ASSESSMENT OF WATER QUALITY OF HAND-DUG WELLS IN CENTRAL BOSSO LOCAL GOVERNMENT AREA, NIGER STATE

BY

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DECLARATION

I hereby declare that this project work is a record of a research work that was undertaken and written by me. It has not been presented before for any degree or diploma or certificate at any university or institution. Information derived from personal communications, published and unpublished work were duly referenced in the text.

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28-02-2012

Date

CERTIFICATION

This is to certify that the project entitled "Assessment of Water Quality of Hand-dug Wells in Central Bosso Local Government Area, Niger State" by Kolade, Michael Opeyemi meets the regulations governing the award of the degree of Bachelor of Engineering (B. ENG.) of the Federal University of Technology, Minna, and it is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This project work is dedicated to my God, the creator of heaven and earth, my parents and the down trodden masses of Nigeria.

ACKNOWLEDGEMENTS

Blessed is the name of God through his son Jesus Christ for his unshaken love and mercy shown to me throughout my undergraduate study. My great and profound gratitude goes to my supervisor, Engr. Dr. N. A. Egharebva, for his guidance, instruction and help during the cause of this project work. I sincerely appreciate your fatherly way in which you guided me throughout the project period. I also appreciate the encouragement from my first year level adviser Engr. (Mrs.) H. I. Mustapha who charged me to study hard throughout my five years in order to be a responsible leader of my classmates. I acknowledge the motherly help, instructions and advice of my level adviser Mrs. B. A. Orhebva who encourage and treated me like her own son throughout my academic year, may the good Lord bless your children. Worth of mention is the immerse contribution of all my lecturers from first year to this present year, especially all the lecturers of the Department of Agricultural and Bioresources Engineering, Federal University of Technology, Minna. I am so grateful to my parents Evang. J. O. Kolade and Mrs. A. M. Kolade, I thank you for your strive day and night in order to establish me as an independent man. My thanks also extend to my brothers, Engr. Seyi and Adefisayo, also to my sisters Ayobami and Anuoluwapo and to my beautiful niece, Sarah Oluwafunbi. I extend my appreciation to my close friends, Matthew Udekwe, Christopher, Augustine, Euphemia, Daniel, Baliat, Mark and all my colleagues that gave me their support throughout my years as a student of FUT Minna. I acknowledge the love of all members of ABE 500, including my project group colleagues, Teri, Oluwatosin, Olawale and Moses.

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ABSTRACT

Hand-dug wells are important sources of water for drinking and other domestic functions; however, they are under threat from pollution and have become a thing of health concern both in urban and rural areas. This prompted the project work to the subject of assessing quality of water from the hand-dug wells of Central parts of Bosso Local Government of Niger State. Water samples were collected from 3 different wells. The water samples were analyzed for physical, chemical and bacteriological parameters present. The parameters examined were Turbidity, Color, Suspended Solids, Electrical Conductivity, pH, Nitrate, Nitrite, Sulphate, Fluoride, Copper, Chloride, Ammonia, Hardness, HCO_3^- , PO_4^{3-}, BOD, COD and Coliform count. The results obtained for Turbidity, Color, Suspended Solids, Electrical Conductivity, Iron and Escherichia Coliform were 363ftu, 2120PtCo, 259mg/l, 1110us/cm, 1.49mg/l and 460cfu/100ml respectively. These results were compared with WHO standard and Nigeria Standard for Drinking Water Quality, in order to ascertain the safety of this water and their conformity with the specified standards. However, the high values of these parameters which are above the permissible WHO/NSDWQ values are of great concern to the public health when the water from these wells is consumed by people without treatment. The water from the sampled wells should be treated before consumption and the wells should be properly covered.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

Water is considered to be one of the most important natural resources in the life of man, animal and plants, without it, their survival will be rear. The concept of water as a natural resource is essential, as growing population with corresponding food demand ever increases the demand as well as the supply of quality water. The importance of this natural resource cannot be over emphasized base on the fact that man's prime need in his environment is for good quality water for domestic and other potential use. It is therefore essential that the extent of water consumption should be proportional to the treatment given and its corresponding quality (Solley et al. 1998).

However, anthropogenic pressure and other sources of contaminants reduce the degree of quality possessed by this free gift of nature. Liquid and solid wastes from human environment therefore increase the unpleasant and unhealthy condition of water. The safety and reliability of water for various activities require that, it must satisfy the standard qualitative requirement recommended by international organizations. These requirements are classified base on their possessed parameters and these are; Physical, Chemical and Biological. In this wise, water quality can then be said to be a measure of the condition of water relative to the requirements of one or more biotic species and or to any human need or purpose (Murdoch et al., 1998). However, parameters for water quality are determined by the intended use.

1.2 Historical water-quality data

Reliable data that could be used to establish a baseline for drinking-water quality in the country are hard to come by. The water supply data that do exist come mostly from state water agencies and other sources, such as the Federal Office of Statistics (MICS, 1999), the Federal Ministry of Water Resources and UNICEF. While urban water supply agencies carry out routine water quality analyses at the treatment plants on a daily or weekly basis, there is usually no record kept of the results of such analyses. Rural water supply and sanitation agencies do not carry out routine water quality tests, but usually do water quality test on every new borehole drilled to ascertain that it is suitable for human consumption. Also, the format for data gathering is not uniform across the Nigerian states that do keep records of their water quality data and there are no specific guidelines as to which parameters are to be tested.

Prior to the Rapid Assessment of Drinking-Water Quality (RADWQ) project, a rapid assessment of water quality was carried out nationwide in 2003. The goal was to examine the status of water quality management in the country and to discover any problems of water quality in the supply system. The assessment revealed that the iron content was high in virtually all groundwater-based water supplies, and that high turbidity was a common problem for supplies relying on surface water, especially in the rainy season when rivers carry a high sediment load (Ince et al., 2010). For some water supplies, public health was a real concern owing to the levels of chemicals that were either of natural geological origin (from rock-water interaction), or of anthropogenic origin (caused by human activities). The preliminary assessment from the RADWQ project also identified the following concerns (Ince et al., 2010):

i) Fluoride levels were elevated in water supplies in parts of Gombe (Kaltungo, Billiri, Gombe, Pindiga and Dass) and Plateau States (Langtang area), as well as in some boreholes from Abia State.

ii) There were appreciable levels of cyanide in groundwater from boreholes in Gombe Township.

iii) Arsenic was present at one location (an abandoned mining pond used for water supply) in Bukuru, Plateau State.

iv) Saltwater intrusion threatened water supplies in the coastal zones, which could put large populations at risk of water shortages and associated hazards.

v) The groundwater in inland basins was contaminated by saline (e.g. in the Uju, Guma and Songo areas of Benue State).

In urban and pre-urban settings across the country, there is a real threat that shallow groundwater and streams will become polluted from on-site sanitation systems, industrial effluent discharges and nonpoint pollution sources. Some of the major water supplies are drawn from rivers that are heavily polluted by chemical and biological industrial discharges, and by domestic septic tanks.

1.3 Statement of the Problem

Groundwater, such as water from hand-dug well is an important water resource in both urban and rural area of Nigeria, but in the cities, pipe-borne water is also available. Rural dwellers rely basically on hand-dug wells for portable water supply as the streams usually dry up in the dry season. These resources are under threat from pollution either from human life style manifested by the low level of hygiene practice in the developing nations. Environmental health involves all the factors, circumstances and conditions in the environment or surroundings of human's that can influence health and well being. The neglect of rural and semi urban areas such as Bosso Local

Government Area in terms of basic infrastructure such as pipe borne water and sanitation facilities has exposed the villagers to health related problems, such as water borne diseases.

1.4 Objectives of the Study

The objectives of the study are to:

i.) Analyse the physical, chemical and biological parameters in water from some hand-dug wells in Bosso L.G.A.,

ii.) Interprete the results and

iii.) Compare the observed results with national and international water standards.

1.5 Justification of the Study

The justifications of the study are itemized below:

i.) The quality of water from hand-dug wells should be assessed in order to protect the health of individuals and community using the water for domestic and drinking purposes.

ii.) Assessment of the water quality provides the basis for control, monitor and development of management strategy for protecting water quality.

iii.) The study will also contribute to the data bank on the water pollution study in the environment.

1.6 Scope of the Study

The assessment of the quality of the water from hand-dug wells in Bosso local government areas of Niger state was limited to rainy season period (June to September 2011), due to time and resources constraint.

CHAPTER TWO

2.0 REVIEW OF LITERATURE

2.1 Water Quality

Water quality affects all humans, animals, wildlife and crops. It's becoming increasingly important as population increases and the need for food and fiber expands, however, increasing use of fertilizers and pesticides, farming operations, irrigation and drainage practices, agricultural and municipal wastes and other factors have contributed to a general decrease in water quality with time (Schwab, et al., 1993). Water quality is determined by the concentration of biological, chemical and physical contaminants. Most water pollution is the result of human activities. Biological contaminants results from human and animal wastes plus some industrial processes. Chemical enters the water through industrial processes and agricultural use of fertilizers and pesticides. Physical contaminants result from erosion and disposal of solid waste. Since all these sources contribute to degradation of water quality, standards have been developed for drinking water by the Nigeria Standard for Drinking Water Quality(NSDWQ), World Health Organization(WHO), U.S. Public Health Service(USPHS), Ireland Environmental Protection Agency(IEPA), to mention but a few. These standards strive to prevent health problems by defining the quality of water available for human consumption. Many local, state and federal regulations have been instituted to prevent contamination of surface and ground water supplies. However, sources of water pollution are recognized as point or non point in origin. Point sources include animal feedlots, chemical dump sites, storm drain and sewer outlets, acid mine outlets and other identifiable points of origin. Nonpoint sources include runoff from forest and agricultural land, hillside seepage, small subsurface drain outlets and other diffuse sources. Nonpoint pollution is often more difficult to identify and to correct (Schwab et al., 1993).

2.2 Classification of Water

The existence of water is in three phases, which are physical in nature i.e. solid, liquid and gas. It is present in greater or lesser quantities in or on virtually all the earth, its atmosphere and all things either living or dead. The importance of these resources from the standard point of water resource development falls into the group of atmospheric water, surface water and subsurface water. However, atmospheric water and precipitation are the source of replenishment of surface and subsurface water. Surface and subsurface water are the direct source of our developable water resources, (Schwab et.al, 1993).

2.2.1 Ground Water

Ground water is mostly referred to as the subsurface water available for development. It results predominantly from precipitation that has got to the zone of saturation in the earth through the process of infiltration and percolation. The development of ground water for use is through wells, springs or dugout ponds, (Schwab et at., 1993).

2.2.2 Well

Water well is a hole drilled in the ground for the purpose of extracting groundwater. The well may be tube well or shallow well in nature (World vision International, 2011). On the other hand, water well is expressed as a hole, usually vertical, extending into the water-bearing formation bellow the ground surface (Michael and Ojha, 2006). However, a shallow well as described by World Vision International is a well bellow 8m of depth, which is excavated by commonest hand tools. Moreover, Michael and Ojha, (2006) classified shallow wells as wells having a pumping water level at 6m or less from the ground surface.

2.3 Groundwater Composition

2.3.1Physical and Chemical Properties

A water molecule consists of two atoms of hydrogen (H) and of oxygen (O), so it has the chemical formula H_2O. At sea level, its freezing point is 0^0C and its boiling point is 100^0C. Water is good solvent and natural water always contain some chemicals in solution. The total amount of dissolved solids in a water sample (TDS) is expressed in mg/l and water is classified according to the TDS as fresh, brackish, saline or brine. The limit in this classification varies from country to country and even from study to study. The major cations in groundwater are usually sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}) and the major anions are chloride (Cl^-) bicarbonate (HCO_3^+), sulphate (SO_4^-) and nitrate (NO_3^-). Among the solute that occur in minor amounts the following are mentioned, because of their influence on the water use: iron (Fe; taste and staining), boron (toxicity to plants), fluoride (F; health risk), aluminum (Al; health risk), nitrate (NO_3^-; health risk). Very small amounts of other ions, usually called trace elements are often present in natural water. Furthermore, small amounts of the isotopes of hydrogen, such as Deuterium 2H, Tritium 3H and oxygen 180 occur in natural waters. Groundwater that comes from the deep aquifers (>200m) or from aquifers in contact with subterranean (volcanic) heat sources may have high temperature and may be use as a source of geothermal energy. Water with a particular chemical composition may be exploited as 'mineral water' for bottling and for 'medical' use in health resorts (Anderson and Woessner, 1992).

