CHARACTERIZATION OF POLLUTION HAZARDS OF SELECTED SURFACE AND GROUNDWATER SYSTEMS IN BIDA CATCHMENT AREA OF NIGER STATE, NIGERIA

Water quality analysis was done for both surface and groundwater samples. For surface water, samples were taken from the upstream; middle; and downstream sections of the river Landzun. Similarly, for groundwater, samples were collected from specific locations around the Bida catchment area of Niger State, Nigeria such in a manner to allow for effective spread. Water samples for both surface and underground regimes were collected during the dry wet seasons. Laboratory analysis was used to evaluate some water quality parameters. The laboratory results were subjected to further statistical test to be able to objectively determine acceptance or rejection, in other words, critical thresholds. Based on the results, for wet season surface water, maximum values of parameters fell within the recommended limit of WHO (2004) and FAO (2000) for drinking and irrigation water quality. Total hardness (110.10mg/l) and total dissolved solids (5546.4mg/l) were higher than acceptable limit of WHO (2004) and FAO (2000) standards. Total coliform (1.00mg/l – 56.00mg/l) was also above WHO (2004) standards for drinking water quality. Similarly, maximum values of various parameters at dry season fell within the permissible limit of WHO (2004) standard. Nitrate (71.60mg/l) and magnesium hardness (64.00mg/l) were higher than WHO (2004) standard. Total coliform (3.00mg/l – 140.00mg/l) and E-coli(0 – 22.00mg/l) were also higher than the recommended limit of WHO (2004) standard. For surface water at wet season, maximum values of various parameters fell within the acceptable limit by WHO (2004) standard for drinking water quality. Total coliform (340.00mg/l – 1060.00mg/l) and E-coli (20.00mg/l – 60.00mg/l) were above recommended limit by WHO (2004) standards. However, maximum values of various parameters at dry season, fell within acceptable limit by WHO (2004) and FAO (2000) standards. Turbidity (22.60mg/l – 57.70mg/l) was higher than acceptable limit of WHO (2004) for drinking water quality. Based on the findings, groundwater at both wet and dry seasons were not suitable for domestic and agricultural purposes. Similarly, surface water at wet season was not suitable for use, but dry season surface water was suitable since turbidity has no negative impact on human health. Hence, it was recommended that adequate measures like building of water treatment plants should be ensured for sustainable quality water in the study area; the habit of waste water and solid waste carelessly exposed in the area should be discouraged through enlightenment campaign and by providing improved methods of using dustbins for collecting solid wastes and suck-away pits dug far away (at least 20m) from groundwater systems for collecting waste water.

CHAPTER ONE

1.0 INTRODUCTION

1.1. Background to the Study

Characterization of water quality simply represents the physical parameters (colour; taste; odour; temperature; and turbidity), chemical parameters (Alkalinity; Calcium Hardness; Magnesium Hardness; Calcium ion; Potassium; and trace elements) and bacteriological parameters (*E-Coli* and *Feacal Coliform*). According to WHO, an estimation was made that about 80% of water is waste which is unfit for domestic; agricultural; and industrial purposes (Guru *et al*., 2011). The improper management of water systems may cause serious problems in availability and quality of water (Guru *et al.*, 2011).

In developing countries only a small proportion of the waste produced by sewered communities is treated. Developing country governments and regulatory agencies, as well as local authorities (which may be city or town councils, or specific waste water treatment authorities, or more generally water and sewerage authorities), need to understand that domestic and other wastewaters require treatment before discharge or, preferably, re-use in agriculture and/or aquaculture (Duncan, 2003). Municipal wastewater effluents may contain a number of toxic elements including heavy metals, because under practical conditions wastes from many small and informal industrial sites are directly discharged into the common sewer system. These toxic elements are normally present in small amounts and, hence, they are called trace elements. Some of them may be removed during the treatment process but others will persist and could present phytotoxic problems. Thus, municipal wastewater effluents should be checked for trace elements toxicity hazards, particularly when trace elements contamination is suspected (Pescod, 1992). Open dumps are the oldest and the most common way of disposing solid wastes, although, in recent years thousands have been closed, many are still being used. In many cases, they are located wherever land is available, without regard to safety, health hazard, and aesthetic degradation. The waste is often piled up as high as equipment allows. In some instances, the refuse was ignited and allowed to burn. In others, the refuse was periodically leveled and compacted. As a general rule, open dumps tend to create a nuisance by being unsightly, breeding pests, creating a health hazard, polluting the air, and sometimes polluting groundwater and surface water (Keller, 1982).

Landfill is an engineered waste disposal site facility with specific pollution control technologies designed to minimize potential impacts. Landfills are usually either placed above ground or contained within quarries, and pits. Landfills are sources of groundwater and soil pollution due to the production of leachate and its migration through refuse (Chistensen and Stegmann, 1992). Recent times, much importance has been made with regards to environmental quality which is main focus on water because of its importance in maintaining the human health and health of the ecosystem. Fresh resource is becoming day by day at the faster rate of deterioration of the water quality as is now a global problem. Direct contamination of surface water with metals in discharges from mining, smelting and industrial manufacturing, is a long standing phenomenon. Today, there is trace contamination not only of surface water but also of groundwater bodies, which are susceptible to leaching from waste dumps, mine tailing and industrial production sites (Subba, 2011). These impurities may give water a bad taste, color, odor or turbidity and causes hardness, corrosiveness, staining or frothing (Vollenwinder, 1998). Groundwater is an increasingly important resource all over the world. The term ground water is usually reserved for the sub-surface water that occur beneath the water table in soils and geologic formation that are fully saturated (Parvesh, 2003). It supports drinking water supply; livestock needs, irrigation, industrial and many commercial activities (Veslind, 1993). Groundwater is generally less susceptible to contamination and pollution when compared to surface water bodies (Zaman, 2002). Also, the natural impurities in rainfall which replenish ground water systems get removed while infiltrating through soil strata (Veslind, 1993).

However, ground water can also be contaminated by naturally occurring sources. Soil and geologic formation containing high levels of heavy metals can leach those metals into groundwater. This can be aggravated by over pumping wells, particularly, for agriculture (Gay and Proop, 1993). Pollution caused by fertilizers and pesticides used in agriculture, often dispersed over large areas, is a great threat to fresh groundwater ecosystems. Pollution of groundwater due to industrial effluents and municipal waste in water bodies is another major concern in many cities and industrial clusters. Groundwater is very difficult to remediate, except in small defined areas and therefore, the emphasis has to be on prevention.

1.2. STATEMENT OF THE PROBLEM

The general importance of water cannot be over-emphasized because man’s prime need in his environment is for quality water both for domestic and agricultural use, but as a result of the increase in population of the study area and the world at large, there is the possibility of an increased rate of man’s activities on the water systems which will directly or indirectly alter the quality of water in the study area. Fresh water resources are threatened not only by over exploitation and poor management but also by ecological degradation. Besides, animals and other natural contaminants have also contributed to the detriment of water pollution in various communities.

1.3. Aim and Objectives of the Study

This study is aimed at evaluating the quality of surface and groundwater systems in Bida

catchment area of Niger State, Nigeria.

To accomplish this task, the specific objective is:

To evaluate the physio-chemical and bacteriological test of surface (river Landzun) and groundwater (hand dug well and boreholes) systems in Bida catchment area of Niger State, Nigeria.

1.4. Justification

Water is known as an essential entity to man, but over the years it was observed that its quality has been altered; hence, man should see it as a challenge to explore ways of making quality water available for domestic and agricultural purposes in order to minimize the hazardous impact of using untreated water for domestic and agricultural purposes.

1.5. Scope and Limitations of the Study

The scope and limitations of this study was the evaluation of surface (river Landzun) and

groundwater (boreholes and hand dug wells) quality in Bida catchment area considering the physical; chemical; and bacteriological parameters.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1. Hydrology

In any hydrological setting, surface water and groundwater are the major sources of water. Surface water encompasses water from rivers, streams and lakes whereas groundwater constitute water from borehole, hand dug wells, and springs. The two major source of water are prone to pollution and contamination, hence, the quality of water needs to be assessed. However, Emphasis had been made on the fact that the quality of water is just as significant as its quantity (Abimbola, 1999; Adeyemi *et al*., 2008). Basically, water is domestically required for drinking, bathing, cooking, and general sanitation such as laundry, flushing of closet and other household chores, where as for agricultural purpose, it is specifically for irrigation purpose. Therefore, an assured supply of water both qualitatively and quantitatively for this purposes greatly improve the social, economic and agricultural activities of the people.

2.2. Water Pollution and Contamination

It is a factual knowledge that clean water is essential for healthy living. Adequate supply of fresh water and clean drinking water is a basic need for all human beings on the earth yet it has been observed that millions of people worldwide are deprived of this. The main sources of fresh water pollution can be attributed to discharge of untreated waste, dumping of industrial effluent, and run off from agricultural fields. Industrial growth, urbanization, and the increasing use of synthetic organic substances have serious and adverse impact on freshwater bodies. It is a generally accepted fact that the developed countries suffer from problems of chemical discharge into the water sources mainly groundwater, while developing countries face problems of agricultural run-off in water sources. Contaminant sources that are particularly important in rural areas include fertilizers; pesticides; septic tank effluent; animal wastes; and agricultural and municipal sludge. Particulate and gaseous emissions, such as smokestack or vehicle discharges, may be transported long distances through the atmosphere before eventual deposition in the landscape. Many areas of groundwater and surface water are now contaminated with heavy metals, POPs (persistent organic pollutants), and nutrients that have an adverse effect on health. Water-borne diseases and water caused health problems are mostly due to inadequate and incompetent management of water resources.

2.2.1. Sources of Water Pollution

Saltwater encroachment associated with over drafting of aquifers or natural leaching from natural occurring deposits are natural sources of groundwater pollution. Most concern over groundwater contamination has centered on pollution associated with human activities. Human groundwater contamination can be related to waste disposal (private sewage disposal systems, land disposal of solid waste, municipal wastewater, wastewater impoundments, land spreading of sludge, brine disposal from the petroleum industry, mine wastes, deep-well disposal of liquid wastes, animal feedlot wastes, radioactive wastes) or not directly related to waste disposal (accidents, certain agricultural activities, mining, highway deicing, acid rain, improper well construction and maintenance, road salt*) (www.lenntech.com/groungwater*).

Large quantities of organic compounds are manufactured and used by industries, agriculture and municipalities. These man-made organic compounds are of most concern. The organic compounds occur in nature and may come from natural sources as well as from human activities. In many locations groundwater has been contaminated by chemicals for many decades, though this form of pollution was not recognized as serious environmental problem until the 1980s (*www.lenntech.com/groungwater/pollution).*

2.2.1.1. Natural

Groundwater contains some impurities, even if it is unaffected by human activities. The types and concentrations of natural impurities depend on the nature of the geological material through which the groundwater moves and the quality of the recharge water. Groundwater moving through sedimentary rocks and soils may pick up a wide range of compounds such as magnesium, calcium, and chlorides. Some aquifers have high natural concentration of dissolved constituents such as arsenic, boron, and selenium. The effects of these natural sources of contamination of groundwater qualities depend on the types of contaminant and its concentrations. (U.S. Environmental Protection Agency. *http://www.epa. waterpollutants*).

2.2.1.2. Agricultural

Pesticides, fertilizers, herbicides and animal waste are agricultural sources of groundwater contamination. The agricultural contamination sources are varied and numerous: spillage of fertilizers and pesticides during handling, runoff from the loading and washing of pesticide sprayers or other application equipment, using chemicals uphill from or within a few hundred feet of a well. Agricultural land that lacks sufficient drainage is considered by many farmers to be a low income land, so they prefer to install drain tiles or drainage wells to make the land more productive. Storage of agricultural chemicals near conduits to groundwater such as open and abandoned wells, sunk holes, or surface depressions where ponded water is likely to accumulate could as well cause contamination of groundwater. Contamination may also occur when chemicals are stored in uncovered areas, unprotected from wind and rain, or are stored in locations where the groundwater flows from the direction of the chemical storage to the well *(http://www.epa.gov/ebtpages/watewater*).

2.2.1.3. Industrial

Manufacturing and service industries have high demands for cooling water, processing water and water for cleaning purposes. Groundwater pollution occurs when used water is returned to the hydrological cycle. Modern economic activity requires transportation and storage of material used in manufacturing, processing, and construction. Along the way, some of this material can be lost through spillage, leakage, or improper handling. The disposal of wastes associated with the above activities contributes to another source of groundwater contamination. Some businesses, usually without access to sewer systems, rely on shallow underground disposal.

They use cesspools or dry holes, or send the wastewater into septic tanks. Any of these forms of disposal can lead to contamination of underground sources of drinking water. Dry holes and cesspools introduce wastes directly into the ground. Septic systems cannot treat industrial wastes. Wastewater disposal practices of certain types of businesses, such as automobile service stations, dry cleaners, electrical component or machine manufacturers, photo processors, and metal platters or fabricators are of particular concern because the waste they generate is likely to contain toxic chemicals. Other industrial sources of

contamination include cleaning off holding tanks or spraying equipment on the open ground, disposing of waste in septic systems or dry wells, and storing hazardous materials in uncovered areas or in areas that do not have pads with drains or catchment basins. Underground and above ground storage tanks holding petroleum products, acids, solvents and chemicals can develop leaks from corrosion, defects, improper installation, or mechanical failure of the pipes and fittings. Mining of fuel and non-fuel minerals can create many opportunities for groundwater contamination. The problems stem from the mining process itself, disposal of wastes, and processing of the ores and the wastes creates groundwater contamination (U.S. Environmental Protection Agency. http://www.epa. waterpollutants.html).

2.2.1.4. Residential

Residential wastewater systems can be a source of many categories of contaminants, including bacteria, viruses, nitrates from human waste, and organic compounds. Injection wells used for domestic wastewater disposal (septic systems, cesspools, drainage wells for storm water runoff, groundwater recharge wells) are of particular concern to groundwater quality if located close to drinking water wells. Improperly storing or disposing of household chemicals such as paints, synthetic detergents, solvents, oils, medicines, disinfectants, pool chemicals, pesticides, batteries, gasoline and diesel fuel can lead to groundwater contamination. When stored in garages or basements with floor drains, spills and flooding may introduce such contaminants into the groundwater. When thrown in the household trash, the products will eventually be carried into the groundwater because community landfills are not equipped to handle hazardous materials. Similarly, wastes dumped or buried in the ground can contaminate the soil and leach into the groundwater. (U.S Environmental Protection Agency *www.epa/watewaterpollutants.html*)

2.3. Hazardous Effects of Polluted Water to the Environment

This can be assessed based on the health condition of the inhabitants in the environment as well as the effect on irrigation.

2.3.1. Health Impact of Water Pollution

Polluted water like chemicals in drinking water causes problem to health and leads to water-borne diseases which can be prevented by taking adequate measures. Water borne diseases are transmitted through contaminated water. They are normally caused by the presence of micro – biological parameters in water. However, the absence of such parameters as pathogenic bacteria, and viruses would not guarantee the safety of water. The prevention of water borne diseases is therefore, left to many precautions to be taken from the source of raw water to the ultimate consumers. Some of the water-borne diseases are discussed below (Hammer, 1997).

Cholera: In conjunction with high fatality rate, cholera remains at the top of the list of water borne diseases. It is caused by bacteria called *vibrio-cholerae*. Flies and food especially, cut fruit eaten raw food may be the major factors in spreading cholera. The micro – organisms involved in this acute infectious disease is *vibrio-comma* with habitat in faeces of infected patient and water. Optimum temperature for growth is 37^0C (limits 14^0C - 40^0C). It is killed in 10minutes at 55^0C. Sanitary measures have kept the disease under control with the exception of area where primitive conditions exist. It can be eliminated by hygienic living and good water supply.

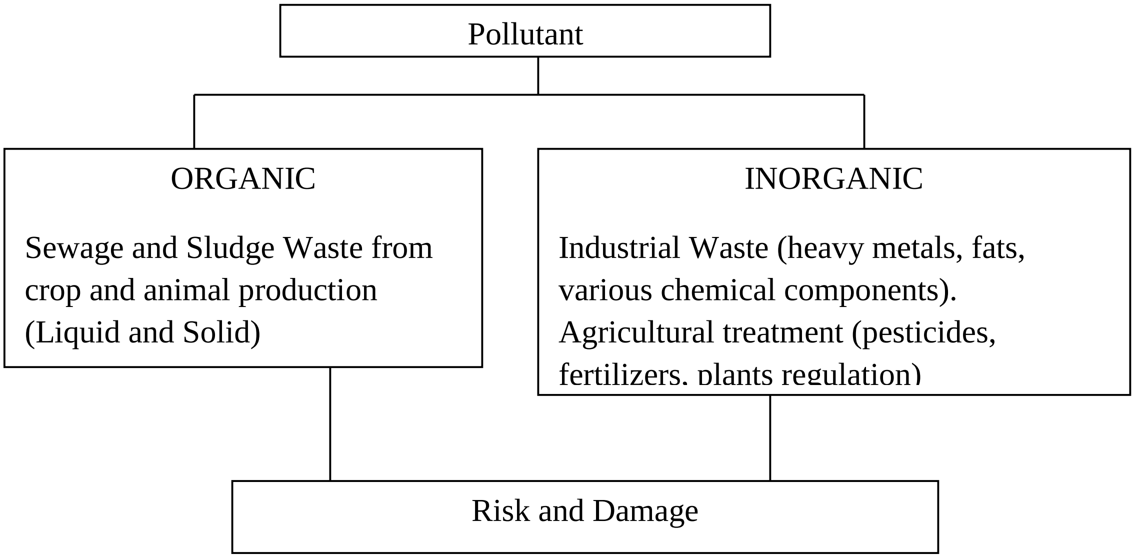
Typhoid fever: The spread of typhoid fever has reduced due to vaccination, water treatment and improved general sanitation, typhoid remains the most serious among the communicable diseases. It is caused by bacteria called *salmonella typhi*. The micro – organism is *salmonella typhosa*. Its habitat is stool of infected patient. Its optimum temperature for growth is 37^0C (limits 4^0C to 46^0C) and can be destroyed by a temperature of 56^0C in 20minutes. The expected means of dissemination is water, milk, food, flies, and direct contact. Major epidemic have been attributed to contaminated water supply.

Diarrhea, Dysentry, and enteritis: These are major cause of death in all developing countries. It also leads to frequent illness and impaired growth in children. They are not prevalent in tropical climates and are caused by bacillary dysentery and amoebic dysentery. They are spread when the infected faeces of one person reach the mouth of another either in water or food. Dysentery is accompanied by the passage of blood in the faeces. The two groups of causes, bacteria of the germs, *shigella* and *protozoa* called *entamoeba histolytica*.

Skin and eye infection: Infective skin disease is related to water availability, though it varies with climate and socio – cultural conditions. It is easier to measure than diarrhea since it is visible. In medical records skin infections appear as skin sepsis, skin ulcer, scatries, and leprosy. Parasitic worms: These are relatively long lived organisms. One general feature of parasitic worms in man is that they do not multiply within the human host so that someone cannot acquire more except by being exposed to further infection. They are *ascans*, *trichuris*, guinea worm, and *stustosomiasis* (Hammer, 1997).

2.3.2. Effect of Water Pollution on Irrigation

Natural waters become polluted when they become unsuitable following the addition of substances (contamination) other than those normally present. The use of water of less than optimal quality for irrigation introduces various kinds of risk (agronomic, sanitary, and environmental) and can cause damage of direct and indirect types, depending on the form of pollution involved as indicated in the figure below.



