third principal component account for 74.960% of the total variation of water quality in Dry season, and 83.835% for the third component in Dry season. Screen plot of the eigen values of dry and raining season is shown in Figure 4.15

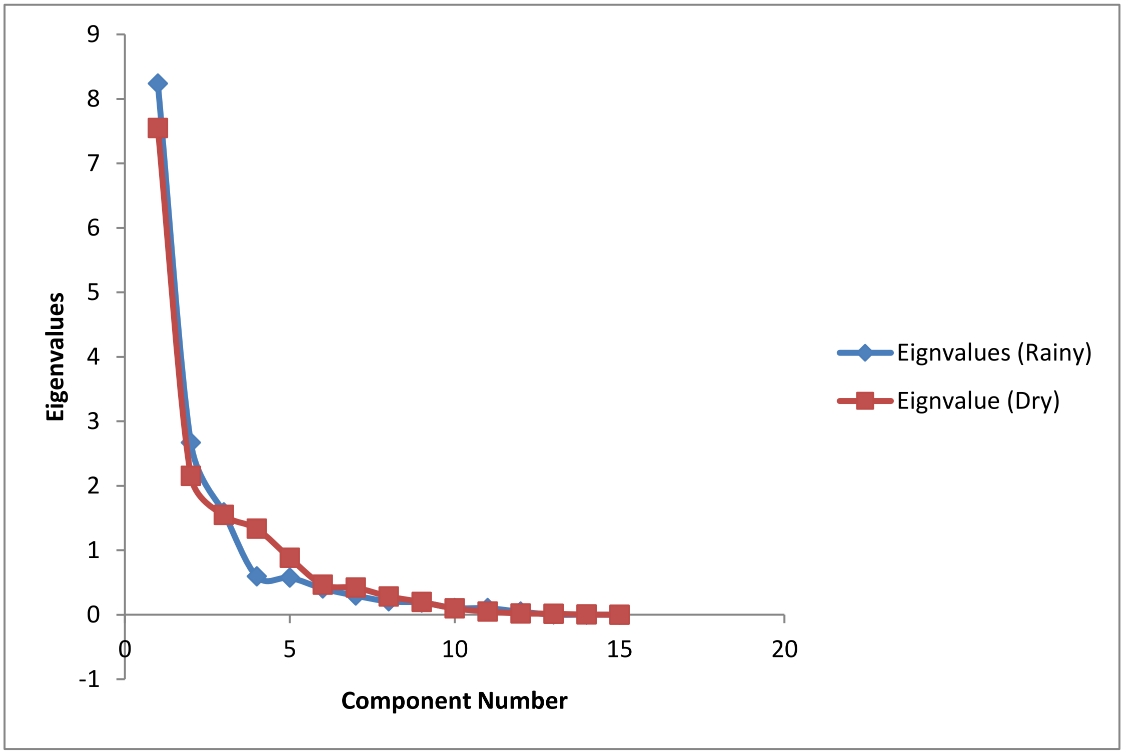


Figure 4.16: Screen Plot of the Eigen Values of Dry and Rainy Season

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The 25 selected hand-dugged wells water from Bida local government area of Niger state Nigeria were analysed for physical, chemical and bacterial evaluation in both rainy and dry season for domestic suitability. The value obtained for most of the water sample were found to be within the safe limits of WHO and NSDWQ and suitably for human consumption and other uses like agricultural purposes for both rainy and dry season. Although, the study revealed that the well water sample from Mayaki legbodza has the highest total dissolved solid in both rainy and dry season, this could be as a result of proximity of hand dug well to the pit latrine, soak ways and dump sites or natural geochemistry of the soil in the area.

The Result also revealed that there is variation in volume of water during dry and rainy season; More water Was found in the well in rainy season due to rain while it falls and percolate in to the ground there by increasing it content and reduces it chemical and bacteria concentration.