2.4 Groundwater hydrology

Groundwater hydrology is the science of water in the unsaturated and saturated zones below the earth's surface. The profile of the earth is divided into two primary rock zones; the zone of rock fracture and the zone of flowage. In the zone of rock fracture, interstitial water is contained in the pores of the soil or in the interstices of gravel and rock formation. Groundwater however, occurs only in the zone of saturation, while the water that exists in unsaturated zone may be referred to as perched water. Meanwhile, good example of perched and ground water tables can be observed shallow and deep wells, respectively (Schwab et al., 1993). Since the depth of perched water is shallow, groundwater, which extends continuously downward, is of greater importance. Groundwater is often referred to as pheutic (well) water. Formation from which groundwater is derived in the zone of saturation have considerably different characteristics than the soil near the surface. A good water bearing formation has high hydraulic conductivity and high drainable porosity, called specific yield, as shown in Table 2.1. Sand and gravel have high conductivity characteristics, although fractured limestone and rock formation are also good aquifers. However, movement of water in aquifers is highly dependent of the permeability of the aquifer material. Permeable material possesses interconnected cracks or spaces that are both numerous enough and large enough to allow water to move freely. In some permeable materials groundwater may move several meters in a day; in other places, it moves only a few centimeters in a century. Groundwater moves very slowly through relatively impermeable materials such as clay and shale.

Table 2.1 Approximate Characteristics of Good Water Aquifers

Soil Material	Total Porosity (%)	Specific Yield (%)	Relative Hydraulic Conductivity
Dense Limestone/Shale	5	2	1
Sandstone	15	8	700
Gravel	25	22	5000
Sand	35	25	800
Clay	45	3	1

Source: Schwab et al. (1993)

2.5 Hydrological Cycle

The hydrological cycle, also known as the water cycle, is the constantly-occurring process whereby, in simplified terms, water falls to the ground as rain, or other precipitation, runs along the ground under the force of gravity or percolates down to an impermeable layer of soil or rock, appears again at the surface, eventually reaches the sea or a lake and evaporates to form clouds which produce rain. This process is represented graphically in Figure 2.1. In its use of water for various activities, the world's population intervenes in this cycle at a number of points. For the purpose of this project, interest is only in the exploitation of water as it passes through shallow aquifers, when it is referred to as groundwater (Seamus, 2000).

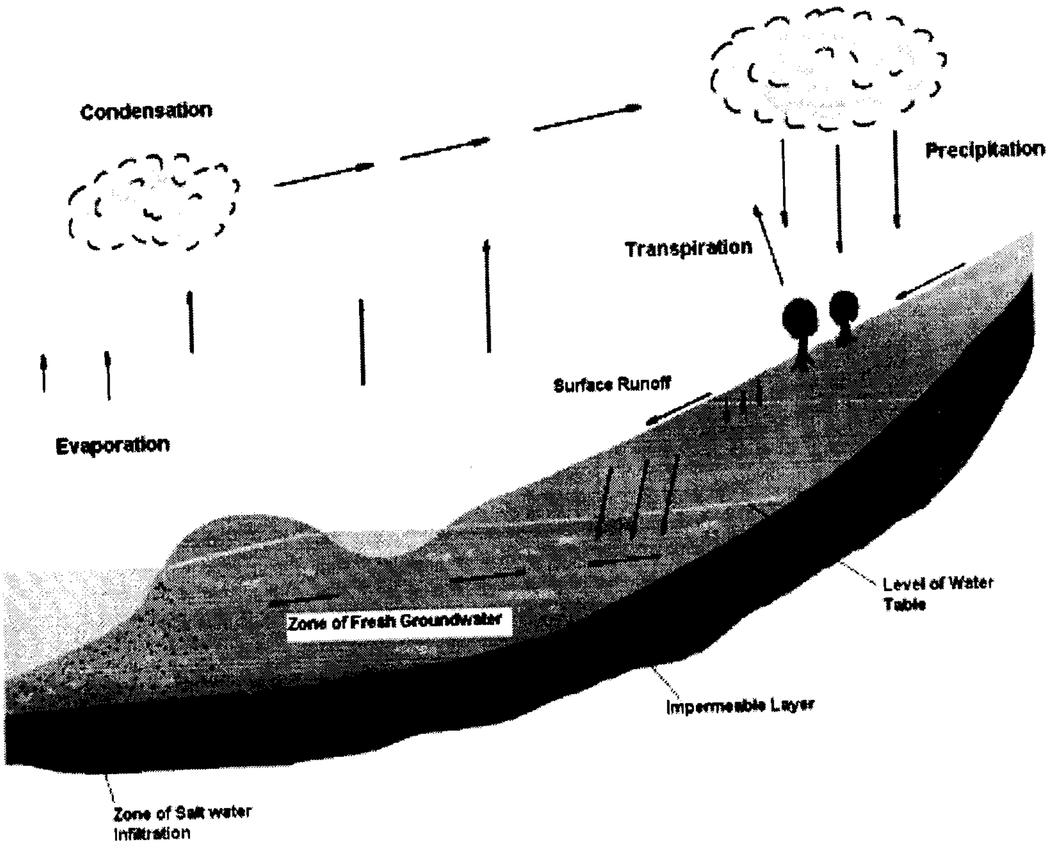

Fig 2.1 Hydrological Cycles (Seamus, 2000)

2.6 Types of Aquifer

Figure 2.2 illustrates the various types of aquifer which can occur. Aquifers may be classified broadly in three categories, namely;

Confined aquifers, are water-bearing strata which lie between two impermeable layers. Water in these aquifers is often under pressure and, if the upper impermeable layer is breached by a borehole, the water from the aquifer will rise to its piezometric level. Where this piezometric level is above ground level, water will emerge from the borehole under pressure and will gush up into the air. This is referred to as an artesian well. In a case where the piezometric level is below ground level, but above the level of the top of the confined aquifer, this is known as a subartesian well. The piezometric pressure line refers only to the water in the confined aquifer

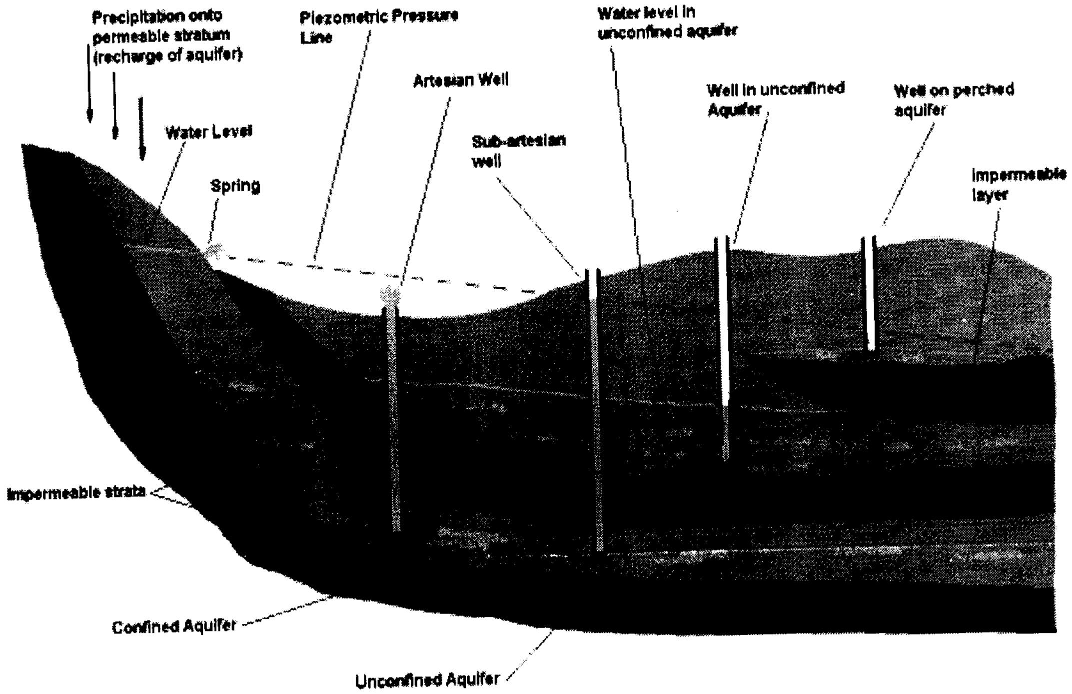

Fig 2.2 Types of Aquifer (Seamus, 2000)

Unconfined aquifers occur when the water bearing stratum is not covered by an impermeable layer. In this situation, the water in the aquifer is not under pressure, and will not rise in a borehole or well which reaches the level of the aquifer. The level of water in this aquifer will fluctuate with the seasons.

Perched aquifers are a special case of unconfined aquifers. These occur where water, as it percolates down from the surface, is trapped by an isolated impermeable layer, of limited extent, within otherwise permeable strata. Unless the impermeable stratum is very extensive, a perched aquifer is recharged only by locally-occurring rainfall and will provide at best a seasonal supply of water (Seamus, 2000).

2.7 Water Contaminants

2.7.1Biological Contaminants

In agriculture, biological contaminants are primarily from animal and human waste. Feedlots, dairies and septic systems are major sources of biological pollution. Bacteria are the most common organisms; however, viruses and other microorganisms may also be present and all can create serious health problems. Biological contamination can be controlled by proper disposal of wastes; separation of septic systems, feedlots and other sources from drinking and surface water supplies; and treatment of drinking water before consumption (Schwab et al,1993).

2.7.2 Chemical Contaminants

Chemicals are a major source of water contaminants. Some chemicals occur naturally in the water, others are introduced during water movement through geological materials, but most problems are caused by manufactured chemicals. Fertilizers and pesticides are the major contributors to chemical pollution from agriculture. These chemicals may be applied to soil or foliage over large areas and hence become potential sources of nonpoint pollution; however, fertilizer and pesticides have contributed to a high quality and abundant food supply at reasonable cost. Nitrates are a common chemical pollutant of water. Estimate indicate that U.S. cropland received 10.4 million tons of nitrogen in 1986 through nitrogen fertilizers(USDA, 1988) and similar amount through animal manures, crop residue and natural sources. A maximum nitrate concentration greater than 3 mg/L was found in 20 percent of 124,000 wells analyzed over a 25year period (Madison and Brunett, 1985). Nitrate concentration greater than 3 mg/L usually relates to human activities such as fertilizer applications and septic systems. The U.S. federal drinking water standard of 10 mg/L was exceeded in 6 percent of the samples.

In U.S., forty-six pesticides have been detected in ground water and confirmed to come from nonpoint sources (Williams et al., 1988). One or more pesticides have been detected in the ground water of 26 states and attributed to agricultural use. The most common detected pesticides are atrazine and aldicard. Pesticides usage was about 300,000 kg in 1988(USDA, 1988a). Gianessi and Puffer (1988) reported that the cornbelt states used more than 59 percent of the U.S. total.

The development and implementation of practices and policies to reduce water contamination by agriculture are essential. A better understanding of the fundamental processes affecting the transport and fate of agricultural chemicals must be developed. This knowledge must be used to develop new or improved farming systems that protect, improve or remediate the quality of water supplies.

2.7.3 Physical Contaminants

The most common physical contaminant of water is suspended sediments. Other physical contaminants include organic materials such as plant residues. Most sediment occurs because of soil erosion; however, sand may be obtained during pumping from wells. Where sediment is deposited on sandy soil, the textural composition and fertility may be improved; however, if the sediment has been derived from eroded area, it may reduce fertility or decrease in soil permeability. Eroded sediments not only indicate erosion loss, but carry attached chemical ions, such as phosphorus and potassium, which contribute to chemical pollution as well. Sediment must be removed from water used in micro irrigation system to prevent plugging. Sands may cause excessive wear to pump impellers and to the nozzles in sprinkler irrigation systems (Schwab et al., 1993).