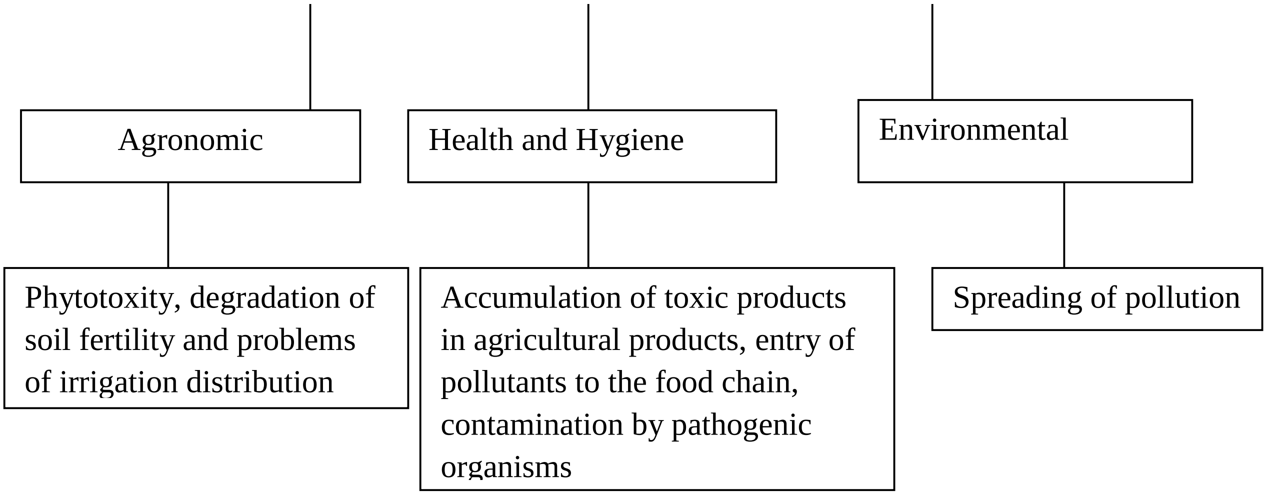


Figure 2.1: Flow chart of risk and damage in relation to agricultural use of polluted water.

Source: (Egharevba, 2009)

For water from conventional sources, it is usually sufficient to check the following characteristics: content of sodium, magnesium, calcium, sulphates, chlorides, boron, sodium absorption ratio (SAR) and electrical conductivity (EC). In the case of waste water, however, it is necessary to check for the presence of organic substances, nitrogen, phosphorus, potassium, micro-organisms and heavy metals (Egharevba, 2009).

2.4. Water Treatment Processes

Whenever the quality of a water supply does not meet the standards for its intended use, some type of treatments will be necessary. Treatment processes vary in sophistication, but all add to the cost of the water. Application of best management practices can markedly improve the quality of water supply, reducing treatment costs as well as providing environmental benefits. Treatment methods may include physical, chemical, and biological processes, either alone or in combination. A treatment method is selected to best fit the type of water quality problem, the intended use of the treated water, and the economics of the situation (AWWA, 1990).

2.4.1 Clarification

Settling is often the first step in water treatment. Large or heavy particulates will fall to the bottom quickly in still water. Very fine suspended particulates can be made to settle more quickly by addition of flocculating agents such as gypsum or polyacrylamide. Adjustment of pH may be needed. Flocs that do not settle may be removed by skimming, if they float, or by subsequent filtration.

2.4.2. Filtration

Filtration can be effective for removal of particulate contaminants. The size and amount of particulates present determines the type of filter that is appropriate. Filters are needed with micro-irrigation systems to remove suspended particulates, which may include fine sands, silt, clay, or algae. They are also common in public and private water treatment systems. Sand filters have varying capacities and efficacies, depending on the size of the filter and the media used, and are easily regenerated by backwashing. Sand filters can remove most suspended materials but are not effective with very fine particulates or bacteria.

Cartridge filters can be constructed with finer pores than sand filters. Materials include paper fiber, fiberglass, ceramics, and precision-etched polycarbonates. The finer pore structure requires more cross-sectional area than for a sand filter for equivalent capacities. Cartridge filters are most effective where the concentration of particulates is low, so that cleaning or replacement is required less frequently. Cartridge filters can remove bacteria but should be regularly maintained in drinking water systems, as the cartridge itself could become a problem if bacteria accumulate and multiply.

Some cartridge filters contain carbon, which can remove chlorine and some organic compounds. For very demanding purposes, micro- (0.1-2 (micro) mm), ultra- (0.001-0.1(micro) mm), and nanofiltration are available. Nanofiltration can remove organic compounds having molecular weights of 300 to 1000g and reject some salts.

2.4.3. Ion Exchange

The most familiar ion exchange treatment process is water softening. Sodium ions are stored in a filter bed of zeolite (an aluminosilicate resin). As hard water flows through the bed, sodium ions are exchanged for calcium and magnesium ions. The zeolite bed is periodically regenerated (Na^+ and Cl^-) by flushing with brine. De-ionized water is produced in a similar process. Ions in the water are exchanged for (H^+ and H^-) which can then combine to form water. Deionization is used where extremely pure water is needed. Deionization will not generally remove nonionic compounds, organics, or pathogens.

2.4.4. Disinfection

Chlorination is the most common method of disinfection. Chlorine gas is added to the water after pretreatments (clarification, and filtration) to kill microbes. An excess of chlorine is added to provide a residual concentration (usually about 5 ppm) to control re-growth throughout the distribution system. If other organic compounds are present, chlorine tends to react with them first, forming chloramines or chlorinated hydrocarbons that may be carcinogens. This reaction also increases the amount of chlorine needed to achieve disinfection. Sodium hypochlorite and calcium hypochlorite are alternative sources of chloride that are less dangerous to handle than chlorine gas. These are commonly used in small or private water systems or as algicides in micro-irrigation systems (AWWA, 1990). Ozonation is another method of disinfection which uses ozone (O_3), a powerful oxidant, to kill pathogens. Unlike chlorine, ozone will not leave a lasting residual, so there is the possibility of subsequent re-growth of pathogens. Because of this, ozonation should not be used alone where water may reside in the system for extended periods before use. However, Ionizing radiation, such as ultraviolet light, can kill many pathogens. Ultraviolet light can also break down low-level organics. Like ozonation, it has no residual effect, which limits its application.

2.4.5. Reverse Osmosis

In reverse osmosis, a pressure difference on the order of 1000-7000 KN/m^2 drives water across special membranes, rejecting nearly all organics and 90-99 percent of all ions. Over 99.9 percent of viruses and bacteria are also removed. A fraction of the source water, the concentrate or reject water, carries the rejected ions and other constituents to disposal. The fraction that passes through the membrane, the permeate is the desired product. Many types of membranes are commercially available to meet different permeate requirements.

2.4.6. Distillation

Distillation is the collection of condensed steam that is produced by boiling water. This can remove all types of impurities, although organics with boiling points near that of water require very close control and perhaps multiple distillations. Distillation is energy intensive, but can produce water with impurity concentrations as low as 10 parts per trillion (AWWA, 1990).

2.5. Water Quality and International Standards

Water quality is determined by the concentration of biological, chemical, and physical contaminants. Most water pollution is the result of human and animal wastes plus some industrial processes. Chemicals enter the water supply from industrial processes and agricultural use of fertilizers and pesticides. Physical contaminants results from erosion disposal of solids waste. Since all of these sources contribute to degradation of water quality, standards have been developed for drinking water from different bodies in the world. 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 both surface and ground water supplies.

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, industrial waste 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 (Glenn *et al.*, 2000).

2.5.1. Physical Properties of Water

The most common contaminants and by far the largest (by mass) is sediment i.e. soil particles that have become suspended either through erosion from upland areas (agricultural and other disturbed lands), stream bank erosion or detachment of stream particles. The size and amount of sediment that can be transported depend on the energy of the flow – fast – flowing streams have higher capacities for transport than do slow – flowing streams. Vigorous flow can move boulders, whereas the quiet flows in lakes can transport only the finest silts and clays. Deposition of sediment can occur wherever flowing water slows. Sediment also includes carbonaceous materials, whether derived from geologic formations (such as coal) or modern plant detritus. Organic materials provide a food source for microbes and may harbor pathogens. Carbonate and silica biocrystals are a minor source of sediment. Biocrystals are formed by organisms such as mollusks, foraminifers, sponges and diatoms.

Excessive sediment can degrade aquatic habitat by restricting penetration of light, which affects photosynthetic activity and predator – prey relationships, and by altering benthic habitat. Deposition of sediment in impoundments and channels also reduces capacity increasing the frequency of flooding. Sediment from agricultural lands may carry nutrients or pesticides. Sediment can also change the benthic environment by filling in the spaces between rocks and gravels. However, turbidity is another physical contaminant which refers to the murkiness of the water. It is quantified by measuring the degree to which light is scattered by suspended particulates (sediment and organic matter) in the water. The common unit is the Nephilometric Turbidity Unit (NTU). A number of sensors are commercially available for laboratory or field use. The sechic disk provides a method for quick evaluation of turbidity, although its visibility is influenced by colour of the water in addition to particulates. Turbidity is not a health threat in itself. Organic matter that contributes to turbidity can harbor pathogens and tends to deplete dissolved Oxygen. Turbidity affects growth of phytoplankton, algae, and aquatic plants, generally favouring those organisms closest to the surface. Elevated turbidity places fish under stress, reducing feeding success, growth, and hatching rates. Benthic invertebrates may suffer from reducing oxygen levels (Mallin, 1994).

2.5.2. Chemical Properties of Water

The chemical characteristics of water are quantified in terms of the inorganic and organic constituents that may be present.

2.5.2.1. Inorganic Chemicals

There are thousands of chemicals that can be in water. Solubility and toxicity vary widely. However a few of the most common that are subject to federal regulation includes arsenic, barium, beryllium, cadmium, chromium, copper, cyanide, fluoride, lead, mercury, selenium, and thalium. Sources of these chemicals include discharge from metal and petroleum refineries, industrial discharges, and decaying piping systems. Natural mineral deposits may contribute to locally high concentrations. Some are present in fertilizers or are added to animal feeds. Heavy metals are variously used to refer to antimony, arsenic, cadmium, chromium, copper, lead, mercury, and zinc, among others. It has been defined to include all elements with atomic weights from that of copper to that of mercury (Kennish, 1992). Many are essential trace nutrients. Non-essential elements may interfere with organisms by substituting for chemically similar elements. several (e.g. arsenic, lead and mercury) have been used in pesticides, but that practice has been largely discontinued because of the persistence of those elements and their concentration in the food chain.

Inorganic also includes compounds containing common ions such as sodium, calcium, magnesium, and chloride. Water hardness is often defined as the total concentration of the metallic cations (the most common are calcium, and magnesium) in solution that react with sodium soaps to produce solids or scummy residue and that react with anions. Hardness is a common problem in ground water in areas underlain by carbonate rocks such as limestone. Natural rainfall is slightly acidic and gradually dissolves these minerals as it percolates through them. Excessive hardness interferes with detergents and can cause scale deposits in heating systems or irrigation equipment. Excessive sodium (relative to calcium and magnesium) in solids tends to disperse clays, which restricts the movement of air and water through the soil profile. Chlorides in excess of 250mg/l in the presence of sodium gives water a salty taste. Crops have varying tolerances to salt concentration in the soil water.

2.5.2.2 Organic Chemicals

Organic chemicals include thousands of compounds, both synthetic and natural. Those of greatest concern for water quality includes pesticides (e.g. alachlor, atrazine,carbofuran, lindane) and industrial chemical, particularly solvents (e.g. benzene, toluene, xylene carbon, tetrachloride). Many such organics are confirmed or suspected carcinogins. The trend in pesticides development has been towards high specificity and short lives in the environment. This is a great improvement over persistent pesticides based on arsenic, mercury, and chlorinated hydrocarbons (e.g. DDT). Many ground water contaminant incidents could be traced to operators who dumps unused pesticides mixes and equipment rinsed with water directly on the ground often next to the well that supplied the water.

Current best management practice requires a concrete pad with a sump located some distance from the well where chemical mixing and equipment cleaning are performed. proper handling of the water collected in the sump prevents direct contamination of the soil and ground water. The great variety and complexity of organic materials found in water makes discrete analytical description impractical for many purposes, organic materials can be quantified with collective parameters, such as chemical oxygen demand (COD), Biological Oxygen Demand (BOD), dissolved organic carbon (DOC), and Total Organic Carbon (TOC) (Stumm and Morgan, 1996).

2.5.3 Biological Properties of Water

Micro-organisms in drinking water are a problem throughout the world. They include viruses, bacteria, algae, and protozoa. Although, most microorganisms are harmless or beneficial, many are pathogenic. The very young, very old, and immune compromised are most susceptible to water – borne pathogens. The most common sources of these pathogens are human and animal wastes. Biological contaminants are discussed below:

a. Protozoa: Protozoan range from 2 to 15 microns. The most common include Guadia lamblia, Entamoeba, Instolytica, and Crystosparidum. These cause diarrhea and gastroenteritis. Schistosomiasis is found in stream banks in the tropics and is a major cause of disease in those regions (McCutcheon *et al.*, 1992).

b. Bacteria: Bacteria range in size from 0.2 to 0.6 microns. They can cause cholera (*Vibrio cholera*), typhoid fever (*Salmonella sera*-group *Typhi*), and epidemic dysentery (*Shigela dysenteriae Typhi*), among others. Water borne bacterial infections usually are associated with poor sanitation and hygiene. Escherichia Coli includes many *Coliflrm* bacteria, mostly benign, that inhabit the instines of warm blooded animals. A test for fecal *Coliform* is commonly used as an indicator of fecal contamination of a water supply. In recent decades, several toxic strains have been discovered that can cause diarrhea and even kidney failure (Mean and Griffin, 1998).

Infection is usually via contaminated, uncooked, or undercooked foods or via direct contact with infected individuals.

c. Viruses: viruses are the smallest microorganisms, ranging from 0.01 to 0.03 microns. Enteric virus infect the gastro - intestinal tract of mammals and are excreted in faeces, Where water supplies are contaminated by faeces. There is the potential for transmission. Water – borne viruses of particular concern includes; Hepatitis A, Norwalk type viruses, Rotaviruses, Adenoviruses, Enteroviruses, and Reoviruses (AWWA, 1990), most of which infect the intestine and/or the upper respiratory tract. Viruses can also cause aseptic meningitis, encephalitis, polomeyelitis, and myicarditis. The most effect means of prevention are good sanitation and hygiene.

2.5.4 Water Quality for Drinking

It has been estimated that 8% of worldwide water used is for household purposes**.** These include drinking water, bathing, cooking, sanitation, and gardening. Basic household water requirements have been estimated by Peter Gleick at around 50 litres per person per day, excluding water for gardens. Drinking water is water that is of sufficiently high quality so that it can be consumed or used without risk of immediate or long term harm. Such water is commonly called potable water. Nigeria is the most populous country in Africa, with a population of over 140 million, the country is endowed with generous resources of water bodies. The span of water bodies within the country is estimated at 900 km^2. This water provides resources for fishery, transportation, irrigation, recreation and domestic uses. Different regulations put in place to protect the marine environment in Nigeria have not been effective in controlling the indiscriminate dumping of effluent into open water bodies.

These effluents range from chlorides, phosphates, oil and grease, nitrates, heavy metals to name a few. The heavy metals present in most Nigerian rivers and found in concentrations well above acceptable and permissible levels are lead, copper, zinc, nickel, chromium, Cadmium and Iron (Olayinka and Alo, 2004; Esoka and Umaru, 2006; Eniola *et al.*, 2010). Degradation of water quality is most severe in the four states that contain 80 percent of the nations industries; Lagos, Rivers, Kano and Kaduna States. This has continued to pose a threat on health and economic development in Nigeria (Olayinka and Alo 2004; Adekunle *et al*., 2007; Adeyemi *et al*., 2008; Mustapha 2008; Adewolu *et al*., 2009). Enforcement of emission standards have not been done strictly and the Federal Ministry of Environment still faces some challenges in helping industries adopt cleaner technologies (Adelegan, 2004). Although findings related to industrial pollution of water resources have been disturbing, the category of pollution that has received much attention in Nigeria is sewage pollution of portable drinking water. This has been managed with the weight of such bodies as United Nations International Children Education Fund (UNICEF) established in Nigeria in 1952 and Water Aid which began work in Nigeria in 1995 to assist with the vast water and sanitation needs found and has since been assisting the Water and Sanitation Units (WASU) of Local Government Councils to deliver water and sanitation services to the poor.

However, about 60 percent of the Nigerian populace both rural and some urban dwellers still source for domestic water and sometimes drinking water from ponds, streams and shallow wells justifying the concern for increases in the level of pollutants in surface and groundwater, thus, making water monitoring even more vital (Adelegan, 2004; Water Aid, 2007). Presently, very little if any has been done on an integrated level concerning industrial pollution abatement in Nigerian waters (Olayinka and Alo, 2004; Essoka and Umaru, 2006). The Federal Government of Nigeria only gave attention toenvironmental abuse after the discovery of an Italian ship dumping toxic wastes in Nigeria in May 1998, giving rise to the establishment of the “Federal Environmental Protection Agency” FEPA later that year. The establishment of FEPA was also followed by the publication of “National Guidelines and Standards for Environmental Pollution” which focused mainly on industrial pollution. This body was renamed in September 1999 and is presently the ‘ministry of environment. Fifty years ago, the common perception was that water was an infinite resource. At this time, there were fewer than half the current numbers of people on the planet. People were not as wealthy as today, consumed fewer calories and ate less meat, so less water was needed to produce their food. They required a third of the volume of water we presently take from rivers. Today, the competition for water resources is much more intense. This is because there are now nearly seven billion people on the planet, their consumption of water-thirst meat and vegetables is rising, and there is increasing competition for water from industry, urbanization and biofuel crops. In future, even more water will be needed to produce food because the Earth's population is forecast to rise to 9 billion by 2050. United Nations Press Release POP/952 (13 March 2007).

An additional 2.5 or 3 billion people, choosing to eat fewer cereals and more meat and vegetables could add an additional five million kilometers to the virtual canal mentioned above. An assessment of water management in agriculture was conducted in 2007 by the International Water Management Institute in Sri Lanka to see if the world had sufficient water to provide food for its growing population. Molden, D. (Ed). Earth scan/IWMI (2007). It assessed the current availability of water for agriculture on a global scale and mapped out locations suffering from water scarcity. It found that a fifth of the world's people, more than 1.2 billion, live in areas of physical water scarcity, where there is not enough water to meet all demands. A further 1.6 billion people live in areas experiencing economic water scarcity, where the lack of investment in water or insufficient human capacity makes it impossible for authorities to satisfy the demand for water. The report found that it would be possible to produce the food required in future, but that continuation of today's food production and environmental trends would lead to crises in many parts of the world. To avoid a global water crisis, farmers will have to strive to increase productivity to meet growing demands for food, while industry and cities find ways to use water more efficiently (Chartres and Varmas, 2010).

In some areas of the world irrigation is necessary to grow any crop at all, in other areas it permits more profitable crops to be grown or enhances crop yield. Various irrigation methods involve different trade-offs between crop yield, water consumption and capital cost of equipment and structures. Irrigation methods such as furrow and overhead sprinkler irrigation are usually less expensive but are also typically less efficient, because much of the water evaporates, runs off or drains below the root zone. Other irrigation methods considered to be more efficient include drip or trickle irrigation, surge irrigation, and some types of sprinkler systems where the sprinklers are operated near ground level. These types of systems, while more expensive, usually offer greater potential to minimize runoff, drainage and evaporation. Any system that is improperly managed can be wasteful; all methods have the potential for high efficiencies under suitable conditions, appropriate irrigation timing and management.

Some issues that are often insufficiently considered are salinization of sub-surface water and contaminant accumulation leading to water quality declines. FAO Retrieved (2009-03-12). As global populations grow, and as demand for food increases in a world with a fixed water supply, there are efforts under way to learn how to produce more food with less water, through improvements in irrigation FAO Retrieved (2009-03-12). Methods Fao.org. Retrieved (2009-03-12) and technologies, agricultural water management, crop types, and water monitoring.

Aquaculture is a small but growing agricultural use of water. Freshwater commercial fisheries may also be considered as agricultural uses of water, but have generally been assigned a lower priority than irrigation Methods Fao.org. Retrieved (2009-03-12).

However, World health organization (WHO, 2004), has presented Water Quality Guidelines for some Parameters as below;

Table 2.1: WHO, 2004. Approved drinking water quality standards (all parameters are in mg/l).

Parameters	Guideline Values
Ammonia	1.5
Chloride	250
Copper	5
Hardness	500
Iron	0.3
pH	6.5 – 8.0
Sodium	200
Sulphate	250
TDS	1000
Turbidity	5cfu
Fluoride	1.5
Nitrate	50
Coliform	-
E-Coli	-

Source: (WHO, 2004)

2.5.5 Water Quality for Irrigation

All irrigation waters contain some dissolved salts. Dissolved salts are present because some chemical elements have a strong attraction for water and a relatively weak attraction for other elements. Two such chemical elements, for example, are sodium and chloride. The amounts of these elements contained in water must be very high before sodium will combine with chloride to form the solid material sodium chloride (common table salt). The total amount and kinds of salts determine the suitability of the water for irrigation use. Water from some sources may contain so much salt that it is unsuitable for irrigation because of potential danger to the soil or crops. Irrigation water quality can best be determined by chemical laboratory analysis (Samuel and Halin, 1990).

