ASSESSMENT OF HAND-DUG WELL WATER QUALITY IN KATCHA, NIGER STATE

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ABSTRACT

This study presents the assessment of water quality of hand-dug wells in Katcha Local Government Area of Niger State, North Central Nigeria. Twenty hand-dug well water samples were analyzed in both rainy season and dry season. Standard method of water quality measurement were used to determine the Physico-chemical and Bacteriological parameters in accordance with American public health association (APHA, 1992). Values of temperature which range from 28-29^{0}C, pH which range from 6.20-7.17 meter, electric conductivity from 323-592µs/cm, total hardness from 136-260mg/l, total alkalinity from 26-78mg/l, dissolved oxygen is 5-9mg/l, chemical oxygen demand from 12.65-17.42mg/l, biochemical oxygen demand from 2-5mg/l, phosphate is 0.46-2.04mg/l, nitrate is 3.55-6.46mg/l, sodium is 13.81-28.35mg/l, potassium is 3.22-6.72mg/l, calcium is 38.81-72.36mg/l, magnesium is 10.74-22.81mg/l, carbonate is 10.82-37.63mg/l, iron is 1.93-4.44mg/l, manganese is 0.36-2.52mg/l, cupper is 0.05-0.42mg/l, lead NDmg/l, zinc is 0.40-0.13mg/l for rainy season and value of temperature which range from 29-30^{0}C, pH which range from 6.28-7.16 meter, electric conductivity from 66-413µs/cm, total hardness 130-192mg/l, total alkalinity 74-114mg/l, dissolved oxygen 5-8mg/l, chemical oxygen demand 5.9-7.36mg/l, biochemical oxygen demand 2-4mg/l, phosphate from 0.12-0.23mg/l, nitrate is 0.24-2.22mg/l, sodium is 5.2-9.6mg/l, potassium is 1.7-3.5, calcium is 18.75-46.92mg/l, magnesium is 4.22-7.75mg/l, carbonate is 35.56-56.19mg/l, iron is 0.24-2.22mg/l, manganese is 0.01-1.33mg/l, cupper is 0.03-0.35mg/l, lead NDmg/l, zinc is 0.01-0.30mg/l for dry season. The bacteriological parameters range for Echerichial coli is 9×10^6-15×106cfu/ml, total coliform is 5-350cfu/100ml and total bacteria is 42×106 - 69×106cfu/100ml for rainy season and Echerichial coli is 3×106-12×106cfu/ml, total coliform is 2-300cfu/100ml and total bacteria is 42×10^6-69×10^6cfu/100ml for dry season. The average water quality index (WQI) of 75.22 for rain season and 57.83 in dry season indicates that the untreated well water from rural areas in Katcha Local Government Area of Niger state is of fair quality and however must be treated before drinking to avoid water borne diseases. Therefore, the results of this research recommend that there is need for the government to take appropriate measures in safeguarding the health of its citizens and also educate them on the related water diseases that can be found in this water when consumed.

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ABBREVIATIONS

WHO: World Health Organization

FAO: Food and Agricultural Organization for United Nations

UN: United Nations

NGO: Non-Governmental Organization

EPA: Environmental Protection Agency

DWAF: Department Of Water Affairs and Forestry

MGS: Maryland Geological Survey

NPC: National Population Census

NSADP: National Suitable Agricultural Plan

APHA: American Public Health Association

E.Coli: Escherichia Coli

TC: Total Coliform

FC: Faecal Coliform

TBC: Total Bacteria Count

CFU: Colony Forming Unit

pH: Potency of Hydrogen

NTU: Nephlelomatic Turbidity Units

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

A well is an excavation or structure created in the ground by digging, driving, or drilling to access liquid resources usually water. The requirement of clean and sustainable quality of water cannot be over emphasized as it is of great important for human survival. An agricultural purpose such as irrigation also requires enough water supplies from a good recharge but due to the unavailability of good water sources, the rural communities rely in hand dug well water. Water is no doubt one of the most essential resources on earth and remains man's prime need in his environment. It is also a fact that portable water supply is of shortage or lacking in many communities despite being one of the most available resource on universe. Due to rapid growth in technology the extensive use of chemical fertilizers for agriculture are some of the factors that have direct effects on the quantity and quality of groundwater resources.

According to Mustapha and Yusuf (2015), poor water quality can pose health problem enough to threaten human life if consumed. Humans may survive for several weeks without food, but barely few days without water because constant supply of water is needed to replenish the fluid lost through normal physiological activities, such as respiration, perspiration, urination, (Chinedu *et al*., 2011). The pollution of ground water sources may be from industries, agricultural and domestic wastes. According to Chukwurah (2001), World Health Organization (WHO, 2016) recommended that wells should be located at least 30 m away from latrines and 17 m from septic tanks.

According to Okpokwasili and Akujobi, (1996), the presence of faecal coliforms or *Escherichia coli* is an indicator for the presence of water borne pathogens. Bacteriological examination of water is therefore a powerful tool in order to foreclose the presence of micro-organisms that might constitute health hazards (Singh and Mosley, 2003). (WHO, 2011) recommended that no faecal coliform should be present in 100 ml of drinking water. Good quality water should be odourless, colourless, tasteless and free from faecal contamination and chemicals in excess of (WHO, 2010) tolerable levels.

Insufficient solid waste management is a vital environmental problem in rural community, the contributing factors ranged from technical problem to educational and financial limitations. The challenge of appropriate refuse disposal (solid waste) is immensely and has become very serious problem. Unfortunately, most of the refuse is permanently disposed at groundwater recharge points, open space or burrow pits, pit latrines, septic tanks for human wastes. Effluent is admitted through the major drainage networks and finally emptied into river with the negative impact on groundwater and the environment. This study is to assess the bacteriological quality of hand dug well for both domestic and irrigative purposes in the rural area to ascertain the danger of contamination that may be present in such type of wells and as well as it effects to human health.

1.2 Statement of the Research Problem

Shallow well water may contain both organic and inorganic substances including heavy metals and pathogenic microorganisms which are harmful to human and also plants. These wells however may not produce water with good qualities as specified by (WHO, 1985) and Food and Agricultural organization for United Nations (FAO, 1972). Hence in most of the countries, the ground water is the major source of potable water. It is also widely used for agriculture and industrial purposes in several nations. The availability of groundwater has great influence on human life as well as other forms of life. Groundwater is an important renewable natural resource of socio-ecological significance. Due to rapid growth in population, urbanization, industrialization and the extensive use of chemical fertilizers for urban and peri- urban Agriculture are some of the factors that have direct effects on the quantity and quality of groundwater resources especially in arid and semi – arid region of Northern Nigeria (Al – Nozaily & Alshaebi, 2009). Globally, the quantity and quality of groundwater reserves is diminishing on daily basis. Therefore, any study that can aid in identifying new sources of threats to groundwater is desirous not only around the study area but everywhere (Abdullahi *et al*., 2010)

In order to meet the progressive demand of water requirement, the development and management of groundwater potential zone is very essential by keeping eyes on specific issues and peculiar hydrological conditions of rural area. Since, the ground water studies of this area have not received much appreciation and poorly attempted earlier. Therefore, assessment of hand dug wells water quality is a primary and essential action to be performed prior to any development action. To avoid such problems and to make any domestic and irrigation based development actions sustainable, hand dug wells must be evaluated. Lack of evaluation on shallow wells water for domestic and irrigative uses in the rural area has resulted to vital problems which includes; Lack of knowledge on water properties such as physico-chemical and heavy metal concentration which can affect the agricultural production and the health of the populace and, bacteriological contamination of water which may affect human health otherwise known as water borne diseases. All these to be evaluated in this research work.

1.3 Aim and Objectives of Study

This study was aimed at assessing the water quality of hand-dug wells from Katcha for both drinking and irrigative purposes. The objectives are as follows:

i. To determine the water quality of shallow wells for domestic and irrigative uses
ii. To determine the seasonal variations of shallow wells water in the rural areas.
iii. To analyze hand-dug well water samples under (WHO, 2017) and (FAO, 2017) standard
iv. To determine the water quality standard using water quality index

1.4 Scope of Study

The study involves obtaining the samples of hand-dug well water from different villages in Katch, Niger State and ascertain their bacteriological qualities by standard method of measurement and their physico-chemical parameters such as temperature (^{0}C), pH meter, electric conductivity (μs/cm), total hardness (mg/l), total alkalinity (mg/l), dissolved oxygen is (mg/l), chemical oxygen demand (mg/l), biochemical oxygen demand (mg/l), phosphate (mg/l), nitrate (mg/l), sodium (mg/l), potassium (mg/l), calcium (mg/l), magnesium (mg/l), carbonate (mg/l), and heavy metals such as iron (mg/l), manganese (mg/l), cupper (mg/l), lead (mg/l), zinc (mg/l) for rainy season and dry season.

1.5 Justification of Study

The research will aid in the provision of more hand-dug well for domestic and irrigative purposes and will contribute in solving the problem of water quality, recommend appropriate measures and also create sensitization about water quality, water borne diseases and create investment returns if properly justified. It will provide useful information to north central region especially Katcha, Niger State, researchers and other development organizations such as NGO`s to develop strategies, policies to provide quality and accessible water sources to the communities.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Preamble

Natural water contains many dissolved substances: bacteria such as shigella, salmonella, E.coli etc, viruses such as cryptospodium, heavy metals, nitrates and salt have polluted water supplies due to inadequate treatment and disposal of wastes from humans and livestock, industrial discharges and over use of limited water resources (Singh and Mosley, 2003). Groundwater use for irrigation, drinking and other purposes is increasing with increasing population globally and related food insecurity problems. In Africa, increasing agricultural productivity is a key to poverty reduction (FAO, 2017). Talukder *et al*. (2018) reported that poor quality irrigation water reduces soil productivity, changes soil physical and chemical properties, creates crop toxicity and ultimately reduces yield.

The United Nations (UN) set a goal in their Millennium Declaration to reduce the amount of people without safe drinking water by half in the year 2015 (UN, 2010). Safe drinking water for human consumption should be free from pathogens such as bacteria, viruses and protozoan parasites, meet the standard guidelines for taste, odour, appearance and chemical concentrations, and must be available in adequate quantities for domestic purposes (Kirkwood, 2016). However, inadequate sanitation and persistent faecal contamination of water sources is responsible for a large percentage of people in both developed and developing countries not having access to microbiologically safe drinking water and suffering from diarrhoeal diseases (WHO, 2002). Diarrhoeal diseases are responsible for approximately 2.5 million deaths annually in developing countries, affecting children younger than five years, especially those in areas devoid of access to potable water supply and sanitation (Kosek *et al.,* 2003). Water pollution is defined as contamination of water or alteration of the physical, chemical or biological properties of natural water. Water is the most available and important natural resource which support the life on Earth. Oceans hold 97% of Earth's surface as saline water and the remaining 3% only occurs as fresh water, of this 2.4% is frozen in glaciers and polar ice caps and the rest 0.6% is in liquid fresh water forms and available in rivers, lakes, and ground water etc. About 22% of liquid fresh water exists as ground water, which constitutes about 97% of all liquid fresh water available for human use which represents the availability of ground water is meager in Earth's total global water content (Foster, 2016). Water is said to be polluted when it changes its quality or composition either naturally or as a result of human activities, thus becoming unsuitable for domestic, agricultural, industrial, recreational uses and for the survival of wildlife. However shallow wells have types such as Dug/bored wells which are holes in the ground dug by shovel or back holes, line casing with stones and large diameter of approximately 10 to 39 feet deep and are not case continuously. Driven wells which constructed by driving pipe into the ground. Case continuously and shallow approximately 30 to50 feet deep. Driving is contaminated easily because they draw water from aquifers near the surface and drilled wells which are constructed by percussion or rotary drilling machines, they can be thousands of feet deep and required the installation of casing, therefore they lower have risks of contamination due to their depth and continuous use of casing (U. S. Geological survey, groundwater well 2016) . A water pollutant can be defined as an agent affecting aesthetic, physical, chemical and biological quality and wholesomeness of water. (kolpin *et al.,* 2002)

Anthropogenic practices like mining and disposal of untreated waste effluents from slaughter houses, mechanical workshops, and hospitals containing toxic heavy metals are some of the causes of groundwater pollution because these heavy metals finally infiltrate into the soil and could reach the groundwater table and hence the water become polluted (Laar *et al*., 2011).

2.2 Water Quality Assessment

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

2.3 The Microbiological Quality of Water

Water supplies in developing countries are devoid of treatment and the communities have to make use of the most convenient supply (Sobsey, 2002; Moyo *et al*., 2004). Many of these water supplies are unprotected and susceptible to external contamination from surface runoff, windblown debris, human and animal faecal pollution and unsanitary collection methods (Chidavaenzi *et al*., 1998).

Detection of each pathogenic microorganism in water is technically difficult, time consuming and expensive and therefore not used for routine water testing procedures (Grabow, 1996). Instead, indicator organisms are routinely used to assess the microbiological quality of water and provide an easy, rapid and reliable indication of the microbiological quality of water supplies (Grabow, 1996).

2.4 Temperature

Water bodies undergo temperature variations along with normal climatic fluctuations. These variations occur seasonally and, in some water bodies, over periods of 24 hours. The temperature of surface waters is influenced by latitude, altitude, season, time of day, air circulation, cloud cover and the flow and depth of the water body. In turn, temperature affects physical, chemical and biological processes in water bodies and, as a result, the concentration of many variables. As water temperature increases, the rate of chemical reactions generally increases together with the evaporation and volatilization of substances from the water. Increased temperature also decreases the solubility of gases such as O_2, CO_2, N_2, and CH_4 in water.

The metabolic rate of aquatic organisms is also related to temperature. In warm waters respiration rates increase leading to increased oxygen consumption and increased decomposition of organic matter. Growth rates also increase (this is most noticeable for bacteria and phytoplankton which double their populations in very short time periods) leading to increased water turbidity, macrophyte growth and algal blooms, when nutrient conditions are suitable (Chapman & Kimstach, 1996).

2.5 Physico-chemical Characteristics

The most existing physical contaminants of water are suspended sediments. These are properties which are often visible to the eyes such as colour, odour, taste and turbidity. Chemicals are the major sources of water contamination. Some chemicals are existing during movement through geological materials or when thrown away directly into water bodies.