2.8 Environmental impact on water quality

The quality of water resources can be as important as or even more important than water quantity. Water quality affects natural ecosystems, human health, and economic activities. At the same time, human activities directly affect water quality. Concentrated pollutants entering surface waters from specific locations (point-source discharges) and dispersed pollutants generated from local or small-scale activities (non-point source discharges) add large quantities of nutrients, pathogens, and toxins to the nation's water resources. These problems are often exacerbated by human withdrawals of water for myriad uses, which can lead to concentrations of contaminants. Global climate changes have the potential to significantly alter water quality by changing temperatures, flows, runoff rates and timing, and the ability of watersheds to assimilate wastes and pollutants. Higher flows of water could reduce pollutant concentrations or increase erosion of land surfaces and stream channels, leading to higher sediment, chemical, and nutrient loads in rivers. Changes in storm flows will affect urban runoff, which already has adverse water-quality impacts on discharges to the oceans. Lower flows could reduce dissolved oxygen concentrations, reduce the dilution of pollutants, and increase zones with high temperatures. For almost every water body or source of water, land use and agricultural practices have a significant impact on water quality. Changes in these practices, together with technical and regulatory actions to protect water quality, can be critical to future water conditions. The net effect on water quality for rivers, lakes, and groundwater in the future therefore depends not just on how climate conditions might change but also on a wide range of other human actions (Gleick, 2000). In a review of potential impacts of climate change on water quality, Murdoch et al. (2000) conclude that significant changes in water quality are known to occur as a direct result of short-term changes in climate. They noted that water quality in ecological transition zones and areas of natural climate extremes is vulnerable to climate changes that increase temperatures or change the variability of precipitation and argue that changes in land and resource use will have comparable or even greater impacts on water quality than changes in temperature and precipitation. They recommended that long-term monitoring of water quality is critical for identifying severe impacts, as in developing appropriate management strategies for protecting water quality. Water quality is a direct result of the chemical inputs received from air and the surrounding land and the biogeochemical processes that transform those inputs (Murdoch et al., 2000). Direct chemical contributions come from atmospheric deposition or point source discharges. Indirect contributions come from water that flows off watersheds through vegetation, soils, and aquifers, each of which contributes to water chemistry. Climate changes will influence water quality by altering these contributions, particularly through changes in temperature and moisture. A comprehensive summary of many of these changes can be found in Murdoch et al. (2000). Global and regional increases in air temperature, and the associated increases in water temperature, are likely to lead to adverse changes in water quality, even in the absence of changes in precipitation. The southeastern U.S., for example, has significant variability in stream flow due to seasonal changes in evapotranspiration rates. Mulholland et al. (1997) projected increased rates of oxygen depletion in already eutrophied waters of this region if global warming occurs. Warming has been shown to increase the rate of biological production and decomposition by increasing rates of metabolism, the duration of the growing season, and the volume of lakes that are biologically active (Covich et al., 1997, Hauer et al., 1997). In oxygen-poor waters, increased productivity could lead to oxygen depletion, which would subsequently limit overall productivity. Fang and Stefan (1997) evaluated changes in lake stratification in cold regions of the north-central United States under conditions of climate changes. They showed that winter stratification would be weakened as average temperatures increased and that the anoxic zone could disappear. Moore et al., (1997) reported that increased water temperatures enhance the toxicity of metals in aquatic ecosystems and that increased lengths of biological activity could lead to increased accumulation of toxics in organisms. Ironically, increased bioaccumulation could decrease the concentration of toxics in the water column, improving local water quality. Similarly, higher temperatures may lead to increased transfer of chemicals from the water column to sediments. Changes in terrestrial ecosystems will also lead to changes in water quality by altering nutrient cycling rates and the delivery of nutrients to surface waters. Nitrification rates in soils are temperature dependent and in some regions, mean annual nitrate concentrations in streams are highly correlated with average annual air temperature (Murdoch et al., 1998). Similarly, a significant correlation has been observed between soil respiration rates and temperature. Alexander et al., (1996) looked at nutrient loadings to coastal zones as a function of stream flow volume. Stream flows along Atlantic coast states increased 55 under many climate scenarios, nutrient loads also increased. Extended droughts in boreal regions have been shown to increase the risk of acidification of streams due to the oxidation of pools of organic sulfur in soils (Schindler, 1997). Ultimately, the water quality response to climate change will depend on specific temperature changes, biogeochemical processes, existing thresholds for plant and animal species, and other factors. Changes in precipitation will also play a crucial role by affecting water quantity, flow rates, and flow timing. Decreased flows can exacerbate temperature increases, increase the concentration of pollutants, increase flushing times, and increase salinity in arid regions (Schindler 1997, Mulholland et al., 1997). Decreased surface-water volumes can increase sedimentation, concentrate pollutants, and reduce non-point source runoff (Moore et al., 1997, Rouse et al., 1997, Mulholland et al., 1997). Where surface runoff decreases, erosion rates and sediment transport may drop and lake clarity may increase with increased penetration of ultraviolet-B (UV-B) radiation (Murdoch et al., 2000). Increases in water flows can dilute point-source pollutants, increase loadings from non-point source pollutants, decrease chemical reactions in streams and lakes, reduce the flushing time for contaminants, and increase export of pollutants to coastal wetlands and deltas (Jacoby 1990, Mulholland et al. 1997, Schindler 1997). On the other hand, higher flows increases turbidity in lakes and reduce UV-B penetration.

2.9 Water analyses

All analyses should be made in accordance with the Standard Methods. The interpretation of water analyses is based primarily on the sanitary survey of the water system and an understanding of the criteria used in the development of the standards used to establish water quality. A water supply that is coagulated and filtered will be expected to be practically clear, colorless and free of iron, whereas the presence of some turbidity, color and iron in an untreated surface water supply may be accepted as normal. According to Salvato (1992), a properly developed, protected and chlorinated well water supply showing an absence of coliform organisms can usually be assumed of being free of viruses, protozoa and helminthes if supported by a satisfactory sanitary survey. However, chemical examinations are needed to ensure the absence of toxic organic and inorganic chemicals. In view of this, the results of a microbiological or chemical examination reflect the quality of the water only at the point of sampling and must be interpreted in the light of the sanitary survey. Moreover, inorganic chemical examination results from well water supplies are not likely to change significantly from day to day or week to week when collected under the same conditions. Nevertheless, any change is an indication of probable contamination and reason for investigation to determine the cause. The chemical characteristics of well water are a reflection of the geological formations penetrated.

2.9.1 Physical Analyses

Electrical Conductivity: This reflects the mineral salt content of water and it is also referred to as *electrical conductivity* and, not wholly accurately as *specific conductance*, the conductivity of water is an expression of its ability to conduct an electric current. As this property is related to the ionic content of the sample which is in turn a function of the dissolved (ionisable) solids concentration, the relevance of easily performed conductivity measurements is apparent. In itself conductivity is a property of little interest to a water analyst but it is an invaluable indicator of the range into which hardness and alkalinity values are likely to fall, and also of the order of the dissolved solids content of the water. While a certain proportion of the dissolved solids (for example, those which are of vegetable origin) will not be ionised (and hence will not be reflected in the conductivity figures) for many surface waters the following *approximation* will apply:

Conductivity (µs/cm) x 2/3 = Total Dissolved Solids (mg/l).

In samples from a source which is regularly tested, a rapid conductivity analysis may be an adequate replacement for other, longer determinations. It is important to note that there is an interrelationship between conductivity and temperature, the former increasing with temperature at a rate of some 2 per cent per degree C rise (EPA, 2001). There is a regrettable lack of uniformity in the terms in which conductivity is reported. Some UK methods manuals report the results at 20°C while the standard US reference manual uses 25°C. A difference of 10 percent can therefore arise depending on how the results are quoted. An error of this magnitude could not be tolerated, especially where conductivity readings are being used to estimate salinity.

Odor: Odor should be absent or very faint for water to be acceptable, less than 3 threshold odor number is permissible (Salvato, 1992). Water for food processing, beverages and pharmaceutical manufacture should be essentially free of taste and odor. The test is very subjective, being dependent on the individual senses of smell and taste. The cause may be decaying organic matter, wastewater including industrial wastes, dissolved gasses and chlorine in combination with certain organic compounds such as phenols. Odors are sometimes confused with tastes. The sense of smell is more sensitive than taste. Activated carbon adsorption, aeration, chemical oxidation (chlorine, chlorine dioxide, ozone, potassium permanganate) and coagulation and filtration will usually remove odors and tastes. Priority should first be given to a sanitary survey of the watershed drainage area and the removal of potential sources or causes of odors and tastes.

Taste: The taste of water should not be objectionable; otherwise, the consumer will resort to other sources of water that might not be of satisfactory sanitary quality. Algae, decomposing organic matter, dissolved gases, high concentrations of sulfates, chlorides and iron or industrial waste may cause taste and odors. Bone and fish oil and petroleum products such as kerosene and gasoline are particularly objectionable. Phenols in concentrations of 0.2 ppb in combination with chlorine will impart a phenolic or medicinal taste to drinking water. The taste test like the odor est is very subjective and may be dangerous to the laboratory personnel. As in odor, emphasis should be placed on the removal of potential causes of taste problems.

Turbidity: Turbidity is due to suspended material such as clay, silt, or organic and inorganic materials. Drinking water regulations required that the maximum contaminant level for turbidity not exceed one turbidity unit as determined by a monthly average. A 2-day turbidity average may not exceed five turbidity units. A monthly average of five turbidity units may be permitted by the regulatory agency if it can be demonstrated that he turbidity does not interfere with disinfection, the maintenance of a minimum of 0.2 mg/l free chlorine residual at representative points within the distribution system, or microbiological determinations. Turbidity measurements are made in terms of Nephelometric Turbidity Units (NTU) and Formazin Turbidity Units (FTU) and

Jackson Turbidity Units (JTU). The lowest turbidity value that can be measured directly on the Jackson candle turbidmeter is 25 units. There is no direct relationship between NTU or FTU readings and JTU readings (Clesceri et al., 1989). NTU is the standard measure, requiring use of a nephelometer, which measure the amount of light scattered, usually at 90° from the light direction, by suspended particles in the water test sample. It can measure turbidity less than one unit and differences of 0.02 units. Turbidity is a good measure of sedimentation, filtration and storage efficiency, particularly if supplemented by the total microscopic and particle count. Turbidity will interfere with proper disinfection of water, harbor microorganisms and cause taste and odors. An increase in turbidity of well water after heavy rains may indicate the entrance of inadequately purified groundwater.

Color: Color should be less than 15 true color units, although persons accustomed to clear water may notice a color of only 5 units. The goal is less than 3 units. Color is caused by substances in solution, known as true color and by substances in suspension, mostly organics causing apparent or organic color. Iron, copper, manganese and industrial wastes may also cause color. Water that has drained through peat bogs, swamps, forests, or decomposing organic matter may contain a brownish or reddish stain due to tannates and organic acids dissolved from leaves, bark and plants. Excessive growths of algae or microorganisms may also cause color.

Temperature: The water temperature should preferably be less than ambient. Ground waters and surface waters from mountainous areas are generally in the temperature range of 10 to 16^0C. Design and construction of water systems should provide for burying or covering of transmission mains to keep drinking water cool and prevent freezing in cold climates or leaks due to vehicular traffic. High water temperatures accelerate the growth of nuisance organisms and taste and odor problems are intensified. Low temperatures somewhat decrease the disinfection efficiency.

pH: It is a physical characteristic of all waters/solutions. By definition, pH is the negative logarithm of the hydrogen ion concentration of a solution and it is thus a measure of whether the liquid is acid or alkaline. The pH scale (derived from the ionization constant of water) ranges from 0 (very acid) to 14 (very alkaline). The range of natural pH in fresh waters extends from around 4.5, for acid, peaty upland waters, to over 10.0 in waters where there is intense photosynthetic activity by algae. However, the most frequently encountered range is 6.5-8.0.

In waters with low dissolved solids, which consequently have a low buffering capacity (i.e. low internal resistance to pH change), changes in pH induced by external causes may be quite dramatic. Extremes of pH can affect the palatability of water but the corrosive effect on distribution systems is a more urgent problem (see Appendix 4). The effect of pH on fish is also an important consideration and values which depart increasingly from the normally found levels will have a more and more marked effect on fish, leading ultimately to mortality. The range of pH suitable for fisheries is considered to be 5.0-9.0, though 6.5-8.5 is preferable.

Apart from the aspects just mentioned, pH values govern the behavior of several other important parameters of water quality. Ammonia toxicity, chlorine disinfection efficiency, and metal solubility are all influenced by pH.

2.9.2 Chemical Analyses

Ammonia (NH_3): From the viewpoint of human health the significance of ammonia is marked because it indicates the possibility of sewage pollution and the consequent possible presence of pathogenic micro-organisms. The form of the ammonia - whether it is "free" (as NH_3) or "saline" (as NH_4^+) in slightly acid waters - depends on the pH and these forms are not distinguished from one another during analysis. The different terms commonly applied to the forms of ammonia are as follows:

total ammonia (NH_3 &NH_4^+), *total ammonium* (NH_3& NH_4^+)

free ammonia (NH_3) *free and saline ammonia* (NH_3 &NH_4^+)

ionised ammonia (NH_4^+) *and un-ionised ammonia* (NH_3).

The different forms arise from the pH/temperature related equilibrium reactions:

1) $NH_3 + H_2O \Leftrightarrow NH_3.H_2O$
2) $NH_3.H_2O \Leftrightarrow NH_4^+ + OH^-$.

Arising from the complex relationship between total ammonia concentration, pH and temperature there emerges a level for total ammonia of around 0.3 mg/l NH_3 which is considered to be that which would contain the limiting amount of un-ionised ammonia. Because of the ease of natural interconversion from one form to another - this could be brought about by pH changes caused by algal activity, for example – the total ammonia levels should be very low.

Before the advent of microbiological techniques for assessing the portability of water, the analysis for ammonia was used as an indication of sewage contamination, often in conjunction with chloride, because both are present in significant quantities in sewage. The formation of chloramines compounds (which are much less potent disinfectants than free chlorine) by reaction between the added chlorine and the ammonia present in the water necessitates an increased use of chlorine if disinfection efficiencies are to be maintained.