The result of principal component analysis revealed relationship between several parameters it was indicated that PCA was a valid method for processing large data set and effective for creating analytical process, about 15 water quality parameters were reduced to three important principal components in rainy season by PCA explaining 83.260% of the total variance of the original data set while in dry season water quality parameters were reduced to four important components by PCA Explaining 83.835% of the total variance of the original data set. A Review of several water quality assessment using statistical method revealed that any water body can be evaluated when provided with a minimum number of samples and parameters to work with yielding beneficial results in terms of control and management of ground water

5.2 Recommendations

1. Water treatments are required in the area in both rainy and dry season for the water to be safe for drinking.
2. The open well water in the area should pass through recommended filter and ultraviolet radiation (UVR) tube before consumption
3. The construction of new tube wells and open wells in the area should be develop and far away from existing animals wastes, soakaways/pit latrine and dump site, for at least 10m away from the source of contaminant.
4. principal component analyses and correlation matrix should be introduce to engineering students especially water resources and environmental engineering.

5.3 Contribution of the Thesis to Knowledge

The research established that there are more impurities in hand–dugged wells during dry season. The work among other findings, revealed total coliform count ranges from 60 cfu/100ml to 34cfu/100ml in rainy season and 9 cfu/100ml to 72 cfu/100ml in dry season. The total bacterial count ranges from 18 cfu/ml x10^4 to 42 cfu/ml x10^4 in rainy season and 14 cfu/ml x10^4 to 66 cfu/ml x10^4 in dry season. The nitrate ranges from 0.76 mg/l to 8.22 mg/l and 1.75 mg/l in rainy season and dry season respectively. These and other parameters explored were all within the permissible limits of World Health Organizations and Nigeria Standards for Drinking Water Quality.

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APPENDIXES

Apendixe1: Shows the Result of Physicochemical Parameters of sample points during Rainy Season

SAMPLE ID	pH	EC µS/cm	TA (mg/l)	TH (mg/l)	Ca (mg/l)	Mg (mg/l)	Cl (mg/l)	HC0$_3$ mg/l	TDS mg/l	N0$_3$ mg/l	P0$_4$ mg/l	COD mg/l	BOD mg/l	TBC cfu/ml (x10^4)	TCC cfu/100ml
A	7.81	243	8.00	104	29.43	7.44	60.76	1.61.	77.76	5.86	0.30	40.00	13.3	28	13
B	6.74	671	6.00	86	26.91	4.58	29.40	0.52	214.72	4.20	0.29	24.00	14.00	33	18
C	7.66	253	16.00	100	25.23	9.02	68.60	5.67	80.16	2.55	0.30	64.00	17.00	26	13
D	7.18	1583	80.00	240	62.23	20.64	147	38.66	506.56	7.16	4.39	56.00	15.00	18	6
E	7.33	1034	12.00	140	37.00	11.61	117.6	3.61	330.88	5.89	0.33	28.00	13.20	24	17
F	7.31	902	70.00	150	40.37	12.00	88.20	33.51	288.64	4.34	0.40	56.00	13.00	18	9
G	7.27	832	12.00	70	21.02	4.27	68.60	3.60	266.24	3.72	0.28	32.00	16.60	37	22
H	7.67	381	6.60	58	14.29	5.44	53.90	0.83	121.92	0.76	0.27	22.00	9.00	30	16
I	7.9	169	6.00	30	7.56	2.70	58.80	0.52	54.08	3.52	0.40	16.00	8.00	24	13
J	7.54	476	38.00	110	30.27	8.39	44.10	17.01	152	2.14	0.34	16.00	10.00	28	22
K	7.05	1178	98.00	190	47.93	17.15	127.4	47.94	376.96	4.88	0.35	32.00	11.00	42	24
L	6.98	1348	80.00	240	58.87	22.69	156.8	38.66	422.74	6.95	0.40	24.00	10.80	26	12
M	6.93	1391	55.60	246	65.60	20.05	161.7	25.77	442.56	8.22	0.34	48.00	17.00	56	24
N	7.81	173	12.00	34	6.72	4.19	49.00	3.61	52.36	1.54	0.28	24.00	11.00	22	16
O	7.73	150	10.00	30	9.25	1.68	29.40	2.58	46.22	1.86	0.28	32.00	16.52	34	20
P	7.12	593	12.00	108	29.43	8.41	88.20	3.60	187.42	4.72	0.21	16.00	14.00	38	26
Q	7.41	205	9.20	34	10.09	2.14	29.40	2.17	62.38	4.22	0.26	16.00	12.00	32	18
R	7.17	434	10.00	70	16.82	6.83	73.50	2.58	136.25	3.88	0.28	40.00	13.00	24	8
S	7.05	420	14.00	90	26.91	5.56	53.90	4.64	135.55	4.31	0.25	32.00	11.00	42	34
T	6.68	1276	110	228	67.28	14.64	142.1	54.12	378.41	6.68	0.64	16.00	11.80	26	18
U	7.3	205	9.00	38	8.41	4.14	143.08	2.06	62.68	2.84	0.23	48.00	10.40	22	16
V	7.47	145	6.00	30	8.41	2.19	34.30	0.55	44.08	3.65	0.12	40.00	10.00	18	12
W	7.18	258	18.00	56	13.45	5.46	36.26	6.70	80.12	4.72	0.18	18.00	11.00	26	16
X	6.94	358	19.20	118	21.02	15.98	46.06	7.32	111.54	3.84	0.26	24.00	11.60	26	18
Y	7.27	93	10.80	16	3.36	1.85	29.40	2.99	25.96	1.54	0.18	18.00	12.00	34	22
WHO	6.5-8.5	1400	500	1000	100	250	250	No guidline	500	10	5	-	-	Nil	<=1cfu/ml
NSDWQ	6.5-8.5	1000	500	500	-	250	250	No guideline	500	50	5	-	-	Nil	<=1cfu/ml