The two most important measures for determining irrigation water quality are: The total amount of dissolved salts in the water and The amount of sodium (Na) in the water compared to calcium (Ca) plus magnesium (Mg). The total dissolved salt content is estimated by measuring how well the water conducts electricity. Salty water is a good conductor of electricity. Electrical Conductivity (EC) is measured in units of micromhos/cm (μmhoms/cm). The ppm salt concentration of the water is estimated by multiplying 0.65 times the EC value. For example, water having an electrical conductivity of 1000 micromhos/cm would contain about 660 ppm salt.

However, other analytical procedures are used to measure the amounts of individual chemicals, such as sodium in the water. The list of chemicals (and their symbol or formula) routinely measured to determine irrigation water quality follows: Electrical Conductivity (μmhos/cm), Chloride (Cl), Sodium (Na), Nitrate (NO3), Calcium (Ca), Carbonate (CO3), Magnesium (Mg), Bicarbonate (HCO3), and Sulfate (SO4) (Samuel and Halin, 1990).

2.5.5.1 Problem with Salinity.

Saline conditions restrict or inhibit the ability of plants to take up water and nutrients, regardless of whether the salinity is caused by irrigation water or soil water which has become saline because of additions of salty water, poor drainage, or a shallow water table. Plants uptake water through a process of ‘osmo-regulation’, wherein elevated salt concentration within plants causes water to move from the soil surrounding root tissue into the plant root. When the soil solution salinity is greater than the internal salinity of the plant, water uptake is restricted. The result is often a smaller plant than one not affected by salinity. Yield reduction may occur even where plant symptoms appear minimal. In situations of especially elevated salinity, plant tissue may die, thereby exhibiting necrosis at the leaf edges. Additionally, saline water may lead to concentrations of some elements which can be toxic to plants. Some examples of frequently occurring specific-ion toxicities include boron, sodium, and chloride.

Table 2.2. General guidelines for assessment of Salinity hazard of irrigation water.

		Limitation	
	None	Moderate	Severe
EC_W (ds/m)	<0.75	0.75 – 3.0	<3.0
TDS (mg/l)	<450	450 – 2000	>2000

Source: (Miller and Gardiner, 2007).

2.5.5.2 Problem with Sodicity

This implies the amount of sodium relative to the amount of calcium and magnesium. Sodic water is water with a high concentration of sodium, relative to the concentration of calcium and magnesium. Sodic water is not the same as saline water. Sodium adsorbs onto cation exchange sites of the soil, which causes aggregates of some soils to break down (disperse), leading to sealing of soil pores and a reduction in permeability to water flow. This typically only happens to soil with a relatively high percentage of smectite clay, which is a group of clay minerals that includes montmorillonite and bentonite. This type of mineral tends to swell when exposed to water. Once a clay-dominated soil disperses, the soil will either become anaerobic (lacking oxygen), saline, or compacted/consolidated.

The tendency for sodium to increase its proportion on the cation exchange sites at the expense of other types of cations (primarily calcium and magnesium) is estimated by the sodium adsorption ratio (SAR), which is the ratio of sodium concentration to the concentration of the square root of the average calcium plus magnesium concentration in either irrigation water or the soil solution. Numerically, SAR can be expressed as:

$$\text{SAR} = \frac{Na^{+} meq/l}{\sqrt{\frac{(Ca^{++} meq/l) + (Mg^{++}\ meq/l)}{2}}} \qquad (2.1)$$

where, Na^{+} = Sodium ion, Ca^{++} = Calcium ion, and Mg^{++} = Magnesium ion.

Numerous references refer to sodicity problems associated with irrigation water as permeability. Complicating the issue of sodicity is the fact that at very low salinity levels (even though the ratio of sodium to calcium plus magnesium may be high), soil flocculation and aggregation (which occurs with any high salt concentration) is lost and permeability decreases. Thus, irrigation water which is very low in salt concentration (< 0.2 dS/m) accentuates poor permeability resulting from high SAR. This principle is illustrated in Table 3, which provides a summary of guidelines for assessment of sodium hazard of irrigation water (as applied to dispersive, smectite-rich soils) (Miller and Gardiner, 2007).

Another index that is used to express the phytotoxity of sodium is the Exchangeable Sodium Percentage (ESP), which can be obtained from the following expression:

$$\text{ESP} = \frac{(Na+ \times 100)}{(Na+ + Ca2+ + Mg2+ + K+)} \qquad (2.2)$$

The presence of carbonate corresponds to an increase in the concentration of sodium. The determination of bicarbonate in therefore represents another guideline in the evaluation of irrigation water quality.

Bicarbonate can be evaluated in terms of the Sodium Carbonate Residue (SCR), defined as:

$$SCR \ = \ (CO_3^{2-} + HCO_3) - (Ca^{2+} + Mg^{2+}) \qquad (2.3)$$

Where the concentration of ions are expressed in Meq/L and SCR >0 is for alkaline water.

Water containing a high percentage of HCO_3 ion has the tendency to precipitate Calcium and Magnesium in the form of carbonates. Sodium carbonate can also be formed. With sodium carbonate between 1.2 and 2.5, the water is not easily utilized. Unsuitable waters have sodium carbonate (Na_2 CO_3>2.5meq/l. damages may be caused by the deflocculating of soil colloids which, in turn, causes a definite reduction in soil permeability or clogs trickle/drip irrigation equipment (Egharevba, 2009).

Table 2.3; FAO Guideline for interpretation of water quality for irrigation.

Infiltration (affects infiltration rate of water into the soil; evaluate using EC_W and SAR)		Degree of restriction on use		
		None	Slight to moderate	Severe
EC_w and SAR together)				
SAR 0 – 3	and EC_w =	>0.7	0.7 – 0.2	<0.2
SAR 3 – 6	and EC_w =	>1.2	1.2 – 0.3	<0.3
SAR 6 – 12	and EC_w =	>1.9	1.9 – 0.5	<0.5
SAR 12 – 20	and EC_w =	>2.9	2.9- 1.3	<1.3
SAR 20 – 40	and EC_w =	>5.0	2.9 – 5.0	<2.9
Specific ions Toxicity (affects Sensitive Crops)				
Sodium (Na)				
Surface irrigation	SAR	<3	3 – 9	>9
Sprinkler irrigation	Meg/l	<3	>3	-
Chloride (cl^-)				
Surface irrigation	Meg/l	<4	4 – 10	>10
Sprinkler irrigation	Meg/l	<3	>3	-
Boron (B)	Meg/l	<0.7	0.7 – 3.0	>3.0
Potential irrigation problems				
	Units	None	Slightly to moderate	Severe
Miscellenious effects (on Susceptible Crops)				
Nitrate (No_3 - N)	Meg/l	<5	5 – 30	>30
Bicarbonate (HCO_3^-)	Meg/l	<1.5	1.5 – 8.5	>8.5
pH			Normal range	6.5–8.5

Adopted from Ayers and Westcot (1985).

2.5.5.3 Adjusted SAR (SAR_{adj})

The presence of or introduction of bicarbonate and carbonate ions in the irrigation water increases the permeability hazard as quantified by SAR. Irrigation of calcium rich or magnesium rich soil with water containing carbonate or bicarbonate ions will form insoluble calcium and magnesium carbonate (limestone, dolomite), thereby reducing the concentration of calcium and magnesium applied to the SAR calculation. This consideration in the calculation of SAR results in the adjusted SAR (SAR_{adj}) being greater than the SAR, thereby providing a truer index of the sodicity of the water and the risk of dispersion. Most SAR_{adj} values of irrigation waters are about 10 to 15 percent greater than the unadjusted SAR. Additionally, irrigation water with a low salt concentration and a high SAR will contribute to reduced permeability of dispersive soils eventually. It is important to know if you are dealing with SAR or SAR adjusted when interpreting results. Adjusted SAR can be expressed as:

$$SAR_{adj} = \frac{Na^{+}\ meq/l}{\sqrt{\frac{(Ca^{++}\ meq/l) + (Mg^{++} meq/l)}{2}}}\ (1 + (8.4 - pHc) \qquad (2.4)$$

where, Na^{+} = Sodium ion, Ca^{++} = Calcium ion, pHc = Acid-Base concentration.

Table 2.4: FAO Guideline for assessment of sodium hazard of irrigation water based on adjusted SAR and EC_W.

	Limitation		
	None	Moderate	Severe
		EC_W (ds/m)	
When SAR = 0 - 3 and EC_W	>0.7	0.2 - 0.7	<0.2
When SAR = 3 - 6 and EC_W	>1.2	0.3 - 1.2	<0.3
When SAR = 6 - 12 and EC_W	>1.9	0.5 - 1.9	<0.5
When SAR = 12 - 20 and EC_W	>2.9	1.3 - 2.9	<1.3
When SAR = 20 - 40 and EC_W	>5.0	2.9 - 5.0	<2.9

Source: (Miller and Gardiner, 2007).

2.5.5.4 Important Conversion Equations

A few sample conversions allow for comparison of salinity values measured or reported by different units.

For instance,

- 1ppm = 1mg/l for all practical purposes in dealing with salinity.
- 1ppm = 1mg/l (milligram per kilogram).
- 1 percent concentration = 10,000ppm.
- 1mmolc/l = 1 meq/l.
- 1 mmhos/lcm = 1ds/m.
- 1mmhos/l = 1000µmhos/cm.

TDS (ppm or mg/l) = 640 × EC_w (ds/m or mmhos/cm) when $EC_w < 5$ds/m). (2.5)

TDS (meq/l) = 10 × EC_w (ds/m or mmhos/cm) when $EC_w < 5$ds/m. (2.6)

TDS (ppm or meq/l) = 800 × $Ec_w > 5$ds/m. (2.7)

EC_w (ds/m or mmhos/cm) =

$$\frac{TDS\ (ppm\ or \frac{mg}{l})}{640\ when\ ECw < 5ds/m.} \qquad (2.8)$$

$$\text{Meq/l} = \frac{ppm}{equivalent\ weight} \qquad (2.9)$$

$$\text{Ppm} = \frac{equivalent\ weight}{meq/l} \qquad (2.10)$$

2.5.5.5 Managing Irrigation Water with Salt or Sodium

Leaching of salt below the crop root zone is essential for sustainable irrigated agriculture. With reasonably good irrigation practices on well-drained soils, including periodic leaching either with ample irrigation water or with precipitation, the average salt content of the saturated soil extract will be about 1.5 times the salt content of the irrigation water. Where water is less plentiful, evaporation and transpiration are relatively high, and leaching is less frequent, the saturated soil extract may have a salt concentration three or more times that of the irrigation water – due almost exclusively to the concentrating effect of salt as water either evaporates from the soil or is transpired by the growing crop. Consequently, as a basic guideline, the amount of water – quantity and frequency of availability – needs to be increased as the salinity level of the irrigation water increases.

Managing irrigation water with elevated sodium concentration is somewhat more challenging– due to the complexity of interactions between clay particles, sodium and salt concentration of the irrigation water, and rainfall . As a basic guideline, efforts should be made to avoid applying irrigation water with SAR greater than 63 to irrigated soils with more than 30% smectite clay. It is reasonable to expect that severe problems will occur on these soils if the SAR exceeds 9. Generally speaking, poorer quality water (higher salinity x SAR) can be used to irrigate sandy, well-drained soils with good drainage than can be used to irrigate soils having relatively high clay contents (Miller and Gardiner, 2007).

Table 2.5: FAO Guideline for interpretation of irrigation water quality

	Symbols	Units	Normal ranking in irrigation water
EC	EC_W	ds/m	0 - 3
TDS	TDS	mg/l	0 – 2000
Calcium	Ca^{2+}	me/l	0 - 20
Magnessium	Mg^{2+}	me/l	0 - 5
Sodium	Na^{+}	me/l	0 - 40
Carbonate	CO_3^{2-}	me/l	0 - 1
Bicarbonate	HCO_3^{-}	me/l	0 - 10
Chloride	Cl^{-}	me/l	0 - 30
Sulphate	SO_4^{2-}	me/l	0 - 20
Nitrate-Nitrogen	NO_3-N	mg/l	0 - 10
Ammonium-Nitrogen	NH_4-N	mg/l	0 - 5
Phosphate-phosphorus	PO_4-N	mg/l	0 - 2
Potassium	K^{+}	mg/l	0 - 2
Boron	B	mg/l	0 - 2
Acid/Basic	pH	mg/l	6 - 8.5
Sodium Absorption Ratio	SAR	1-14	0 - 9

Source: (Vasil *et al.,* 2008)

2.5.6. Classification of Water Quality

The most damaging effects of poor-quality irrigation water are excessive accumulation of soluble salts and/or sodium in soil. Highly soluble salts in the soil make soil moisture more difficult for plants to extract, and crops become water stressed even when the soil is moist. When excessive sodium accumulates in the soil, it causes clay and humus particles to float into and plug up large soil pores. This plugging action reduces water movement into and through the soil, thus crop roots do not get enough water even though water may be standing on the soil surface. These two aspects of irrigation water (total salts and percent sodium) are grouped in relation to the levels present and their effects on crops and soils. This classification system is based on research conducted in Oklahoma, other states, and by the USDA Salinity Laboratory at Riverside, California. Since the degree to which sodium is damaging to soil is strongly influenced by the amounts of calcium and magnesium present, the sodium adsorption ration (SAR) is also used (Zhang and Samuel, 1990).

2.5.7 Interpretation of Water Classes

Irrigation waters are grouped into six classes on the basis of soluble salt content and sodium percentage. Interpretation of these classes in relation to their use follows:

Class 1: Excellent- The total soluble salt content and sodium percentage of this water are low enough that no problems should result from its use.

Class 2: Good- This water is suitable for use on most crops under most conditions. Extensive use of Class 2 water on clay soils where little or no leaching occurs may eventually cause a saline or sodic soil problem. Normal rainfall will usually dilute the soluble salts and eliminate the risk of salt accumulation. If the water's Sodium Percentage is high (above 30 percent), gypsum can be used periodically to remedy the problem.

Class 3. Fair- This water can be used successfully for most crops if care is taken to prevent accumulation of soluble salts including sodium, in the soil. Good soil management and irrigation practices must be followed. Class 3 water can be used with little danger on permeable, well-drained soils. The water table should be at least 10 feet below the surface to allow accumulated salts to be leached below the root zone by excessive irrigation when rainfall is limited.

Class 4. Poor- Use of this water is restricted to well-drained permeable soils for production of salt tolerant crops. Irrigation practices must receive careful attention to avoid salt accumulation. Excess water must be applied when rainfall is not adequate to cause periodic salt leaching. Good soil management practices must be used to maintain good physical condition of the soil. Soil fertility levels must be maintained at adequate levels. Use of this water on medium textured soils may cause soil salinity problems if good practices are not followed. This water is not recommended for use on fine textured soils.

Class 5: Very Poor- Use of this water is restricted to irrigation of sandy, well-drained soils in areas of the state which receive at least 30 inches of rainfall. This water should not be used without advice from a trained in irrigation water use.

Class 6: Unsuitable- Water of this quality is not recommended for crop irrigation.

2.6. Previous Water Quality Analysis.

Water quality analysis carried out on river Landzun in 2002 is presented in Table 2.6 below:

Table 2.6: Water Analysis of river Landzun in 2002.

Source of water	River Landzun				River Landzun			
	Week 1(9th, March)				Week 2 (20th, March)			
.Location	A1	A2	B1	B2	C1	C2	D1	D2
pH at 25^{o}c	-	6	0		pHat	29^{o}c	6	4
Phosphate	<0.1mg/l	<0.03	<0.1	<0.2	<0.09	0.08	<0.2	<0.1
Chloride ion	22.82mg/l	67.45	25.46	08.0	23.80	30.02	22.60	25.44
Sulphate	<40ml/g/	62	36	50	34	39	25	35
Total Hardness	16mg/l	46	18mg/l	28.2	18ml	200	17.3	23
Iron	0.5mg/l	0.4	0.1	0.06	0.4	0.8	0.2	0.1
Sodium	0.7	0.97	0.8	0.95	1.20	1.38	0.92	0.98
Magnessium	0.2	0.2	0.14	0.15	0.2	0.08	0.04	0.15
Calcium	5.79	6.0	7.0	8.2	9.10	10.5	8.89	9.0
Nitrate	2.10	2.40	2.5	3.5	2.6	4.0	3.4	3.9
TDS	38	23	22	35	25	18	22	16
Elect.Conductivity	58.4	35	20	18	20.5	30	40.9	45
Temperature at	27^{o}c	-	26	-	29.5	-	28.5	-
pH at	6.0	-	6.9	-	6.4	-	6.2	-

Turbidity	29.53ftu	30.48	28	26	29.4	29.82	30.25	30.1
Total Alkalinity	12.0	16	14.5	14	14.0	14.50	16.04	16.2
Total Silica	<0.06	0.08	0.04	0.06	0.07	0.12	0.06	0.08

Source: (Sodipe, 2002)

Table 2.7: Bacteriological test results.

Water Sample	10.0ml	MPN	EMB	BGBB	E. Coli	Others
Organism	Coli					
4ml	16.0	+ve	+ve	+ve	+ve	+ve

Source: (Sodipe, 2002)

Table 2.8: Analytical report of Ground Water for heavy metals

Parameter	Range in sample	Mean	WHO
pH	6.37 - 8.37	7.09	7.00 – 8.50
ECw	1.018 –950.10	358.35	-
TDS	168.4–890.60	498.03	500.00
Turbidity	0.033 – 22.84	1.147	-
Chloride	32.99–383.99	204.38	200.00
Total Alkalinity	64.00-186.66	93.4	-
Total Hardness	69.33–638.66	352.9	100.00
Ca Hardness	52.00–418.00	256.02	75.00

Mg Hardness	13.33–174.66	96.88	50.00
Nitrate	1.1 – 120	36.97	-
Sodium	39 – 9750	658.94	-
Potassium	0.5 – 470	85.586	-
Sulphate	13.60–116.00	58.33	200.00
Fluoride	0.23–1.45	0.60	1.00
Iron	0.061–0.20	0.45	0.30
Lead	0.079–0.598	0.172	-
Zinc	0.056–1.25	0.134	-
Manganese	2.430–2.898	0.391	0.10
Copper	0.134–0.25	0.068	1.00

Source: (Usha *et al,* 2008)

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of Study Area

Bida lies on latitude 9^0 06’N and longitude 6^0 01’E and located in the southern part of Niger State as shown in Figure 3.1. This geographically places the area almost in the centre of Nigeria. Bida is generally regarded as the capital of Nupe land in Nigeria. Its rapidly increasing population is put presently at more than 600,000 people (Shehu, 2001). Historically, by 1352, the Nupe people were already settled in this location. Geographically this location shares boundaries with the federal capital territory (FCT) in the south-east of Bida and Minna towards Suleja, while to the North it shares boundaries with Zungeru and North-west by Zugurma towards Kontagora. In the south-west end of Jebba it shares boundaries with Yoruba villages near Kabba in the west of river Niger towards Okene down to Lokoja. Hence, the Nupe people are spread over a large space in central Nigeria (Yahaya, 2000).

The study area is majorly occupied by the Nupe people of Niger State, whose common source of water for public and agricultural uses are rivers and groundwater systems spread around the city. Based on field investigation, river Landzun is one of the common rivers used by the inhabitants of Bida and its environs. It originates as a tributary of river Gbako that cut across Bida Catchment area of Niger State.