Calcium (Ca): Calcium naturally occurs in rocks, bones, shells etc in abundant and high levels may be beneficial, while water which are rich in calcium are very palatable. However, this element is the most important and abundant in the human body and an adequate intake is essential for normal growth and health. The maximum daily requirement is of the order of 1 - 2 grams and comes especially from dairy products. There is some evidence to show that the incidence of heart disease is reduced in areas served by a public water supply with a high degree of hardness, the primary constituent of which is calcium, so that the presence of the element in a water supply is beneficial to health. Though, despite the potential health benefits of calcium abundance there are problems associated with hardness.

Chloride (Cl^-): Chloride exists in all natural waters, the concentrations varying very widely and reaching a maximum in sea water (up to 35,000 mg/l Cl^-). In fresh waters the sources include soil and rock formations, sea spray and waste discharges. Sewage contains large amounts of chloride, as do some industrial effluents. Chloride does not pose a health hazard to humans and the principal consideration is in relation to palatability. At levels above 250 mg/l Cl^- water will begin to taste salty and will become increasingly objectionable as the concentration rises further. However, external circumstances govern acceptability and in some arid areas waters containing up to 2,000 mg/l Cl are consumed, though not by people unfamiliar with such concentrations. High chloride levels may similarly render freshwater unsuitable for agricultural irrigation. Because sewage is such a rich source of chloride, a high result may indicate pollution of water by a sewage effluent. Natural levels in rivers and other fresh waters are usually in the range 15-35 mg/l Cl^- much below drinking water standards. What is normally important to note in a series of results from a river, for example, is not the absolute level, but rather the relative levels from one sampling point to another. An increase of even 5 mg/l at one station may give rise to suspicions of a sewage discharge, especially if the free ammonia levels are also elevated. In coastal areas, however, elevated chloride values may be due to sea spray, or sea water infiltration, and not necessarily to discharges. Normal raw water treatment processes do not remove chloride.

Copper (Cu): Copper is not particularly toxic to humans (indeed, it is an essential dietary requirement) and medicinal doses up to 2.0 mg/l are not unknown. However, astringent tastes in water can be caused by levels above 1 mg/l Cu. This element is present naturally in metalliferous areas but more often its presence in waters is due to attack on copper piping. Rarely, its occurrence may be due to its use as an algicide. Unless used with great care for algal control there is a grave risk of fish kills, as it is as a toxicant to fish that copper is of greatest interest. In recent years there has been at least one major fish kill attributed to the improper use of copper as an algal toxicant. Copper is an element the toxicity of which to fish varies widely with the hardness of the water. A problem associated with high levels of copper in water is galvanic corrosion of tanks.

Fluoride (F): This occurs naturally in quite rare instances; arises almost exclusively from fluoridation of public water supplies and from industrial discharges. Health studies have shown that the addition of fluoride to water supplies in levels above 0.6 mg/l F leads to a reduction in tooth decay in growing children and that the optimum beneficial effect occurs around 1.0 mg/l. At levels markedly over 1.5 mg/l an inverse effect occurs and mottling of teeth (or severe damage at gross levels) will arise. For this reason there is a constraint on fluoride levels, the effects of which vary with temperature.

Fluoride levels in fluoridated public water supplies in Ireland are legally restricted to the range 0.8-1.0 mg/l F. The same legislation specifies the distillation procedure for fluoride analysis. In making the 1988 Drinking Water Regulations, the then Minister for the Environment fixed 1.0 mg/l F [1,000 µg/l F] as the MAC. Thus the limit value for fluoride in Ireland is one-third less than that which applies elsewhere in the EU, while NSDWQ specify the range between 0 to 2.00mg/L F^-.

Hardness: Hardness is a natural characteristic of water which can enhance its palatability and consumer acceptability for drinking purposes. Health studies in several countries in recent years indicate that mortality rates from heart diseases are lower in areas with hard water.

Hardness is originally taken to be the capacity of water to destroy the lather of soap, hardness was determined formerly by titration with soap solution. Nowadays, the analysis comprises the determination of calcium and magnesium which are the main constituents of hardness. Although barium, strontium and iron can also contribute to hardness, their concentrations are normally so low in this context that they can be ignored. Thus, *total hardness* is taken to comprise the calcium and magnesium concentrations expressed as mg/l $CaCO_3$. The widespread abundance of these metals in rock formations leads often to very considerable hardness levels in surface and ground waters. Table 2.2 is one of several such arbitrary classifications of waters by hardness:

Table 2.2 Classification of water by hardness

Class	**$CaCO_3$ mg/l**
Soft	Less than 50
Moderately Soft	50 to 100
Slightly Hard	101 to 150
Moderately Hard	151 to 250
Hard	251 to 350
Excessively Hard	Greater than 350

Source: EPA (2001)

A variety of additional terms is used to describe different aspects of hardness. These are frequently encountered and are summarized briefly below:

Calcium Hardness is the expression of the results of the measurement of calcium only, as mg/l CaCO3.

Carbonate Hardness is the hardness derived from the solubilisation of calcium or magnesium carbonate (by conversion of the carbonate to bicarbonate). This hardness is removed by heating.

Magnesium Hardness The difference between total hardness and calcium hardness is taken as the magnesium hardness (all figures as mg/l $CaCO_3^-$).

Non-carbonate Hardness is the hardness due to the solution of calcium chloride or magnesium sulphate, for example.

Permanent Hardness This is equivalent to non-carbonate hardness in that it cannot be reduced or removed by heating.

Temporary Hardness The same as carbonate hardness, this form may be removed by heating the waters, when chemical reactions occur as follows:

$$2HCO_3^{2-} \rightarrow H_2O + CO_2 + CO_3^{2-}$$

$$CO_3^{2-} + Ca^{2+} \rightarrow CaCO_3$$

Calcium Carbonate (insoluble)

This is in fact what happens in most cases when the temporary hardness is deposited as scale in boilers, etc.

Total Hardness is the expression of the results of direct measurement (principally of calcium and magnesium) expressed as mg/l $CaCO_3$.

As has been pointed out earlier (cf. "Copper") hardness levels have a bearing on the toxicity of some metals. In general, these toxic effects are markedly less in waters with a significant degree of hardness. The chief disadvantages of hard waters are that they neutralize the lathering power of soap (though not modern detergent formulations) and, more important, that they can cause blockage of pipes and severely reduced boiler efficiency because of scale formation. These effects will increase as the hardness rises to and beyond 200 mg/l CaCO3.

Iron (Fe): This element is as a result of geological formations (especially under reducing conditions); acid drainage; effluent discharges. The objections to iron are primarily organoleptic, but there has been recent medical concern about high levels in drinking water. Iron is present in significant amounts in soils and rocks, principally in insoluble forms. However, many complex reactions which occur naturally in ground formations can give rise to more soluble forms of iron which will therefore be present in water passing through such formations. Appreciable amounts of iron may therefore be present in ground waters. Severe problems can be caused in drinking water supplies by the presence of iron although there is normally no harmful effect on persons consuming waters with significant amounts of iron. Rather, the problems are primarily aesthetic, as the soluble (reduced) ferrous (Fe^{2+}) iron is oxidized in air to the insoluble ferric (Fei^{3+}) form, resulting in color or turbidity (or, in severe cases, precipitate formation). Laundry becomes stained if washed in water with excessive iron, and vegetables likewise become discolored on cooking. Taste problems may also occur. When waters rich in iron are used to make tea (in which tannins are present) there may be a reaction giving rise to off-color which may in severe cases resemble that of ink. Problems have been reported also with the addition of such waters to whiskey. The metal is quite harmful to aquatic life, as evidenced by laboratory studies, but in nature the degree of toxicity may be lessened by the interaction of the iron with other constituents of water. Should the metal be converted to an insoluble form then the iron deposits will interfere with fish food and with spawning.

Magnesium (Mg): Magnesium is a major constituent of geological formations. However, like calcium, magnesium is abundant and a major dietary requirement for humans (0.3-0.5 g/day). It is the second major constituent of hardness (see above) and it generally comprises 15-20 per cent of the total hardness expressed as $CaCO_3$. Its concentration is very significant when considered in conjunction with that of sulphate. Magnesium sulphate is used medicinally as "Epsom Salts," a laxative.

Nitrate (NO_3^-): This occurs as a result of oxidation of ammonia and through agricultural fertilizer runoff. 11gm/L N (50mg/L NO_2), is hazard to infants. Relatively little of the nitrate found in natural waters is of mineral origin, most coming from organic and inorganic sources, the former including waste discharges and the latter comprising chiefly artificial fertilizers. However, bacterial oxidation and fixing of nitrogen by plants can both produce nitrates. Interest is centered on nitrate concentrations for various reasons. Most importantly, high nitrate levels in waters to be used for drinking will render them hazardous to infants as they induce the "blue baby" syndrome (methaemoglobinaemia). The nitrate itself is not a direct toxicant but is a health hazard because of its conversion to nitrite which reacts with blood haemoglobin to cause methaemoglobinaemia. Of increasing importance is the degree to which fertilizer run-off can contribute to eutrophication problems in lakes. Sewage is rich in nitrogenous matter which through bacterial action may ultimately appear in the aquatic environment as nitrate. Hence, the presence of nitrate in ground waters, for example, is cause for suspicion of past sewage pollution or of excess levels of fertilizers or manure slurries spread on land. (High nitrite levels would indicate more recent pollution as nitrite is an intermediate stage in the ammonia-to-nitrate oxidation). In rivers high levels of nitrate are more likely to indicate significant run-off from agricultural land than anything else. However, it should be noted that there is a general tendency for nitrate concentrations in rivers to increase as a result of enhanced nutrient run-off; this may ultimately lessen their utility as potential sources of public water supply. Nitrite concentrations in rivers are rarely more than 1 - 2 per cent of the nitrate level so that it may therefore be acceptable to carry out the analytically convenient determination of nitrate + nitrite at the same time. This determination is correctly referred to as *total oxidized nitrogen.*

Nitrite (NO_2^-): Nitrite exists normally in very low concentrations and even in waste treatment plant effluents levels are relatively low, principally because the nitrogen will tend to exist in the more reduced (ammonia; NH_3) or more oxidized (nitrate; NO_3) forms, because nitrite is an intermediate in the oxidization of ammonia to nitrate, because such oxidation can proceed in soil, and because sewage is a rich source of ammonia nitrogen, waters which show any appreciable amounts of nitrite are regarded as being of highly questionable quality. Levels in unpolluted waters are normally low, below 0.03 mg/l NO_2, values greater than this may indicate sewage pollution.

The significance of nitrite (at the low levels often found in surface waters) is mainly as an indicator of possible sewage pollution rather than as a hazard itself although, as mentioned above under "Nitrate", it is nitrite rather than nitrate which is the direct toxicant. There is, accordingly, a stricter limit for nitrite in drinking waters. In addition, nitrites can give rise to the presence of nitrosamines by reaction with organic compounds and there may be carcinogenic effects.

Biochemical Oxygen Demand (BOD): Biochemical Oxygen Demand has no direct health implication, but it is an important indicator of overall water quality. However, when organic matter is discharged into a watercourse it serves as a food source for the bacteria present there. These will sooner or later commence the breakdown of this matter to less complex organic substances and ultimately to simple compounds such as carbon dioxide and water. If previously unpolluted, the receiving water will be saturated with dissolved oxygen (DO), or nearly so, and the bacteria present in the water will be aerobic types. Thus the bacterial breakdown of the organic matter added will be an aerobic process - the bacteria will multiply, degrading the waste and utilizing the DO as they do so. If the quantity of waste present is sufficiently large, the rate of bacterial uptake of oxygen will outstrip that at which the DO is replenished from the atmosphere and from photosynthesis, and ultimately the receiving water will become anaerobic.

Chemical Oxygen Demand (COD): Chemical Oxygen Demand is an indicator of overall water quality, having no direct hazard implication and it is natural or, more probably, added organic matter. Except in special cases, the five-day BOD analysis gives a measure of the oxygen demand of biodegradable carbonaceous matter in a sample. The oxidation is not complete and the five-day BOD value in a properly conducted test usually amounts to some 65 percent of the total carbonaceous oxygen demand. To measure the latter in the BOD test would take some four times as long and would involve special measures to counter the side-effects of oxidation of nitrogenous matter, the nitrification referred to above (Biochemical Oxygen Demand).

Dissolved Oxygen: This is a natural characteristic of clean waters. The importance of dissolved oxygen (DO) has already been touched upon in the section on BOD. The prime requirements for DO arise in connection with fish life and it is generally true that if water quality is suitable for fish it will also meet the criteria for most if not all other beneficial uses and be of good ecological status, as required by the Water Framework Directive. The cardinal point about the solubility of oxygen in water is that it has an inverse relationship with temperature (EPA 2001). The consequence is that the actual concentrations of DO in a river will be lowest in summertime when it is usually the case that the risk of damage to a water supply source or of environmental pollution is greatest, especially in areas developed as tourist centers or where such farming operations as silage-making are carried on.