Note: PH=power of hydrogen, EC=Electrical conductivity, TA=Total alkalinity, TH=total hardness ,Ca=calcium, Mg= magnesium,
CL=chloride, HC0$_3$=Bicarbonate, TDS=total dissolve solid, NO$_3$=Nitrate, PO$_4$=phosphate, COD=Chemical oxygen demand

BOD=Biochemical oxygen demand, TBC=Total bacteria count, TCC=Total coliform count.

Apendix 2: Shows the Result of Physicochemical Parameters of sample point during Dry Season

SAMPLE ID	***Ph***	***EC µS/cm***	***TA (mg/l)***	***TH (mg/l)***	***Ca (mg/l)***	***Mg (mg/l)***	***Cl (mg/l)***	***HC03 mg/l***	***TDS mg/l***	***N03 mg/l***	***P04 mg/l***	***COD mg/l***	***BOD mg/l***	TBC cfu/ml ($x10^4$)	TCC Cfu/100 ml
A	*6.63*	*226*	*30.00*	*130.00*	*37.84*	*8.66*	*41.30*	*12.88*	*72.32*	*7.22*	*1.15*	*48.33*	*15.01*	19	14
B	*6.80*	*743*	*36.00*	*150.00*	*49.62*	*6.36*	*184.29*	*15.97*	*237.76*	*6.18*	*1.20*	*38.71*	*20.16*	56	32
C	*5.85*	*465*	*62.00*	*90.00*	*19.34*	*10.17*	*16.80*	*29.38*	*142.6*	*3.61*	*3.84*	*69.27*	*18.50*	22	18
D	*6.40*	*1422*	*62.00*	*300.00*	*73.17*	*28.62*	*186.0*	*29.38*	*451.36*	*11.65*	*7.20*	*84.88*	*20.50*	88	64
E	*6.40*	*1631*	*460.00*	*240.00*	*53.82*	*25.76*	*125.30*	*234.53*	*519.44*	*6.33*	*0.78*	*18.0*	*13.20*	94	77
F	*6.54*	*142*	*12.00*	*34.00*	*15.97*	*6.43*	*102.10*	*3.60*	*42.28*	*5.15*	*0.65*	*63.40*	*17.00*	22	14
G	*6.64*	*645*	*196.00*	*168.00*	*54.66*	*7.68*	*70.25*	*98.45*	*201.65*	*5.50*	*0.65*	*46.01*	*22.40*	14	9
H	*6.82*	*228*	*20.00*	*140.00*	*32.80*	*14.17*	*58.81*	*7.73*	*69.45*	*2.15*	*0.88*	*16.36*	*13.42*	44	18
I	*6.21*	*208*	*10.00*	*38.00*	*17.66*	*6.48*	*64.30*	*2.57*	*63.72*	*3.92*	*1.42*	*21.74*	*10.55*	26	16
J	*6.85*	*466*	*24.00*	*112.00*	*30.27*	*8.88*	*66.72*	*9.79*	*144.23*	*3.08*	*0.28*	*22.0*	*12.40*	58	22
K	*6,62*	*751*	*54.00*	*150.00*	*40.37*	*12.00*	*139.54*	*25.25*	*241.14*	*5.28*	*0.95*	*38.40*	*17.26*	66	41
L	*5.76*	*702*	*102.00*	*160.00*	*67.28*	*22.95*	*172.36*	*50.00*	*221.66*	*8.22*	*2.26*	*31.44*	*14.68*	42	29
M	*6.46*	*1554*	*292.00*	*244.00*	*64.76*	*20.08*	*268.40*	*147.93*	*486.89*	*9.24*	*3.38*	*74.30*	*38.10*	96	72