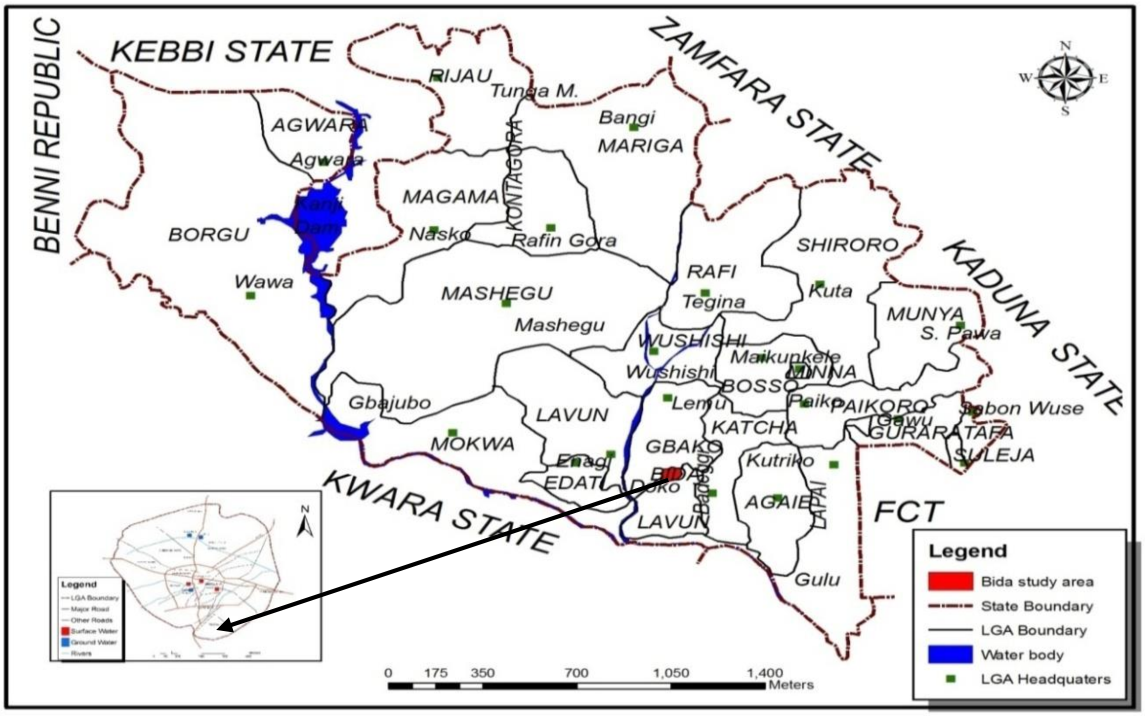
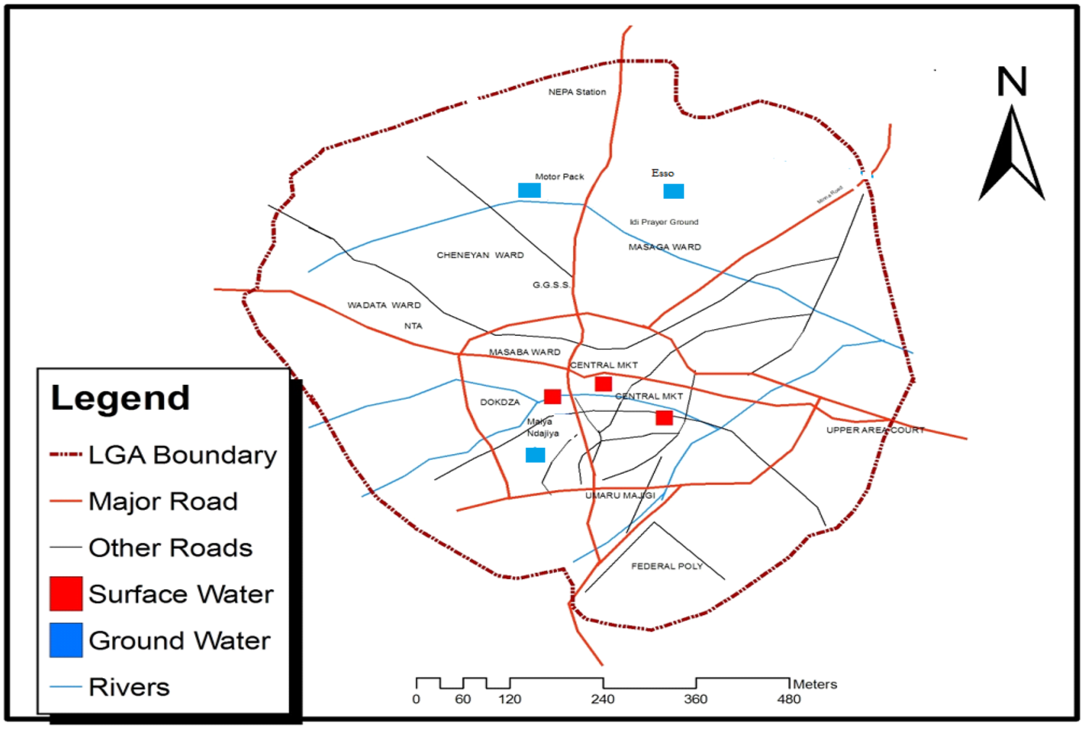


Figure 3.1: Map of Niger State showing Bida Location.



Figure

3.2: Map of Bida showing sample location

3.2 Sample Collection and Transportation

Collection of water samples from river Landzun for laboratory examination was made in six 1 litre clean sterile ragolis water container, three samples were collected at wet season and dry season respectively from three different locations as follows; upstream (Dokodza), middle (Royal cinema), and downstream (Lafiya Clinic). Three of the containers were labeled RWU$_w$, RWM$_w$, and RWD$_w$ for wet season river water sample, likewise, the other three containers were labeled RWU$_d$, RWM$_d$, and RWD$_d$ for dry season river water samples for Physio–Chemical and Bacteriological analysis.

For groundwater, samples were collected also in six 1litre clean sterile ragolis water container, three samples were collected at wet and dry seasons respectively, from three different locations

(Efu Madami: GWI; Park: GWII; Esso: GWIII) around Bida catchment area of the Nupe Basin. Three of the containers were labeled GWI_w, $GWII_w$, and GWIII for wet season ground water samples. Similarly, the three other containers were labeled $GWI_{d,}$ $GWII_d$ and $GWIII_d$ for dry season ground water sample for physic-chemical and bacteriological analysis. The collected water samples were eventually transported to the laboratory the same day for the analysis to be conducted. The water sample collection was made on the 12th of August 2011 for wet season and 11th of March 2012 for dry season. The samples were collected between 9 am and 11am. The coordinates for the sample locations around Bida catchment area of Niger State were noted using GPRS. The location map was drawn with the aid of google earth.

Table 3.1: Coordinates (Longitude and Latitude) of locations where samples were collected.

Sample No	Location	Elevation	Latitude	Longitude
a	Motor park	152m	09^{o}05’47.6’’	06^{o}00’31.9’’
b	Eso	134m	09^{o}03’42.3’’	06^{o}00’32.9’’
c	Efu Madami	140m	09^{o}04’37.9’’	06^{o}00’19.3’’
d	Dokodza	130m	09^{o}04’52.4’’	05^{o}59’33.3’’
e	Royal Cenema	119m	09^{o}04’51.5’’	06^{o}00’37.5’’
F	Lafiya Clinic	107m	09^{o}05’21.3’’	06^{o}01’34.6’’

3.3. Methods for Laboratory Analysis.

The various parameters and their test methods are summarized in Table 3.2 below.

Table 3.2: Parameters and their test methods

Parameter	Test Method	Parameter	Test Method

Conductivity	EC/TDS meter	Sulphate	Turbidimetric method
Tempt	Therm. Thermometer	Mg Hardness	EDTA Titration method
pH	pH meter	Sodium	Flame Photometer
Turbidity	Turbidity meter	Iron	Phenanthroline method\
TDS	EC/TDS meter	Potassium	Flame Photometer
DO2	Std Dissolved Oxygen meter	Ammonia	Nesslerization method
Chloride	Argentomeric Titration meter	Bicarbonate	Titrimetric method
Total Hardness	EDTA Titrimetric method	Carbonate	Titrimetric method
Alkalinity	Titrimetric method	Fluoride	Colorimetric method
Ca Hardness	Titration with EDTA	Copper	Neocuprine method
Nitrate	Cadmium Reduction Method	Coliform	MembranFiltration
Calcium^{2+}	EDTA Titration method	E-Coli	Techniques
Magnesium^{2+}	EDTA Titration method		

3.3.1 Electrical Conductivity (EC)

The Wagtech H1 98311 water proof EC/TDS meter was calibrated in accordance with the manufacturer's instruction manual using Wagtech HI 7031 calibration solution (14413 µS/cm). (WEDIST6 JMP KIT EC/TDS meter manual). After calibration, the probe was submerged in the test sample contained in a plastic beaker to avoid electromagnetic interferences. This was followed by the measurement of the samples after the stability symbol on the top left of the Local Control Display (LCD) disappears. The EC mode was selected with the set/hold button. The measurements were then taken. The EC values automatically compensated for temperatures which were shown on the primary LCD while the secondary LCD shows the temperature of the sample.

3.3.2 Temperature.

Temperature measurements were carried out on-site using the Hanna HI 935005 Microprocessor – based thermocouple thermometer on the degree centigrade (°C) scale.

3.3.3 pH:

After calibrating the Wagtech JMP kit (WG pH Scan 3) instrument with pH buffers 4, 7 and 10 in accordance with manufacturer's instruction manual, pH measurements were carried by dipping the electrode into 100 ml beaker containing the test sample. The samples were stirred once and allowed to stabilize before reading the pH values on the scale.

3.3.4 Turbidity

Field portable WG palm scan TB4 Turbidity meter was used to instantly determine the turbidity values of the samples after calibrating the meter with Turbidity calibration standards (0.02, 20.0, 100, 800 NTU Commercially prepared by Wagtech), as described in the equipment operation manual (WE3140 JMP kit Turbidity meter manual).

3.3.5. Total Dissolved Solids (TDS):

Total Dissolved Solids of all the samples are calculated from the value of electrical conductivity of each sample. Total dissolved solid is calculated from conductivity value as follows;

Calculated TDS = conductivity × (0.55 – 0.7). The adopted value by Regional Water Quality Laboratory Minna is 0.67.

therefore,

TDS = conductivity × 0.67

3.3.6. Dissolved Oxygen (DO)

A standard dissolved oxygen meter model 9200 (Jenway) with probe was used for this determination after it has been calibrated using various concentrations of sodium sulphite solution. The concentration of dissolved oxygen contained in the sample was read directly from the value displayed by the instrument.

3.3.7. Colour (Platinum – Cobolt Standard Method)

Colour may be expressed as apparent or true colour. The apparent colour includes colour from dissolved materials plus that from suspended matter. The true colour can be determined via filtering or centrifuging out the suspended materials. The concentration of

colour was directly measured using HACH 890DR colorimeter in line with the instruments operation manual (Hach DR 890 Data logging colorimeter hand book, method 8039, 1997-1999).

3.3.8. Chloride (Argentomeric Method)

Reagents

Potassium chromate indicator solution: dissolve 50g K_2CrO_4 in a little distilled water. Add $AgNO_3$ solution until a definite red precipitate is formed. Let to stand for 12hours, filter, and dilute to 1L with distilled water. Standard silver nitrate titrant, 0.0141M (0.0141N): dissolve 2.395g $AgNO_3$ in distilled water and dilute to 1000ml. Store in a brown bottle.

Procedure

Chloride was determined by diluting a 100ml sample or a suitable portion to 100ml. If the sample is highly coloured, then, 3ml $Al(OH)_3$ suspension was added and mix, allowed to settle and was filtered. If thiosulphate, sulphide or sulphite was present, then 1ml H_2O_2 was added and stir for 1 min. pH Check was carried out making sure it must be between 5.0 and 9.5 in this procedure. If the pH of the sample is below 5.0, a small amount of calcium carbonate was added and stirred. If the pH is above 9.5, then, 0.1 mol /L nitric acid was added drop by drop to bring the pH to about 8. It was Stirred, and a small amount of

calcium carbonate was added. Hence, 1.0ml K_2CrO_4 indicator solution was added and titrated with a standard $AgNO_3$ titrant to a pinkish yellow end point. Be consistent in end point recognition.

Calculation

$$mg\ Cl\text{-}/L = \frac{A \times N \times 35{,}450}{Ml\ sample\ (100)} \qquad (3.1)$$

Where A = ml titration for sample

N = normality of $AgNO_3$

mg NaCl/L = (mg Cl^-/L) × 1.65

3.3.9. Hardness (EDTA Titrimetric method).

Principle

Water hardness is mainly as a result of the presence of Ca^{2+} and Mg^{2+} in the water. These ions form a chelated soluble complex in the presence of Ethylene diamine tetra acetic acid (EDTA) using Eriochrome Black T. indicator and as the EDTA was added the solution will turn from wine red to blue at the end point. The sharpness of the endpoint is pH dependent (pH 10.0 ± 0.1). To minimize chances of $CaCO_3$ precipitation, the titration should take no more than 5 minutes. The indicator functions best at room temperature.

Chemical / Reagent

i. Buffer solution: 1.179 g EDTA disodium salt and 0.780 g $MgSO_4.7H_2O$ were dissolved in 50 ml Distilled water. The solution was added to 16.9 g NH_4Cl and 143 cm^3 concentrated NH_4OH with mixing and diluted to 250 cm^3 with Distilled water. The buffer was stored in tightly stopper plastic container, (Stability less than 1 month).

ii. Eriochrome black T Indicator: 0.5 g dye and 4.5 g Hydroxylamine hydrochloride were mixed together and the mixture was dissolved in 100 cm^3 of 95 % ethanol.

iii. Standard EDTA titrant, 0.01M**:** 3.723 g EDTA disodium salt ($Na_2 H_2C_{10} O_8N_2.2H_2O$) was dissolved in distilled water and diluted to 1 litre. (Stored in Pyrex bottle).

Procedure

i. 100 cm^3 of samples were measured into 125 cm^3 Erlenmeyer flasks, followed by the addition of 1 cm^3 buffer into the samples to give a pH of 10.0 to 10.1

ii. 1 to 2 drops of indicator were added and titrated slowly with stirring continuously until the last reddish tinge disappears from the solution (adding the last few drops at 3-5 seconds intervals). 1 cm^3 0.0100 M EDTA should be equivalent to 1 mg $CaCO_3$.

Calculations

$$Total\ hardness\ as\ CaCO_3\ =\ mg\ CaC\ = \frac{(A-B)\times D\times 1000}{ml\ of\ sample} \qquad (3.2)$$

where: A = the titre value(cm^3) of the EDTA used in the titration

B = the titre value(cm^3) of the Blank (Distilled Water)

D = mg $CaCO_3$ equivalent to 1 cm^3 EDTA solution

For 0.01M EDTA solution, D = 1 mg $CaCO_3$ / 1 cm^3 of EDTA

3.3.10. Alkalinity (Titrimetric Method)

Reagents

0.02N sulphuric acid or hydrochloric acid: dilute 200ml of 0.1N standard acid to 1litre with distilled water.

0.1N standard sulphuric acid or hydrochloric acid: dilute 3ml conc. H_2SO_4 or 8.3ml conc. HCl to l litre with distilled water.

Bromocresol green indicator solution, pH 4.5 indicator: dissolve 100mg bromocresol green, sodium salt in 100ml distilled water.

Procedure

100ml of the sample was measured out into a 250ml beaker and titrated using 0.02N H_2SO_4. 3 to 4 drops of bromocresol green indicator was added and titrated till the colour changed from green to yellow.

Calculation

Total Alkalinity(T), mg/l as $CaCO_3$

$$= \frac{(A-B)\times 0.02N\times 50,000}{ml\ sample\ (100)} \qquad (3.3)$$

A = ml standard acid used for sample

B = ml standard acid used for blank

N = Normality of acid used (0.02M)

Phenolphthalein Alkalinity (only determined when the ph of the sample is above 8.3)

$$\text{Phenolphthalein Alkalinity (P), mg/l asCaCO}_3 = \frac{(A-B)\times 0.02N\times 50{,}000}{ml\ sample\ (100)} \qquad (3.4)$$

A= ml standard acid used for sample

B = ml standard acid used for blank

N = Normality of acid used (0.02M)

Procedure

measure 100ml of sample, put 2-3 drops of phenolphthalein indicator. If there is colour change continue with the titration using 0.02M H_2SO_4 until colour changes from pin to colourless. If there is no colour change after putting the phenolphthalein indicator, do not continue the titration (this means, though the ph is above 8.3, there is no phenolphthalein alkalinity). Therefore, Bicarbonate (HCO_3^-), carbonate (CO_3^{2-}), and hydroxide (OH^-) can be estimated from phenolphthalein alkalinity. When phenolphthalein alkalinity is equal zero, carbonate and hydroxide equal zero and bicarbonate equals total alkalinity, but if phenolphthalein alkalinity is not equal zero, follow this relationship:

Table 3.3: Alkalinity, Carbonate, and Bicarbonate relationship table.

	Hydroxide as $CaCO_3$	Alkalinity as $CaCO_3$	Carbonate Alkalinity	Bicarbonate Conc. As CaCO
P=0	0	0	T	

$P<\frac{1}{2}T$	0	2p	T-2p
$P=\frac{1}{2}T$	0	2p	0
$P>\frac{1}{2}$	2(T-P)	0	
P=T	T	0	

3.3.11. Calcium and Magnesium

Reagents

i. Hydroxide solution 1N – 56.1g of KOH or 40g of NaOH was dissolved in distilled water and diluted to 1L.

ii. Calver II Calcium indicator – this is manufactured by the Hach company.

iii. Murexide indicator (ammonium purpurate) – changes from pink to purple. This was prepared by dissolving 150mg dye in 100g absolute ethylene glycol. Water solutions of the dye are not stable for longer than 1 day. A ground mixture of dye powder and sodium chloride (NaCl provided a stable form of the indicator which was prepared by mixing 200mg murexide with 100g solid NaCl and grinding the mixture to 40 to 50 mesh.

Procedure

i. Measure a 50ml sample into a 125ml Erlenmeyer flask.

ii. Add 2 ml of the 1N hydroxide solution (to Produce a pH of 12-13 in the 50 ml sample).

iii. Add 0.1 to 0.2g of calver II calcium indicator or murexide indicator.

iii. Titrate slowly with EDTA disodium salt solution (0.01m) until the colour changes to blue for calver ll and pink for murexide

Calculation

Calcium hardness as $CaCO_3$ = $mg\ CaCO_3 L$

$$= \frac{(A-B\ ) \times C \times D \times 1000}{ml\ of\ sample} \qquad (3.5)$$

Calcium ion as mg Ca^{2+}/L = $mg\ CaCO_3 L$ $= \frac{(A-B) \times C \times D \times 400.8}{ml\ of\ sample}$ (3.6)

where: A = the titre value(cm^3) of the EDTA used in the titration

B = the titre value(cm^3) of the Blank (Distilled Water)

D = mg $CaCO_3$ equivalent to 1 cm^3 EDTA solution

For 0.01M EDTA solution, D = 1 mg $CaCO_3$ / 1 cm^3 of EDTA

d. Magnesium hardness (mg $CaCO_3$/l)= total har1 dness – calcium hardness

e. Calculated magnesium as mg^{2+}

mg mg^{2+}/l = magnesium hardness as mg $CaCO_3$/l X 0.244

3.3.12. Nitrate as Nitrogen (NO_3^- - N) (Cadmium Reduction Method)

Reagent

i. Nitrate free water: The preparation of solutions and dilutions were carried out using redistilled or distilled, deionised water of highest purity.

ii. Copper-Cadmium granules: To prepare this, a 25g new or used 20 – 100 mesh Cd granules was washed with 6NHcl and with water. Cadmium (Cd) was swirled with

100ml 2% $CuSO_4$ solution for 5mins or until blue colour partially fades. After decanting, it was repeated with fresh $CuSO_4$ until a brown colloidal precipitate begins to develop and was gently flushed with water to remove all precipitated Copper (Cu).

iii. Colour reagent: 105ml Hcl concentration, 5.0g sulphanilamide and 0.5gN – (1 – naphthyl) ethylenediamine dihydrochloride were added to 20ml of distilled water and stirred until it was dissolved.136g of sodium acetate ($CH_3COONa3H_2O$) was added and again stirred until dissolved. It was further diluted to 500ml with distilled water.this solution was stable for several weeks if stored in the dark.

iv. Ammonium chloride – EDTA solution: this was prepared by dissolving 13g NH4cl and 1.7g disodium ethylenediamine tetra – acetic acid (EDTA) in 900ml distilled water and pH 8.5 was adjusted with conc. NH_4OH and diluted to 1L.

v. Dilute ammonium chloride – EDTA solution: this was prepared by diluting 300ml NH_4Cl – EDTA solution to 500ml with distilled water.

vii. Copper sulphate solution, 2%: it was prepared by dissolving 20g $CuSO_4 \cdot 5H_2O$ in 500ml water and dilute to 1L.

viii. Stock nitrate solution: this was prepared by drying potassium nitrate (KNO_3) in an oven at 105^{o}C for 24hrs and 0.7218g was dissolved in water and diluted to 1000ml (Note: 1.00ml = 1000mg NO_3 – N).This was preserved with 2ml $CHCL_3$/L and can be stable for at least 6 months.