Phosphate (PO_4^{3-}): Phosphorus occurs widely in nature in plants, in micro-organisms, in animal wastes and so on. It is widely used as an agricultural fertilizer and as a major constituent of detergents, particularly those for domestic use. Run-off and sewage discharges are thus important contributors of phosphorus to surface waters.

The significance of phosphorus is principally in regard to the phenomenon of eutrophication (over-enrichment) of lakes and, to a lesser extent, rivers. Phosphorus gaining access to such water bodies, along with nitrogen as nitrate, promotes the growth of algae and other plants leading to blooms, littoral slimes, diurnal dissolved oxygen variations of great magnitude and related problems.

Suspended Solids: Matter which is suspended in quiescent water consists of finely divided light solids which may never settle or do so only very slowly. Indeed, the net effect may be one of apparent turbidity without any discernible solids. In flowing water, on the other hand, the solids which are kept in suspension by the turbulence may be settleable if the water is steady. While the latter would be determinable as "Solids, Settleable," and the former could possibly be assessed as "Turbidity," there will be those solids of intermediate grading which also require estimation. To determine as much as possible of the solids present (not in solution), the determination of "suspended" solids is carried out.

Total Solids: This parameter comprises the total solids present in the whole sample which is analyzed directly without filtration. It is referred to also as *Dry Residue(s)* or *Total Residue(s)*. The drying temperature must he quoted with the results. There are two commonly used drying temperatures - 105°C and 180°C, the latter being favored in some continental European standards.

At 105°C the residue may retain some water even after an hour's drying. There will be some conversion of bicarbonates to carbonates by loss of carbon dioxide but loss of organic matter will be minimal. At 180°C virtually all the water will be lost, as will some organic matter. In addition to loss of carbon dioxide in bicarbonates, some further loss may occur in carbonates. Because of these differences in behavior the temperature must be quoted to obtain the most meaningful picture from the results.

At times the residue from the total solids determination is analyzed further by igniting it for an hour in a furnace at 550-600°C. Under this drastic heat, organic matter will be volatilized and there will be some further loss in weight by destruction of some inorganic compounds. The weight lost represents the *Volatile Solids* and the ultimate residue is the so-called *Fixed Residue* or Non-*Volatile Solids,* present in the sample. While there is no direct correlation between loss in weight on ignition of a sample and its organic content, in certain circumstances (as, for example, an investigation of the extent to which organic sludge is deposited over an area of river bed), the determination of volatile solids will give a useful trace of the levels of organic matter.

Total Dissolved Solids: The parameter is determined as for total solids except that the sample is filtered through a defined medium (membrane or glass fibre paper; cf. "Solids,Suspended") beforehand. The term *Total Filtrable Solids* is also used. It is often convenient and acceptable to use the very rapid determination of conductivity (q.v.) to give an estimation of the total dissolved solids.

As discussed earlier, the *total dissolved solids*, or *TDS* includes ionized and nonionized matter but only the former is reflected in the conductivity. Where TDS are high the water may be "saline" and the applicable parameter "Salinity."

Sulphate (SO_4^{2-}): Sulphates exist in nearly all natural waters, the concentrations varying according to the nature of the terrain through which they flow. They are often derived from the sulphides of heavy metals (iron, nickel, copper and lead). Iron sulphides are present in sedimentary rocks from which they can be oxidized to sulphate in humid climates; the latter may then leach into watercourses so that ground waters are often excessively high in sulphates. As magnesium and sodium are present in many waters their combination with sulphate will have an enhanced laxative effect of greater or lesser magnitude depending on concentration. The utility of a water for domestic purposes will therefore be severely limited by high sulphate concentrations, hence the limit of 250 mg/l SO_4. Other problems are associated with sulphate. In polluted waters in which the dissolved oxygen is zero, sulphate is very readily reduced to sulphide causing noxious odors. Waters containing sulphates in excess will also attack the fabric of concrete sewer pipes.

2.9.3 Biological Analyses

Coliforms, Faecal and Total Coliform: Faecal coliforms originate in human and animal waste. Total coliforms include faecal and also other bacteria with similar properties which originate in soil and are nonfaecal. The risk to consumers of infection from drinking polluted waters will vary very widely from instance to instance because the numbers of pathogenic organisms (i.e. the actual disease-causing organisms) in contaminated waters will show great variations. The number of pathogens in a sewage contaminated water is a function of the number of persons (so-called "carriers") who excrete such organisms. As the latter is an unknown quantity and as the positive identification of specific bacteria may be a very difficult task (and not one suited to the routine bacteriological screening of a water on public health grounds) an indirect approach is universally adopted.

To ensure a high factor of safety, the practice has been to monitor *indicator organisms* which, by definition, should be (i) easily detected and identified, (ii) of the same origin as the pathogens (i.e. from the human or animal intestine), (iii) present in far greater numbers than the pathogens, and (iv) present whenever the pathogens are likely to be present. In addition, they should show the same or better survival characteristics than the pathogens and, of course, *they must not be in themselves pathogenic*. To date the universal indicator organisms have been the coliforms, specifically *Escherichia coli*. These bacteria are of definite faecal origin (human and animal) and they are excreted in vast numbers. The presence of E-coli in a water supply is proof that faecal contamination has occurred and it is therefore a definite indication of the risk that pathogens may be present. The absence of these faecal coliforms indicates strongly the probability that pathogens are absent, because not all coliform organisms (or organisms which show the same test behavior as coliforms) are of faecal origin, some types being able to grow in soil, a second analysis is carried out for the presence of total coliforms, giving an indication of the general level of microbiological contamination of a water. Each microbiological test procedure is designed around some distinctive, characteristic property of the group of organisms under study. In the case of the coliforms this is the ability to grow aerobically on an agar/bile-salt medium and to ferment lactose, producing acid and gas, within 48 hours at 37°C. *E. coli* are distinguished by further individual properties. As indicated above, two distinct analytical procedures are used routinely. The first is a multiple tube technique in which several replicates of each of three different dilutions of sample are incubated in test-tubes containing the appropriate medium. After incubation the number of positive results is noted, i.e. the number of tubes at each dilution in which the production of gas etc. is observed, and the result - the Most Probable Number of organisms in 100 ml of sample, commonly known as the MPN - is obtained from probability tables. It is presumed that each "positive" indication is due to the presence of coliforms and the test is known as the "presumptive coliform test." [Confirmatory tests may then be carried out as required.] Concurrent Most Probable Number determinations are made for faecal and total coliforms (at different incubation temperatures) and the results reported separately. In the MPN technique actual numbers of coliforms are not being determined, as they are in the second commonly used procedure - Membrane Filtration. Here, measured amounts of sample are passed through sterilised filter membranes. The micro-organisms present are retained on the membranes which are transferred to a suitable medium for culturing separately at the appropriate temperatures. The numbers of resulting colonies are counted to give presumptive *E. coli* and total coliform counts. The term presumptive is applied as additional tests would be required to verify that the organisms showed all the reactions characteristic of the coliform group. However, if these extra tests are omitted and waters assessed on the basis of presumptive tests only there is an even greater margin of safety, as a "worst-case" situation is assumed to apply. The philosophy which has been adopted universally is to use the coliforms as definite indicators of sewage (faecal) pollution and to apply strict limits on their presence in water sources and supplies. The interpretation of the results of analysis may be summarized as follows: Where *E. coli* are present in large numbers the inference is that heavy, recent pollution by human or animal wastes has occurred; if the E. coli numbers are low it is inferred that pollution from the same source(s) is either less recent or less severe. If coliforms not including *E. coli* are observed the indication is that either the pollution is recent and non-faecal in origin or of remote, faecal origin such that the intestinal conforms have not survived.

However, if any coliforms at all are found in a treated drinking water supply, following chlorination, it should be concluded that either inadequate treatment is being applied or else that contamination has been introduced during distribution of the water, or in the sampling or handling of the sample(s). Any indication at all of contamination, however apparently mild, must be regarded as a matter of gravity and the circumstances investigated promptly.

Moreover the whole philosophy behind the use of the coliforms as indicators is to give a very high margin of safety. While the exact safety factor would, of course, depend on the ratio of coliforms to pathogens, in practice this is never quantified. Experience has shown this approach to be satisfactory (EPA, 2001).

2.10 Water Quality Standards

The Physical, Chemical as well as Biological standards for drinking water according to WHO (2006), NSDWQ (2007) and FAO (1985) are given in Table 2.3 overleaf.

Table 2.3: Physical, Chemical and Biological Standards for Drinking Water

S/No	Parameters	WHO Acceptable	Permissible (maximum) limit	NSDWQ	FAO
1	Turbidity(NTU)	1.0	10	5.00	5.00
2	Odor (Unit on platinum cobalt scale)	5.0	25		
3	Color	Unobjectionable	unobjectionable	15.00	
4	pH	6.5 to 8.5	<6.5 or >9.2	6.5-8.5	6.5-8.4
5	Temperature (^0C)	-		Ambient	
6	Conductivity (µs/m)	1400	1400	1000	
7	Potassium (mg/l)	55			0-2
8	Total dissolved solids(mg/l)	500	2000	500	450
9	Total hardness (as $CaCO_3$) (mg/l)	200	600	250.00	
10	Chlorides (as Cl) (mg/l)	200	1000	250.00	
11	Sulphate (as SO_4) (mg/l)	200	400	100.00	
12	Fluoride (as F) (mg/l)	1.0	1.5	1.50	
13	Nitrate (NO_3) (mg/l)	45	45	50.00	
14	Calcium (Ca) (mg/l)	75	200		
15	Magnessium (Mg) (mg/l)	<30	150	0.20	0-50
16	Iron (Fe) (mg/l)	0.1	1.0	0.30	5.00
17	Manganese (Mn) (mg/l)	0.05	0.5		0.2
18	Copper (Cu) (mg/l)	0.05	1.5	1.00	0.2
19	Alkalinity (mg/l)	200	600		
20	Zinc (Zn) (mg/l)	5.0	15.0	3.00	0.2
21	Aluminium (Al) (mg/l)	0.03	0.2	0.20	
22	Bicarbonate (mg/l)	varies			
23	HCO_3 (mg/l)	1000			
24	E. coli (or thermotolerant bacteria) (Cfu/100ml)	0	10	0	
25	Total Coliform	0	10	10	

Sources: WHO (2006), NSDWQ (2007), FAO (1985)

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study location

The study area, Bosso Local Government is within Minna, Capital of Niger state, Nigeria. Makunkele which is the Headquarters of the council is about 12 kilometers from central of Minna metropolis. The area is accessible through a major road linking Zungeru – Minna – Suleja. The area map lies between longitude $6^0 13$E and $6^0 40$E and $9^0 23$N and $9^0 50$N covering a total area of about 900km^2. The 2006 National Housing Census put the Human population of the local government at 147,361,000 (NSG, 2007).