2.5.1 Nitrates and nitrites

Nitrate ion (NO_3^-) is the common form of combined nitrogen found in natural waters. It may be biochemically reduced to nitrite (NO_2^-) by denitrification processes, usually under anaerobic conditions. Nitrite ion is rapidly oxidized to nitrate. Natural sources of nitrate in surface waters include igneous rocks, land drainage and plant and animal debris. Nitrate is an essential nutrient for aquatic plants and seasonal fluctuations can be caused by plant growth and decay. Natural concentrations, which seldom exceed 0.1 mg/l, may be enhanced by municipal and industrial waste-waters, including leachates from waste disposal sites and sanitary landfills. In rural and suburban areas, the use of inorganic nitrate fertilizers can be a significant source. Nitrate (NO_3^-) is found naturally in the environment and is an important plant nutrient (Chapman & Kimstach, 1996).

Concentrations of nitrate in surface water can change rapidly owing to surface runoff of fertilizer, uptake by phytoplankton and denitrification by bacteria, but groundwater concentrations generally show relatively slow changes. Some ground water may also have nitrate contamination as a consequence of leaching from natural vegetation.

In general, the most important source of human exposure to nitrate and nitrite is through vegetables (nitrite and nitrate) and through meat in the diet (nitrite is used as a preservative in many cured meats). In some circumstances, however, drinking-water can make a significant contribution to nitrate and, occasionally, nitrite intake. In the case of bottle-fed infants, drinking water can be a major external source of exposure to nitrate and nitrite (WHO, 2011).

2.5.2 Phosphorus compound

Phosphorus is a very important nutrient for living organisms and exists in water bodies as both dissolved and particulate species. In natural water, phosphorus occurs mostly as dissolved orthophosphates and polyphsohpate, and organically bound phosphates. A change between these forms occurs continuously due to decomposition and synthesis of organically bound forms and oxidized inorganic forms.

Phosphorus is hardly found in high concentrations in fresh water as it actively taken up by plants. As a result, there can be considerable seasonal fluctuations in concentrations in surface waters. In most natural surface water, phosphorus ranges from 0.005 to 0.020mg/l P04-p. Concentration as low as 0.001 mg/l P04-p may be found in some pristine waters and as high as 200mg/l P04-p in some enclosed saline water. Average ground water levels are about 0.02mg/l p04-p. (UNESCO, 1978 & UNEP, 2009)

2.5.3 Taste and odour

Water odour may be as a result of volatile organic compounds and may be produced by aquatic plants or decomposition of organic matter. Industrial and human wastes can also create odours, either directly or as a result of the biological activity they initiate. Organic compounds, inorganic substances, lubricants and gas can all impart odour to water although an odour does not automatically indicate the presence of harmful substances. Usually, the presence of an odour suggests higher than normal biological activity and is a simple test for the suitability of drinking water, since the human sense of smell is far more sensitive to low concentrations of substances than human taste. Warm temperatures increase the rate and production of odour-causing metabolic and decay products. Different levels of pH may also affect the rate of chemical reactions leading to the production of odour.

The odour in potable water may be defined as the sensation due to the presence of substances having an appreciable vapour pressure and stimulates the human sensory organs in the nasal and sinus cavities (Nsi, 2007). Odour in water may have natural origins, such as earth, rotten fish, hydrogen sulphide, clayey or artificial flavours; of chlorine, camphor, pharmaceuticals, etc. (Nikoladze & Mints, 1989). Water may have a salty, bitter, sweet or acidic taste. This may be due to dissolved inorganic and organic substances in nature, e.g.

Phenols and chlorophenols. Both taste and odour are subjective properties, which are difficult to measure (Nsi, 2007; Tebbutt, 1983).

2.5.4 Colour

The colour and the turbidity of water determine the depth to which light is transmitted. This, in turn, controls the amount of primary productivity that is possible by controlling the rate of photosynthesis of the algae present. The visible colour of water is the result of the different wavelengths not absorbed by the water itself or the result of dissolved and particulate substances present. It is possible to measure both true and visible colour in water. Natural minerals such as ferric hydroxide and organic substances such as humic acids give true colour to water. True colour can only be measured in a sample after filtration or centrifugation. Apparent colour is caused by coloured particulates and the refraction and reflection of light on suspended particulates. Polluted water may, therefore, have quite a strong apparent colour. A dark or blue-green colour can be caused by blue-green algae, a yellow-brown colour by diatoms. Colour of water aesthetically affects its portability and may not be necessarily harmful (Nikoladze & Mints, 1989; Nsi, 2007).

2.5.5 Turbidity

Turbidity may be defined as the measure of clarity of water. Turbidity is caused by the presence of suspended insoluble materials such as clay and silt particles, discharges of sewage or industrial wastes, or the presence of large numbers of micro-organisms mainly occurring in surface water, which makes them objectionable for almost all uses (Tebbutt, 1983). Excessive turbidity protects microorganisms from effects of disinfectants, stimulates the growth of bacteria in water. There is no constant linear relationship between turbidity and concentration of suspended matters, since the former is affected by shapes, sizes and refractive indices of the particulates (Vesilind & Pierce, 1993; Nsi, 2007). It is therefore measured (NTU) nephlelomatic turbidity units.

2.5.6 Alkalinity

Alkalinity is a water characteristic that shows the capacity of water to neutralize acids by accepting Hydrogen ions (H^+) and preventing sudden changes in the acidity levels of water. Alkalinity is due to the presence of two forms of the Carbonate anions (HCO_3^-), (CO_3^{2-}) and (OH) that act as buffer system (Chris, 2012). Borates, phosphates, silicates and other bases also contribute to alkalinity if present in groundwater. Inorganic ligands (anions) form complexes with metals (cations), this removes free divalent toxic metal ions such as Cd^{2+}, Cu^{2+}, Pb^{2+}, Zn^{2+} or methyl-metal complexes. Metal complexes are not biologically available and hence not toxic. Alkalinity is an important property when determining the suitability of water for other uses such as irrigation, or mixing with pesticides and when treating

This is given as a number expressing the concentration of filterable solids present i contaminated water. Alkalinity is measured in $CaCO_3$ mg/L. According to Fakoyode (2005), pH that is near to neutral (pH 7) is indicative of unpolluted water.

2.5.7 Electrical conductivity

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

2.5.8 pH

Most natured water usually has pH between 6.0 and 9.0. pH can be said to have indirect effect on health since it affects the removal of viruses, bacteria and other harmful organisms. For potable water, the recommended value of the pH is 6.5 to 8.5.

2.5.9 Hardness of water

Hardness may be defined as the concentration of all multivalent metallic cations in solution. The principal ions causing hardness in natural water are calcium and magnesium. Others that may be present however in much smaller quantities include iron, manganese, strontium and aluminum. Ground water is much prone to hardness due to high concentration of calcium and magnesium ions (Nsi, 2007). Hardness of natural water is not harmful to the health of man; on the contrary, calcium promotes removal of cadmium; an element that can adversely affect the cardiovascular system (Nikoladze & Mints, 1989). An elevated hardness, however, makes water unsuitable for domestic and industrial use. Hardness can be determined by methods such as EDTA and titrimetric method (Vesilind & Pierce, 1993). Hardness content in water is very important parameter because of its benefit to human health. Water harness can be classified based on calcium carbonate as shown in Table 2.1;

Table 2.1 Classification of Ground Water Hardness

Hardness range (mg/l of CaCo3)	Water classification
0-73	Soft
73-150	Moderate
150-290	Hard
>290	Very hard

Salvem, 2014

2.5.10 Zinc

Zinc is an essential trace element found in virtually all food and potable water in the form of salts or organic complexes. The diet is normally the principal source of zinc. Although levels of zinc in surface water and groundwater normally do not exceed 0.01 and 0.05mg/litre, respectively, concentrations in tap water can be much higher as a result of dissolution of zinc from pipes.

JECFA (1982) proposed a PMTDI for zinc of 1mg/kg of body weight. The daily requirement for adult men is 15–20mg/day. It was considered that, taking into account recent studies on humans, the derivation of a guideline value is not required at this time. However, drinking-water containing zinc at levels above 3mg/litre may not be acceptable to consumers. WHO (2011) Zinc in drinking-water. Background document for preparation of WHO (2011) Guidelines for drinking-water quality.

2.5.11 Lead

Lead is used principally in the production of lead-acid batteries, solder and alloys. The organic lead compounds tetraethyl and tetra methyl lead have also been used extensively as antiknock and lubricating agents in petrol, although their use for these purposes in many countries is being phased out. Owing to the decreasing use of lead containing additives in petrol and of lead-containing solder in the food processing industry, concentrations in air and food are declining, and intake from drinking-water constitutes a greater proportion of total intake. Lead is rarely present in tap water as a result of its dissolution from natural sources; rather, its presence is primarily from household plumbing systems containing lead in pipes, solder, fittings or the service connections to homes. The amount of lead dissolved from the plumbing system depends on several factors, including pH, temperature, water hardness, and standing time of the water, with soft, acidic water being the most plumb solvent.

Lead is not essential in nutrition and has high toxicity level. Placental transfer of lead occurs in humans as early as the 12th week of gestation and continues throughout development. Young children absorb 4–5 times as much lead as adults, and the biological half-life may be considerably longer in children than in adults. Lead also interferes with calcium metabolism, both directly and by interfering with vitamin D metabolism. These effects have been observed in children at blood lead levels ranging from 12 to 120mg/dl, with no evidence of a threshold. There is electrophysiological evidence of effects on the nervous system in children with blood lead levels well below 30mg/dl. It has a maximum tolerable level of 0.01mg/l in surface and underground water (WHO, 2011).

2.5.12 Manganese

Manganese is one of the most abundant metals in the Earth's crust, usually occurring with iron. It is used principally in the manufacture of iron and steel alloys, as an oxidant for cl eaning, bleaching and disinfection as potassium permanganate and as an ingredient in various products. Manganese greensands are used in some locations for potable water treatment. Manganese is an essential element for humans and other animals and occurs naturally in many food sources. The most important oxidative states for the environment and biology are Mn^{2+}, Mn^{4+} and Mn^{7+}. Manganese is naturally occurring in many surface water and groundwater sources, particularly in anaerobic or low oxidation conditions, and this is the most important source of drinking-water.

The greatest exposure to manganese is usually from food. Manganese is an essential element for humans and other animals. Adverse effects can result from both deficiency and overexposure. Maximum tolerable limit is 0.05mg/l. However, this limit is not determined by its toxicity, but because they stain clothing and ceramic plumbing fixtures (Nsi, 2007)

2.5.13 Iron

Iron is one of the most abundant metals in the Earth's crust. It is found in natural fresh waters at levels ranging from 0.5 to 50 mg/litre. Iron may also be present in drinking water as a result of the use of iron coagulants or the corrosion of steel and cast iron pipes during water distribution. Iron is an essential element in human nutrition. Estimates of the minimum daily requirement for iron depend on age, sex, physiological status and iron bioavailability and range from about 10 to 50mg/day (WHO, 2011).

2.5.14 Copper

Copper and its compounds are used in electrical wiring, water pipes, cooking utensils, and electroplating, and as algaecides and food additives. Copper concentrations in drinking-water vary widely as a result of variations in pH, hardness, and copper availability in the distribution system. Levels of copper in running water tend to be low, whereas those of standing or partially flushed water samples are more variable and can be substantially higher, particularly in areas where the water is soft and corrosive. Adult intake of copper from food is usually 1-2 mg/day and may be considerably increased by consumption of standing or partially flushed water from a system that contains copper pipes or fittings. Copper is an essential nutrient, required for the proper functioning of many important enzyme systems. In mammals, absorption of copper occurs in the upper gastrointestinal tract and is controlled by a complex homeostatic process. Absorption is influenced by the presence of competing metals, dietary proteins, fructose, and ascorbic acid. The major excretory pathway for absorbed copper is bile. In humans, the highest concentrations of copper are found in the liver, brain, heart, kidney, and adrenal glands. The liver of newborn infants contains about 10 times as much copper as the adult liver and accounts for 50-60% of the total body copper.

Acute gastrointestinal effects may result from exposure to copper in drinking-water, although the levels at which such effects occur are not defined with any precision. Long-term intake of copper in the diet in the range 1.5-3 mg/day has no apparent adverse effects. Daily intake of copper below this range can lead to anaemia, neutropenia, and bone demineralization in malnourished children. Adults are more resistant than children to the symptoms of copper deficiency.

A copper level of 2 mg/litre in drinking-water should not cause any adverse effects and provides an adequate margin of safety. The epidemiological and clinical studies conducted to date are too limited to allow a clear effect level to be established with any accuracy. Thus, it is recommended that this guideline value for copper of 2 mg/litre remain provisional as a result of uncertainties in the dose - response relationship between copper in drinking-water and acute gastrointestinal effects in humans. It is also noteworthy that copper is an essential element.

It is stressed that the outcome of epidemiological studies in process in Chile, Sweden, and the USA may permit more accurate quantification of effect levels for copper-induced toxicity in humans, including sensitive subpopulations. Staining of laundry and sanitary ware occurs at copper concentrations above 1 mg/litre. At levels above 5 mg/litre, copper also imparts a colour and an undesirable bitter taste to water.

2.5.15 Biological contaminant

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

Chemical Oxygen Demand (COD) is a second method of estimating how much oxygen would be depleted from a body of receiving water as a result of bacterial action. The COD test has the advantage of not being subject to interference from toxic materials, as well as requiring only two or three hours for test completion, as opposed to five days for the BOD test. In the case of biodegradable organics, the COD is normally in the range of 1.3 to 1.5 times the BOD. When the result of a COD test is more than twice that of the BOD test, there is good reason to suspect that a significant portion of the organic material in the sample is not biodegradable by ordinary microorganisms. (UNESCO, 1978) and (WHO, 2011).