Ix. Intermediate nitrate solution: the preparation for this was carried out by diluting 100ml stock nitrate solution to 1000ml with water (1.00ml = 10.0mg NO_3 – N). it was then preserved with 2ml $CHCl_3$ and can be stable for 6 months.

Procedure

i. Preparation of reduction column: this was prepared by inserting a glass wool plug into the bottom of reduction column and fill with water. Cu – Cd granules was added sufficiently to produce a column 18.5cm long. The water level above Cu – Cd granules was maintained to prevent entrapment of air. The column was washed with 2ml diluted NH4Cl – EDTA solution, and column was activated by passing through it, at 7 to 10ml/min., at least 100ml of a solution composed of 25% 1.0mg NO3-N/l standard and 75% NH4Cl – EDTA solution.

ii. pH adjustment: pH meter and diluted Hcl or NaOH was used for the adjustment of pH to between 7 and 9 as necessary in this method to ensure a pH of 8.5 after adding NH4Cl – EDTA solution. Sample was reduced to 25ml samples or a portion diluted to 25ml by adding 75ml NH4Cl – EDTA solution and mixed properly. The mixed sample was poured into a column and collected at a rate of 7 to 10ml/min. 25ml was initially discarded and the rest of it was collected in original sample flask. Colour development and measurement was carried out not more than 15mins after reduction by adding 2.0ml colour reagent to 50ml sample and mixed between 10min. and 2hrs, afterwards, absorbance was measured at 543nm against a distilled water reagent blank. It was importantly noted that remaining of the reduced samples was used to make an appropriate dilution and analyzed again only if NO_3^-N concentration exceeds the standard curve range (about 1mgN/l).

v. Standards: Standards was prepared in the range of 0.05 to 1.0mg NO_3- N/l by diluting the following volumes to 100ml in volumetric flasks: 0.5, 1.0, 2.0, 5.0, and 10.0ml using the intermediate NO_3^-N solution. However, reduction of standard was carried out exactly as described for samples. A standard curve was obtained by plotting absorbance of standards against NO_3^-N concentration and hence standard curve was used directly for computing sample concentration.

3.3.13. Sulphate (Turbidimetric Method).

Reagents

i. Conditioning reagent: this was prepared by mixing 50ml glycerol with a solution of 30ml conc. HCl, 300ml DDW, 100ml 95% ethyl or isoprophyl alcohol, and 75g sodium chloride.

ii. Barium chloride: this was prepared using crystals, 20-30 mesh.

iii. Stock sulphate solution: this was prepared by dissolving 1.479g of anhydrous sodium sulphate Na_2SO_4 in distilled water and diluted to 1L.(Note: 1.00ml = 1000mg $SO_4^{2-)}$

Procedure

Sulphate concentration in water sample was determined by measuring a 100ml sample into a 250ml Erlenmeyer flask and 5ml exactly of conditioning reagent was added and mixed using the magnetic stirrer and stiring bar, while stirring was in progress a small scoop (0.2 to 0.3g) of $Bacl_2$ crystals was added and timing begins immediately. The stirring was continuously made at constant speed for exactly 1min. At the end of the stirring period, the sample was placed in a 5cm, cuvette and the absorbance at 420nm was measured after exactly 4mins. Eventually, the absorbance at the calibration standards was plotted against the calibration concentrations and the samples concentration was computed directly from the standard curve.

3.3.14. Potassium and Sodium (Using Flame Photometer)

Principle

The electrons of the ions are excited to higher energy state when metal ions in solution are aspirated into a low temperature flame (in an aerosol form). The excitation energy of those electrons can be lost as they return to the ground state and a discrete wavelength of visible light is emitted. Besides, a suitable photo – detector can be used to detect the amount of light emitted as an optical filter is used to separate the light wavelength from other light wavelength. The amount of light emitted is proportional to (for low concentrations of metal ion only) the number of ions in the flame and hence the number of ions in solution. The electrical signal from the photo – detector is amplified and displaced on a digital readout.

Procedure

The determination of potassium and sodium concentration in water sample can be achieved by turning on the fuel at the source and switching on the air compressor. The power of the Light Emitting Diode (LED) will be illuminated on the ignition cycle will commence thereafter. As a result, if the flame on LED is not illuminated at the end of the ignition cycle then the setting of the fuel control should be checked for appropriate measure. The filter selection was set to the required position and then the nebulizer inlet tube was inserted into a beaker containing 100ml of diluents and allowed for 15min. for the operating temperature to stabilize. At this point a stable burner temperature will be ensured as solutions are aspirated, after the warm up period. During the warm up period a set of calibration solution was prepared to cover the required measurement range. To obtain maximum linearity, Sherwood Scientific recommend that the highest standard concentration does not exceed 30 mg/l for sodium, 10 mg/l for potassium and 10 mg/l for lithium, while for aspirating diluents, the blank control was adjusted so that the display reads 0.0. the highest concentration standard was aspirated and allowed for 20 seconds for a stable reading and then adjusted coarse and fine controls for a convenient reading e.g. 20mg/l of sodium can be set to read 20 on the display.

The standard solution was removed and waited for 10seconds, then a blank solution of diluents was aspirated for 20 seconds and the blank control was adjusted for 0.0 reading. The blank solution was removed and waited for 10 seconds. Paragraph 8, 9, 10 was repeated until the blank reading is 0.0 (within ± 0.2) and the calibration reading was within ±1%. If a chart recorder is being used set zero on the blank solution and set span while aspirating the calibration curve. Each of the remaining calibration standards was aspirated for 20 seconds (starting with the lowest concentration to avoid carry over) and again allowed for 10 seconds between measurements. The value of each standard was noted and the results were plotted on a graph against standard concentration on linear graph paper and thereafter, calibration standards and blank readings were checked. Dilute the unknown solutions with diluents to give a concentration of the element under test within the range of the calibration standards. Several attempts might be necessary to determine the correct dilution ratio. Each of the diluted unknowns was aspirated for 20 seconds, and the readings were noted. The concentration of the element in the unknown sample was calculated by reading the sample concentration from the calibration curve and multiplying it by the dilution factor.

3.3.15. Iron (Total) Phenanthroline Method

Reagents

i. Concentrated HCl, containing less than 0.00005% iron.

ii. Hydroxylamine Hydrochloride solution: this was prepared by dissolving 10g $NH_2OH.HCl$ in 100ml water.

iii. Ammonium acetate buffer solution: this was prepared by dissolving 125g $NH_4C_2H_3O_2$ in 75ml water and 700ml (glacial) acetic acid concentration was added.

iv. Phenanthroline solution: it was prepared by dissolving 100mg 1,10-phenanthroline monohydrate $C_{12}H_8N_2H_2O$ in 100ml water by stirring and heating to $80^{o}C$. Do not boil. Discard the solution if it darkens. Heating is unnecessary if two drops of conc. HCl are added to the water. 1ml of this reagent is sufficient for no more than 100mg Fe.

v. Stock iron solution: this was prepared by adding slowly 20ml conc. H_2SO_4 to 50 ml distilled water and dissolve 1.404g $Fe\ (NH_4)_2(SO_4)_2{}^{\cdot}6H_2O$. In addition, 0.1mol^{-1} potassium permanganate (kmn04) was added drop by drop until a faint pink colour persists. Dilute to1L with distilled water and mix.(1.00ml = 200mgFe).

vi. A standard iron solution: A pipette of 50.00ml stock solution was taken into1l volumetric flask and diluted to mark with distilled water (1ml=10.0mg Fe). Pipette 5.00ml of stock solution into a 1l volumetric flask and dilute to the mark with distilled water 1ml=1.00mg Fe.

Preparation of calibration graph: Prepare a blank and a series of standards to a range of 100-400 using100ml volumetric flask or 50-200 range using 50ml volumetric flask using 1cm cell. The blank and standards were treated as indicated in the procedure. The instrument was zeroed against distilled water and measure the absorbance of the standard and the blank was measured. However, the absorbance of the blank was subtracted from the absorbance of the standards to obtain the net absorbance. Hence, a calibration graph relating net absorbance to the amount of iron was prepared.

Procedure

The sample was thoroughly mixed and 50ml of the sample was measured into a 125ml Erlenmeyer flask. If the sample contains more than 200µg iron, then a smaller accurately measured portion was used and was diluted to a 50ml and 2ml of HCl concentration as well as 1 ml of hydroxylamine hydrochloride solution was added. A few glass bead was dropped and boiled until the volume was reduced to 10 – 20ml and was allowed to cool to room temperature. The mixture was transferred to 50ml or 100ml volumetric flask and 10ml ammonia acetate buffer solution as well as 2ml of phenanthroline solution were added and diluted to the mark with distilled water. This was thoroughly mixed and set aside for 10 – 15 minutes for full colour development. However, the colour absorbance intensity photo was measured metrically at510nm. The absorbance of the blank was subtracted from that of the sample to determine the net absorbance.

Calculation:

$$\text{Concentration of Fe} = .\frac{\mu g Fe}{ml\ sample}\left(\frac{mg}{l}\right) \qquad (3.6)$$

3.3.16. Ammonia (Nesslerization Method)

Chemicals / Reagents

i. Stock Ammonium Chloride (NH_4Cl), 0.073 M: 3.819 g was dissolved in 1 litre volumetric flask and make up to the mark with distilled water.(1 ml = 1.0 mg N (NH_3) / l).

ii. Nessler's Reagent: This was prepared by dissolving 100 g mercuric iodide (HgI_2) and 70 g potassium iodide (KI) in a small quantity of distilled water in a beaker. In a 1 litre volumetric flask, 160 g sodium hydroxide (NaOH) in 500 cm^3 distilled water was added with stirring. The solution was allowed to cool thoroughly and slowly the HgI_2 – KI solution was added to the volumetric flask with stirring and diluted to 1 litre.

iii. Distilled water (Ammonia free).

Procedure

i. Preparation of calibration curve. In 50 cm^3 volumetric flasks the following volumes of the stock ammonium chloride solution were added and make up to the mark with distilled water.

2 cm^3 of Nessler's reagent were added to each 50 ml flask containing various volumes of stock NH_4Cl using 10 cm^3 volumetric pipette.

Table 3.4: Stock ammonium chloride solution and volume of distilled water in cm^3

Stock Solution	Distilled Water
0	50 cm^3 (Blank)

10	45 cm^3
15	35 cm^3
20	30 cm^3
25	25 cm^3
30	20 cm^3
40	10 cm^3
50	0 cm^3

ii. The Nesselerised standards were immediately mixed and allowed to stay for exactly 20 minutes reaction period.

iii. After 20 minutes, the standards were mixed again and their absorbance were read at 430nm using 1 cm path length curvette after setting the colorimeter to zero using blank solution treated in the same way as the standards.

The concentrations of the samples were then determined at 430nm by extrapolating their absorbance from the calibrations curves (Figure. 3.1).

3.3.17. Flouride

These are all determined using DR/820-DR/850-DR/890 Datalogging Colorimeter made by Hach Company. The colorimeter handbook should be referred to for comprehensive procedure for each of them.

3.3.18. Copper (Neocuproine Method).

Reagents

i. Stock copper solution: 10ml water and 5ml concentrated HNO3 was added to 200mg polished electrolytic copper wire or foil in a 250ml conical flask, after the reaction has slowed, it was gently warmed to complete dissolution of the copper and boil to expel oxides of nitrogen using precautions to avoid loss of copper. Cool and add about 50ml water then it was transferred quantitatively to a 1-L volumetric flask, and diluted to the mark with water(1ml = 200µg Cu).

ii. Standard copper solution: dilute 50ml stock copper solution to 500ml with water; 1ml=20 µg Cu Sulfuric acid, H_2SO_4, concentration.

iii. Hydroxylamine-hydrochloride solution: Dissolve 50g $NH_2OH.HCl$ in 450ml water.

iv. Sodium citrate solution: 150g $Na_3C_6H_5O_7.2H_2O$ in 400ml water. Add 5ml $NH_2OH.HCl$ solution and 10ml neocuproine reagent. Extract with 50ml $CHCl_3$ to remove copper impurities and discard $CHCl_3$ layers.

v. Ammonium hydroxide, NH_4OH, 5N: dilute 330ml conc NH_4OH(28-29%) to 1000ml with water. Store in a polyethylene bottle Congo red paper, or other pH test paper showing a colour change in the pH range of 4 to 6.

vi. Neocuproine reagent: dissolve 100mg 2,9-dimethyl-1,10- phenantroline hemihydrates in 100ml methanol. This solution is stable under ordinary storage conditions for a month or more.

vii. Chloroform, $CHCl_3$: avoid or redistill material that comes in containers with metal-lined caps.

viii. Methanol, CH_3OH, reagents grade.

vx. Nitric acid, HNO_3, concentration.

x. Hydrochloric, HCl, concentration.

Procedure

i. Preparation of calibration curve: this was carried out by pipetting 50 ml water into a 125ml separatory funnel for use as a reagent blank. Standards were Prepared by pipetting 1 to 10ml(20 to 200 µg Cu) standard copper solution into a series of 125ml separatory funnels, and diluted to 50ml with water. 1ml conc. H_2SO_4 was added. A calibration curve was constructed by plotting absorbance versus micrograms of copper. The preparation of a calibration curve for smaller amounts of copper was made by diluting 10ml standard copper solution to 100ml. in addition, 1 to 10ml volumes of this diluted standard was carried through the previously described procedure, but 5cm cells was used to measure absorbance.

ii. Treatment of sample: this was done by transferring 100ml sample to a 250ml beaker, and 1ml conc. H_2SO_4 and 5ml conc. HNO_3 was added. Add a few boiling chips were added and cautiously evaporate to dense white SO_3 fumes on a hot plate. If solution remains coloured, cool, add another 5ml conc. HNO_3, and again evaporate to dense white fumes. Repeat, if necessary, until solution becomes colourless. Cool, add about 80 ml water, and bring to a boil. Cool and filter into a 100ml volumetric flask.

Make up to 100ml with water using mostly beaker and filter washings. Pipette 50ml or other suitable portion containing 4 to 200 µgCu, from the solution obtained from preliminary treatment, into a 125ml separatory funnel. Dilute, if necessary, to 50 ml with water. Add 5ml $NH_2OH.HCl$ solution and 10ml sodium citrate solution, mix thoroughly. Adjust pH to approximately 4 by adding 1ml increments of NH_4OH until congo red paper is just definitely red (or other suitable pH test paper indicates a value between 4 and 6). Add 10ml neocuproine reagent and 10ml $CHCl_3$. Stopper and shake vigorously for 30s or more to extract the copper neocuproine complex into the $CHCl_3$ layer into a 25ml volumetric flask, taking care not to transfer any of the aqueous layer. Repeat extraction of the water layer with an additional 10ml $CHCl_3$ and combine extracts. Dilute combined extracts to 25ml with CH_3OH, stopper, and mix thoroughly. Transfer an appropriate portion of extract to a suitable absorption cell(1cm for 40 to 200 µg Cu;5cm for lesser amounts) and measure absorbance at 457nm or with a 450- to 460-nm filter. Use a sample blank prepared by carrying 50ml water through the complete digestion and analytical procedure. Determine micrograms copper in final solution by reference to the appropriate calibration curve.

3.3.19. Total *Coliforms* and *Escherichia Coli (E. Coli*) by Membrane Filtration Techniques.

Choice of Medium for Isolation and Enumeration

Membrane lauryl sulphate broth (MLSB) (PHLS/SCA 1980a) is recommended for the isolation and enumeration of total *coliforms* and *E. coli.* This is available commercially as a complete dehydrated medium.

Procedure

For each sample, an absorbent pad was placed into each of two empty sterile Petri dishes, and sufficient MLSB was added to saturate the pad. It was then allowed to soak in and pour off any excess fluid. Dilutions were prepared and filtered as necessary; two membranes were set up for each sample and place on the pads soaked in MLSB. The two membranes were both Incubate at 30^{o}C for 4 hours and then one of the membrane was transferred to 37^{o}C for total *coliforms* and the other to 44^{o}C for *E. coli*. In this case incubators or water baths was used for incubation. Accurate temperature control and even temperature distribution are essential, especially for *E. coli* at 44^{o}C. False positive results will be obtained at temperatures below that recommended and some strains will fail to multiply at higher temperatures. The membranes were Incubated at 37^{o}C or 44^{o}C for 14 hours to give a total incubation time of 18 hours. If an early indication of a result is required urgently, the membranes may be examined for presumptive positive results after a total incubation time of 12 hours but must be returned to the incubator for the full period of 18 hours before results can be regarded as negative. From a water treatment point of view it may be convenient to incubate a single membrane at 37^{o}C.

In this case, an immediate operational response should be made to any presumptive positive result and should be treated as *E.coli* until the confirmatory tests for *coliforms* and *E.coli* have been completed. It should be assumed that any presumptive indication is treated as *E. coli* and remedial action taken. After the incubation, the membranes were examined under good light, if necessary with a hand lens. All yellow colonies (however faint) were counted irrespective of size within a few minutes of being removed from the incubator. Colours are liable to change on cooling and standing. It is important to note whether pink colonies are present in numbers which may interfere with the growth of *coliforms*. The detection of acid production is influenced by the pH of the medium, thus, it is important that the medium is of the correct pH. If the growth of pink colonies is considered to be such that they may be obscuring lactose-fermenting colonies, a further sample should be taken and examined by membrane filtration.

3.4. Statistical Analysis

The results obtained for the physio-chemical and bacteriological parameters from laboratory test were analyzed statistically using descriptive statistics from SPSS package, 15.0 versions

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Results of Analysis

The statistical summary of the results of the physio-chemical and bacteriological analysis are presented in Tables 4.1 – 4.4.

Table 4.1: Statistical summary of wet season ground water samples from Bida Catchment area of Niger State (All parameters are in mg/l.)

Parameters	Min	Max	Mean	Std Dev	WHO	FAO
Conductivity	98.00	784.00	440.33	343.00	-	-
Temperature (^{0}C)	27.00	27.00	440.33	27.00	25-29	25
pH	6.58	6.66	6.62	0.04	6.5-8.0	6-8.5
Turbidity	0.85	2.42	1.62	0.79	5.00	-
TDS	68.30	5546.4	1973.53	3096.47	1000	0-2000
Dissolved Oxygen	5.20	6.10	5.78	0.50	-	-
Chloride	57.10	122.30	81.53	35.54	250	-
Total Hardness	18.20	110.10	54.47	48.92	500	-
Alkalinity	15.00	70.00	38.00	28.58	-	-
Calcium Hardness	3.10	61.20	32.10	25.59	75.00	-
Nitrate	1.59	2.12	1.90	0.28	50.00	-
Calcium ion	8.10	23.00	13.53	8.23	-	-
Sulphate	3.00	10.00	5.67	3.79	250.00	-
Mg Hardness	5.10	48.90	22.37	23.32	50.00	-
Sodium	2.50	13.50	6.83	5.89	200.00	-
Iron	0.04	0.18	0.11	0.07	0.3	-
Potassium	3.35	4.69	4.21	0.75	-	0-20
Ammonia	0.36	0.48	0.43	0.06	-	-

Bicarbonate	15.00	70.00	38.00	28.58	-	0-6
Carbonate	0.00	0.00	0.00	0.00	-	0-30
Fluoride	0.01	0.01	0.06	0.05	1.50	-
Copper	0.00	0.02	0.01	0.01	5.00	-
Coliform (cfu/100ml)	1.00	56.00	27.67	27.54	0.00	-
E-Coli (cfu/100ml)	0.00	0.00	0.00	0.00	0.00	-

Table 4.2: Statistical summary of dry season ground water samples from Bida Catchment area of Niger state. (All parameter are in mg/l).