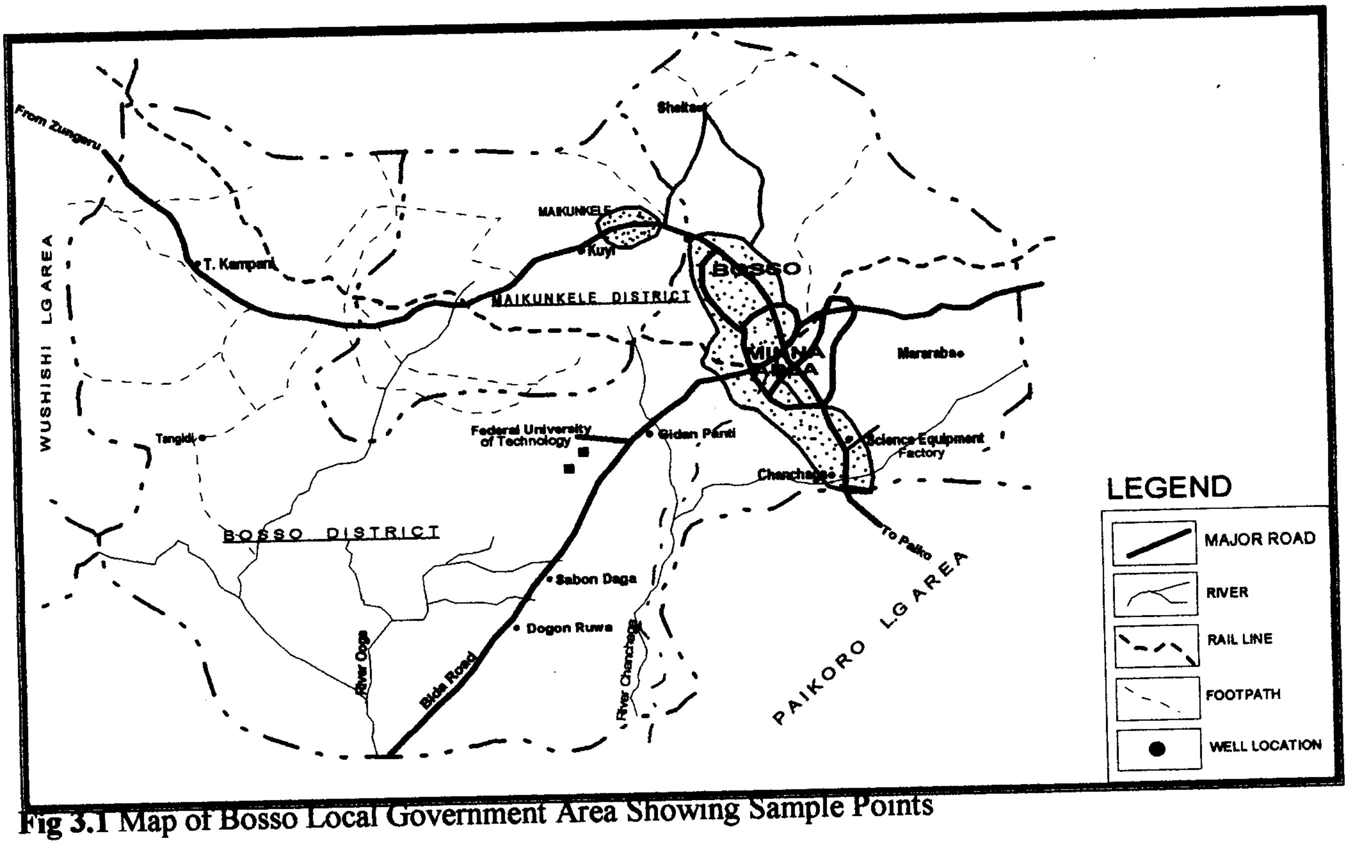

Fig 3.1 Map of Bosso Local Government Area Showing Sample Points

Climate, vegetation and land use: Bosso has a special savannah climate with distinct rainy, dry and harmattan season respectively. The dry season occurs between October/November and ends at about March/April while the rainy season starts at about April/May through September/October and harmattan period starts around November through February. Temperature prevailing in the area is generally high with values ranging from 24^0C to 35^0C with an annual mean of about 30^0C. The average rainfall is about 250mm (NSG, 2007).

Bosso has the largest inhabitant in Niger State, villages and hamlets are scattered around the state, peasant farmers who cultivate yam, rice, guinea corn, maize, pepper, vegetables and tomatoes, which thrives abundantly due to the availability of sandy soil from weathered rocks of the Minna batholiths (NSG, 2007).

Drainage and Relief: The relief of the area is flat lying of the landscape occurring in only a few parts of the area. The topography of the area is controlled by its geology. The area was steep sloppy and the major soil found in the area was sandy loam classified as oxic plaustalf type of soil. It is friable with low water retaining capacity. It is slightly acidic in nature. It has high organic matter level. The areas close to the main road have a good drainage network that generally keeps the area partially dry and free from flooding during the rainy season. However, some parts are water logged in the study area.

3.2 Sampling methods/procedure

Three water samples were collected from hand dug wells within the study area. The samples were collected using a clean water drawer that was made up of rope tied to a plastic bucket. The water was drawn from each of the three wells with the aid of the drawer and poured directly into the sterilized bottle first and other glass bottles. Bottles that were used for sample collection were pre-washed clean with detergent solution, rinsed with clean running water and air-dried in a dust free environment. However, the bottles used in collecting samples for bacteriological examination were sterilized using electrically powered oven at 350°C. The collected bottled waters were then preserved in cooler containing iced water in order to regulate multiplication effect of bacterial content of the water samples. The samples were collected in Sheita, Kuyi and Chanchaga at 8.32am, 10.06am and 11.21am respectively, on 6th of June, 2011.

The water analysis commenced immediately the samples were registered in the laboratory of Niger State Water Board, Minna on 6th June, 2011.

Apparatus: The various devices used during the water analysis process include:

Steel tape, global positioning system (GPS), water drawer, Thermometer, sterilized bottles, glass bottles, aluminum foil, spectrophotometer, Curette cork, conductimeter, color comparator, incubator, autoclave, McCarthy bottles, Bunsen burner, sterile needle and syringe (5ml and 10ml), measuring cylinder, distilled water, conical flask, geographical map, beaker, oven, cell plate, nitraver 5, nitriver 3, sulfaver 4, ferrover iron ferroxine, aluver 3, thiocyanate, SPADN.

Table 3.1 outlines a brief explanation of some of these devices and their uses during the water analysis.

Device	Uses
Steel Tape	To measure distances of wells from other physical features around it, also used to determine the depth, diameter and head of the water well.
Global Positioning System (GPS)	To obtain the location of the water wells.
Water Drawer	To draw water from the wells.
Thermometer	To obtain the temperature of the samples.
Sterilized Bottle	Used to collect samples for bacteriological test analysis.
Glass Bottle	For collection of water samples needed for laboratory tests.
Aluminum Foil	To cover the rim of the bottle, especially those used for bacteriological analysis.
Spectrophotometer	Used to obtain values of physical and chemical parameters of water samples.
Color Comparator	To obtain color value of water samples
Autoclave	Used to sterilize all metallic and glass materials used for the water analysis.
Incubator	For chemical and bacteriological analysis of samples.
Sterilized Needle and Syringe	Used in titration process of the chemical analysis of water samples.
Measuring Cylinder	To measure volume of water sample.
Conical Flask	Used in mixture of sample solutions.
Cell Plates	Used during bacteriological test for coliform count.
Oven	Used in the sterilization of petridish can, glass ware, and scalpels.
SPADN	This is a reagent used in the test for fluoride.

Location

Table 3.2 shows the location of sample points

S/N	SAMPLE LOCATION	DESCRIPTION	SAMPLE SOURCE
A	Sheita (Goiko- jita)	Plain rocky field with fine sandy-clayey soil texture	Hand dug sallow well with no apron or cover, unlined and highly exposed to runoff.
B	Kuyi	Plain low grass area with sandy loamy soil	Well lined hand dug well, with adequate apron and lockable cover that protect it from external materials.
C	Chanchaga	Rocky and highly dense area with sandy soil	Unlined hand dug well with cemented apron, but not perfectly covered when unused.

Table 3.3 shows the description of sample points in tabular form.

	Hand-dug well		
Description	A	B	C
Location	Sheita	Kuyi	Chanchaga
Age	January,2011	1877	2004
Depth	3.4m	42.3m	7.2m
Diameter	1.3m	1m	1.1m
Sanitary Condition	Poor	Moderate	Fair
Purpose	Domestic	Domestic	Domestic
Water Level	0.3m	7.6m	3.5m

Purpose

The three sample points were dug for the purpose of drinking and other domestic functions. Meanwhile, sample point C was restricted for only domestic function with the exclusion of drinking, because of the supply of municipal water.

Consumption

Samples A and B were used by mostly the villagers living in the village while sample C was being used by the residence of the house where it was situated.

Lining

Only sample point B was lined with concrete material out of the entire sample points.

Nature of the sample points

Sample A was an open shallow well, with no protective cover either during the day or at night. Sample B was a covered deep well with apron and usually opened for only 12hours per day (6am-6pm). Sample C was an open well with apron round it and it is left opened through the 24 hours of the day.

Sanitation

Sample point A was located on the plain field, open to surface run-off of water and prone to animal and human waste intrusion. However, it has a very low sanitary condition.

Sample point B was situated within the village houses and it's a closed lined well with apron to eliminate surface run-off intrusion. It was positioned near bathroom, pen house, cattle dung heap and domestic drainage system which are 9.0m, 15.1m, 9.3m and 8.3m respectively.

Sample point C was situated within the residence and it was 8.8m, 13.3m and 13.6m away from domestic drainage, bathroom and pit latrine respectively.

Sample point bearings and elevation

With the use of GPS, the details of sample point locations were presented in the Table 3.3 below

Table 3.4 Sample point bearings and elevation

Sample point	Name	Easting	Northing	Elevation
A	Sheita	$6^{0}31^{\prime}$E	$9^{0}44^{\prime}$	321m
B	Kuyi	$6^{0}26^{\prime}$	$9^{0}40^{\prime}$	262m
C	Chanchaga	$6^{0}34^{\prime}$	$9^{0}32^{\prime}$	228m

3.3 Laboratory Analyses

Color determination

Using spectrophotometer, the stored program number (120) for true color was entered. "Read/Enter" was then pressed and Dial nm455. The nub of the wavelength dialed was rotated until the small display showed 455nm, then "Read/Enter" was pressed. The display showed platinum cobalt (PtCo). A sample cell (the blank) was filled with 25ml of deionized water. The blank was placed into the cell holder. The light shield was closed. "zero" was pressed. The display showed "wait" and then 0. Units PtCo color was shown. The water sample (A) from clay pot, which was measured into a cell, was placed into the holder. The light shield was closed, "Read/Enter" was pressed and the display showed "wait" and then the result platinum cobalt units was displayed. When the display stabilized, the result was recorded.

Determination of Turbidity

The stored program number for turbidity was entered into the spectrophotometer. 750 "Read/Enter" was pressed. The display showed; "Dial" nm to 450. The wavelength dialed was rotated until the small display showed; 450nm "Read/Enter" was pressed. The display showed; FTU Turbidity. 25ml of deionized water (the blank) was poured into a simple cell. The blank was placed into the cell holder. The light shield was closed, zero was pressed; on the spectrophotometer. Then, 0 formazin turbidity unit (FTU) was shown; 25ml of sample A was poured into another cell. Immediately, the sample cell was placed into the cell holder. The light shield was closed. "Read/Enter" was pressed. The display showed "wait". Then the results in formazin Turbidity units (FTU) were displayed. When the display stabilized, the results were recorded. Same was done to samples B and C.

Determination of Total Dissolved Solid

A conductometer was used in determining TDS (Total Dissolved Solid). The electrode was placed in deionized water and swilled to stabilize the electrode. This electrode was then placed into sample A in a beaker and the reading was displayed on the conductometer screen. Same was done to sample B and C.

Determination of Potential Hydrogen (pH)

The pH was determined using universal pH strip and lovibond color comparator with phenol red as an indicator. Two cleaned 10ml curettes were used. Distilled water was filled in one of the 10ml curette and 1 to 2 drops of phenol red was added. The phenol red disc was placed in the lovibond comparator. It was then rotated for color matching. The reading was then recorded. The method was repeated for samples B and C.

Determination of suspended solid

The stored program was entered for suspended solids. 630R "Read/Enter" was pressed. The display showed; "Dial" nm to 810. The wavelength dialed was rotated until the small display shows; 810nm. "Read/Enter" was pressed. The display showed; Mg/L suspended solids. The sample cell was filled with 25ml of deionized water (the blank). The blank was placed into the cell holder. The light was closed, "Zero" was pressed, the display showed "Wait". Then, 0.mg/l suspended solid was shown, the prepared sample cells were covered to remove any gas bubbles and uniformly suspended residue. The prepared sample was placed into the cell holder. The light shield was closed. "Read/Enter" was pressed, the display showed; "Wait". Then the result in mg/l suspended solids was displayed and recorded. Same procedure was done for sample B and C.

Determination of temperature

Temperature/Conductivity/TDS meter was switch on by pressing the appropriate button. The probe was immersed in the beaker containing the sample A, moved up and down and taped on the beaker to free any bubbles from the electrode area. The probe was immersed beyond the vent holes. The reading was recorded in degree Celcius (°C). Same procedure was done for sample B and C.

Determination of Sulphate

The stored program for sulphate (SO_4) was entered. 680 "Read/Enter" was pressed. The display showed "Dial" nm to450. The wavelength dialed was rotated until the small display showed 450nm. "Read/Enter" was pressed. The display showed mg/l SO_4^{2-}. A clean sample cell was filled with 25ml of sample; the content of one sulfaver 4-reagent powder pillow was added to the sample (the prepared sample). It was swirled to dissolve. A while turbidity developed unifying the presence of sulphate. "Shift timer" was pressed. A 5minutes reaction period began. The cell was allowed to stand undisturbed. When the timer beeps, the display showed; mg/l SO_4^{2-}. A second sample cell was filled with 25ml of sample (the blank). The blank was placed into the cell holder, the light shield was closed, "Read/Enter" was pressed. The display showed "Wait". Then the result in mg/l SO_4^{2-} was displayed. Same was repeated for samples B and C.

Determination of Chloride

100ml of the sample and Mercuric Nitrate ($Hg(NO_3)_2$) titration cartridge corresponding to the volume of the sample was selected. A clean delivery tube was inserted into the titration cartridge. Digital titrator with the cartridge tip pointed up. Delivery knob was turned to eject air and a few drops of the titrant. The counter was reset to zero and the tip was wiped. A clean graduated measuring cylinder was used to measure 100ml of the sample A. the sample was transferred into 250ml of conical flask. One Diphenyl carbazone powder pillow was added and swirled to mix. The delivery tube was placed into the solution and swirled while titrating with the mercuric nitrate from pale yellow to light pink color. The number of digits was recorded. Same was done for samples B and C.