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

2.6 Micro-Biological Parameters

2.6.1 Total and faecal coliforms

According to Bodoczi (2010), the sanitary quality of water is appreciated by the presence or absence of pathogenic micro-organisms indicated by presence of coliforms. There is practically no geological environment at or near the earth's surface where pH will not support some form of organic life, also at this depth water pressures are not high enough to deter microbial activity (Chapman, 1996). Pathogenic bacteria can survive long underground and may have a life span of about 4 years (Hamil and Bell, 1986). Coliform group of bacteria are a large group of disease causing bacteria that inhabit intestine of man and animals (Sigh *et al.,* 2003). WHO (1985), specified that potable drinking water should be devoid of total and faecal coliforms in any given water source, MPN (maximum permissible number) of 0cfu/100ml.

2.6.2 Faecal coliforms

Faecal Coliform presences are the most reliable indicators of faecal bacterial contamination of surface and groundwater waters in different countries (WHO, 1989). Faecal coliform bacteria are bacteria found in faeces, they are subset of a larger group of organisms known as coliform bacteria which are facultative anaerobes that can survive in the absence of oxygen, gram negative, non-spore forming, rod-shaped bacteria that ferment lactose, producing gas and acid at about high temperatures of $35^{O}C$. Human waste contaminant in water causes water borne diseases such as diarrhea, typhoid, hepatitis and flu-like symptoms such as nausea, vomiting, fever (FAO, 1995). High coliform counts in water samples are an indication of poor sanitary conditions in the community. According to Adekunle *et al*. (2007) and Hamil. L and Bell, (1986), inadequate and unhygienic handling of solid wastes in the rural and urban areas leads to high concentrations of microbial organisms.

In 2006, the Environmental Protection Agency (EPA) published the ground water rule in the United States to keep microbial pathogens out of public water sources to reduce disease incidence associated with disease causing micro-organisms (EPA, 2012).

2.7 Classification of Water Quality Assessment

The microbial content is a very important water quality parameter because of its relations to human health. Water can be classified based on microbial quality as shown in Table 2.2; for human use safely. Department of water affairs and forestry (DWAF, 1996)

Table 2. 2. Classification of water micro-biological limits (DWAF, 1996)

Parameter	Good	Marginal	Poor
TC	10 cfu.100 ml^{-1}	11-100 cfu.100 ml^{-1}	> 100 cfu.100 ml^{-1}
FC	0 cfu.100 ml^{-1}	1-10 cfu.100 ml^{-1}	> 10 cfu.100 ml^{-1}

Cfu = colony forming units, good = fit for human consumption, poor = poses a health risk

1. Good (negligible risk of microbial infection; fit for human consumption)

2. Marginal (slight risk of microbial infection; must be treated before consumption)

3. Poor (risk of infectious disease transmission; not fit for human consumption)

2.8. Impact of Dry and Wet Seasons on Groundwater Quality

Seasonal variations change the aesthetic quality of the water and bring discomfort amongst consumers. Seasonal variations in water quality arise due to variations in ecosystem, ecological activity, rainfall and geology/geographical conditions of the area. Artesian rock wells constructed in unconsolidated sediments tend to respond slowly to rainfall, possibly several days or weeks later because of the poor permeability of the confining layer (MGS, 2012). The eco-system, characteristics of the surrounding area, residence time and geological characteristics affect the physico-chemical and micro-biological seasonal variations of groundwater parameters (Howarth & McGillivray, 2001).

2.9 Environmental Effect

Heavy metals and fertilizers also stress environmental health, which in turn can lead to public concern, streams and lakes polluted with the same heavy metals that cause human effect experience declines in fish population and loss of aquatic plant biodiversity. When excessive nitrate enters aquatic system, algae growth becomes rapid and available oxygen become consumed as these organisms die and decompose. As the oxygen disappears aquatic animals are suffocated if oxygen is not reinforcing into the water in time (U.S center for disease control and prevention of drinking water 2010).

2.10 Solution to Environmental Effect

Technology is increasingly becoming more efficient at detecting and removing contaminations from drinking water. One to help minimize the amount of fertilizer applied in the residential lawns. This reduces the amount of nitrate that can be washing away to nearby streams (U. S center for disease control preventing of drinking water 2010).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Location of Study Area

The Hand-dug well water samples were collected from five 5 different villages in Katcha Local Government Area of Niger State in North Central Nigeria. Niger state is located within latitudes 80^0 to 11^030^l North and longitudes 03^0 30^l to 07^0 40^l East of the prime meridian with land area of 76,469.903 square kilometers (about 10% of the total land area of Nigeria) out of which 85% is arable with a population of 3,950,249 people (N.P.C, 2006). The state is agrarian and well suited for production of arable crops such as cowpea, yam, cassava, maize and also rice, because of its favorable climatic conditions. The annual rainfall is between 1100mm in the northern part – 1600mm in the southern part, the rainy season last for about 150 days in the northern part to about 120 days in the southern part of the state with average monthly temperature ranges from 23°C and 37°C (NSADP, 1994). The fertile soil and hydrography of the state generally, allow the cultivation of most Nigeria's stable crops and still permit sufficient opportunities for grazing, fresh water and forestry development.

Katcha Local Government Area shown in figure 3. has geographical coordinate of 8^0 37^1N, 6^04^l E and 9^029 ^{1} N, 6^0 28^1E with land area of 1,681 kilometers square with density of 101.0 per person kilometer square. It has the population of 122,176 according to 2006 population census (N.P.C, 2006) and its postal code is 912. The rainy season starts from April to October and the dry season starts from November to March with annual rainfall between 1000mm-12000mm. The annual average temperature of 27.8^0C and average precipitation of 1184mm. The most farming activities (crop) of the people are rice cultivation.

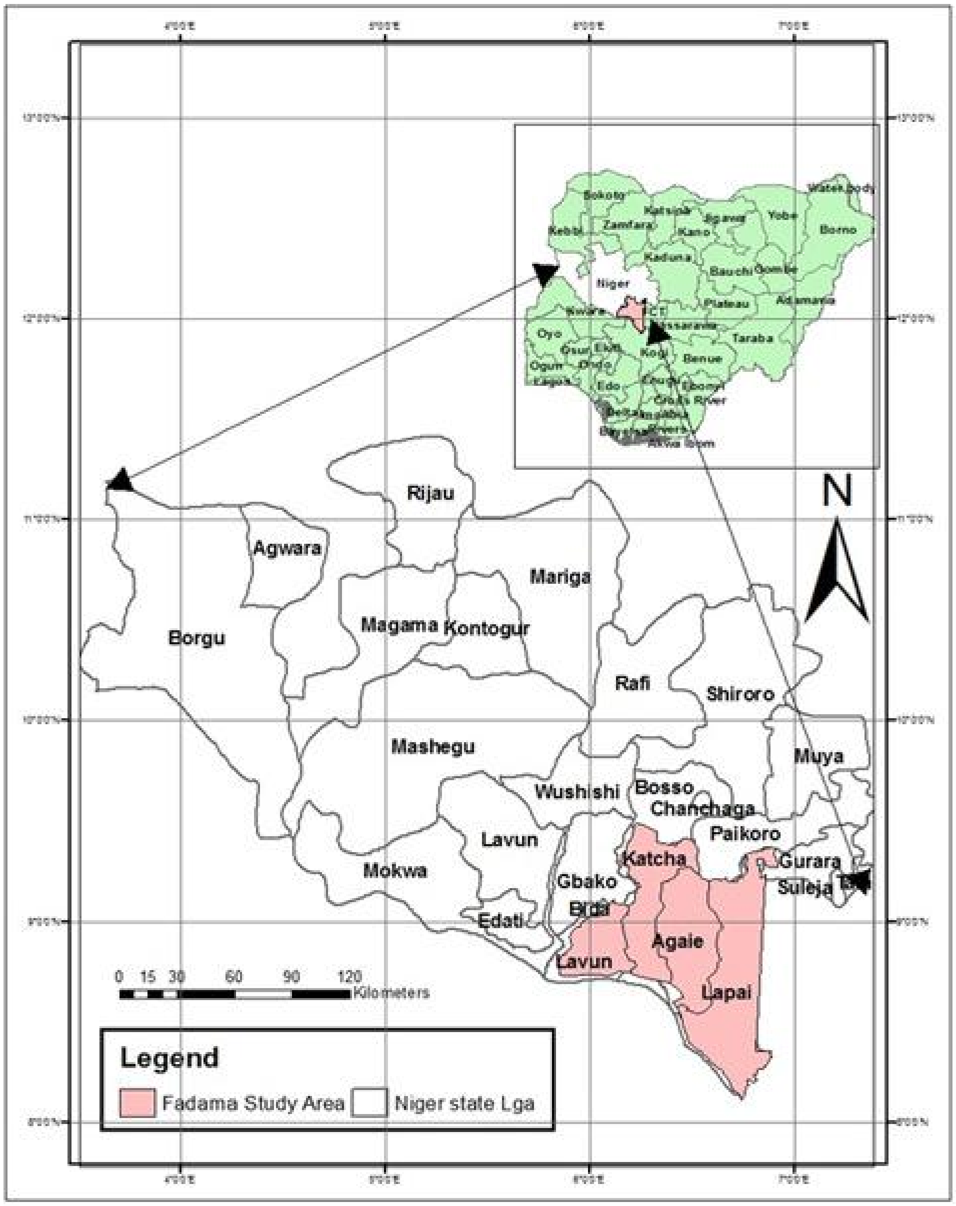


Figure 3.1: Map of the study area Katcha Local Government Area

3.2 Sample Collection

The hand-dug well water was collected from Katcha Local Government Area of Niger State from the following villages;

1. Echegi
2. Zhitu
3. Katch Iraba
4. Katcha Kpata
5. Yintu

3.3 Groundwater Sampling

Representative samples of groundwater was collected from 10 shallow well water from 5 locations for each season that is from October to December, 2019 based on distribution of the wells that represent groundwater and permission from owners prior to sampling. The water was collected in 1 litre plastic containers. Before collection, as part of quality control measures, all the bottles were washed with non-ionic detergent and rinsed with de-ionized water prior to usage. For DO and BOD re agent was added to the water sample immediately at the site. The sampling bottles were rinsed three times with well waters at the point of collection. Each bottle was labeled according to sampling location to avoid mixing error and was carefully preserved at 4^oC and transported directly the laboratory for analysis.

3.4 Sample Preparation and Analysis

3.4.1 Physico-chemical analysis

The following processes were carried out after each sample was collected, standard methods and procedures were adopted (APHA, 1992) to conduct the analysis. An in- situ measurement was made for conductivity, pH, and temperature using Sension Platinum Series, portable pH and conductivity meter (HACH made). The samples were poured into the measuring bottle and the surface of the bottle was wiped with silicon oil. The bottle was then inserted into the turbid meter and the reading was obtained. The water samples for anion analysis were filtered using a hand operated vacuum pump equipped with a 0.45µm cellulose acetate filter membrane. Bicarbonate (HCO_3) was carried out using acid titration, with methyl orange as indicator. Nitrate (NO_3^-), phosphate (Po_4^{2-}) were determined using V2000 multi-analyte photometer, Na and K were carried out with a CORNING FLAME PHOTOMETER 410 after calibrating it with analyte standard while the remaining trace and heavy metals were carried out with a Varian model AA240FS Fast Sequential Atomic Absorption Spectrometer.

3.4.2 Total alkalinity

Method: Titrimetric to PH=4.5 (Methyl Orange)

Apparatus

A. Standard laboratory glassware such as burettes, volumetric flasks and beakers.

Reagents

A. Standard sodium carbonate, approximately 0.05N. 3 to 5g sodium carbonate, Na_2CO_3, at 250°C was dried for 4h and cooled in a desiccator. 2.5±0.2g was weighed to the nearest mg, and dissolved in distilled water and to make 1L.

B. Standard H_2SO_4, approximately 0.1N. 2.8 mL conc. Sulphuric acid was diluted to 1L. Standardize against 40.00mL 0.05N Na_2CO_3 with about 60 mL distilled water, in a beaker by titrating Potentiometric ally to pH 5. Electrodes was lifted out and rinsed into the same beaker and boiled gently for 3 to 5 min under a watch glass cover. Cooled to room temperature, rinsed cover glass into beaker and finished titration to pH 4.3. Normality of Sulphuric acid was calculated:

Normality, N= A × B / 53.00 × C

Where:

A = g Na_2CO_3 was weighed into the 1L-flask for the Na_2CO_3 standard

B = mL Na_2CO_3 solution was taken for standardization titration

C = mL acid used in standardization titration

C. Since case potentiometric titration is not possible bromcresol was used green indicator to complete the titration.

D. Standard sulphuric acid, 0.02N. Approximate 0.1N solution was diluted to 1L. Calculate volume to be diluted as:

ML volume = 20/N

Where:

N = exact normality of the approximate 0.1N solution.

E. Bromcresol green indicator, pH 4.5: Dissolve 100mg bromcresol green sodium salt in 100mL distilled water

Procedure

A. 2 to 3 drops of bromcresol green indicator was added. Titrated until change in colour (blue to yellow, pH 4.9 to 4.3) is observed. Total mL titrant used was recorded.

Calculations

Total alkalinity, mg CaCO /L = TV × N × 50000/50

Where:

TV = total value mL of titrant used to bromcresol green end point

N = normality of titrant (0.02)

Note: For turbid/coloured samples, titration can be performed using a pH meter to end point pH value of 4.5

3.4.3 Biochemical Oxygen Demand (5 days, 27°C) (BOD5-27)

Method: Bottle Incubation for 5-Days at 27°C

Apparatus

A. BOD bottles, 300 mL, narrow mouth, flared lip, with tapered and pointed ground glass Stoppers.

B. Air incubator or water bath thermostatically controlled at 27 ± 1°C. Light entry was prevented in order to avoid photosynthetic oxygen production

C. Accessories: plastic tube, screw-pin and a 5-10 L water container.

Reagents

A. Phosphate buffer solution. 8.5g KH_2PO_4, 21.75g K_2HPO_4, 33.4g $Na_2HPO_4.7H_2O$ and 1.7g NH_4Cl was desolved in 1L distilled water.