N	*6.00*	*180*	*20.00*	*58.00*	*8.41*	*9.02*	*28.64*	*7.73*	*55.34*	*3.99*	*4.40*	*71.15*	*26.30*	36	17
O	*6.45*	*122*	*20.00*	*30.00*	*30.27*	*5.12*	*36.70*	*7.73*	*32.67*	*3.14*	*1.46*	*28.00*	*22.10*	28	12
P	*6.61*	*235*	*12.00*	*114.00*	*12.61*	*20.13*	*116.18*	*3.60*	*148.86*	*5.75*	*1.75*	*36.38*	*24.34*	34	19
Q	*7.22*	*253*	*32.00*	*60.00*	*19.34*	*2.85*	*32.33*	*13.91*	*77.94*	*2.88*	*0.74*	*26.72*	*14.28*	26	14
R	*7.23*	*85*	*22.00*	*34.00*	*13.45*	*2.09*	*78.70*	*8.76*	*24.34*	*5.18*	*0.94*	*48.32*	*76.50*	38	22
S	*6.86*	*266*	*90.00*	*108.00*	*26.91*	*9.95*	*58.45*	*43.81*	*81.17*	*6.12*	*0.48*	*38.6*	*16.20*	52	28
T	*7.25*	*366*	*10.00*	*104.00*	*26.91*	*8.97*	*126.33*	*2.57*	*113.89*	*4.48*	*1.20*	*34.70*	*16.74*	28	16
U	*6.11*	*158*	*8.00*	*26.00*	*21.02*	*4.46*	*156.12*	*1.54*	*48.22*	*3.18*	*1.34*	*53.18*	*16.00*	22	14
V	*7.14*	*78*	*8.00*	*20.00*	*4.20*	*2.31*	*39.25*	*1.54*	*22.14*	*4.41*	*0.75*	*36.74*	*13.62*	38	20
W	*6.95*	*587*	*42.00*	*122.00*	*20.18*	*17.47*	*44.32*	*19.07*	*192.22*	*5.26*	*1.24*	*15.30*	*13.14*	24	10
X	*6.03*	*234*	*46.00*	*96.00*	*13.45*	*15.22*	*49.70*	*21.13*	*71.33*	*4.42*	*0.74*	*28.60*	*13.20*	32	24
Y	*7.19*	*91*	*20.00*	*42.00*	*7.56*	*5.63*	*36.40*	*7.73*	*25.36*	*1.75*	*0.45*	*26.30*	*15.30*	*29*	*27*
WHO	6.5-8.5	1400	500	1000	100	250	250	No guidline	500	10	5.0	-	-	Nil	<=1cf/ml
NSDWQ	6.5-8.5	1000	500	500	-	20	250	No guideline	500	50	5.0	-	-	Nil	<=1cf/ml

Note: P^H=power of hydrogen, EC=Electrical conductivity, TA=Total alkalinity, TH=total hardness ,Ca=calcium, Mg= magnesium,
CL=chloride, HC03=Bicarbonate, TDS=total dissolve solid, NO3=Nitrate, PO4=phosphate, COD=Chemical oxygen demand
BOD=Biochemical oxygen demand, TBC=Total bacteria count, TCC=Total coliform

Plate I: 25 Hand dug well water samples

Plate II: Water level indicator

Plate III: Process of Determining water level

Plate IV: Global Positioning Satellite

Plate V: Process of taking water sample at Banyagi area

Plate VI: Process of taking water sample at Dokodza Area

Plate VII; Water sample preparation

Plate VIII: Determination of Electrical Conductivity and Temprature using multiparameter apparatus