Calculation: Digit×Digit Multiplier=mg/l Chloride.

Determination of Conductivity

Conductivity/T.D.S. meter was switch on by pressing the appropriate button; the probe of the meter was immersed in the beaker containing the de-iodized water to rinse. The probe was immersed in the meter containing the sample and was moved up and down, then taped to the beaker in order to free any bubble from the electrode area. The probe was immersed beyond the vent holes. The reading was recorded in micro siemens/cm (µs/cm) or mili-siemen/cm (ms/cm)

Determination of Alkalinity

100ml of the sample was measured and sulphuric acid (H_2SO_4). Titration catridge corresponding to the expected alkalinity concentration in mg/l was chosen, cleaned delivery tube was inserted to the titration catridge, and the catridge was then inserted into the titration body. Digital titrate was held with catridge tip pointing up and the delivery knob was turned to eject out few drop of titrant. The counter was reset to zero and the tip was wiped. A graduated cylinder was used to measure the sample volume and one phenolphthalein indicator power pillow was added and swirled to mix. The solution was the titrated to a colourless end point with the sulphuric acid. While titrating, the flask was swirled mixed and the digit was recorded. One bromo green methyl red indicator powder pillow was added to the contents and swirled to mix; the titration was then continued with sulphuric acid to a light greenish blue-grey, a light grey or light pink color as required.

Total Alkalinity mg/l = total digits required x digits multiple.

Determination of total Hardness, magnesium and Calcium

100ml water sample was poured in a 100ml graduated mixing cylinder, 1.0ml calcium and magnesium indicator solution using 1.0ml measuring dropper was added and inverted for thorough mixing.1.0ml of Alkali solution for calcium and magnesium test using a 1.0ml measuring dropper was added and mixed. 25ml solution was poured into each of the sample cells, one drop of 1M EDTA solution was added to one cell (the blank) and was swirled to mix, after which one drop of solution was added to another cell (the prepared sample) and swirled to mix. A stored program number for magnesium was entered, the wavelength dial was also rotated until the small display showed 522nm, then the READ/ENTER button was pressed and "Mg/l $CaCO_3$mg" was displayed. The blank was placed in the cell holder, the light shield closed and the zero key pressed. The display showed "WAIT" then 0.00mg/l $CaCO_3$mg shown. The prepared sample was then placed in the cell holder and the light shield was closed. READ/ENTER was pressed, "WAIT" was displayed, then the result in mg/l as $CaCO_3$ was recorded. CONFIG button was pressed two times, a stored program number for calcium was entered, 220 READ/ENTER for units of mg/l $CaCO_3$ was pressed, then "DIAL NM to 522" was displayed. READ/ENTER was pressed and mg/l $CaCO_3$ Ca. Zero was pressed, then "WAIT" was displayed, followed by "0.00mg/l $CaCO_3$ Ca". then the third sample cell was placed into the cell holder, READ/ENTER was pressed, the display showed "WAIT" then the result in mg/l Ca as $CaCO_3$ was displayed.

Determination of Chemical Oxygen Demand (COD) Using Reactor Digestion Method

The sample was shacked beginning with second step, COD reactor was turned on and was pre-heated to about 150^0C the cap of the COD digestion reagent vial was removed, the vial was held at about 45^0 angle, 2.0ml of the sample was measured into the vial and the vial was capped. The COD vial was rinsed with de-ionized water and wiped with clean towel. The vial was held by the cap, and over a sink, it was inverted thoroughly to mix the contents. The vial was placed in the pre-heated reactor. The blank was prepared by repeating the above procedure, substituting 2.0ml with de-ionized water for the sample. The vial was heated for 1 to 2 hours. The reactor was turned on and allowed to stay for 20minutes to cool to 120^0C or less. The vial was inverted, several times while still warm. The vials were placed into a rack, and they were allowed to cool to room temperature. Colorimetric determination techniques were used to determine the sample concentration and process are as follows:

The program number for COD, 430 READ/ENTER was pressed, then "DIALNM to 420". The wavelength dial was rotated until the small display showed 420nm. The READ/ENTER was pressed, then "mg/l COD" was displayed. The Cod vial adapter was placed into the cell holder with the marker to the right. The outside of the cell, containing the blank was wiped, with a clean towel; the blank was placed in the adapter. Zero was pressed, then "WAIT" and "0mg/l COD" was displayed. The outside of the sample vial was wiped with clean towel and placed in the adapter, while READ/ENTER was pressed, and "WAIT" was displayed, followed by the result in mg/l COD.

Fecal Coliforms and Escherichia Coli (E. coli)

Most portable method was used

i. To detect the presence of coliform in the water samples

ii. To detect the presence of faecal coliform.

Set of three series of the three sample groups were prepared inside test tubes. The test tubes was labeled according to water sample and volume of sample inoculated. The tubes were incubated at 37^{0}C for 48hours. Preparation of each of the samples in the tubes is shown below;

Three tubes of double strength + 10ml of sample

Three tube of single strength + 1.0ml of sample

Three tube of single strength + 0.1ml of sample

CHAPTER FOUR

4.0 RESULT AND DISCUSSION

4.1 Presentation of Results

The results obtained from the laboratory analyses are presented in Table 4.1, the results include the physical, chemical and bacteriological analyses of the water samples collected within the study area.

Table 4.1 Physico-chemical and bacteriological analysis of water samples

S/N	PARAMETER	SHEITA (A)	KUYI (B)	CHANCHAGA (C)	NSDWQ (2011)	WHO (2006)	EPA (2001)
1	Turbidity (FTU)	363.00	0	3.00	5.00	1.00	NS
2	Colour (PtCo)	2,120.00	2.00	12.00	15.00	Unobjectionable	NS
3	Suspended Solids (mg/L)	254	0	0	NS		NS
4	E. Conductivity (us/cm)	40	180	1,110	1000	1400	2500
5	TDS (mg/L)	20	90	560	500	500	NS
6	Total Solids (mg/L)	274	90	560	NS		NS
7	Temperature (^{0}C)	24.9	24.6	24.8	Ambient	Below ambient	NS
8	pH	6.53	7.47	7.95	6.5-8.5	6.5-8.5	6.5-9.5
9	Nitrate (mg/L)	0.00	7.51	87.96	50.00	50	50
10	Nitrite (mg/L)	0.02	0.02	0.03	0.20		0.5
11	Sulphate (mg/L)	0.00	1.00	72.00	100.00	500	250
12	Fluoride (mg/L)	0.00	0.58	0.33	1.50	1.5	
13	Copper (mg/L)	0.06	0.05	0.02	1.00	2.0	2.0

14	Iron (mg/L)	1.49	0.14	0.05	0.30	0.2	0.2
15	Chloride (mg/L)	12.50	14.50	180.44	250.00	200	250
16	NH_3 (mg/L)	0.00	2.07	24.28	NS		0.1
17	Total Hardness (mg/L)	14.00	81.00	231.00	150.00	200	NS
18	Calcium Hardness (mg/L)	7.00	40.00	103.00	NS		101-200
19	Magnesium Hardness (mg/L)	7.00	41.00	128.00	NS		NS
20	Total Alkalinity (mg/L)	30.00	104.00	228.00	NS	200	NS
21	HCO_3^- (mg/L)	30.00	104.00	228.00	NS	1000	NS
22	CO_3^- (mg/L)	0	0	0	NS	Varies	NS
23	PO_4^{3-} (mg/L)	0.13	2.00	0.12	NS		NS
24	COD (mg/L)	36.00	14.00	27.00	NS		
25	BOD (mg/L)	19.80	7.70	14.85	NS		≤ 5
26	Dissolved Oxygen (mg/L)	4.05	4.57	5.79	NS		≥6and ≤9
27	E. Coli cfu/100mL	460	160	54	0	0	0
28	T. Coliform cfu/100mL	760	220	120	10	0	0
29	F. Streptococci cfu/100mL	460	160	54	0	0	0

NSDWQ- Nigerian Standard for Drinking Water Quality. NS-Not Stated.

FAO- Food and Agricultural Organization . TDS- Total Dissolved Solids

WHO- World Health Organization.

4.2 Discussion of Results

The laboratory analyses of the water samples exposed the constituents of each sample in which some of the physical, chemical and biological parameters present were beyond any international standard, most especially, water drinking standards, also the parameters that are needed to be present in drinking water, example of which are sulphate, chloride to mention but few, were determined to be short in value. These results pose a great risk to the health of the consumers. The results are analyzed below;

4.2.1 Turbidity

Out of the three samples, sample A had the highest turbidity value of 363ftu, while the remaining sample B and C had 0 and 3ftu respectively. This could be connected to the high level of suspended solids in the samples. However, the high turbidity value of sample A could be said to be as a result of low depth of its well and the exposure to surface intrusion. Also, the nature of the soil (sandy clay) contributed to the high value of the sample water. B had the lowest value, being zero due to the depth of its well, while sample C had 3ftu which was also below the maximum permissible limits stipulated by international standards.

4.2.2 Suspended Solid

In relation to the turbidity of sample A, the suspended solid is high to level of 254mg/l. though the maximum permissible limit was not specified by Nigeria Standard for Drinking Water Quality and World Health Organization, but mere comparison with other values (Samples Band C of zero values) shows that the suspended solid was too high.

4.2.3 Color

The values of color possessed by samples B and C were below the maximum limit value of international standards like N.S.D.W.Q. and W.H.O. which were 15PtCo. However, sample A had2120PtCo value due to the presence of substances in suspension, which were mostly organic in nature. The high level of iron present in the water also contribute to the high true color unit of sample A, moreover, copper, manganese, industrial waste, swampy decomposing organic matter may possess brownish or reddish stain which contribute to the color value. The growth of algae or microorganisms may also cause the high color value.

4.2.4 Electrical Conductivity

Electrical Conductivity reflects the mineral salt content of water (EPA, 2001). Literally, the higher the content of ionisable solids, the higher the conductivity of water. Therefore, in relation to the high iron content in sample A, its electrical conductivity would have been justifiable if it had been high, but possessed a very low value which is likened to the very low mineral salt value. Sample C had EC value above the standard limit which was 1110µs/cm, this may be connected to its high dissolved solids, while sample B had a lower value of 90µs/cm corresponding to its dissolved solids value.

4.2.5 Total Dissolved Solids

Sample C had the highest value of 560µs/cm, while sample A and B had 20 and 90µs/cm respectively. However, with the high value of TDS, sample C may be said to be saline.

4.2.6 Total Solids

This is the combination of suspended and dissolved solids present in each sample, though the permissible limit was not specified by Nigeria Standard for Drinking Water Quality (NSDWQ) but, the test result were 274mg/l, 90mg/l and 560mg/l in Sheita, Kuyi and Chanchaga respectively,

4.2.7 Temperature

All the three samples had temperature of 24.9^{0}C, 24.6^{0}C and 24.8^{0}C for Sheita, Kuyi and Chanchaga water samples respectively.

4.2.8 pH

According to WHO and NSDWQ standards, the pH value of drinking water must be within the range of 6.5 to 8.5 value of pH in which the three water samples complied and having their pH to be of 6.53, 7.47 and 7.95 for samples A, B and C respectively.

4.2.9 Nitrate

The maximum permissible value of nirate is 50mg/l in which samples A and B were of 0.0 and 7.514mg/l respectively, but sample C had a value beyond the standard which was 87.96. The high value of C nitrate may be as a result of waste discharge and fertilizer application residue run-off.

4.2.10 Nitrite

Samples A, B and C have 0.019, 0.016 and 0.03 of nitrite value respectively. These all fell shor of the standard permissible value of NSDWQ and WHO of 0.2mg/l, though EPA,2001 had its syandard to be 0.03mg/l. in comparison with all standards of drinking water, the level of nitrite of the samples were low and this may be attributed to existence of nitrogen in more oxidized (Nitrate;NO_3) form.

4.2.11 Sulphate

Sample C had a recognizable value of sulphate, 72mg/l, while samples A and B have 0 and 1mg/l respectively. High value of sulphate in sample C may be linked to the presence of sedimentary rocks which possesses iron sulphides which when oxidized formed sulphate.

4.2.12 Fluoride

The low value of fluoride in the samples especially sample A may not provide the immunity against tooth decay. EPA, 2001 recommended drinking water to have appreciable value of 0.6mg/l F which leads to reduction in tooth decay in growing children.

4.2.13 Copper

With all the samples' copper value less than 0.1mg/l, the danger of toxicity caused by the element is eliminated and thereby renders the water safe for aquatic fisheries, though not particularly toxic to human.