B. Magnesium sulphate solution. 22.5g $MgSO_4.7H_2O$ was dissolved in 1L distilled water.

C. Calcium chloride solution. 27.5g $CaCl_2$ was dissolved in 1L distilled water.

D. Ferric chloride solution. 0.25g $FeCl_3.6H_2O$ was dissolved in 1L distilled water.

E. Acid and alkali solution. 1N NaOH and 1N H_2SO_4. Was used for neutralizing samples.

F. Glucose-glutamic acid solution (was prepared fresh). 150mg dry reagent grade glucose and 150 mg dry reagent grade glutamic acid was dissolved in 1L distilled water

G. Sample dilution water. 1 mL each of phosphate buffer, $MgSO_4$, $CaCl_2$ and $FeCl_3$ Solutions per litre were added with distilled water.

Procedure

A. Required amount of dilution water at the rate of 1000 to 1200mL per sample per dilution was prepared. Diluted water was brought to temperature of 27°C. Saturated with air by shaking in a partially filled bottle, by bubbling with organic free filtered air or by storing in cotton-plugged bottles for a day.

B. Some samples do not contain sufficient microbial population (for example, high temperature wastes, or wastes with extreme pH values). Seed from a surface water body receiving the waste may also be suitable. Seed volume such that the DO uptake of the seeded dilution water was added enough between 0.6 and 1.0 mg/L. Surface water samples usually do not require seeding.

C. Dilution of sample. Dilutions was result in a sample with a residual DO (after 5 days of incubation) of at least 1 mg/L and a DO was uptake of at least 2mgl/L. Several dilutions was made using the Table and experience with the particular sample source. Polluted surface water may have 5 to 25 mg/L BOD

Calculations

BOD = BOD1- BOD5

WHERE BOD1= DO1, 2, 3… N

BOD5 = biochemical oxygen demand for five days.

3.4.4 Chemical Oxygen Demand (COD)

Method: Open Reflux

Apparatus

A. Reflux flasks, consisting of 250mL flask with flat bottom and with 24/29ground glass neck

B. Condensers, 24/29 and 30cm jacket Leibig or equivalent with 24/29 ground glass joint, or air cooled condensers, 60cm long, 18mm diameter, 24/29ground glass joint.

C. Hot plate or gas burner having sufficient heating surface.

Reagent

A. Standard potassium dichromate solution, 0.0417M (0.25N): 12.259 g $K_2Cr_2O_7$ was dissolved; Primary standard grade previously dried at 103°C for 2 hours, in distilled water and diluted to1L.

B. Sulphuric acid reagent: 5.5g Ag_2SO_4 technical or reagent grade was added, per kg of conc. H_2SO_4, was kept for a day or two to dissolved.

C. Ferroin indicator solution: 1.485g1, 10-phenanthroline monohydrate was dissolved and 695mg $FeSO_4.7H_2O$ in distilled water and diluted to 100mL. Commercial preparation was also available.

D. Standard ferrous ammonium sulphate (FAS), titrant, 0.25M: 98g Fe $(NH_4)_2$ $(SO_4)2.6H_2O$ was dissolved in distilled water, 20 mL conc. H_2SO_4 was added, cooled and diluted to 1L, standardized daily as follows.

E. Standardization: 10mL standard $K_2Cr_2O_7$ to about 100mL was diluted, 30mL conc H_2SO4, cooled was added. 2 drops of ferroin indicator and titrate was added with FAS.

F. 0.25Volume of FAS used, Ml Volume of 0.0417M K_2Cr_2O, Ml Molarity FAS = 227 ×g. Mercuric Sulphate, H_2SO_4, powder

H. Potassium hydrogen phthalate (KHP) standard: Lightly crush and dry potassium hydrogen phthalate (HOOCC6H4COOK), at 120^oC, cooled in desiccator, 425mg was weighed and distilled in water and diluted to 1L.

Procedure

A. An aliquot diluted to 50mL was added with distilled water in a 500Ml refluxing flask. 1g H_2SO_4 was added, few glass beads, and 5mL sulphuric acid reagent, was mixed, cooled. 25mL of 0.0417 M $K_2Cr_2O_7$ solutions was added and mixed. The flask was connected to the condenser. Turned on cooling water, additional 70mL of sulphuric acid reagent through open end of condenser was added, with swirling and mixing.

B. Reflux for 2 hours; cooled, washed down condenser with distilled water to double the volume of contents, cool.

C. 2 drops of Ferroin indicator titrate was added with FAS the remaining potassium dichromate, until a colour changed from bluish green to reddish brown. a distilled water blank was refluxed and titrated with reagents.

D. 0.00417M $K_2Cr_2O_7$, Standard was used and 0.025M FAS, when analyzing very low COD samples.

E. the technique and reagents by conducting the test on potassium hydrogen sulphate solution was evaluated.

F. Grease at the Leibig jacket was not added to prevent jamming, water used instead.

Calculation

COD = (blank sample) × 0.25 × 8 × 1000/50

Where,

0.25 =molarity of Fes04,

8 = equivalent weight of oxygen in water

1000 = conversion to mg/l

50 = volume of sample used.

3.4.5 Dissolved Oxygen (DO)

Method: Winkler Azide Modification Titrimetric

Apparatus

A. DO sampler, for collection of undisturbed samples from surface waters.

B. BOD bottles, 300mL, narrow mouth, flared lip, with tapered and pointed ground glass Stoppers.

C. A siphon tube, for laboratory use.

Reagents

A. Manganous sulphate solution. 480g $MnSO_4$ .4H2O, 400g MnSO4.2H_2O was dissolved in distilled water, filtered and diluted to IL.

B. Alkali-iodide-azide reagent. 500g NaOH was dissolved and 135g NaCI in distilled water and diluted to IL. 10g NaN_3 was added and dissolved in 40mL distilled water.

C. Sulphuric acid, conc.

D. Starch indicator. 2g laboratory grade soluble starch was dissolved and 0.2g salicylic acid as a preservative, in 100mL hot distilled water.

E. Standard sodium thiosulphate titrant, 0.025M (0.025N). 6.205g $Na_2S_2O_3.5H_2O$ was dissolved in distilled water. 1.5mL 6NNaOH was added and diluted to 1000mL. Standardized with bi-iodate solution.

F. Standard potassium bi-iodate solution, 0.0021M (0.0126N), 812.4mg KH (I03)2 was dissolved in distilled water and diluted to 1000mL.

Standardization: 100 to 150mL distilled water in an Erlenmeyer flask was taken. Approximately 2g KI was added and dissolved.1mL 6N H_2S0_4 and 20 mL bi-iodate solution was added. 200mL was diluted and liberated iodine was titrated with thiosulphate titrant to a pale straw colour. A few drops of starch indicator was added. titration to first disappearance of blue colour was continued.

Procedure

A. Any liquid in the flared lip of the BOD bottle containing the sample was drained.

B. 1 mL of $MnSO_4$ followed by 1 mL alkali-iodide-azide reagent was added and after stopper was removed. The pipette tip just below the liquid surface touching the side of the bottle was hold. The pipette before returning to the reagent bottles was washed.

C. Stopper air bubbles were carefully to excluded. Mixed by inverting the bottle a few times.

D. The brown manganese hydroxide floc (white floc indicates absence of DO) to settle approximately to half the bottle volume was allowed, 1.0 mL conc H_2SO_4 was added and re-stoppered. Mixed by inverting several times until dissolution is complete.

E. 201mL with standard $Na_2S_2O_3$ as for standardization procedure described above was titrated.

Calculation

DO = TV × 0.025 × 8 × 1000/10

Where:

V =10 = volume (Ml) of thiosulphate solution used

M = 0.025 = molarity of thiosulphate titrant

8 = equivalent weight of oxygen in water

100 = conversion to mg/l.

3.4.6 Electrical Conductivity (EC)

Method: Conductivity Cell Potentiometric

Apparatus

A. Conductivity meter capable of measuring conductivity with an error not exceeding 1% or

0.1µs/m whichever is greater.

B. Conductivity cell, Pt electrode type. For new cells not already coated and old cell giving erratic readings platinize according to the following procedure. The cell with chromic - sulphuric acid cleaning mixture to be cleaned. Prepare platinizing solution by dissolving 1g chloroplatinic acid, H_2Pt Cl6.6H2O and 12mg lead acetate in 100 mL distilled water. Immerse electrodes in this solution and connect both to the negative terminal of a 1.5V dry cell battery (in some meters this source is built in). Connect the positive terminal to a platinum wire and dip wire into the solution. Continue electrolysis until both cell electrodes are coated with platinum

black.

Reagent

A. Conductivity water - distilled water boiled shortly before used to minimize CO_2 content was done. Electrical conductivity was less than 0.01 mS/m (< 0.1 µmho/cm).

B. Standard potassium chloride solution, KCl, 0.01M, conductivity 141.2 mS/m at 25^{o}C. 745.6mg anhydrous KCl (dried 1 hour at 180°C) in conductivity water was dissolved and diluted to 1000mL. This reference solution is suitable when the cell has a constant between 1 and 2per cm.

Procedure

A. Conductivity cell with at least three portions of 0.01M KCl solution was rinse. Resistance of a fourth portion was measured and the temperature was noted.

B. In case the instrument indicates conductivity directly, and has internal temperature compensation, after rinsing as above, adjust temperature compensation dial to 0.0191/ °C and with the probe in standard KCl solution, adjust meter to read 141.2 us/m (or 1412µmho/cm) continue at step d.

C. the cell constant was computed, KC according to the formula:

$$K_C = 1412/c_{kci} * [0.0191(t\ 25) + 1]$$

Where:

Kc = the cell constant, 1/cm

CK_{Cl} = measured conductance, µmho

t = observed temperature of standard KCl solution, °C

The value of temperature correction [0.0191 x (t-25) +1]

D. More portions of sample of the cell were rinsed. The level of sample aliquot was above the vent holes in the cell and no air bubbles were allowed inside the cell. The temperature of sample to about 25°C (outside a temperature range of 20 - 30°C, error increases as the sample temperature increasingly deviates from the reporting temperature of 25°C) was adjust. Sample conductivity was taken and temperature to nearest 0.1°C was noted.

E. The cell was thoroughly rinsed in distilled water after measurement, kept in distilled water when not in use.

3.4.7 Total Hardness (TH)

Method: EDTA Titrimetric

Reagents

A. Buffer solution1: Dissolve 16.9g NH_4Cl in 143 mL conc. NH_4OH. 1.25g magnesium salt of ethylenediaminetetraacetate (EDTA) was added and diluted to 250mL with distilled water. Plastic bottle stoppered tightly for no longer than one month was stored.

B. Complexing agent: Magnesium salt of 1,2 cyclohexanediaminetetraacetic acid. 250mg per 100mL sample only if interfering ions are present was added and sharped end point was not obtained.

C. Indicator: Eriochrome Black T sodium salt. 0.5g dye in 100mL triethanolamine or 2 ethylene glycol monomethyl ether was dissolved. The salt was also used in dried powder form by grinding 0.5g dye with 100g NaCl.

D. Standard EDTA titrant, 0.01M: 3.723g di-sodium salt of EDTA was weighed, dihydrate, dissolved in distilled water and diluted to 1000mL. Stored in polyethylene bottle.

E. Standard Calcium Solution: 1.000g anhydrous $CaCO_3$ in a 500 mL flask was weighed. 1 +1HCl were added slowly through a funnel till all $CaCO_3$ was dissolved. Add 200mL distilled water and boil for a few minutes to expel CO_2. a few drops of methyl red indicator was cooled, added and adjusted to the intermediate orange colour by adding 3NNH_4OH or 1 + 1 HCl, as required. Transferred quantitatively and diluted to 1000mL with distilled water, 1mL = 1mg CaCO3.

Procedure

A. 25 mL sample to 50 mL with distilled water was diluted. 1 to 2 mL buffer was diluted to give a pH of 10.0 to 10.1. 1 to 2 drops of indicator solution was added and titrated with EDTA titrant to change the colour from reddish tinge to blue. A sample volume that requires less than 15mL EDTA titrant was selected and completed titration within 5min after buffer addition.

B. Standardize the EDTA titrant against standard calcium solution using the above procedure.

Calculations

Total hardness = Tv × 0.001 × 100 × 1000/50

Where, Tv = total value

0.001 = standard of EDTA (ethylenediaminetetraacetic acid dehydrate) limit

1000 = conversion to mg/l

50 = volume of sample used

3.4.8 Temperature (T)

Method: Mercury Thermometer

Apparatus

A. Mercury thermometer having a scale marked for every 0.1^{o}C.

Procedure

A. thermometer was immersed in the sample up-to the mark specified by the manufacturer and read temperature after equilibration.

B. When a temperature profile at a number of different depths is required a thermistor with a sufficiently long lead may be used.

3.5 Bacteriological analysis

3.5.1 Standard plate count

The standard plate count is an agar method for estimating bacteria's population, it consists of essentially the following procedure:

A. For each sample, an absorb pad was placed into an empty sterilized Petri dishes

B. 2ml of membrane lauryl sulfate both (MLSB) was added to it to saturate the padin different petri dishes and it was allowed to soak and all excess fluid was poured away.

C. Each water sample was filtrated by using 0.0045 and 45um, using membrane filtration techniques.

D. After filtration, the filtrated paper was placed on the absorb pad in the petri dishes containing the media. This procedure was repeated for rest of water samples.

E. Also for the media such as nutrient agar (NA), the agar was boiled at 30^0C for 4 hours and then was transferred; some membrane was transfer to 37^0C for total coliforms and other to 44^0C for Escherichia coli (E. coli).

F. An incubator was used for incubations, the temperature control was set to be accurate and it was making sure then even temperature is distributed, especially for E. coli.

G. incubate membrane was set at 37^0C and 44^0C for 14 hours to give a total incubation time of 18 hours before it was regarded as negative.