Parameters	Min	Max	Mean	Std Dev.	WHO	FAO
Conductivity	67.00	130.00	88.67	35.81	-	-
Tempt (^{0}C)	29.60	29.70	29.63	0.06	25 – 29	25.00
Ph	5.30	5.90	5.63	0.31	6.5 – 8.0	6-8.5
Turbidity	1.49	6.24	3.48	2.47	5.00	-
TDS	43.50	87.10	58.93	24.43	1000	0-20
Dissolved Oxygen	3.84	5.21	4.34	0.76	-	-
Chloride	24.80	154.30	68.53	74.28	250	-
Total Hardness	14.00	120.00	50.00	60.63	500	-
Alkalinity	7.00	21.00	12.33	7.57	-	-

Calcium Hardness	6.00	56.00	23.33	28.31	75.00	-
Nitrate	11.10	71.60	32.77	33.71	50.00	-
Calcium ion	2.41	22.40	9.34	11.32	-	-
Magnesium ion	1.95	15.60	6.50	7.88	-	-
Sulphate	0.00	2.00	0.67	1.15	250	-
Mg Hardness	8.00	64.00	26.67	32.33	50.00	-
Sodium	7.09	74.90	30.03	38.86	200.00	-
Iron	0.00	0.09	0.04	0.05	0.00	-
Potassium	7.46	44.80	19.91	21.56	-	0 – 20
Ammonia	3.04	19.60	8.97	9.22	-	-
Bicarbonate	7.00	21.00	12.33	7.57	-	0 – 60
Carbonate	0.00	0.00	0.00	0.00	0.00	0 – 30
Fluoride	0.12	0.14	0.18	0.01	1.50	-
Copper	0.00	0.00	0.00	0.00	5.00	-
Coliform (cfu/100ml)	3.00	140.00	62.33	70.00	0.00	-
E-Coli (cfu/100ml)	0.00	22.00	7.33	12.70	0.00	-

Table 4.3: Statistical summary of wet season surface water samples from Bida Catchment area of Niger state.

Parameters	Min	Max	Mean	Std Dev	WHO	FAO

Conductivity	100.00	415.00	294.33	169.93	-	-
Temperature (^{0}C)	26.90	27.00	26.93	0.06	25-29	25.00
pH	6.84	7.58	7.27	0.38	6.5-8.0	6.0-8.5
Turbidity	2.46	26.20	12.12	12.47	5.00	-
TDS	69.70	289.30	205.17	118.46	1000	0-2000
Dissolved Oxygen	4.33	5.68	4.94	0.68	-	-
Chloride	57.10	114.10	81.53	29.36	250.00	-
Total Hardness	39.00	102.20	60.43	36.18	500.00	-
Alkalinity	11.00	90.00	37.67	45.32	-	-
Calcium Hardness	24.00	2.00	35.03	14.91	75.00	-
Nitrate	0.04	2.65	0.92	1.49	50.00	-
Calcium ion	16.20	27.00	20.40	5.79	-	-
Sulphate	2.00	16.00	7.67	7.37	250.00	-
Mg Hardness	11.00	50.20	25.40	21.57	50.00	-
Sodium	7.00	15.50	10.87	4.30	200.00	-
Iron	0.02	0.06	0.04	0.02	0.3	-
Potassium	3.40	5.36	4.37	0.98	-	0-20
Ammonia	0.40	0.60	0.51	0.10	-	-

Bicarbonate	11.00	12.10	11.70	0.61	-	-
Carbonate	0.00	0.00	0.00	0.00	-	0-30
Fluoride	0.03	0.04	0.03	0.01	1.50	-
Copper	0.02	0.04	0.03	0.01	5.00	-
Coliform(cfu/100ml)	340.00	1060.00	640.00	374.69	0.00	-
E-Coli(cfu/100ml)	20.00	60.00	40.00	20.00	0.00	-

Table 4.4: Statistical summary of dry season surface water samples from Bida Catchment area of Niger State.

Parameters	Min	Max	Mean	Std Dev	WHO	FAO
Conductivity	70.00	155.00	114.33	42.62	-	-
Temperature (^{0}C)	29.50	29.80	29.67	0.15	25-29	2500
pH	6.50	7.00	6.77	0.25	6.5 – 8.0	6-8.5
Turbidity (NTU)	22.60	57.70	34.33	20.24	5.00	-
TDS	46.90	103.80	76.60	28.53	1000	0-2000
Dissolved Oxygen	3.52	5.27	4.26	0.90	-	-
Chloride	17.70	37.20	25.97	10.08	250	-
Total Hardness	22.00	90.00	50.57	35.23	500	-
Alkalinity	20.00	58.00	35.33	20.03	-	-
Ca Hardness	18.00	66.00	40.67	24.11	75.00	-

Nitrate	7.90	26.20	15.23	9.68	50.00	-
Calcium ion	7.21	26.40	16.54	9.61	-	-
Magnesium ion	0.48	5.85	2.43	2.97	-	-
Sulphate	2.00	15.00	7.33	6.81	250.00	-
Mg Hardness	2.00	24.00	10.00	12.17	50.00	-
Sodium	6.07	25.30	15.89	9.62	200.00	-
Iron	1.38	2.43	2.00	0.55	0.30	-
Potassium	6.40	16.00	10.67	4.89	-	0-20
Ammonia	2.16	7.19	4.18	2.66	-	-
Bicarbonate	20.00	58.00	35.33	20.03	-	-
Carbonate	0.00	0.00	0.00	0.00	-	0-30
Fluoride	0.00	0.16	0.05	0.09	1.50	-
Copper	0.04	0.08	0.06	0.02	5.00	-
Coliform (cfu/100ml)	0.00	0.00	0.00	0.00	0.00	-
E-Coli (cfu/100ml)	0.00	0.00	0.00	0.00	0.00	-

4.2. Discussion of Results

4.2.1. Electrical Conductivity (EC_w)

Electrical Conductivity is the measure of the capability of water to conduct electricity. Based on the analysis carried out on ground water during wet season, the values obtained ranged from a minimum of 98µS/cm to a maximum of 784µS/cm at Eso and Efu Madami locations respectively.

Similarly at dry season the values of electrical conductivity ranged from a minimum of 67µS/cm to a maximum of 130µS/cm at Efu Madami and Park locations respectively. comparing the obtained values for both seasons with the WHO (2004) and FAO (2000), recommended standards, ground water in the study area was suitable for both domestic and public purposes, since the values fall below the permissible limits in Tables 4.1 and 4.2. Electrical conductivity of ground water at wet season in the study area indicated a higher mean value of 440µS/cm than at dry season with a mean value of 88.67µS/cm.

4.2.2. Temperature

The values obtained from the analysis carried out on ground water during wet season showed that there is no variation in temperature at the three locations in the study area. Similarly, at dry season temperature of ground water was similar at Efu Madami and Eso, but slightly different from that at Park location. This vividly indicated that values of temperature obtained fall within the recommended limit for drinking water quality ranging from 25 – 29^0C by WHO (2004), depicted in Tables 4.1 and 4.2, but slightly above the permissible limit of 25^0C by FAO Standards. It is important to note that temperature has no any negative impact on the consumer, therefore, it is clear that ground water in the study area is suitable for domestic and public purposes

4.2.3. pH

this is the measure of the acidity or basic nature of water. It has no direct effect on consumers, however, pH permissible limit by WHO (2004) and FAO (2000) are 7.0 – 8.5 and 6.0 – 8.5 respectively. pH values above 7.0 indicated that water is probably hard and contains calcium and magnesium. Sequel to the analysis carried out on ground water, the pH values during wet season ranged from a minimum of 6.58 to maximum of 6.66 at Park and Efu Madami locations respectively. This showed that the values fall within the permissible limit by WHO (2004) and FAO (2000) Standards, hence, water is suitable for both domestic and public purpose. Similarly at dry season, the pH values ranged from a minimum of 5.30 to a maximum of 5.90 at Park and Eso locations respectively as tabulated in Table 4.1 and 4.2. The values therefore, falls below WHO (2004) and FAO (2000) recommended standards which gives the necessity for the addition of soda ash or lime to make it suitable for the proffered purpose. Considering the mean value for both seasons, it clearly indicated that the value for wet season was higher than that of dry season in the study area.

4.2.4. Turbidity

This could be seen as a measure of the relative clarity or cloudiness of water. Turbidity of water is initiated by suspended and colloidal matter, such as silt, clay, finely divided organic and inorganic matter, plankton and other microscopic organisms. Based on the analysis carried out on ground water, turbidity concentration ranged from a minimum of 0.85 NTU to a maximum of 2.42 NTU at Eso and Park locations respectively. Similarly, at dry season, turbidity concentration ranged from a minimum of 1.49 NTU to a maximum of 6.24 NTU at Park and Efu Madami locations respectively. Comparing values obtained at both seasons with the permissible limit by WHO (2004), it is therefore observed that ground water is suitable for domestic and public purposes since values are below WHO (2004) permissible limit of 5 NTU, except turbidity at Efu Madami which was slightly above the acceptable limit, but not withstanding, water can still be used since water with turbidity up to 25NTU can be used for the proffered purpose in the absence other option. Besides, ground water at dry season recorded a higher turbidity concentration with a mean value of 3.48 NTU than at wet season with a mean value of 1.62 NTU.

4.2.5. Total Dissolved Solids

This referred only to the solids in solution or the solids remaining in the filtrate after all the suspended solids have been removed from the filter. Total dissolved solids of ground water samples are due to vegetable decay, evaporation, disposed of effluent and chemical weathering of rocks. Total dissolved solids in water are composed majorly of carbonates, bicarbonates, chlorides, phosphates and nitrates of calcium, magnesium, sodium, potassium and manganese, organic matter, salt and other particles. However, based on the analysis carried out during wet season, total dissolved solids ranged from a minimum of 68.3mg/l to a maximum of 5546.4mg/l at Eso and Efu Madami locations respectively. The higher concentration of TDS at Efu Madami may also cause gastrointestinal irritation in human and could have laxative effect specifically upon transit WHO (2004). At dry season the concentration of total dissolved solids (TDS) ranged from a minimum of 43.5mg/l to a maximum of 87.1mg/l at Efu Madami and Park locations respectively. Ground water at both seasons was found suitable for domestic and public purposes, since its values falls below the recommend limit by WHO (2004) and FAO (2000) Standards, except at Efu Madami during wet season that recorded a higher value than the recommended limit. This condition clearly qualifies ground water in that area not suitable for drinking but suitable for agriculture. The recorded value for both wet and dry seasons indicated that groundwater in the study area is less contaminated with total dissolved solids (TDS) at dry season than at wet season.

4.2.6. Dissolved Oxygen

Dissolved Oxygen in ground water during wet season ranged from a minimum of 5.20mg/l to a maximum of 6.10mg/l at Eso and Park locations respectively. Similarly, at dry season the value of dissolved oxygen ranged from a minimum of 3.84mg/l to a maximum of 5.21mg/l at Park and Efu

Madami locations respectively. The result therefore, showed that ground water has higher dissolved oxygen at wet season than at dry season as the mean value for wet and dry seasons are recorded as 5.78mg/l and 4.34mg/l respectively. The low concentration of dissolved oxygen in water might be the result of the presence of microorganisms in the water, whereas high concentration might be resulted from the ability of water to hold oxygen or the absence of micro-organism in the water.

4.2.7. Chloride (Cl)

Chloride can be seen as a substance that is widely distributed naturally, as sodium (Nacl) and potassium (Kcl) salts. Concentration of chloride above recommended limit makes water to have a bad taste and also may cause corrosion in the distribution system. However, based on the analysis carried out on ground water during wet season, chloride concentration ranged from a minimum of 57.1mg/l to a maximum of 122.3mg/l at Eso and Park locations respectively. Similarly, chloride concentration during dry season ranged from a minimum of 24.8mg/l to a maximum of 154.3mg/l at Park Park and Efu Madami locations respectively. Chloride concentration of ground water for both seasons falls below the permissible limit by WHO (2004) standard, hence, groundwater in the study area is suitable for domestic and public purposes. Besides, ground water at wet season recorded a higher chloride concentration with a mean value 81.53mg/l than at dry season with a mean value of 68.53mg/l.

4.2.8. Total Hardness

Hardness is primarily due to the presence of carbonate, sulphates and chlorides of calcium and magnesium. Hardness could lead to scaling of hot water pipes, boilers and other house hold appliances. Total hardness of ground water in the study area during wet season ranged from a minimum of 18.2mg/l to a maximum of 110.1mg/l at Eso and Efu Madami locations respectively. Similarly, at dry season, total hardness ranged from a minimum 14mg/l to a maximum 120mg/l at Park and Efu Madami locations respectively. The values were found to have exceeded the permissible limit at Efu Madami during the two seasons. This could be as a result of the accumulation of salts in the well. However, the mean concentration for total hardness at wet season is found higher than the mean concentration at dry season in the study area.

4.2.9. Alkalinity

Alkalinity concentration in groundwater during wet season ranged from a minimum of 15mg/l to a maximum of 70mg/l at park and Esso locations respectively. Similarly, at dry season, alkalinity ranged from a minimum of 7mg/l to a maximum of 21mg/l at park and Esso locations respectively. The mean values for both season clearly showed that wet season ground water was more concentrated than dry season groundwater.

4.2.10. Calcium Hardness

The concentration of calcium hardness in groundwater during wet season ranged from a minimum of 13.10 mg/l to a maximum of 61.20mg/l at Eso and Efu Madami locations respectively. Similarly at dry season, the concentration of calcium hardness ranged from a minimum of 6.0mg/l to a maximum of 56mg/l at Park and Efu Madami locations respectively. it is therefore, clear that groundwater in the study area for both seasons was suitable for domestic and public purposes, since the calcium hardness values falls below permissible limit by WHO (2004) Standards. Besides, groundwater at wet season recorded a higher chloride concentration with a mean value 81.53mg/l than at dry season with a mean value of 68.53mg/l.

4.2.11. Nitrate (NO_3^-)

Nitrate is a form of nitrogen and a vital nutrient for growth, reproduction and the survival of organisms. The major toxic effect of nitrate contamination in drinking water is methaemoglobinaemia, which leads to reduced oxygen transfer to the body tissues. Nitrate concentration during wet season in the study area ranged from a minimum of 11.1mg/l to a maximum of 71.6mg/l at Park and Efu Madami locations respectively. Nitrate concentrations during wet season fall s below the permissible limit of 50mg/l by WHO (2004), whereas, the concentration of nitrate at Efu Madami during dry season exceeded the permissible limit of 50mg/l. however, the rate of nitrate concentration in ground water during wet season in the study are permits the use for domestic and public purposes, but the concentration of nitrate at Efu Madami was not suitable for use for domestic and public use. The mean concentration of nitrate at wet season was lower than the nitrate concentration in ground water at dry season. This was because nitrates are usually built up during dry seasons and high concentrations of nitrates are only observed during early wet seasons. The reason for this is that initial rains flush out deposited nitrates from near surface soils and nitrate concentration is minimized drastically as wet season progresses. High concentration of phosphate and nitrate may result to eutrophication, which eventually increases algae growth and ultimately minimizes dissolved oxygen levels in the water.

4.2.12. Calcium ion ($Ca^{2+)}$

Calcium ion concentration obtained for groundwater during wet season ranged from a minimum of 8.10mg/l to a maximum of 23.0mg/l at Park and Efu Madami location respectively. Similarly, at dry season, calcium ion concentration obtained ranged from a minimum of 2.41mg/l to a maximum of 22.4mg/l at Park and Efu Madami locations respectively. However considering the mean values obtained for ground water at both seasons clearly confirm that groundwater at wet season contains higher calcium ion concentration than at dry season in the study area.

4.2.13. Magnesium ion (Mg^{2+})

Magnesium ion concentration obtained for ground water during wet season ranged from a minimum of 1.24mg/l to a maximum of 11.9mg/l at Eso and Efu Madami locations respectively. In the same vein, magnesium ion concentration obtained in ground water during dry season ranged from a minimum of 1.95mg/l at Eso and Park to a maximum of 15.6mg/l at Efu Madami locations respectively. However, from the mean values obtained at wet season and dry season, it has been observed that dry season recorded higher concentration than ground water at wet season in the study area.

4.2.14. Sulphate (SO_4^-)

Sulphate concentration in ground water during wet season ranged from a minimum of 3.0mg/l to a maximum of 10.0mg/l at Efu Madami and Eso locations respectively. Similarly, sulphate concentration in ground water at dry season was not found at Efu Madami and Eso, but was found to be 2.0mg/l at Park. Comparing the values obtained for both seasons with the recommended limit by WHO (2004) and FAO (2000) Standards it has been noticed that ground water for both seasons was suitable for domestic and public purposes, since values falls below that of WHO, (2004) and FAO (2000) Standards. However, from the mean value obtained for wet and dry season, it was observed that wet season groundwater was more concentrated with sulphate than the dry season ground water in the study area

4.2.15. Magnesium Hardness

The concentration of magnesium hardness in ground water during wet season ranged from a minimum of 5.10mg/l to a maximum of 48.90mg/l at Eso and Efu Madami locations respectively. Similarly, at dry season, the concentration of magnesium hardness in ground water ranged from a minimum of 8.0mg/l at Park and Eso to a maximum of 64.0mg/l at Efu Madami locations respectively. However, ground water during dry season posses a higher concentration of magnesium hardness with a mean value of 26.67mg/l than at wet season with a mean value of 22.37mg/l. ground water at both season was therefore, suitable for domestic and public purposes, since values fall below the permissible limit of 50mg/l by WHO (2004).

4.2.16. Sodium (Na^+)

Sodium concentration present in ground water during wet season in the study area ranged from a minimum of 2.5mg/l to a maximum of 13.50mg/l at Efu Madami and Park locations respectively. Similarly, at dry season, sodium concentration in ground water ranged from a minimum of 7.09mg/l to a maximum of 74.90mg/l at Eso and Efu Madami locations respectively. The sodium concentration in ground water at dry season posses a higher mean value of 30.03mg/l than at wet season with a mean value of 6.83mg/l. however, ground water in the study area is suitable for domestic and public uses, since values fall below the permissible limit by WHO (2004) and FAO (2000) Standards.

4.2.17. Iron (Fe)

Iron is the most abundant heavy metal and excessive of it in water gives it a bad taste and can also cause staining of laundry and plumbing fixtures. It is identified as an essential element in human nutrient and deficiencies of it can lead to impaired mental development in children, it also reduces work performance in adults and in severe cases, anemia or impaired oxygen delivery. Sequel to the analysis carried out on ground water during wet season, iron concentration in ground water ranged from a minimum of 0.04mg/l to a maximum of 0.18mg/l at Park and Efu Madami locations respectively. At dry season, iron concentration in ground water does not show up at Eso location but 0.04mg/l and 0.09mg/l were recorded at Park and Efu Madami locations respectively. Ground water at both seasons therefore, was suitable for domestic and public purposes, since values fall below the permissible limit of 0.3mg/l by WHO (2004). However, ground water at wet season recorded higher iron concentration with a mean value of 0.11mg/l than dry season concentration with a mean value of 0.04mg/l.

4.2.18. Potassium (K^+)

Potassium concentration in ground water during wet season in the study area ranged from a minimum of 3.35mg/l at Eso to a maximum of 4.69mg/l at Park and Efu Madami locations respectively. Similarly, potassium concentration in ground water during dry season ranged from a minimum of 7.46mg/l at Park and Eso to a maximum44.8mg/l at Efu Madami. However, based on the values obtained for potassium concentration for both seasons ground water was not suitable for domestic and public purposes, since the values are higher than the permissible limit by WHO (2004) and FAO (2000) Standards. The mean values estimated for both seasons clearly indicated that ground water was highly contaminated at dry season than at wet season in the study area.

4.2.19. Ammonia (NH_3)

Ammonia concentration in ground water during wet season ranged from a minimum of 0.36mg/l to a maximum of 0.48mg/l at Park and Efu Madfami locations respectively. Similarly, at dry season, ammonia concentration in ground water ranged from a minimum of 3.04mg/l to a maximum of 19.6mg/l at Park and Efu Madami locations respectively. The mean concentration of ammonia recorded higher value in ground water at dry season than at wet season in the study area.

4.2.20. Bicarbonate (HCO_3^-)

Bicarbonate concentration in ground water in the study area during wet season ranged from a minimum of 15.0mg/l to a maximum of 70mg/l at Eso and Park locations respectively. Consequently, at dry season, bicarbonate concentration in ground water ranged from a minimum of 7.0mg/l to a maximum of 21mg/l at and Efu Madami locations respectively. The estimated mean concentration of bicarbonate in ground water in the study area at wet season recorded a higher value than at dry season.

4.2.21. Carbonate (CO_3^-)

Carbonate concentration in ground water at both season was nil throughout the three locations where samples were collected. This condition of carbonate concentration clearly indicated that ground water in the study area was suitable for domestic and public purposes.