4.2.14 Iron

The maximum permissible level of iron in drinking water is 0.3mg/l. However, iron exists as a result of geological formations, effluent discharge and acid drainage. Also, its significant presence in soil and rocks which are insoluble in water may not pose threat to human life, though its presence in soil has effect on turbidity and color of ground water.

4.2.15 Chloride

With its medicinal effects, NSDWQ and WHO maximum permissible level is between 200 to 250mg/l. It exists in all natural water and its sources include soil, rock formations, sea spray and water discharge. Also, sewage contain high amount of chloride and from the results of the three samples, the level of chloride fell short of the standards, though it is known to be 15 to 3mg/l as normal level in fresh water.

4.2.16 Ammonia

The presence of ammonia indicates he possibility of sewage pollution and consequent presence of pathogenic microorganisms. Sample A had no presence of ammonia, sample B and C had 2.07 and 24.28mg/l respectively.

4.2.17 Hardness

Hardness of water enhances water palatability. Sample A had 14mg/l total hardness and it was referred to as soft water, sample B of 81mg/l total hardness was referred to as moderately soft water, while sample C was moderately hard due to its 231mg/l total hardness value.

4.2.18 Phosphate

Sample B had he highest phosphate value of 2.0mg/l, while samples A and C had 0.13 and 0.12mg/l respectively. It occurs in nature and other biological maters. It is make use of in agricultural fertilizer and serve as a major constituent of detergents.

4.2.19 Oxygen Demand

Both the Chemical Oxygen Demand and Biological Oxygen Demand serve as determination of pollution potential in groundwater quality assessments. All the samples have the presence of biochemical and chemical oxyen demand. Sample A had 19.80 and 36.00 Of BOD and COD respectively; sample B had 7.70 and 14.00, while C had 14.85 and 27.00 of BOD and COD respectively.

4.2.20 Bacterial Examination

The presence of bacteria and total coliform in the well water indicate contamination by human and animal wastes. These pathogens may pose a special health risk for infants, young children and people with severely compromised immune systems. The World Health Organization (WHO) had recommended zero value for bacteria and total coliform count in drinking water. The high level of Escherichia Coliform (E. coli) of samplesA, B and C were 460, 160 and 54cfu/100ml respectively and these are extremely high, especially in groundwater which is being used for dinking purposes. The results indicated the pollution of the wells through faecal matters.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Analyses of the physical, chemical and biological parameters of the sampled well water indicated a very high in physical parameter values, of such were Turbidity, Color and Electrical Conductivity having 363ftu, 2120PtCo and 259mg/l respectively, while their bacteriological parameter results were above zero, which is the standard value. However, these can be related to the sanitary condition of the wells and that of their surroundings. Also, high values of bacteriological parameters will pose a threat of water borne diseases like typhoid, diarrhea, etc. Meanwhile, on comparison with the regulating standards on water quality, it can be conclusively said that high values recorded pose a pollution hazards. This however, in return has implication on human health as these wells are the main source of drinking water supply to the residents. It was also observed that some water parameters (Fluoride and Hardness) that are required to some percentage in water for drinking were recorded to have low value in two of the sample points. Generally, results of most parameters in uncovered, unlined and low depth wells were beyond the limit of the regulating standards (WHO and NSDWQ).

5.2 Recommendation

This study therefore recommends that wells should not be dug near contamination sources, be properly lined and have a good apron or cover on it which must be closed when wells are not being used. Also the apron should be at a height good enough to prevent runoff of precipitation from getting direct access into the well water. It is therefore suggested that in both rural and urban areas, well water should be treated and at least boiled before consumed.

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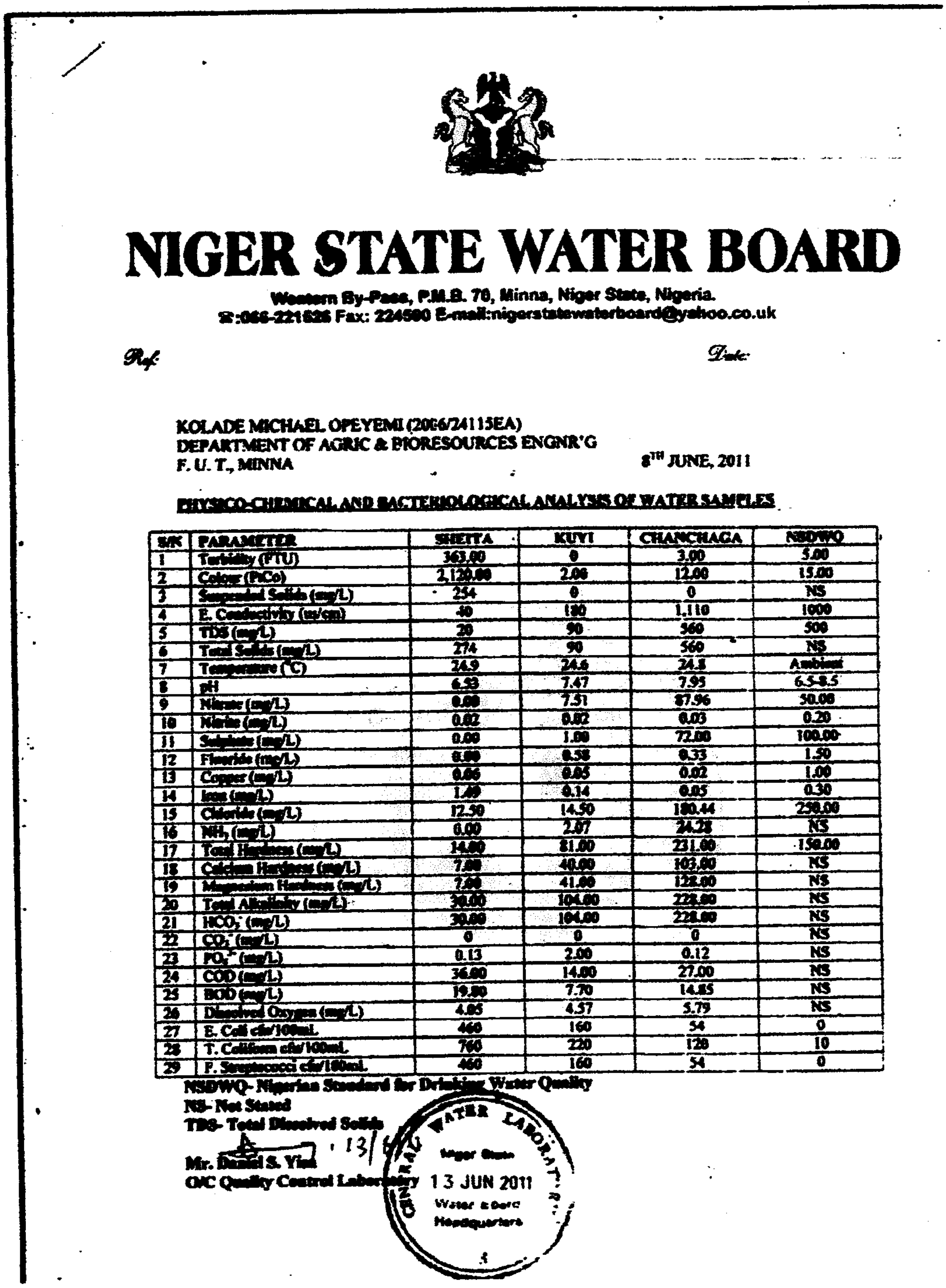
APPENDICES

APPENDIX A: Original copy of laboratory result



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KOLADE MICHAEL OPEYEMI (2006/24115EA)
DEPARTMENT OF AGRIC & BIORESOURCES ENGNR'G
F. U. T., MINNA 8TH JUNE, 2011

PHYSICO-CHEMICAL AND BACTERIOLOGICAL ANALYSIS OF WATER SAMPLES

S/N	PARAMETER	SHEITA	KUYI	CHANCHAGA	NSDWQ
1	Turbidity (FTU)	363.00	0	3.00	5.00
2	Colour (PtCo)	2,120.00	2.06	12.00	15.00
3	Suspended Solids (mg/L)	254	0	0	NS
4	E. Conductivity (us/cm)	40	180	1,110	1000
5	TDS (mg/L)	20	90	360	500
6	Total Solids (mg/L)	274	90	560	NS
7	Temperature (°C)	24.9	24.6	24.8	Ambient
8	pH	6.53	7.47	7.95	6.5-8.5
9	Nitrate (mg/L)	0.00	7.51	87.96	50.00
10	Nitrite (mg/L)	0.02	0.02	0.03	0.20
11	Sulphate (mg/L)	0.00	1.00	72.00	100.00
12	Flouride (mg/L)	0.00	0.58	0.33	1.50
13	Copper (mg/L)	0.06	0.05	0.02	1.00
14	Iron (mg/L)	1.49	0.14	0.05	0.30
15	Chloride (mg/L)	12.50	14.50	180.44	250.00
16	NH_3 (mg/L)	0.00	2.07	24.28	NS
17	Total Hardness (mg/L)	14.00	81.00	231.00	150.00
18	Calcium Hardness (mg/L)	7.00	40.00	103.00	NS
19	Magnesium Hardness (mg/L)	7.00	41.00	128.00	NS
20	Total Alkalinity (mg/L)	30.00	104.00	228.00	NS
21	HCO_3^- (mg/L)	30.00	104.00	228.00	NS
22	CO_3^- (mg/L)	0	0	0	NS
23	PO_4^{3-} (mg/L)	0.13	2.00	0.12	NS
24	COD (mg/L)	36.00	14.00	27.00	NS
25	BOD (mg/L)	19.80	7.70	14.85	NS
26	Dissolved Oxygen (mg/L)	4.05	4.57	5.79	NS
27	E. Coli cfu/100mL	460	160	54	0
28	T. Coliform cfu/100mL	760	220	128	10
29	F. Streptococci cfu/100mL	460	160	54	0

NSDWQ- Nigerian Standard for Drinking Water Quality
NS- Not Stated
TDS- Total Dissolved Solids

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Mr. Daniel S. Yisa
O/C Quality Control Laboratory

13 JUN 2011

APPENDIX B: Physico-chemical and bacteriological analysis of water samples with range, mean and standard deviation.

S/N	PARAMETER	SHEITA (A)	KUYI (B)	CHANCHAGA (C)	RANGE	MEAN	STANDARD DEVIATION
1	Turbidity (FTU)	363.00	0	3.00	361	364	362.50
2	Colour (PtCo)	2,120.00	2.00	12.00	2,118	2,134	2,127.03
3	Suspended Solids (mg/L)	254	0	0	254	254	0
4	E. Conductivity (us/cm)	40	180	1,110	1,070	443	581.57
5	TDS (mg/L)	20	90	560	540	223	293.66
6	Total Solids (mg/L)	274	90	560	470	308	236.84
7	Temperature (^{0}C)	24.9	24.6	24.8	0.3	24.76	0.153
8	pH	6.53	7.47	7.95	1.42	7.31	0.72
9	Nitrate (mg/L)	0.00	7.51	87.96	87.96	31.82	48.76
10	Nitrite (mg/L)	0.02	0.02	0.03	0.01	0.02	0.01
11	Sulphate (mg/L)	0.00	1.00	72.00	71.00	25.00	30.25
12	Fluoride (mg/L)	0.00	0.58	0.33	0.25	0.30	0.29
13	Copper (mg/L)	0.06	0.05	0.02	0.04	0.04	0.02
14	Iron (mg/L)	1.49	0.14	0.05	1.44	0.56	0.81
15	Chloride (mg/L)	12.50	14.50	180.44	167.94	69.15	96.38
16	NH_3 (mg/L)	0.00	2.07	24.28	22.21	8.78	13.46
17	Total Hardness (mg/L)	14.00	81.00	231.00	217.00	108.67	111.11
18	Calcium Hardness (mg/L)	7.00	40.00	103.00	96.00	50.00	48.77
19	Magnesium Hardness (mg/L)	7.00	41.00	128.00	58.67	121.00	62.40

20	Total Alkalinity (mg/L)	30.00	104.00	228.00	198.00	120.67	100.05
21	HCO_3^- (mg/L)	30.00	104.00	228.00	198.00	120.67	100.05
22	CO_3^- (mg/L)	0	0	0	0	0	0
23	PO_4^{3-} (mg/L)	0.13	2.00	0.12	1.88	0.75	1.08
24	COD (mg/L)	36.00	14.00	27.00	22.00	25.67	11.06
25	BOD (mg/L)	19.80	7.70	14.85	12.10	14.12	6.08
26	Dissolved Oxygen (mg/L)	4.05	4.57	5.79	1.74	4.80	0.89
27	E. Coli cfu/100mL	460	160	54	406.00	224.67	210.58
28	T. Coliform cfu/100mL	760	220	120	640.00	366.67	344.29
29	F. Streptococci cfu/100mL	460	160	54	406.00	224.67	210.58