3.5.2 Determination of water quality index

The calculation of the WQI will be done using weighted arithmetic water quality index which was originally proposed by Horton (1965) and developed by Brown *et al.,* (1972). The weighted arithmetic water quality index (WQI_A) is in the following form:

$$WQWQIA = \sum wiqi \,/\, \sum wini \qquad (3.1)$$

Where n is the number of variables or parameters, wi is the relative weight of the ith parameter and qi is the water quality rating of the ith parameter. The unit weight (wi) of the various water quality parameters are inversely proportional to the recommended standards for the corresponding parameters. According to Brown *et al.,* (1972), the value of qi is calculated using the following equation:

$q_i = \quad qi = 100[(Vi - vid)/\ (si - vid)]$ (3.2)

Where Vi is the observed value of the ith parameter, Si is the standard permissible value of the ith parameter and Vid is the ideal value of the ith parameter in pure water. All the ideal values (Vid) are taken as zero for drinking water except pH and dissolved oxygen (Tripaty and Sahu, 2005). For pH, the ideal value is 7.0 (for natural/pure water) and a permissible value is 8.5 (for polluted water). Therefore, the quality rating for pH is calculated from the following equation:

$qPHJ = 100[(vpH - 7.0)\ /\ (8.5 - 7.0)\ ]$ (3.3)

Where VpH = observed value of pH.

For dissolved oxygen, the ideal value is 14.6 mg/L and the standard permissible value for drinking water is 5 mg/L. Therefore, its quality rating is calculated from the following equation:

$qDO = 100[(Vdo - 14.6)/(5.0 - 14.6)]$ (3.4)

Where V_{DO} = observed value of dissolved oxygen.

Table 3.1 Shows the summary for water quality index (WQI) and their corresponding water quality status (WQS), from 0-25 the wqs is said to be excellent and can be used for drinking, irrigation and industrial, from 26-50 is good for domestic, irrigation and industrial, 51-75 is fair for irrigation and industrial uses only, 76-100 is poor can be used only for irrigation, 101-150 is very poor and restricted for irrigation only and greater than 150 is unfit for consumption which proper treatment must be done before use

Table 3.1 summary of (WQI) and WQI

S/**No**	**WQI**	**WQS**	**Possible Uses**
1	0-25	Excellent	Drinking, Irrigation and Industrial
2	26-50	Good	Domestic, Irrigation and Industrial
3	51-75	Fair	Irrigation and Industrial
4	76-100	Poor	Irrigation
5	101-150	Very poor	Restricted use for Irrigation
6	>150	Unfit for Consumption	Proper Treatment Essential before use

Source: Life Science Informatics Publications (2019). www.rjibpcs.com

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Preamble

This chapter focuses on the results and discussions of the data collected from shallow wells water from rural areas for both domestic and irrigative uses in Katcha Local Government Area from 5 five different locations as well as determination statistical variations of physico-chemical and bacteriological parameters using (WQI) for rain and dry season as compared with (WHO) and (FAO) standard.

4.2 Physico-Chemical Analysis during Rainy Season

Table 4.1 shows the Physico-chemical parameters of 10 hand-dug wells water during the rainy season.

Table 4.1 Physico-Chemical Analysis during Rainy Season

	(SAMPLES)											
Parameters	1	2	3	4	5	6	7	8	9	10	WHO	FAO
Temp.(°C)	28	29	28	28	28	29	28	28	28	28	30-35	3.5-13
Ph	6.41	6.51	6.49	6.46	6.43	6.45	6.80	6.20	6.60	7.17	6.5-7.5	7.0-8.0
EC (µs/cm)	386	350	592	543	566	539	323	586	383	420	300	700-3000
TH (mg/l)	224	168	260	188	172	162	168	174	136	152	500	-
TA (mg/l)	78	64	77	64	44	32	30	26	34	26	500	-
DO (mg/l)	8	5	6	6	8	6	6	5	7	9	5.0	-
COD (mg/l)	14.6	12.18	16.25	15.11	15.86	15.30	12.65	17.42	12.65	14.28	2000-6000	-
BOD (mg/l)	2	3	4	4	4	4	4	3	4	5	0-5	15
PO_4 (mg/l)	0.63	0.46	1.38	1.22	1.54	1.36	0.76	2.04	0.53	0.85	-	0-2
NO_3^- (mg/l)	5.82	4.16	6.25	5.75	6.46	6.22	3.71	6.38	3.55	4.27	50	30
Na (mg/l)	14.65	13.81	17.25	23.17	28.35	25.17	20.78	17.12	19.36	18.62	50	200
k (mg/l)	3.85	3.22	5.7	8.35	6.72	5.85	4.21	5.33	4.65	3.97	55	20
Ca (mg/l)	56.48	59.71	66.23	54.15	72.36	38.81	45.98	40.26	48.30	51.13	75	100
Mg (mg/l)	14.22	18.75	22.81	16.52	21.38	10.74	16.30	14.18	16.36	12.74	150	50
HCO_3(mg/l)	37.63	30.41	36.66	29.38	20.10	13.92	12.88	10.82	14.95	10.82	1000	125
Fe (mg/l)	2.85	1.93	3.58	3.12	3.65	3.72	1.95	4.44	2.11	3.26	0.3	5.0
Mn (mg/l)	1.13	0.81	2.33	1.65	1.44	1.81	0.36	2.52	1.16	1.74	0.1	0.20
Cu (mg/l)	0.11	0.11	0.31	0.28	0.33	0.13	0.05	0.42	0.13	0.16	1.0	0.20
Pb (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.01	5.0
Zn (mg/l)	0.06	0.04	0.10	0.1	0.1	0.1	0.05	0.13	0.07	0.09	5.0	2.0

4.2.1 Temperature (T)

Sample 2 and 6 having the highest temperature of 29^0C and the rest Sample having the lowest temperature of 28^0C

4.2.2 Electrical conductivity (EC)

Sample 3 is having the highest Electrical conductivity EC with Sample 7 having the lowest EC **4.2.3 Total hardness (TH) and total alkalinity (TA)**

Sample 1 is having the highest TH and TA with Sample 9 having the lowest TH and 8 and 10 having the least TA

4.2.4 Dissolved oxygen (DO) and chemical oxygen demand (COD)

Sample 2 and 8 are having the lowest DO and Sample 10 is having the highest DO while Sample 8 having the highest COD with sample 2 having the lowest COD

4.2.5 Biochemical oxygen demand (BOD) and Phosphate (PO_4)

Sample 1 is having the lowest BOD with Sample 10 as the highest and Sample 2 is having the lowest PO_4 follow by Sample 9 with 8 having the highest PO_4

4.2.6 Nitrate (NO_3^-) and (Na)

Sample 5 is having the highest NO_3^- and Na, but Sampl 9 which has the lowest NO_3^- with Sample 1 having the lowest Na

4.2.7 Potassium (K) and calcium (Ca)

Sample 2 having the lowest K with Sample 4 having the lowest K as Sample 5 is having the highest Ca with Sample 6 having the lowest Ca

4.2.8 Magnesium (Mg) and hydro-carbonate (HCO_3)

Mg while Sample 2 is having the highest Mg, Sample 1 and is having the highest HCO_3 with Sample 8 and 10 having the lowest HCO_3,

4.2.9 Iron (Fe), manganese (Mn) and copper (Cu)

Sample 10 is having the lowest Fe with Sample 7 having the highest Fe, but has the lowest Mn and Cu with Sample 8 having the highest Mn and Cu.

4.2.10 Lead (Pb) and zinc (Zn)

Pb has no presence in all the Sample in the test carried out therefore Sample 2 has the lowest Zn with Sample 8 having the highest Zn.

4.2.11 Potency of hydrogen ($_P$H)

The pH of Sample 10 is the highest with Sample 8 having the lowest. All the pH of the Sample the WHO and FAO standards, but failed to meet up (EC) standard for both WHO and FAO. TH, TA, standard was not met up for WHO and FAO except for DO which meet up WHO standard only. COD, BOD was not meet up for the entire Sample except for PO_4 which most of the Sample meet up FAO standard except Sample 8. NO_3^-, Na, K, Ca, Mg, HCO_3 Fe, Mn, Cu, Pb, and Zn standard for (WHO) and (FAO) were not met up respectively.

4.3 Physico-Chemical Analysis during Dry Season

4.3.1 Temperature (T)

From Table 4.2, Sample 3, 5 and 8 having the lowest temperature of 29^0C and the rest Sample having the highest temperature of 30^0C

Table 4.2 Physico-chemical analysis during dry season

(SAMPLES)

Parameters	1	2	3	4	5	6	7	8	9	10	WHO	FAO
Temp.(^oC)	30	30	29	30	29	30	30	29	30	30	30-35	3.5-13
PH	7.16	6.68	6.50	6.28	6.36	6.45	6.36	6.44	6.46	6.40	6.5-7.5	7.0-8.0
EC (μs/cm)	69	66	76	288	413	402	400	408	396	400	300	700-3000
TH (mg/l)	192	148	136	176	150	146	160	166	130	144	500	-
TA (mg/l)	74	84	78	90	78	86	104	114	80	96	500	-
DO (mg/l)	6	5	6	6	5	5	6	8	5	5.4	5.0	-
COD (mg/l)	7.28	5.9	5.55	6.2	7	7.36	7.18	7.22	6.98	7.58	2000-6000	-
BOD (mg/l)	4	2	3	3	2	3	4	3	2.4	3	0-5	15
PO_4 (mg/l)	0.16	0.18	0.12	0.65	0.22	0.20	0.18	0.23	0.19	0.17	-	0-2
NO_3^- (mg/l)	0.35	0.42	0.24	1.34	1.84	2.22	1.65	1.33	1.75	1.42	50	30
Na (mg/l)	5.2	6.83	5.9	8.7	7.6	9.2	9.6	8.8	7.2	9.3	50	200
k (mg/l)	1.8	2.6	1.7	2.3	2.1	3.5	3.3	3.1	2.2	3.4	55	20
Ca (mg/l)	24.66	18.75	22.78	29.44	38.47	36.44	34.58	42.77	46.92	44.75	75	100
Mg (mg/l)	5.36	4.22	4.88	6.26	7.75	5.98	5.24	7.36	5.86	6.13	150	50
HCO_3(mg/l)	35.56	40.72	37.63	43.81	37.62	41.75	51.03	56.19	38.66	46.91	1000	125
Fe (mg/l)	0.38	0.42	0.24	1.32	1.84	2.22	1.65	1.33	1.75	1.42	0.3	5.0
Mn (mg/l)	0.01	0.01	0.46	0.49	0.65	0.48	0.39	0.55	1.33	1.16	0.1	0.20
Cu (mg/l)	0.04	0.03	0.03	0.16	0.13	0.21	0.18	0.41	0.35	0.32	1.0	0.20
Pb (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.01	5.0
Zn (mg/l)	0.01	0.01	0.01	0.18	0.22	0.16	0.30	0.26	0.22	0.28	5.0	2.0

4.3.2 Electrical conductivity (EC)

Sample 5 is having the highest EC with Sample 2 having the lowest EC

4.3.3 Total hardness (TH) and total alkalinity (TA)

Sample 1 is having the highest TH as Sample 9 has the lowest and TA of Sample 1 having the lowest and sample 8 having the highest

4.3.4 Dissolved oxygen (DO) and chemical oxygen demand (COD)

DO of Sample 8 is the highest with Sample 2, 5,6 and 9 having the lowest DO, while Sample 10 has the highest COD with lowest Sample in 3

4.3.5 Biochemical oxygen demand (BOD) and Phosphate (PO_4)

The highest BOD appears in 1 and 7 with Sample 2 and 6 having the lowest BOD; PO_4 of Sample 8 is the highest with Sample 3 having the lowest PO_4

4.3.6 Nitrate (NO_3^-) and (Na)

Sample 6 NO_3^- is the highest with Sample 2 having the lowest, while the Na of Sample 7 is the highest with the lowest in Sample 1

4.3.7 Potassium (K) and calcium (Ca)

Sample 3 have the lowest K and sample 6 is having the highest K while Sample 9 having the highest Ca with Sample 2 as the lowest

4.3.8 Magnesium (Mg) and hydro-carbonate (HCO_3)

Sample 5 is having the highest Mg with Sample 3 having the lowest Mg, the HCO_3 of Sample 8 is the highest with Sample 1 as the lowest

4.3.9 Iron (Fe), manganese (Mn) and copper (Cu)

Fe of Sample 3 is the lowest with Sample 6 as the highest, whereby Sample 1 and 2 are having the lowest Mn with Sample 8 having the highest as Sample 1, 2 and 3 are having the lowest Cu with Sample 8 as the highest

4.3.10 Lead (Pb) and zinc (Zn)

Pb was not detected in the Samples however Sample 10 is having the highest Zn with Sample 1, 2 and 3apppearing with the lowest Zn

4.3.11 Potency of hydrogen ($_P$H)

The pH of Sample 7 is the highest with station 4 having the lowest, all the P^H of the stations are within WHO standard and FAO range but none of them meet up to Electrical conductivity standard for WHO and FAO, TH, TA, DO standard for WHO did not meet up to standard as there is no standard of these parameter for FAO, therefore all the stations did not meet up BOD standard for both WHO and FAO, as there is no WHO standard for PO_4 although the stations are within FAO standard range except station 5 which is above standard for the PO_4, NO_3, K, Ca, Mg, HCO_3. Fe did not meet up WHO and FAO standard, and also Mn, Cu and Zn with no detection of Pb in all the stations.

4.4 Bacteriological Analysis during Rainy Season

From Table 4.3 none of the stations meet up the (WHO) standard under E. coli and total bacterial count except Sample 3 and 8 which are below standard of WHO under total coliform only with the rest of the Sample been above standard when compared .

Table 4.3 Bacteriological Analysis during Rainy Season

Parameters/ Stations	E. coli (cfu/ml)	Total coliform (cfu/100ml)	Total bacteria count (cfu/ml)
1	14×10^6	26	48×10^6
2	15×10^6	79	52×10^6
3	12×10^6	8	47×10^6
4	10×10^6	26	70×10^6
5	14×10^6	180	68×10^6
6	12×10^6	26	42×10^6
7	12×10^6	350	46×10^6
8	10×10^6	5	49×10^6
9	9×10^6	17	63×10^6
10	10×10^6	11	69×10^6
WHO	0	10	0-100

4.5 Bacteriological Analysis during Dry Season

Table 4.4 shows that Sample 3 and 8 are below WHO standard for total coliform with all the rest Samples been above (WHO) standard under E.coli, total coliform and total bacterial count with only station 10 that meet up (WHO) standard under total coliform after comparison.