4.2.22. Fluoride (F)

Fluoride affect bone development and excessive concentration results to dental or in critical level skeletal fluorosis. Skeletal fluorosis is a painful disease that results to physical impairment. However, too little of fluoride has also been affiliated with dental caries and other dental health problems. Fluoride concentration in ground water during wet season in the study area ranged from a minimum of 0.01mg/l to a maximum of 0.10mg/l at Park and Efu Madami locations respectively. Similarly, fluoride concentration during dry season ranged from a minimum of 0.12mg/l to a maximum of 0.14mg/l at Eso and Efu Madami locations respectively. Ground water in the study area at both seasons was suitable for domestic and public purposes, since all three values fall below the permissible limit by WHO (2004) standards.

4.2.23. Copper (Cu)

Copper is naturally seen as a metal and as minerals. Excessive quantity of copper in water usually leads to bad taste and causes staining of laundry and plumbing of fixtures. Copper is highly essential element in human metabolism and deficiencies of it leads to a variety of clinical disorders, including nutritional anemia in infants. Following the analysis conducted on ground water during wet season, copper concentration in ground water ranged from a minimum of 0.0mg/l to a maximum of 0.02mg/l at Eso and Efu Madami locations respectively. Consequently, at dry season, copper concentration was not found in ground water at the three locations. Therefore, ground water at both seasons was suitable for domestic and public purposes, since values falls below permissible limit of 1mg/l by WHO (2004) Standard.

4.2.24. *Coliform*

The total *coliform* count found in ground water at the three locations in the study area were 56cfu at Efu Madami, 1cfu at Esozhi, and 26cfu at Eso per 100ml of water which showed that ground water in the study area during wet season requires serious disinfection before it can be used for domestic and public purpose. The higher count of total *coliform* in ground water in the study area may be as a result of high concentration of dissolved oxygen in the water. Similarly, ground water at dry season contains high *coliform* count at the three locations in the study area above the recommended limit of o cfu per 100ml of water sample by WHO (2004), which also requires disinfection before use.

4.2.25. *E-Coli*

Based on the analysis carried out on ground water during wet season, *E-Coli* count was not found in ground water which makes it to meet the required permissible limit of 0cfu per 100ml of water sample by WHO (2004) Standard for drinking water. Similarly, E-Coli count in ground water was not found during dry season at Park and Eso locations, which also qualifies ground water at those locations suitable for domestic and public use except at Efu Madami with *E-Coli* count of 22cfu per 100ml of water sample. The condition makes water unsuitable for domestic and irrigation purpose

4.2.26. Electrical Conductivity (ECw)

Electrical Conductivity of surface water during wet season ranged from a minimum of 100µS/cm to a maximum of 415µS/cm as in Table 4.3, at Dokodza and Lafiya Clinic locations respectively. Similarly, electrical conductivity during dry season range from a minimum of 70µS/cm to a maximum of 155µS/cm at Dokodza and Lafiya clinic locations respectively. It suffices to note that based on the mean values obtained for both season in the study area for surface water at both seasons, wet season posses a higher mean value of 294.33µS/cm than at dry season with a mean value of 114.33µS/cm as tabulated in Table 4.4. The higher value at wet season may be as a result of high levels of various anions and nutrients in the water.

4.2.27. Temperature

The values obtained from the analysis carried out on surface water for temperature ranged from a minimum of 26.9^{o}c at royal cinema and Dokodza to a maximum of 27^{o}c at Lafiya Clinic locations respectively. Similarly, temperature values obtained during dry season ranged from a minimum of 29.5^{o}c to a maximum of 29.8^{o}c at Royal cinema and Dokdza locations respectively as tabulated in

Tables 4.3 and 4.4. The mean value of temperature at dry season in the study area was higher than the mean value at wet season.

4.2.28. pH

Based on the analysis carried out on surface water during wet season, pH ranged from a minimum of 6.84 to a maximum of 7.58 at Dokodza and Lafiya Clinic locations respectively. Similarly, pH values obtained for surface water during dry season ranged from a minimum of 6.50 to a maximum of 7.0 at Dokodza and Lafiya Clinic locations respectively. However, from the obtained values for both seasons, it clearly indicated that surface water was suitable for domestic and public purposes, since values falls within the permissible limit as stipulated by WHO (2004) and FAO (2000) standards as depicted in Tables 4.3 and 4.4. Considering the mean values for both seasons, it was obvious that pH concentration in surface water during wet season was higher than the mean value for dry season.

4.2.29. Turbidity

Turbidity concentration in surface water during wet season ranged from a minimum of 2.46 NTU to a maximum of 26.2 NTU in Table 4.3, at Lafiya Clinic and Dokodza locations respectively. Similarly, values obtained at dry season ranged from a minimum of 22.6NTU to a maximum of 57.7 NTU in Table 4.4, at Lafiya Clinic and Royal Cinema locations respectively. The high values of turbidity in surface water at Royal Clinic and Dokodza as well as the three locations at dry season may be as a result of suspended and colloidal matter, such as silk, clay, finely divided organic and inorganic matter as well as plankton and other microscopic organisms. Surface water in the study area requires the use of chlorine for disinfection before it can be used for its proffered purpose so as to avoid the spread of water born diseases in the study area. However, based on the mean values obtained for turbidity, it was vividly indicated that surface water was highly contaminated at dry season than at wet season.

4.2.30. Total Dissolved Solids (TDS)

This includes inorganic salts and small amounts of organic matter that are dissolved in water. Based on the analysis carried out on surface water during wet season, it was found that TDS concentration in surface water ranged from a minimum of 69.7mg/l to a maximum of 289.3mg/l in Table 4.3 at Dokodza and Lafiya Clinic locations respectively. Similarly, during dry season values obtained ranged from a minimum of 46.9mg/l to a maximum of 103.8mg/l in Table 4.4, at Dokodza and Lafiya Clinic locations respectively. The high values of TDS at Lafiya Clinic sample location at both seasons may cause excessive hardness, poor taste, mineral deposits and may cause corrosion in pipes used for distribution on the farm for irrigation. Comparing the obtained values for TDS in surface water in the study area with WHO (2004) and FAO Standards, it vividly showed that water is suitable for domestic and public purposes, since it fell below the permissible limit by WHO (2004) and FAO (2000) Standards. However, considering the mean values obtained for both seasons, it was clear that surface water at wet season was highly concentrated than dry season in the study area.

4.2.31. Dissolved Oxygen (DO)

Dissolved Oxygen for surface water during wet season ranged from a minimum of 4.33mg/l to a maximum of 5.68mg/l in Table 4.3 at Dokodza and Lafiya Clinic locations respectively. Similarly, dissolved oxygen in surface water during dry season ranged from a minimum of 3.52mg/l to a maximum of 5.27mg/l in Table 4.4, at Royal Cinema and Lafiya Clinic locations respectively. However, the mean values of dissolved oxygen in surface water at both seasons showed clearly that mean value at wet season was higher than mean value at dry season which means that surface at wet season contains more dissolved oxygen concentration. The higher concentration of dissolved oxygen in surface water may be as a result of the ability of water to hold oxygen.

4.2.32. Chloride (Cl)

The concentration of chloride in surface water during wet season ranged from a minimum of 57.10mg/l to a maximum of 114.10mg/l in Table 4.3, at Dokodza and Royal Cinema locations respectively. Similarly, during dry season, chloride concentration in surface water ranged from a minimum of 17.70mg/l to a maximum of 37.2mg/l in Table 4.4, at Dokodza and Lafiya Clinic locations respectively. Considering the mean values obtained for chloride concentration in surface water at both seasons, it clearly indicated that the mean value for wet season recorded higher value for wet season recorded higher value than the mean value at dry season. Surface water in the study area was found suitable for domestic and public purposes, since values fell below permissible limit by WHO (2004) Standard.

4.2.33. Total Hardness

Following the analysis carried out on surface water during wet season, total hardness values ranged from a minimum of 39mg/l to a maximum of 102.2mg/l in Table 4.3, at Dokodza and Royal

Cinema locations respectively. Similarly, values for total hardness obtained during dry season ranged from a minimum of 22mg/l to a maximum of 40mg/l in Table 4.4, at Dokodza and Lafiyal Clinic locations respectively. However, considering values obtained for both seasons, it showed that the hardness of surface water in the study area does not limit the use for domestic and public purposes, since, values falls below the permissible limit of 100mg/l by WHO (2004) Standard, except at Royal Cinema which was slightly higher than the permissible limit probably as a result of dissolved polyvalent metallic ions in the water. The mean value of hardness during wet season was found higher than the mean value at dry season.

4.2.34. Alkalinity

Alkalinity in surface water during wet season ranged from a minimum of 11.0mg/l to a maximum of 90.0mg/l in Table 4.3, at Royal Cinema and Lafiya Clinic locations respectively. Similarly, alkalinity in surface water during dry season ranged from a minimum of 20.0mg/l to a maximum of 58mg/l in Table 4.4, at Dokodza and Lafiya Clinic locations respectively. Surface water in the study area at wet season vividly showed its high alkalinity level than at dry season.

4.2.35. Calcium Hardness

Calcium hardness in surface water during wet season ranged from a minimum of 24mg/l to a maximum of 52mg/l in Table 4.3, at Dokodza and Royal Cinema locations respectively. Similarly, at dry season, Calcium hardness in surface water ranged from a minimum of 18mg/l to a maximum of 66mg/l in Table 4.4, at Dokodza and Lafiya Clinic locations respectively. Looking at the values obtained for both seasons, it was clear that values fall below the permissible limit suggested by WHO (2004) Standard. Therefore, surface water in the study area was suitable for domestic and public purposes. Considering the mean values obtained for both seasons, it clearly indicated that surface water at dry season was highly affected by calcium hardness than surface water at wet season in the study area.

4.2.36. Nitrate (NO_3^-)

Nitrate in surface water during wet season in the study area ranged from a minimum of 0.04mg/l to a maximum of 2.65mg/l in Table 4.3, at Lafiya Clinic and Dokodza locations respectively. Consequently, nitrate at dry season ranged from a minimum of 7.9mg/l to a maximum of 26.2mg/l in Table 4.4, at Lafiya Clinic and Royal Cinema locations respectively. However, considering the concentration of nitrate values obtained for both seasons, it was clear that values fall below the permissible limit of 50mg/l by WHO (2004) Standard. Based on the mean values obtained for nitrate concentration at both seasons, it was indicated that dry season surface water was highly concentrated than wet season surface water in the study area.

4.2.37. Calcium ion (Ca^{2+})

Calcium ion concentration in surface water during wet season in the study area ranged from a minimum of 16.2mg/l to a maximum of 27mg/l in Table 4.3, at Dokodza and Royal Cinema locations respectively. Similarly, during dry season, calcium ion concentration ranged from a minimum of 7.21mg/l to a maximum of 26.4mg/l in Table 4.4, at Dokodza and Lafiya Clinic locations respectively. However, from the mean values obtained for Calcium ion concentration in surface water at both seasons, it was clearly indicated that surface water at wet season contained more calcium ion than at dry season.

4.2.38. Magnesium ion (Mg^{2+})

Magnesium ion concentration in surface water during wet season Ranged from a minimum of 2.68mg/l to a maximum of 12.3mg/l in Table 4.3, at Lafiya Clinic and Royal Cinema locations respectively. Similarly, magnesium ion concentration in surface water at dry season ranged from a minimum of 0.48mg/l to a maximum of 5.85mg/l in Table 4.4, at Royal Cinema and Lafiya Clinic locations respectively. However, based on the mean value of magnesium ion concentration obtained for surface water at both seasons, indicated that wet season surface water have a high mean value than dry season surface water in the study area.

4.2.39. Sulphate (SO_4^-)

Sulphate concentration in surface water during wet season ranged from a minimum of 2.0mg/l to a maximum of 16.0mg/l at Dokodza and Royal Cinema locations respectively. Similarly, sulphate concentration in surface water during dry season ranged from a minimum of 2.0mg/l to a maximum of 15mg/l at Lafiya Clinic and Dokodza locations respectively. Besides, the values obtained for both seasons fell below the permissible limit by WHO (2004) standard, which makes the water suitable for domestic and public purposes. The mean values for sulphate concentration for both seasons indicated that wet season surface water contains higher sulphate concentration than at dry season in the study area.

4.2.40. Magnesium Hardness

Magnesium Hardness of surface water during wet season ranged from a minimum of 11.0mg/l to a maximum of 50.20mg/l in Table 4.3, at Lafiya Clinic and Royal Cinema locations respectively. Similarly, Magnesium Hardness concentration in surface water at dry season in the study area ranged from a minimum of 2mg/l to a maximum of 24mg/l in Table 4.4, at Royal Cinema and Lafiya Clinic locations respectively. Based on the Magnesium hardness concentration of surface water at both seasons, values obtained at all locations falls below the permissible limit by WHO (2004) Standard, except at Royal Cinema which was slightly higher than the permissible limit, hence, surface water in the study area was suitable for domestic and public purposes.

4.2.41. Sodium (Na^+)

The Sodium concentration in surface water ranged from a minimum of 7mg/l to a maximum of 15.5mg/l in Table 4.3, at Dokodza and Royal Cinema locations respectively. Similarly, at dry season, sodium concentration in surface water ranged from a minimum of 6.07mg/l to a maximum of 25.30mg/l in Table 4.4, at Dokodza and Lafiya Clinic locations respectively. However, based on the values of sodium concentration obtained at both seasons, it was discovered that values fall below the permissible limit by WHO (2004) standard. Considering the mean value for both seasons, it was clear that sodium concentration at dry season was higher than that at wet season in the study area.

4.2.42. Iron (Fe)

The concentration of iron in surface water during wet season ranged from a minimum of 0.02mg/l to a maximum of 0.06mg/l in Table 4.3, at Royal Cinema and and Dokodza locations respectively. Similarly, iron concentration at dry season ranged from a minimum of 1.38mg/l to a maximum of 2.43mg/l in Table 4.4, at Dokodza and Royal Cinema locations respectively. However, the mean values of iron concentration for surface water recorded at both seasons showed that dry season surface water contained higher iron concentration than at wet season in the study area. The values of iron concentration in surface water during wet season falls below the permissible limit by WHO (2004) standard, whereas, dry season surface water recorded values above the permissible limit by WHO (2004) Standard. This implies that surface water at wet season was suitable for domestic and public purposes except dry season surface water that requires disinfection before it can be used to avoid harmful effect on the consumers.

4.2.43. Potassium (K)

Potassium concentration in surface water during wet season ranged from a minimum of 3.40mg/l to a maximum of 5.36mg/l in Table 4.3, at Lafiya Clinic locations respectively. Similarly, at dry season, potassium concentration in surface water ranged from a minimum of 6.40mg/l to a maximum of 16mg/l in Table 4.4, at Dokodza and Lafiya Clinic locations respectively. However, from the mean values of potassium concentration for both wet and dry seasons, it was observed that dry season surface water was more concentrated than at wet season in the study area.

4.2.44. Ammonia (NH_3)

Ammonia concentration in surface water at wet season ranged from a minimum of 0.40mg/l to a maximum of 0.60mg/l in Table 4.3, at Lafiya Clinic and Royal Cinema locations respectively. Similarly, at dry season, ammonia concentration in surface water ranged from a minimum of 2.16mg/l to a maximum of 7.19mg/l in Table 4.4, at Lafiya Clinic and Royal Cinema locations respectively. However, from the mean concentration of ammonia at both wet and dry seasons in the study area, it was clearly observed that surface water at dry season was highly concentrated than at wet season.

4.2.45. Bicarbonate (HCO_3^-)

Bicarbonate concentration in surface water during wet season ranged from a minimum of 11.0mg/l at Royal Cinema to a maximum of 12mg/l in Table 4.3, at Dokodza and lafiya locations respectively. Similarly, at dry season, bicarbonate concentration in surface water ranged from a minimum of 20mg/l to a maximum of 58mg/l in Table 4.4, at Dokodza and Lafiya Clinic locations respectively. However, considering the mean concentration of bicarbonate for both wet and dry seasons, it was observed that dry season surface water was highly contaminated than wet season surface water in the study area.

4.2.46. Carbonate (CO_3^-)

The surface water in the study area vividly indicated the absence of carbonate concentration in surface water for both seasons it therefore, showed that surface water in the study area was suitable for domestic and public purposes as shown in Tables 4.3 and 4.4.

4.2.47. Fluoride (F)

The variation of fluoride in surface water at wet season ranged from a minimum of 0.03mg/l at Lafiya Clinic and Royal cinema to a maximum of 0.04mg/l in Table 4.3, at Dokodza locations respectively. Similarly, at dry season fluoride concentration was not found in surface water at Dokodza and Royal Cinema locations but was found at Lafiya Clinic to be 0.16mg/l in Table 4.4. The absence of fluoride in surface water at Dokodza and Royal Cinema may cause high dental caries; therefore, fluoride is required to be added to the surface water in those areas to prevent the problem of dental caries. Based on the mean values of fluoride obtained for both wet and dry season, it was clearly indicated that dry season surface water contains more fluoride concentration than wet season surface water.

4.2.48. Copper (CU)

The concentration of copper in surface water ranged from a minimum of 0.02mg/l to a maximum of 0.04mg/l in Table 4.3, at Royal Cinema and Dokodza locations respectively. Similarly, at dry season, copper concentration in surface water ranged from a minimum of 0.04mg/l to a maximum of 0.08mg/l in Table 4.4, at Dokodza and Royal Cinema locations respectively. Surface water therefore, in the study area was safe for domestic and public purposes, since values fall below the permissible limit of 1mg/l by WHO (2004). Besides, based on the mean values obtained for both season, surface water at dry season marked a higher mean value than wet season.

4.2.49. *Coliform*

The total *Coliform* count obtained from surface water during wet season ranged from a minimum of 340cfu to a maximum of 1060cfu per 100ml of water sample in Table 4.3, at Royal Cinema and Dokodza locations respectively. These results clearly showed that the surface water at the three locations in the study area does not conform to the permissible limit of ocfu per 100ml of water by WHO (2004). Therefore, surface water needs a thorough treatment before it can be consumed domestically, so as to prevent the spread of water born diseases in the study area. The high *coliform* count recorded during wet season may be as a result of high amount of dissolved oxygen in the water and could also be resulted from the availability of rain water that neutralizes some of the chemical from detergents used by the inhabitants of the area. But not withstanding the results fall below the permissible limit of 1000cfu per 100ml of water by FAO (2000) Standard for irrigation water, except at Dokodza. These showed that water was suitable for irrigation except water at Dokodza. Similarly, at dry season, *Coliform* pathogen was not found in surface water at all the three locations in the study area, it therefore, conformed to the permissible limit by WHO (2004). This does not mean that water in this area was 100 percent pure for consumption but could be as a result of detergent in the water which could have killed all micro-organisms in the water.

4.2.50. *E-Coli*

E-Coli (Escherischia Coli) pathogens found in surface water during wet season ranged from a minimum of 20cfu to a maximum of 60cfu per 100ml of water in Table 4.3, at Lafiya Clinic and Dokodza locations respectively. This means that surface water was contaminated with micro-organisms which makes the water unsafe for direct use for domestic and public purposes since count at all three locations are higher than the permissible limit of 0cfu per 100ml of water as suggested by WHO (2004). Hence, water was not suitable for use. Similarly, at dry season Table 4.4, clearly showed that E-Coli pathogens were not found in surface water at the three locations in the study area which makes water suitable for the proffered use and meet the permissible limit by WHO (2004).