Table 4.4 Bacteriological analysis of shallow wells water in dry season

Parameters/ Stations	E. coli (cfu/ml)	Total coliform (cfu/100ml)	Total bacteria count(cfu/ml)
1	10×10^6	30	41×10^6
2	12×10^6	80	50×10^6
3	7×10^6	3	38×10^6
4	3×10^6	20	40×10^6
5	10×10^6	100	68×10^6
6	9×10^6	20	31×10^6
7	10×10^6	300	29×10^6
8	4×10^6	2	36×10^6
9	7×10^6	12	13×10^6
10	4×10^6	10	69×10^6
WHO	0	10	0-100

4.6 Result of (WQI)

4.6.1 WQI of sample 1 during rainy season

Table 4.5 shows the computation of samples 1 collected during rainy season showing the observe values (vi), standard drinking water values (si) according to (WHO) and (FAO), unit weight (wi), water quality rating (qi) and wiqi of physico-chemical parameters of pH, Ec(μs/cm), TH (mg/l), TA (mg/l), DO (mg/l), COD (mg/l), BOD (mg/l), NO_3 (mg/l), Ca (mg/l), Mg (mg/l), with WQI value as 55.07. Means that the water quality sample is fair in terms of index number and therefore unfit for drinking and domestic uses but can be used for irrigation and industrial purposes.

Table 4.5 WQI of sample 1 (rainy season)

Parameters	Observe value (vi)	Standard value (si)	Unit weight (wi)	Quality rating (qi)	Wiqi
PH	6.41	8.5	0.2190	-39.33	-8.64
EC (μs/cm)	386	300	0.3710	128.67	47.74
TH (mg/l)	224	500	0.0062	44.80	0.2778
TA (mg/l)	78	500	0.0155	15.60	0.2418
DO (mg/l)	8	5.0	0.3723	68.75	25.596
COD (mg/l)	14.6	6000	0.02507	0.24	0.0060
BOD (mg/l)	2	5.0	0.3723	40	14.892
NO_3 (mg/l)	5.82	50	0.0412	11.64	0.4796
Ca (mg/l)	56.48	75	0.250	75.31	1.8828
Mg (mg/l)	14.22	150	0.0610	3.76	0.5783
			$\sum W_n$=1.50857		$\sum W_n q_n$=83.0803

Water quality index= 83.0803 / 1.50857 = 55.07

4.6.2 WQI of sample 2 during rainy season

Table 4.6 shows the computation of WQI of sample 2 collected during rainy season showing the observe values (vi), standard drinking water values (si), unit weight (wi), water quality rating (qi) and wiqi of physico-chemical parameters of pH, $Ec_{(\mu s/cm)}$, $TH_{(mg/l)}$, $TA_{(mg/l)}$, $DO_{(mg/l)}$, $COD_{(mg/l)}$, $BOD_{(mg/l)}$, NO_3 (mg/l), $Ca_{(mg/l)}$, $Mg_{(mg/l)}$, with water quality index (WQI) value as 65.74. This means that the water quality sample is fair when compared with index number and therefore unfit for drinking and domestic uses but can be used for irrigation and industrial purposes.

Table 4.6 WQI of sample 2 (rainy season)

Parameters	Observe value (vi)	Standard value (si)	Unit weight (wi)	Quality rating (qi)	Wiqi
PH	6.51	8.5	0.2190	-32.66	-7.1525
EC (µs/cm)	350	300	0.3710	116.67	43.280
TH (mg/l)	168	500	0.0062	33.6	0.2083
TA (mg/l)	64	500	0.0155	12.8	0.1984
DO (mg/l)	5	5.0	0.3723	100	37.230
COD (mg/l)	12.18	6000	0.02507	0.20	0.0050
BOD (mg/l)	3	5.0	0.3723	60	22.3380
NO_3 (mg/l)	4.16	50	0.0412	8.32	0.3428
Ca (mg/l)	56.48	75	0.250	76.61	1..9153
Mg (mg/l)	18.75	150	0.0610	12.50	0.7625
			$\sum W_n$=1.50857		$\sum W_n q_n$= 99.128

Water quality index= 99.128 / 1.50857 = 65.74

4.6.3 WQI of sample 3 (rainy season)

Table 4.7 shows the computation of sample 3 collected during rainy season showing the observe values (vi), standard drinking water values (si), unit weight (wi), water quality rating (qi) and wiqi of physico-chemical parameters of pH, Ec(µs/cm), TH (mg/l), TA (mg/l), DO (mg/l), COD (mg/l), BOD (mg/l), NO_3 (mg/l), Ca (mg/l), Mg (mg/l), with water quality index (WQI) value as 88.23 means that the water quality sample is poor and classified as poor and unfit for both drinking and domestic uses but can only be used for irrigational purposes.

Table 4.7 WQI of sample 3 (rainy season)

Parameters	Observe value (vi)	Standard value (si)	Unit weight (wi)	Quality rating (qi)	Wiqi
PH	6.49	8.5	0.2190	-34.0	-7.446
EC (µs/cm)	592	300	0.3710	197.33	73.21
TH (mg/l)	260	500	0.0062	50	0.3100
TA (mg/l)	77	500	0.0155	15.4	0.2387
DO (mg/l)	6	5.0	0.3723	89.58	33.3586
COD (mg/l)	16.25	6000	0.02507	0.27	0.00677
BOD (mg/l)	4	5.0	0.3723	80	29.7840
NO_3 (mg/l)	6.25	50	0.0412	12.5	0.5150
Ca (mg/l)	66.23	75	0.250	88.30	2.2075
Mg (mg/l)	22.81	150	0.0610	15.20	0.9272
			$\sum W_n$=1.50857		$\sum W_n q_n$= 133.104
	Water quality index= 133.104 / 1.50857 = 88.23				

4.6.4 WQI of sample 4 (rainy season)

Table 4.8 shows the computation of WQI of sample 4 collected during rainy season showing the observe values (vi), standard drinking water values (si) according to world health organization (WHO, 2017), unit weight (wi), water quality rating (qi) and wiqi of physico-chemical parameters of pH, Ec(µs/cm), TH (mg/l), TA (mg/l), DO (mg/l), COD (mg/l), BOD (mg/l), NO_3 (mg/l), Ca (mg/l), Mg (mg/l), with water quality index (WQI) value as 83.38. This means that the water quality sample is also classified as poor and unfit for both drinking and domestic uses but can only be used for irrigational purposes.

Table 4.8 WQI of sample 4 (rainy season)

Parameters	Observe value (vi)	Standard value (si)	Unit weight (wi)	Quality rating (qi)	Wiqi
PH	6.46	8.5	0.2190	-36.0	-7.884
EC (µs/cm)	543	300	0.3710	181.0	67.15
TH (mg/l)	188	500	0.0062	37.6	0.2331
TA (mg/l)	64	500	0.0155	12.8	0.1984
DO (mg/l)	6	5.0	0.3723	89.58	33.351
COD (mg/l)	15.11	6000	0.02507	0.25	0.0063
BOD (mg/l)	4	5.0	0.3723	80.0	29.784
NO_3 (mg/l)	5.75	50	0.0412	11.5	0.4738
Ca (mg/l)	54.15	75	0.250	72.2	1.8050
Mg (mg/l)	16.52	150	0.0610	11.01	0.6716
			$\sum W_n$=1.50857		$\sum W_n q_n$ = 125.789
Water quality index= 125.789 / 1.50857 = 83.38					

4.6.5 WQI of sample 5 (rainy season)

Table 4.9 shows the computation of WQI of sample 5 collected during rainy season showing the observe values (vi), standard drinking water values (si), unit weight (wi), water quality rating (qi) and wiqi of physico-chemical parameters of pH, Ec(µs/cm), TH (mg/l), TA (mg/l), DO (mg/l), COD (mg/l), BOD (mg/l), NO_3 (mg/l), Ca (mg/l), Mg (mg/l), with water quality index (WQI) value as 80.35. This means that the water quality sample is also classified as poor and unfit for both drinking and domestic uses but can only be used for irrigational purposes.

Table 4.9 WQI of sample 5 (rainy season)

Parameters	Observe value (vi)	Standard value (si)	Unit weight (wi)	Quality rating (qi)	Wiqi
PH	6.43	8.5	0.2190	-38.0	-8.322
EC (µs/cm)	566	300	0.3710	188.67	69.99
TH (mg/l)	172	500	0.0062	34.4	0.2133
TA (mg/l)	44	500	0.0155	8.8	0.1364
DO (mg/l)	8	5.0	0.3723	68.75	25.596
COD (mg/l)	15.86	6000	0.02507	0.26	0.0065
BOD (mg/l)	4	5.0	0.3723	80	29.7840
NO_3 (mg/l)	6.46	50	0.0412	12.92	0.5323
Ca (mg/l)	72.36	75	0.250	96.48	2.4120
Mg (mg/l)	21.38	150	0.0610	14.25	0.8693
			$\sum W_n$=1.50857		$\sum W_n q_n$ = 121.217

Water quality index= 121.217 / 1.50857 = 80.35

4.6.6 WQI of sample 6 (rainy season)

Table 4.10 shows the computation of WQI of sample 6 collected during rainy season showing the observe values (vi), standard drinking water values (si), unit weight (wi), water quality rating (qi) and wiqi of physico-chemical parameters of pH, Ec(µs/cm), TH (mg/l), TA (mg/l), DO (mg/l), COD (mg/l), BOD (mg/l), NO_3 (mg/l), Ca (mg/l), Mg (mg/l), with water quality index (WQI) value as 85.00 means that the water quality sample is also classified as poor and unfit for both drinking and domestic uses but can only be used for irrigational purposes.

Table 4.10 WQI of sample 6 (rainy season)

Parameters	Observe value (vi)	Standard value (si)	Unit weight (wi)	Quality rating (qi)	Wiqi
PH	6.45	8.5	0.2190	-36.66	-8.0285
EC (µs/cm)	539	300	0.3710	179.67	66.65
TH (mg/l)	162	500	0.0062	32.4	0.2009
TA (mg/l)	32	500	0.0155	6.4	0.0992
DO (mg/l)	6	5.0	0.3723	89.58	33.3506
COD (mg/l)	15.30	6000	0.02507	0.28	0.0070
BOD (mg/l)	4	5.0	0.3723	80	29.7840
NO_3 (mg/l)	6.22	50	0.0412	12.44	0.5125
Ca (mg/l)	38.81	75	0.250	51.74	1.2935
Mg (mg/l)	10.74	150	0.0610	7.16	4.3676
			$\sum W_n$=1.50857		$\sum W_n q_n$ = 128.229

Water quality index= 128.229/ 1.50857 = 85.00

4.6.7 WQI of sample 7 (rainy season)

Table 4.11 shows the computation of WQI of sample 7 collected during rainy season showing the observe values (vi), standard drinking water values (si), unit weight (wi), water quality rating (qi) and wiqi of physico-chemical parameters of pH, Ec(µs/cm), TH (mg/l), TA (mg/l), DO (mg/l), COD (mg/l), BOD (mg/l), NO_3 (mg/l), Ca (mg/l), Mg (mg/l), with water quality index (WQI) value as 72.21 means that the water quality sample is classified is fair in terms of index number and therefore unfit for drinking and domestic uses but can be used for irrigation and industrial purposes.

Table 4.11 WQI of sample 7 (rainy season)

Parameters	Observe value (vi)	Standard value (si)	Unit weight (wi)	Quality rating (qi)	Wiqi
PH	6.80	8.5	0.2190	-13.33	-2.9193
EC (µs/cm)	323	300	0.3710	107.67	39.95
TH (mg/l)	168	500	0.0062	33.6	0.2083
TA (mg/l)	30	500	0.0155	6	0.0930
DO (mg/l)	6	5.0	0.3723	89.58	33.3506
COD (mg/l)	12.65	6000	0.02507	0.211	0.00523
BOD (mg/l)	4	5.0	0.3723	80	29.7840
NO_3 (mg/l)	3.71	50	0.0412	7.42	0.3057
Ca (mg/l)	45.98	75	0.250	61.30	1.5325
Mg (mg/l)	16.30	150	0.0610	10.86	6.6246
			$\sum W_n$=1.50857		$\sum W_n q_n$ = 108.935
Water quality index= 108.935 / 1.50857 = 72.21					

4.6.8 WQI of sample 8 (rainy season)

Table 4.12 shows the computation of WQI of sample 8 collected during rainy season showing the observe values (vi), standard drinking water values (si), unit weight (wi), water quality rating (qi) and wiqi of physico-chemical parameters of pH, Ec(µs/cm), TH (mg/l), TA (mg/l), DO (mg/l), COD (mg/l), BOD (mg/l), NO_3 (mg/l), Ca (mg/l), Mg (mg/l), with water quality index (WQI) value as 89.85 means that the water quality sample is classified as poor and unfit for both drinking and domestic uses but can only be used for irrigational purposes.

Table 4.12 WQI of sample 8 (rainy season)

Parameters	Observe value (vi)	Standard value (si)	Unit weight (wi)	Quality rating (qi)	Wiqi
PH	6.20	8.5	0.2190	-53.33	-11.6793
EC (µs/cm)	586	300	0.3710	195.33	72.47
TH (mg/l)	174	500	0.0062	34.8	0.2158
TA (mg/l)	26	500	0.0155	5.2	0.0806
DO (mg/l)	5	5.0	0.3723	100	37.2300
COD (mg/l)	17.42	6000	0.02507	17.42	4.3672
BOD (mg/l)	3	5.0	0.3723	60	22.3380
NO_3 (mg/l)	6.38	50	0.0412	12.76	0.5257
Ca (mg/l)	40.26	75	0.250	53.68	1.3420
Mg (mg/l)	14.18	150	0.0610	14.18	8.6498
			$\sum W_n$=1.50857		$\sum W_n q_n$ = 135.539
Water quality index=135.539 / 1.50857 = 89.85					

4.6.9 WQI of sample 9 (rainy season)

Table 4.13 shows the computation of WQI of sample 9 collected during rainy season showing the observe values (vi), standard drinking water values (si), unit weight (wi), water quality rating (qi) and wiqi of physico-chemical parameters of pH, Ec(μs/cm), TH (mg/l), TA (mg/l), DO (mg/l), COD (mg/l), BOD (mg/l), NO_3 (mg/l), Ca (mg/l), Mg (mg/l), with water quality index (WQI) value as 42.97 means that the water quality sample is classified as good according to water quality classification that is can be use for domestic, irrigation and industrial purposes.

Table 4.13 WQI of sample 9 (rainy season)

Parameters	Observe value (vi)	Standard value (si)	Unit weight (wi)	Quality rating (qi)	Wiqi
PH	6.60	8.5	0.2190	-26.66	-58.3854
EC (μs/cm)	383	300	0.3710	127.67	47.37
TH (mg/l)	136	500	0.0062	27.2	0.1686
TA (mg/l)	34	500	0.0155	6.8	0.1054
DO (mg/l)	7	5.0	0.3723	100	37.2300
COD (mg/l)	12.65	6000	0.02507	0.112	0.005289
BOD (mg/l)	4	5.0	0.3723	80	29.7840
NO_3 (mg/l)	6.38	50	0.0412	7.1	0.2925
Ca (mg/l)	40.26	75	0.250	64.40	1.610
Mg (mg/l)	14.18	150	0.0610	10.90	6.649
			$\sum W_n$=1.50857		$\sum W_n q_n$ = 64.8294
Water quality index= 64.8294 / 1.50857 = 42.97					

4.6.10 WQI of sample 10 (rainy season)

Table 4.14 shows the computation of WQI of sample 4 collected during rainy season showing the observe values (vi), standard drinking water values (si), unit weight (wi), water quality rating (qi) and wiqi of physico-chemical parameters of pH, Ec(μs/cm), TH (mg/l), TA (mg/l), DO (mg/l), COD (mg/l), BOD (mg/l), NO_3 (mg/l), Ca (mg/l), Mg (mg/l), with water quality index (WQI) value as 90.41 means that the water quality sample is classified as poor and unfit for both drinking and domestic uses but can only be serve for irrigational purposes.

Table 4.14 WQI of sample 10 (rainy season)

Parameters	Observe value (vi)	Standard value (si)	Unit weight (wi)	Quality rating (qi)	Wiqi
PH	7.17	8.5	0.2190	11.33	2.4813
EC (μs/cm)	420	300	0.3710	140	51.94
TH (mg/l)	152	500	0.0062	30.4	0.1885
TA (mg/l)	26	500	0.0155	5.2	0.0806
DO (mg/l)	9	5.0	0.3723	100	37.2300
COD (mg/l)	14.28	6000	0.02507	0.24	0.0060
BOD (mg/l)	5	5.0	0.3723	100	37.2300
NO_3 (mg/l)	4.27	50	0.0412	8.54	0.3518
Ca (mg/l)	51.13	75	0.250	68.17	1.7043
Mg (mg/l)	12.74	150	0.0610	8.49	5.1789
			$\sum W_n$=1.50857		$\sum W_n q_n$ = 136.39
Water quality index= 136.39 / 1.50857 = 90.41					

4.6.11 WQI of sample 1 (dry season)

Table 4.15 shows the computation of WQI of sample 1 collected during dry season showing the observe values (vi), standard drinking water values (si), unit weight (wi), water quality rating (qi) and wiqi of physico-chemical parameters of pH, $Ec_{(\mu s/cm)}$, $TH_{(mg/l)}$, $TA_{(mg/l)}$, $DO_{(mg/l)}$, $COD_{(mg/l)}$, $BOD_{(mg/l)}$, NO_3 (mg/l), $Ca_{(mg/l)}$, $Mg_{(mg/l)}$, with water quality index (WQI) value as 50.07 means that the water quality sample is good in terms of index number and fit for domestic, irrigation and industrial uses

Table 4.15 WQI of sample 1 (dry season)

Parameters	Observe value (vi)	Standard value (si)	Unit weight (wi)	Quality rating (qi)	Wiqi
PH	7.16	8.5	0.2190	10.67	2.3367
EC (µs/cm)	69	300	0.3710	23	8.533
TH (mg/l)	192	500	0.0062	38.4	0.2381
TA (mg/l)	74	500	0.0155	14.8	0.2294
DO (mg/l)	6	5.0	0.3723	89.58	33.35
COD (mg/l)	7.28	6000	0.02507	0.121	0.0030
BOD (mg/l)	4	5.0	0.3723	80	29.784
NO_3 (mg/l)	0.35	50	0.0412	0.7	0.0288
Ca (mg/l)	24.66	75	0.250	32.88	0.822
Mg (mg/l)	5.36	150	0.0610	3.57	0.2178
			$\sum W_n$=1.50857		$\sum W_n q_n$ = 75.54

Water quality index= 75.54 / 1.50857 = 50.07

4.6.12 WQI of sample 2 (dry season)

Table 4.16 shows the computation of WQI of sample 2 collected during dry season showing the observe values (vi), standard drinking water values (si), unit weight (wi), water quality rating (qi) and wiqi of physico-chemical parameters of pH, Ec(µs/cm), TH (mg/l), TA (mg/l), DO (mg/l), COD (mg/l), BOD (mg/l), NO_3 (mg/l), Ca (mg/l), Mg (mg/l), with water quality index (WQI) value as 37.60 means that the water quality sample is good in terms of index number and fit for domestic, irrigation and industrial uses.

Table 4.16 WQI of sample 2 (dry season)

Parameters	Observe value (vi)	Standard value (si)	Unit weight (wi)	Quality rating (qi)	Wiqi
PH	6.69	8.5	0.2190	-21.33	-4.6713
EC (µs/cm)	66	300	0.3710	22	8.162
TH (mg/l)	148	500	0.0062	29.6	0.1835
TA (mg/l)	84	500	0.0155	16.8	0.2604
DO (mg/l)	5	5.0	0.3723	100	37.23
COD (mg/l)	5.9	6000	0.02507	0.09	0.0023
BOD (mg/l)	2	5.0	0.3723	40	14.892
NO_3 (mg/l)	0.31	50	0.0412	0.62	0.0255
Ca (mg/l)	18.75	75	0.250	18.75	0.4689
Mg (mg/l)	4.22	150	0.0610	2.81	0.17141
			$\sum W_n$=1.50857		$\sum W_n q_n$ = 56.745
Water quality index=56.745 / 1.50857 = 37.60					

4.6.13 WQI of sample 3 (dry season)

Table 4.17 shows the computation of WQI of sample 3 collected during dry season showing the observe values (vi), standard drinking water values (si), unit weight (wi), water quality rating (qi) and wiqi of physico-chemical parameters of pH, Ec(µs/cm), TH (mg/l), TA (mg/l), DO (mg/l), COD (mg/l), BOD (mg/l), NO_3 (mg/l), Ca (mg/l), Mg (mg/l), with water quality index (WQI) value as 39.23 means that the water quality sample is good in terms of index number and fit for domestic, irrigation and industrial uses.

Table 4.17 WQI of sample 3 (dry season)

Parameters	Observe value (vi)	Standard value (si)	Unit weight (wi)	Quality rating (qi)	Wiqi
PH	6.5	8.5	0.2190	-33.3	-7.2927
EC (µs/cm)	76	300	0.3710	25.33	9.39743
TH (mg/l)	136	500	0.0062	27.2	0.16864
TA (mg/l)	78	500	0.0155	15.6	0.2418
DO (mg/l)	6	5.0	0.3723	89.58	33.3510
COD (mg/l)	5.55	6000	0.02507	0.09	0.0023
BOD (mg/l)	3	5.0	0.3723	60	22.3380
NO_3 (mg/l)	0.38	50	0.0412	0.76	0.0313
Ca (mg/l)	22.78	75	0.250	30.37	0.7593
Mg (mg/l)	4.88	150	0.0610	3.25	0.1983
			$\sum W_n$=1.50857		$\sum W_n q_n$ = 59.195
Water quality index= 59.195 / 1.50857 = 39.24					

4.6.14 WQI of sample 4 (dry season)

Table 4.18 shows the computation of WQI of sample 4 collected during dry season showing the observe values (vi), standard drinking water values (si), unit weight (wi), water quality rating (qi) and wiqi of physico-chemical parameters of pH, Ec(µs/cm), TH (mg/l), TA (mg/l), DO (mg/l), COD (mg/l), BOD (mg/l), NO_3 (mg/l), Ca (mg/l), Mg (mg/l), with water quality index (WQI) value as 54.89 means that the water quality sample is fair in terms of index number, unfit for drinking and domestic purposes but can be used for irrigation and industrial purposes.

Table 4.18 WQI of sample 4 (dry season)

Parameters	Observe value (vi)	Standard value (si)	Unit weight (wi)	Quality rating (qi)	Wiqi
PH	6.28	8.5	0.2190	-48	-10.512
EC (µs/cm)	288	300	0.3710	96.00	35.616
TH (mg/l)	176	500	0.0062	35.20	0.21824
TA (mg/l)	90	500	0.0155	18.00	0.279
DO (mg/l)	6	5.0	0.3723	89.58	33.351
COD (mg/l)	6.2	6000	0.02507	0.10	0.0025
BOD (mg/l)	3	5.0	0.3723	60	22.338
NO_3 (mg/l)	3.44	50	0.0412	6.88	0.2835
Ca (mg/l)	29.44	75	0.250	39.25	0.9813
Mg (mg/l)	6.26	150	0.0610	4.17	0.2544
			$\sum W_n$=1.50857		$\sum W_n q_n$ = 82.812
Water quality index= 82.812 / 1.50857 = 54.89					

4.6.15 WQI of sample 5 (dry season)

Table 4.19 shows the computation of WQI of sample 5 collected during dry season showing the observe values (vi), standard drinking water values (si), unit weight (wi), water quality rating (qi) and wiqi of physico-chemical parameters of pH, Ec(µs/cm), TH (mg/l), TA (mg/l), DO (mg/l), COD (mg/l), BOD (mg/l), NO_3 (mg/l), Ca (mg/l), Mg (mg/l), with water quality index (WQI) value as 63.84 which means that the water quality sample is fair also in terms of index number, unfit for drinking and domestic purposes whereas it can be used for irrigation and industrial purposes.

Table 4.19 WQI of sample 5 (dry season)

Parameters	Observe value (vi)	Standard value (si)	Unit weight (wi)	Quality rating (qi)	Wiqi
PH	6.36	8.5	0.2190	-42.67	-9.345
EC (µs/cm)	413	300	0.3710	137.67	51.076
TH (mg/l)	150	500	0.0062	30.00	0.186
TA (mg/l)	78	500	0.0155	15.60	0.2418
DO (mg/l)	100	5.0	0.3723	100	37.23
COD (mg/l)	7	6000	0.02507	0.11	0.0028
BOD (mg/l)	2	5.0	0.3723	40.00	14.892
NO_3 (mg/l)	5.26	50	0.0412	10.52	0.4334
Ca (mg/l)	38.47	75	0.250	51.29	1.2823
Mg (mg/l)	7.75	150	0.0610	5.17	0.3154
			$\sum W_n$=1.50857		$\sum W_n q_n$ = 96.315
Water quality index= 96.315 / 1.50857 = 63.84					

4.6.16 WQI of sample 6 (dry season)

Table 4.20 shows the computation of WQI of sample 6 collected during dry season showing the observe values (vi), standard drinking water values (si), unit weight (wi), water quality rating (qi) and wiqi of physico-chemical parameters of pH, Ec(μs/cm), TH (mg/l), TA (mg/l), DO (mg/l), COD (mg/l), BOD (mg/l), NO_3 (mg/l), Ca (mg/l), Mg (mg/l), with water quality index (WQI) value as 68.65 which means that the water quality sample is fair also in terms of index number, unfit for drinking and domestic purposes although it can be used for irrigation and industrial purposes.

Table 4.20 WQI of sample 6 (dry season)

Parameters	Observe value (vi)	Standard value (si)	Unit weight (wi)	Quality rating (qi)	Wiqi
PH	6.45	8.5	0.2190	-36.67	-8.0307
EC (μs/cm)	402	300	0.3710	134.00	49.714
TH (mg/l)	146	500	0.0062	29.20	0.18104
TA (mg/l)	86	500	0.0155	17.20	0.2666
DO (mg/l)	5	5.0	0.3723	100	37.23
COD (mg/l)	7.36	6000	0.02507	0.12	0.0030
BOD (mg/l)	3	5.0	0.3723	60	22.34
NO_3 (mg/l)	4.96	50	0.0412	9.92	0.4087
Ca (mg/l)	36.44	75	0.250	48.59	1.2148
Mg (mg/l)	5.98	150	0.0610	3.99	0.2434
			$\sum W_n$=1.50857		$\sum W_n q_n$ = 103.571
Water quality index= 103.571 / 1.50857 = 68.65					

4.6.17 WQI of sample 7 (dry season)

Table 4.21 shows the computation of WQI of sample 7 collected during dry season showing the observe values (vi), standard drinking water values (si), unit weight (wi), water quality rating (qi) and wiqi of physico-chemical parameters of pH, Ec(µs/cm), TH (mg/l), TA (mg/l), DO (mg/l), COD (mg/l), BOD (mg/l), NO_3 (mg/l), Ca (mg/l), Mg (mg/l), with water quality index (WQI) value as 69.89 which means that the water quality sample is fair also in terms of index number, unfit for drinking and domestic purposes however it can be used for irrigation and industrial purposes.

Table 4.21 WQI of sample 7 (dry season)

Parameters	Observe value (vi)	Standard value (si)	Unit weight (wi)	Quality rating (qi)	Wiqi
PH	6.36	8.5	0.2190	-42.67	-9.3447
EC (µs/cm)	400	300	0.3710	133.30	49.45
TH (mg/l)	160	500	0.0062	32.00	0.1984
TA (mg/l)	104	500	0.0155	20.80	0.3224
DO (mg/l)	6	5.0	0.3723	89.58	33.35
COD (mg/l)	7.18	6000	0.02507	0.12	0.003
BOD (mg/l)	4	5.0	0.3723	80.00	29.784
NO_3 (mg/l)	3.65	50	0.0412	7.30	0.3008
Ca (mg/l)	34.58	75	0.250	46.11	1.1528
Mg (mg/l)	5.24	150	0.0610	3.49	0.229
			$\sum W_n = 1.50857$		$\sum W_n q_n = 105.43$
Water quality index = 105.43 / 1.50857 = 69.89					

4.6.18 WQI of sample 8 (dry season)

Table 4.22 shows the computation of WQI of sample 8 collected during dry season showing the observe values (vi), standard drinking water values (si), unit weight (wi), water quality rating (qi) and wiqi of physico-chemical parameters of pH, Ec(µs/cm), TH (mg/l), TA (mg/l), DO (mg/l), COD (mg/l), BOD (mg/l), NO_3 (mg/l), Ca (mg/l), Mg (mg/l), with water quality index (WQI) value as 61.54 which means that the water quality sample is fair also in terms of index number, unfit for drinking and domestic purposes but it can be used for irrigation and industrial purposes.