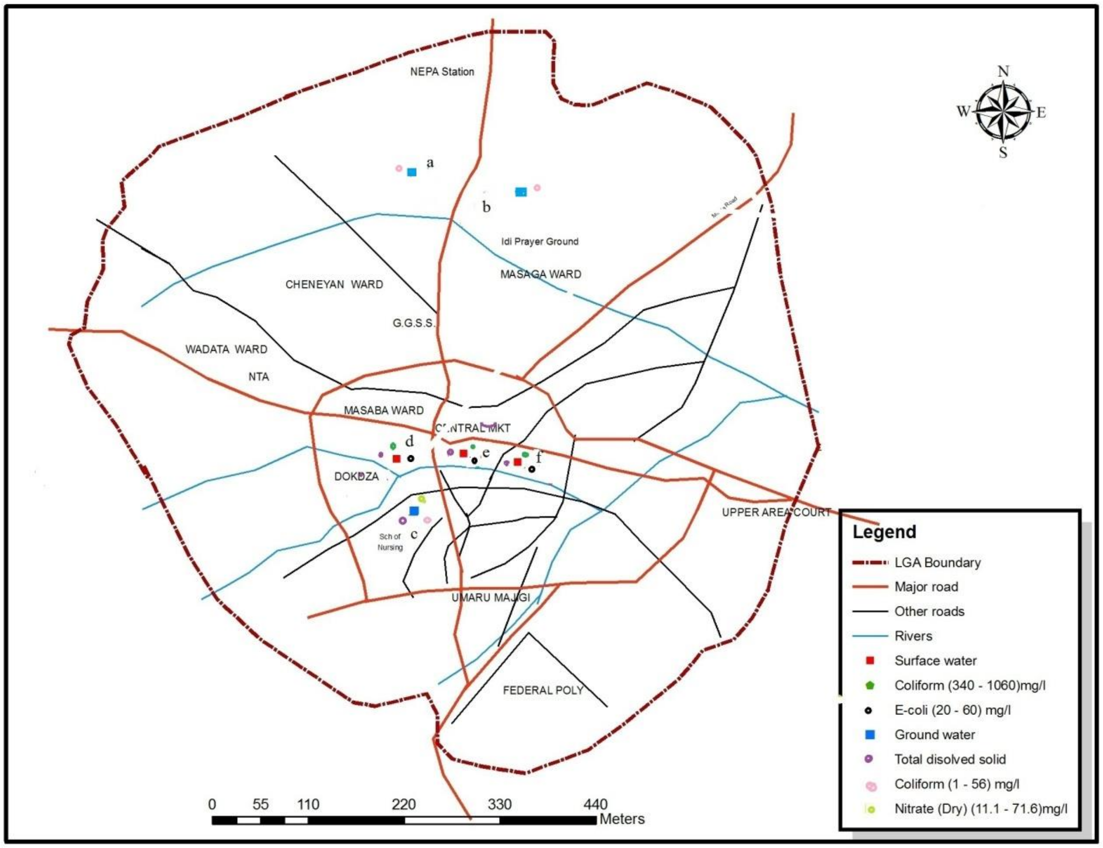


Figure 4.1: Location map of Bida showing parameters with excessive concentrations

in surface and groundwater.

The excessive concentration of *Coliform* and *E-Coli* pathogens in surface water at all locations as well as Coliform and total dissolved solids (TDS) in Ground Water as indicated in Figure 4.1 may cause the out-break of water borne diseases in the study area if proper measures are not put in place.

4.3. Converted ions and calculated parameters for Irrigation Water Quality

Tables 4.5-4.8, represents statistical summary of some converted ions (mg/l to meq/l) and calculated parameters for Surface and Ground water analyzed during wet and dry seasons respectively. These results are strictly for irrigation purpose.

Table 4.5: Statistical summary of some ions converted from mg/l to meq/l and calculated parameters for ground water at wet season (all parameters in meq/l) in the study area.

Parameter	Min.	Max.	Mean	Std Dev.	FAO
Ca^2	0.41	1.15	0.68	0.41	0-20
Mg^{2+}	0.10	0.99	0.45	0.47	0-5
So_4^-	0.06	0.21	0.12	0.08	0-20
Na^+	0.11	0.59	0.29	0.26	0-40
Hco_3^-	0.25	1.15	0.63	0.47	0-10
Cl^-	1.61	3.45	2.3	1	0-30
SAR	0.11	1.89	1.01	0.89	0-9
ESP	4.64	42.45	23.15	18.92	
SCR	1.66	0.47	-0.5	1.08	

The maximum values obtained for ions (Ca^{2+}, $Mg^{2+,}$ SO_3^-, Na^+, HCO_3^-, and Cl^-) concentration in ground water at both wet and dry seasons fall within the permissible range by FAO, (2000) Standard. Therefore, groundwater in the study area is suitable for irrigation purpose. Sodium Absorption Ratio (SAR) obtained by calculation for ground water during wet season ranged from a minimum of 0.11meq/l to a maximum of 1.89meq/l in Table 4.5, at Eso and Efu Madami locations respectively. Similarly, at dry season, Sodium Adsorption Ratio ranged from a minimum of 0.10meq/l to a maximum of 2.96meq/l in Table 4.6, at Eso and Efu Madami locations respectively. The maximum values for both seasons clearly showed that Sodium Adsorption Ratio (SAR) for groundwater is suitable for irrigation purpose since maximum values fall between 0 and 9meq/l as permitted by FAO (2000) standard. From the mean values obtained and tabulated in Tables 4.5 and 4.6, Sodium Adsorption Ratio (SAR) for ground water at dry season is higher than that of wet season in the study area.

Exchangeable Sodium Residue (ESR) obtained for ground water during wet season ranged from a minimum of 4.64meq/l to a maximum of 42.45meq/l in Table 4.5 at Efu Madami and Motor park locations respectively. Similarly, at dry season, it ranged from a minimum of 7.27meq/l to a maximum of 47.7meq/l at Eso and Efu Madami locations respectively.

Table 4.6: Statistical summary of some ions converted from mg/l to meq/l and calculated parameters for ground water at dry season for irrigation purpose (all parameters in meq/l) in the study area.

Parameter	Min.	Max.	Mean	Std Dev.	FAO
Ca^{2+}	0.12	1.12	0.47	0.57	0-20
Mg^{2+}	0.16	1.3	0.54	0.66	0-5
So_4^-	0.00	0.04	0.01	0.02	0-20
Na^+	0.31	3.26	1.31	1.69	0-40
Hco_3^-	0.12	0.34	0.2	0.12	0-10
Cl^-	0.69	4.35	1.93	2.09	0-30
SAR	0.1	2.96	1.34	1.47	0-9

ESP	7.27	47.73	32.56	22.05
SCR	-2.08	-0.16	-0.8	1.11

Sodium Carbonate Residue (SCR) calculated for ground water during wet season ranged from a minimum of -1.66meq/l to a maximum of -0.47meq/l in Table 4.5, at Efu Madami and Motor Park locations respectively. Similarly, at dry season, Sodium Carbonate Residue (SCR) ranged from a minimum of -2.08meq/l to a maximum of -0.16meq/l in Table 4.6, at Efu Madami and Motor Park locations respectively. The maximum values obtained at both seasons fall below zero (0), that is, (SCR<0). This clearly indicated that ground water is not

alkaline as permitted by standard (Egharevba, 2009), except at Motor Park location that was greater than zero (0) hence, water is suitable for irrigation purpose. However, from the mean value obtained for both season indicated that water at wet season has higher Sodium Carbonate Residue (SCR) than dry season ground water.

Table 4.7: Statistical summary of some ions converted from mg/l to meq/l and calculated parameters for surface water at wet season for irrigation purpose (all parameters in meq/l) in the study area.

Parameter	Min.	Max.	Mean	Std Dev.	FAO
Ca^{2+}	0.81	1.35	1.02	0.29	0-20
Mg^{2+}	0.22	1.03	0.52	0.44	0-5
So_4^-	0.04	0.33	0.16	0.15	0-20
Na^+	0.3	0.68	0.47	0.19	0-40
Hco_3^-	0.18	0.19	0.19	0.01	0-10
Cl^-	1.61	3.21	2.29	0.82	0-30
SAR	0.4	0.61	0.53	0.12	0-9
ESP	19.61	26.67	22.43	3.74	
SCR	-2.2	-0.93	-1.35	0.73	

The maximum values obtained for ions (Ca^{2+}, $Mg^{2+,}$ SO_3^-, Na^+, HCO_3^-, and Cl^-) concentration in surface water at both wet and dry seasons fall within the permissible range by FAO (2000)

Standard. Hence, surface water in the study area is suitable for irrigation purpose. Sodium Adsorption Ratio (SAR) for surface water during wet season ranged from a minimum of 0.40meq/l to a maximum of 0.61meq/l in Table 4.7, at Dokodza (upstream) and Royal Cinema locations respectively. Similarly, at dry season, Sodium Adsorption Ratio (SAR) ranged from a minimum of 0.55meq/l to a maximum of 1.16meq/l in Table 4.8, at Dokodza and Lafiya Clinic locations respectively. The maximum values fall between 0 and 9meq/l as stipulated by FAO (2000) Standards, which makes water suitable for irrigation purpose. Exchangeable Sodium Percentage (ESP) obtained for surface water during wet season ranged from a minimum of 19.61meq/l to a maximum of 26.67meq/l in Table 4.7, at Dokodza (upstream) and Lafiya Clinic locations respectively. Similarly, Exchangeable Sodium Percentage (ESP) at wet season ranged from a minimum of 3.01meq/l to a maximum of 39.44meq/l in Table 4.8, at Lafiya Clinic and Royal Cinema location respectively.

Table 4.8: Statistical summary of some ions converted from mg/l to meq/l and calculated parameters for surface water at dry season for irrigation purpose (all parameters in meq/l) in the study area.

Parameter	Min.	Max.	Mean	Std Dev.	FAO
Ca^{2+}	0.36	1.32	0.83	0.48	0-20
Mg^{2+}	0.04	0.49	0.2	0.25	0-5
So_4^-	0.1	0.31	0.24	0.12	0-20
Na^+	0.26	1.1	0.69	0.42	0-40
Hco_3^-	0.33	0.95	0.58	0.33	0-10
Cl^-	0.49	1.05	0.73	0.29	0-30
SAR	0.55	1.16	0.93	0.33	0-9
ESP	3.01	39.44	24.23	18.94	
SCR	-0.86	-0.11	-0.45		

Sodium Carbonate Residue (SCR) calculated for surface water at wet season ranged from a minimum of -2.20meq/l to a maximum of -0.93meq/l in Table 4.7, at Royal Cinema (Middle) and

Dokodza (upstream) locations respectively. Similarly, at dry season, Sodium Carbonate Residue (SCR) ranged from a minimum of -0.86meq/l to a maximum of -0.11meq/l in Table 4.8, at Lafiya Clinic (downstream) and Dokodza (upstream) locations respectively. The maximum values fall below zero (0), which clearly indicated that water was not alkaline according to standard (Egharevba, 2009), hence, surface water for both seasons is suitable for irrigation use.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Physio-chemical and bacteriological tests for Surface (river Landzun) and Ground water in the study area were determined and results were obtained. The maximum values of parameters for wet season groundwater were within the recommended limit by WHO (2004) and FAO (2000) Standard for drinking and irrigation water quality, but the quality of water is not suitable for use, since total dissolved solids (5546.4mg/l) and total *coliform* (1.00mg/l – 56.00mg/l) were above the recommended limit by WHO (2004) and FAO (2000) standards for drinking and irrigation water quality. Maximum values of parameters for dry season groundwater fell within the permissible limit by WHO (2004) and FAO (2000) standards, but water quality is not fit for domestic and irrigation purposes, since values for nitrate (71.60mg/l); magnesium hardness (64.00mg/l); total *coliform* (3.00mg/l-140.00mg/l); and *E-coli* (0-22.00mg/l) were above recommended limit by WHO (2004) and FAO (2000) standards.

Similarly, the maximum values of parameters for wet season surface water were within the recommended limit by WHO (2004) and FAO (2000) standards for drinking and irrigation water quality, but the water quality is not suitable for use as total *coliform* (340.00mg/l – 1060.00mg/l) and *E-coli* (20.00mg/l – 60.00mg/l) were above recommended limit by WHO (2004) and FAO (2000) standards for drinking and irrigation water quality. Maximum values of parameters for dry season surface water fell within the recommended limit by WHO (2004) and FAO (2000) standards for drinking and irrigation water quality. Though, turbidity was high but water quality is suitable for domestic and irrigation purpose as turbidity has no hazard impact on human health and on plants. The high contamination of groundwater at wet season than at dry season could be as a result of leaching from waste materials carelessly dumped around the study area into the ground and surface water as a result of washing of solid waste into water bodies.

5.2 Recommendations

Based on the study, the following recommendations are made:

i. Adequate measures like building of water treatment plants should be ensured for sustainable quality water for domestic and agricultural purposes in the study area.

ii. The habit of waste water and solid waste carelessly disposed in the area should be discouraged through enlightenment campaign and by providing improved methods of dustbins for collecting solid wastes and suck-away pit dug far away from groundwater systems for collecting waste water.

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APPENDIX A

Table 1a.Wet season result of Physio-Chemical/Bacteriological analysis of ground water in August 2011.

		Efu Madami	Park	Esso			
Parameter	Unit	GWI	GWII	GWIII	WHO	FAO	NIS STDS
Conductivity	µS/cm	784	439	98	-	-	1000
Temperature	^{O}C	27.0	27.0	27.0	25-29	25	Ambient
pH	-	6.66	6.58	6.62	6.5–8.0	6 .0-8.5	6-8.5
Turbidity	NTU	1.60	2.42	0.85	5	-	5
TDS	mg/l	5546.4	305.9	68.3	1000	0-2000	500
DO$_2$	mg/l	6.03	6.10	5.20	-	-	-
Chloride	mg/l	65.2	122.3	57.1	250	-	250
Total Hardness	mg/l	110.1	35.1	18.2	500	-	150
Alkalinity	mg/l	29.0	70.0	15.0	-	-	-
Calcium Hardness	mg/l	61.2	22.0	13.1	75	-	-
Nitrate	mg/l	2.12	1.59	1.99	50	-	50
Calcium^{2+}	mg/l	23.0	8.10	9.48	-	-	-
Magnesium^{2+}	mg/l	11.9	3.19	1.24	-	-	-
Sulphate	mg/l	3.00	4.00	10.0	250	-	100
Mg Hardness	mg/l	48.9	13.1	5.1	50	-	-
Sodium	mg/l	2.5	13.5	4.5	200	-	200
Iron	mg/l	0.10	0.04	0.18	0.3	-	0.2
Potassium	mg/l	4.69	4.69	3.35	-	0-2	-

Ammonia	mg/l	0.48	0.36	0.45	-	-	-
Bicarbonate	mg/l	29.0	70.0	15.0	-	0-6	-
Carbonate	mg/l	0.00	0.00	0.00	-	0-30	-
Fluoride	mg/l	0.10	0.01	0.06	1.5	-	-
Copper	mg/l	0.02	0.01	0.00	5	-	-
Coliform	Cfu/100ml	56	1	26	0	-	-
E – Coli	Cfu/100m	0	0	0	0	-	-

Table 2a. Wet season result of Physio-Chemical and Bacteriological analysis of River Landzun in August 2011.

		Dokodza	Royal Cinema	Lafiya Clinic			
Parameter	Unit	RWU	RWM	RWD	WHO	FAO	NIS STDS
Conductivity	µS/cm	100	368	415	-	-	1000
Temperature	ºC	26.9	26.9	27.0	25-29	25	Ambient
pH	-	6.84	7.39	7.58	6.0-8.0	6.0-8.5	6.5 – 8.5
Turbidity	NTU	1.60	2.42	0.85	5	-	5
TDS	mg/l	69.7	256.5	289.3	1000	0-2000	500
DO_2	mg/l	4.33	4.81	5.68	-	-	-
Chloride	mg/l	57.1	114.1	73.4	250	-	250
Total Hardness	mg/l	39.0	102.2	40.1	500	-	150
Alkalinity	mg/l	12.0	11.0	90.0	-	-	-
Calcium Hardness	mg/l	24.0	52.0	29.1	75	-	-
Nitrate	mg/l	2.65	0.08	0.04	50	-	50
Calcium^{2+}	mg/l	16.2	27.0	18.0	-	-	-
Magnessium^{2+}	mg/l	3.66	12.3	2.68	-	-	-
Sulphate	mg/l	2.00	16.00	5.00	250	-	100
Mg Hardness	mg/l	15.0	50.2	11.0	50	-	-
Sodium	mg/l	7.0	15.5	10.1	200	-	200
Iron	mg/l	0.06	0.02	0.04	0.3	-	0.2
Potassium	mg/l	4.34	5.36	3.40	-	0-2	-
Ammonia	mg/l	0.60	0.52	0.40	-	-	-

Bicarbonate	mg/l	12.0	11.0	12.1	-	0-6	-
Carbonate	mg/l	0.00	0.00	0.00	-	0-30	-
Fluoride	mg/l	0.04	0.03	0.03	1.5	-	-
Copper	mg/l	0.04	0.02	0.03	5	-	-
Coliform	Cfu/100ml	1060	340	520	0	l	Nill
E – Coli	Cfu/100ml	60	40	20	0	l	Nill

Table 3a. Dry season result of Physio-Chemical and Bacteriological analysis of ground water in March, 2012.

		Efu Madami	Park	Esso			
Parameter	Unit	GWI	GWII	GWIII	WHO	FAO	NIS STDS
Conductivity	µS/cm	67	130	69	-	-	1000
Temperature	ºC	29.6	29.7	29.6	25-29	25-29	Ambient
pH	-	5.70	5.30	5.90	6.0- 8.0	6.0-8.5	6.5 – 8.5
Turbidity	NTU	6.24	1.49	2.72	50	-	5
TDS	mg/l	43.5	87.1	46.2	1000	0-2000	500
DO_2	mg/l	5.21	3.84	3.96	-	-	-
Chloride	mg/l	154.3	24.8	26.5	250	-	250
Total Hardness	mg/l	120	14	16	500	-	150
Alkalinity	mg/l	21	7.0	9.0	-	-	-
Calcium Hardness	mg/l	56	6.0	8.0	75	-	-
Nitrate	mg/l	71.6	11.1	15.6	50	-	50
Calcium^{2+}	mg/l	22.4	2.41	3.21	-	-	-
Magnesium^{2+}	mg/l	15.6	1.95	1.95	-	-	-
Sulphate	mg/l	0.00	2.0	0.00	250	-	100
Mg Hardness	mg/l	64	8.0	8.0	50	-	-
Sodium	mg/l	74.9	8.10	7.09	200	-	200
Iron	mg/l	0.09	0.04	0.00	0.3	-	0.2
Potassium	mg/l	44.8	7.46	7.46	-	0 -2	-
Ammonia	mg/l	19.6	3.04	4.28	-	-	-

Bicarbonate	mg/l	21	7.0	9.0	-	0-6	-
Carbonate	mg/l	0.00	0.00	0.00	-	0-30	-
Fluoride	mg/l	0.14	0.13	0.12	1.5	-	-
Copper	mg/l	0.00	0.00	0.00	5	-	-
Coliform	Cfu/100ml	140	3	44	0	-	Nill
E-Coli	Cfu/100ml	22	0	0	0	-	Nill

Table 4a. Dry season result of Physio-Chemical and Bacteriological analysis of River Landzun in March, 2012.

		Dokodza	Royal Cinema	Lafiya Clinic			
Parameter	Unit	RWU	RWM	RWD	WHO	FAO	NIS STDS
Conductivity	µS/cm	70	118	155	-	-	1000
Temperature	°C	29.8	29.5	29.7	25-29	-	Ambient
pH	-	6.50	6.80	7.0	6.5-8.0	6.0-8.5	6.5 – 8.5
Turbidity	NTU	22.7	57.7	22.6	5	-	5
TDS	mg/l	46.9	79.1	103.8	1000	0-2000	500
DO_2	mg/l	4.00	3.52	5.27	-	-	-
Chloride	mg/l	17.7	23.0	37.2	250	-	250
Total Hardness	mg/l	22	40	90	500	-	150
Alkalinity	mg/l	20	28	58	-	-	-
Calcium Hardness	mg/l	18	38	66	75	-	-
Nitrate	mg/l	11.6	26.2	7.9	50	-	50
$Calcium^{2+}$	mg/l	7.21	16	26.4	-	-	-
$Magnesium^{2+}$	mg/l	0.97	0.48	5.85	-	-	-
Sulphate	mg/l	15	5.00	2.00	250	-	100
Mg Hardness	mg/l	4.0	2.0	24	50	-	-
Sodium	mg/l	6.07	16.3	25.3	200	-	200
Iron	mg/l	1.38	2.43	2.20	0.3	-	0.2
Potassium	mg/l	6.40	9.60	16	-	0-2	-
Ammonia	mg/l	3.18	7.19	2.16	-	-	-

Bicarbonate	mg/l	20	28	58	-	0 -6	-
Carbonate	mg/l	0.00	0.00	0.00	-	0 -30	-
Fluoride	mg/l	0.00	0.00	0.16	1.5	-	-
Copper	mg/l	0.04	0.08	0.06	5	-	-
Coliform	Cfu/100ml	0	0	0	0	-	Nill
E-Coli	Cfu/100ml	0	0	0	0	-	Nil