Table 4.22 WQI of sample 8 (dry season)

Parameters	Observe value (vi)	Standard value (si)	Unit weight (wi)	Quality rating (qi)	Wiqi
PH	6.44	8.5	0.2190	-37.33	-8.1753
EC (µs/cm)	408	300	0.3710	136.00	50.456
TH (mg/l)	166	500	0.0062	33.20	0.2058
TA (mg/l)	114	500	0.0155	22.80	0.3534
DO (mg/l)	8	5.0	0.3723	68.75	25.59
COD (mg/l)	7.22	6000	0.02507	0.12	0.0030
BOD (mg/l)	3	5.0	0.3723	60.00	22.34
NO_3 (mg/l)	4.08	50	0.0412	8.16	0.3362
Ca (mg/l)	42.77	75	0.250	57.03	1.4258
Mg (mg/l)	7.36	150	0.0610	4.91	0.2995
			$\sum W_n$=1.50857		$\sum W_n q_n$ = 92.8344
Water quality index = 92.8344 / 1.50857 = 61.54					

4.6.19 WQI of sample 9 (dry season)

Table 4.23 shows the computation of WQI of sample 9 collected during dry season showing the observe values (vi), standard drinking water values (si), unit weight (wi), water quality rating (qi) and wiqi of physico-chemical parameters of pH, Ec(µs/cm), TH (mg/l), TA (mg/l), DO (mg/l), COD (mg/l), BOD (mg/l), NO_3 (mg/l), Ca (mg/l), Mg (mg/l), with water quality index (WQI) value as 65.45 which means that the water quality sample is fair also in terms of index number, unfit for drinking and domestic purposes but it can be used for irrigation and industrial purposes

Table 4.23 WQI of sample 9 (dry season)

Parameters	Observe value (vi)	Standard value (si)	Unit weight (wi)	Quality rating (qi)	Wiqi
PH	6.46	8.5	0.2190	-36.00	-7.884
EC (µs/cm)	396	300	0.3710	13.20	48.972
TH (mg/l)	130	500	0.0062	26.00	0.1612
TA (mg/l)	80	500	0.0155	16.00	0.2480
DO (mg/l)	5	5.0	0.3723	100.00	37.230
COD (mg/l)	6.98	6000	0.02507	0.12	0.0030
BOD (mg/l)	2.4	5.0	0.3723	48.00	17.870
NO_3 (mg/l)	4.12	50	0.0412	8.24	0.3395
Ca (mg/l)	46.92	75	0.250	62.56	1.564
Mg (mg/l)	5.86	150	0.0610	3.91	0.2385
			$\sum W_n$=1.50857		$\sum W_n q_n$ = 98.743
Water quality index = 98.743 / 1.50857 = 65.45					

4.6.20 WQI of sample 10 (dry season)

Table 4.24 shows the computation of WQI of sample 10 collected during dry season showing the observe values (vi), standard drinking water values (si), unit weight (wi), water quality rating (qi) and wiqi of physico-chemical parameters of pH, Ec(μs/cm), TH (mg/l), TA (mg/l), DO (mg/l), COD (mg/l), BOD (mg/l), NO_3^- (mg/l), Ca (mg/l), Mg (mg/l), with water quality index (WQI) value as 67.15 which means that the water quality sample is fair also in terms of index number, unfit for drinking and domestic purposes but it can be used for irrigation and industrial purposes.

Table 4.24 WQI of sample 10 (dry season)

Parameters	Observe value (vi)	Standard value (si)	Unit weight (wi)	Quality rating (qi)	Wiqi
PH	-40	8.5	0.2190	-44.00	-8.76
EC (μs/cm)	400	300	0.3710	133.33	49.47
TH (mg/l)	144	500	0.0062	28.80	0.1786
TA (mg/l)	96	500	0.0155	19.20	0.2976
DO (mg/l)	5.4	5.0	0.3723	95.83	35.68
COD (mg/l)	7.58	6000	0.02507	0.13	0.0033
BOD (mg/l)	3	5.0	0.3723	60.00	22.34
NO_3 (mg/l)	4.4	50	0.0412	8.80	0.3626
Ca (mg/l)	44.75	75	0.250	59.67	1.4918
Mg (mg/l)	6.13	150	0.0610	4.09	0.2495
			$\sum W_n$=1.50857		$\sum W_n q_n$ = 101.31

Water quality index = 101.31 / 1.50857 = 67.15

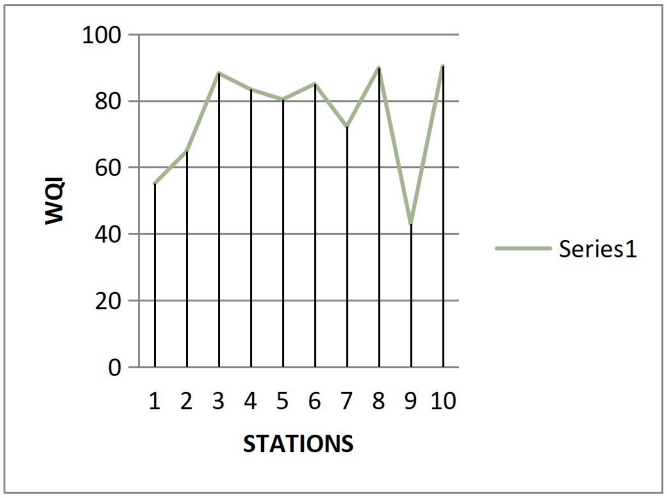
4.7 Comparison of WQI between Rainy and Dry Season Samples

Table 4.25 Statistical analysis of the rainy and dry season stations (WQI totals)

Samples	Rainy Season (WQI)	Dry season WQI
1	55.07	50.07
2	64.74	37.60
3	88.23	39.24
4	83.38	54.89
5	80.35	63.84
6	85.00	68.65
7	72.21	69.89
8	89.85	61.54
9	42.97	65.45
10	90.41	67.1
	Average =75.22	Average = 57.83

4.8 Graphical variations of the rainy and dry season parameters

The below graphs represent the variations and comparison of both the rainy and dry season stations using summary of the statistical analysis of the water quality index (WQI)



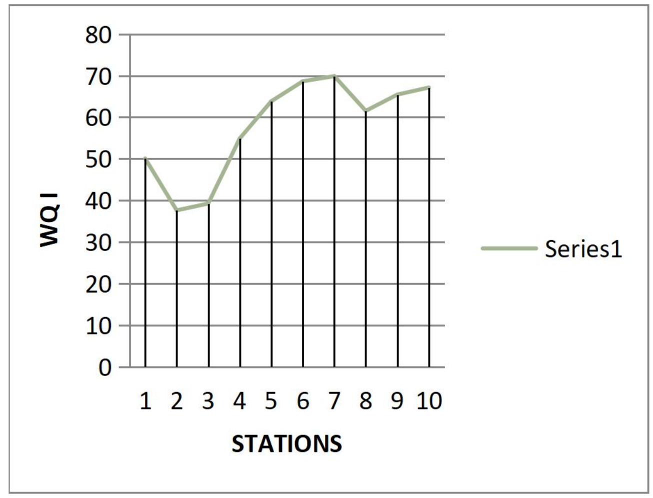


Figure 4.1: Rainy season parameters

Figure 4.2: Dry season parameters

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The Physico-chemical and bacteriological analysis of the shallow wells water in the study area (Katcha) shows that the well water are not safe for consumption as a result of presence of some harmful bacterial such as Escherichial coli also (known as E.2), salmonella, cryptosporidium, vibrio and shigella which can cause water borne diseases to human health as there is no adequate and safe drinking water. The seasonal variation indicates that there is high deposit of heavy metals and transfer of harmful bacterial as mention earlier in the rainy season than the dry season which calls for thorough and proper treatment of the shallow wells water before consumption to avoid hazards. 95% of the well water is good for irrigational purposes which mean they are up to Food and Agricultural Organization for United Nations (FAO) standard but below World Health Organization Standard (WHO).

Water quality index (WQI) indicates that the water quality in terms of index number presents useful information of the overall quality of the water for public or for any other utilities as well as water quality management in order to access it suitability for drinking purposes. The average water quality index (WQI) of 75.22 for rainy season and 57.83 in dry season indicates that the untreated well water from Katcha in Niger state is of fair quality and however must be treated before use to avoid water borne diseases.

5.2 Recommendations

Due to the fact that shallow wells water plays an important role in the people's life of the rural areas for both domestic and irrigational uses;

1. The government in partnership with NGO's should carry out a survey or research work such as this thesis which will be helpful in alleviating the problems facing by the rural areas. Therefore, the results of this research recommend that there is need for the government to take appropriate measures in safeguarding the health of its citizens and also educate them on the related water borne diseases that can be found in this water when consumed
2. There is wide range of 20.52 in the seasonal variations which indicates that there is need for proper treatment before consumptions.
3. Urban areas depends on the rural areas for their agricultural produce therefore a quick respond should be taken to solved the problem of irrigation in such area as it will improve the lives and agricultural activities of the peoples living in the rural areas and improve food supply to the urban area.
4. The government both state and local should make availability of good dams and form a committee that will be monitoring and ensuring good hygiene and sanitations

5.3 Contribution to Knowledge

The research indicates that high levels of Heavy Metals like Fe (0.93- 4.44mg/l), Mn (0.81 – 2.52mg/l). The research also indicates the WQI of the wells to be better during dry season with WQI = 57.83 as against rainy season = 75.22

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APPENDICES

Appendix A I: WHO drinking water standards

Element/substance	symbol/formula	Normally found in fresh water/surface water/ground water	Health based guideline by the WHO
Aluminum	Al		0,2mg/l
Ammonia	NH_4	<0,2mg/l(up to 0,3mg/l in anaerobic waters	No guidelines
Antimonial	Sb	<4µg/l	0.005mg/l
Arsenic	As		0,01mg/l
Asbestos			No guidelines
Barium	Ba		0,3mg/l
Beryllium	Be	<1µg/l	No guidelines
Boron	B	<1mg/l	0,3mg/l
Cadmium	Cd	<1µg/l	0,003mg/l
Chloride	Cl		250 mg/l
Chromium	Cr^{+3},Cr^{+6}	<2 µg/l	0,05 mg/l
Colour			Not mentioned
Copper	Cu		2 mg/l
Cyanide	CN		0,07 mg/l
Dissolved oxygen	O_2		No guidelines
Fluoride	F	< 1,5mg/l(up to10)	1,5 mg/l
Hardness	mg/l$CaCO_3$		No guidelines
Hydrogen sulfide	H_2S		No guidelines
Iron	Fe	0,5 -50mg/l	No guidelines
Lead	Pb		0,01 mg/l
Manganese	Mn		0,5 mg/l
Mercury	Hg	<0,5 µg/l	0,001 mg/l
Molydnium	Mb	<0,01 mg/l	0,07 mg/l
Nicked	Ni	<0,02 mg/l	0,02 mg/l
Nitrate and nitrite	NO_3,NO_2		50 mg/l total nitrogen
Turbidity			Not mentioned
Ph			No guideline
Selenium	Se	<< 0,01 mg/l	0,01 mg/l
Silver	Ag	5-50 µg/l	No guideline
Sodium	Na	< 20 mg/l	200 mg/l
Sulfate	So_4		500 mg/l
Inorganic tin	Sn		No guideline
TDS			No guideline
Uranium	U		1,4 mg/l
Zinc	Zn		3 mg/l

Appendix A II: Organic Compounds in Drinking Water

Group	Substance	Formula	Health based guideline by the WHO
Chlorinated alkanes	Carbon tetrachloride	CCl_4	2µg/l
	Dichloromethane	CH_2CL_2	20µg/l
	1,1-Dichloroethane	$C_2H_4CL_2$	No guidelines
	1,2-Dichloroethane	$CLCH_2CH_2CL_2$	30µg/l
	1,1,1-trichloroethane	CH_3CCL_3	2000µg/l
Chlorinated ethenes	1,1-Dichloroethane	$C_2H_2CL_2$	30µg/l
	1,2-Dichloroethane	$C_2H_2CL_2$	50µg/l
	Trichloroethane	C_2HCL_3	70µg/l
	Tetrachloroethane	C_2CL_4	40µg/l
Aromatic hydrocarbons	Benzane	C_6H_6	10µg/l
	Toluene	C_7H_8	700µg/l
	Xylenes	C_8H_{10}	500µg/l
	Ethylebenzane	C_8H_{10}	300µg/l
	Styrene	C_8H_8	20µg/l
	Polynuclear aromatic hydrocarbons (PAHs)	$C_2H_3N_1O_5P_{13}$	0.7µg/l
Chlorinated benzenes	Monochlorobenzene (MCB)	C_6H_5CL	300µg/l
	Dichlorobenzene (DCB)	$C_6H_4CL_2$	1000µg/l
	Trichlorobenzenes	$C_6H_3CL_3$	20µg/l
Miscellaneous organic constituents	Di(2-ethylhexyl)adipate (DEHA)	$C_{22}H_{42}O_4$	80µg/l
	Di(2-ethylhexyl)phthalate(DEHP)	$C_{24}H_{38}O_4$	8µg/l
	Acrylamide	C_3H_5NO	0.5µg/l
	Epichorohydrin (ECH)	C_3H_5CLO	0.4µg/l
	Haxachlorobutadiene (HCBD)	C_4CL_6	0.6µg/l
	Ethylenediaminetetraacedic (EDTA)	$C_{10}H_{12}N_2O_8$	200µg/l
	Nitrilotriacetic acid (NTA)	$N(CH2COOH)_3$	200µg/l
	Organotins	R_2SNX_2	No guidelines