STUDY ON THE MICROBIOLOGICAL AND PHYSICO-CHEMICAL PARAMETERS OF WATER FROM SELECTED SOURCES IN KATSINA METROPOLIS

BY

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DECLARATION

I hereby declare that this work is the product of research effort undertaken under the supervision of Dr. Shamsuddeen Umar and has not been presented anywhere else for the award of degree or certificate. All sources have been duly acknowledged

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CERTIFICATION

This is to certify that the research work for this thesis and the subsequent write up of this work titled STUDY ON THE MICROBIOLOGICAL AND PHYSICO-CHEMICAL PARAMETERS OF WATER FROM SELECTED SOURCES IN KATSINA METROPOLIS (by Bilkisu Abdullahi) were carried out under my supervision

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DEDICATION

I dedicated this research to the blessed memory of my Father Late Abdul Ibrahim and Maryam Abdul.

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ABSTRACT

Study was carried out on the microbiological and physicochemical qualities of different water sources in Katsina Metropolis. A total of 125 water samples were collected, 25 each from five different locations. The samples were from tap, wells, boreholes, jerry cans and irrigation water. The samples were subjected to microbiological analysis to determine the aerobic mesophilic bacterial counts, coliform counts, fungal counts as well as detection of some micro organisms of public health importance such as *E. coli* and *Salmonella* spp using standard methods. The microbiological analysis of water from Kofar durbi showed the mean Aerobic Plate Count of water from Tap, Well, Borehole, Jerrycan, and Irrigation to be $<1.0 \times 10^1$, 3.18×10^6, $<3.0 \times 10^1$, 9×10^4, and 7.8×10^6cfu/ml respectively. Coliform count (MPN) of 0, 16±4.55, 8±1.47, 8.64±2.39, and 1600 respectively. Fungal count of $<1.0 \times 10^1$, 4.72×10^6, $<1.0 \times 10^1$, 2.0×10^6, and 1.11×10^7 respectively.The microbiological analysis of water from Kofar sauri showed the mean Aerobic Plate Count of water from Tap, Well, Borehole, Jerrycan, and Irrigation to be $<3.0 \times 10^1$, 2.6×10^5, 2×10^1, 1.19×10^4, and 3.9×10^6cfu/ml respectively. Coliform count (MPN) of 0, 29±15.27, 8±2.73, 22±19.53, and 1316±635.04 respectively. Fungal count of $<1.0 \times 10^1$, 3.0×10^5, 8×10^1, 7.8×10^2, and 10.0×10^5 respectively. The microbial and fungal analyses from the remaining sources were equally not wholesome and there exist significant differences between the bacterial counts of these locations ($p<0.05$). The physico-chemical properties of water from most sources in Katsina Town meet the recommended standards for portability as set by WHO except in the case of water use for irrigation purposes where it's Total Dissolved Solids, Dissolved Oxygen, Biochemical Oxygen Demand, Nitrates and Phosphates contents went above the WHO prescribed level. Water monitoring in Katsina should be carried out over a longer period of time using more rapid and discriminatory procedures. Appropriate and affordable water disinfection techniques such as boiling and filtration for the area should be employed.

CHAPTER ONE

1.0 INTRODUCTION

Water is one of the most important of all natural resources known on earth. It is important to all living organisms, most ecological systems, human health, food production and economic development (Postel *et al.,* 2003). The safety of drinking water is an ongoing concern within the global village. Traditionally, the safety of potable water supplies has been controlled by disinfection, usually by chlorination and coliform population estimates. However, it has been reported that coliform-free potable water may not necessarily be free of pathogens (Sim *et al.,* 2006).

The provision of portable water to therural and urban population is necessary toprevent health hazards. Water houses the largest number of living organisms whencompared with other habitats and one of the essential chemicals of life upon which all life forms depend. Physiologically, water is the medium forall biochemical reaction in man. Before water can be described aspotable, it has to comply with certain physical, chemical and microbiological standards, which aredesigned to ensure that the water is palatable and safe for drinking (Tebutt, 1983). Water can be obtained from a number of sources, among which are streams, lakes, rivers, ponds, rain, springs and wells. Unfortunately, clean, pure and safe water only exists briefly in nature and is immediately polluted byprevailing environmental factors andhuman activities(Lamikanra, 1999). The public health significance of water quality cannot be over emphasized. Many infectious diseases are transmitted by water through the fecal-oral route. Diseases contacted through drinking water kill about 5 million children annually and make $^{1}/_{6}{}^{th}$ of the world population sick (WHO, 2004). Water is vital to our existence in life and its importance in our daily life makes it imperative that thorough microbiological and physicochemical examinations be conducted on

water. Water is said to be potable when the physical, chemical and microbiological qualities conform to specified standard. To achieve this, such raw water is subjected to purification processes that range from simple long-term storage to enable sedimentation of some suspended solid to aeration, coagulation, flocculation and disinfection among other treatments (Ajewole, 2005). And therefore, potable water is the water that is free from disease producing microorganisms and chemical substances that are deleterious to health (Lamikanra, 1999).

In Nigeria, majority of the rural populace do not have access to potable water and therefore, depend on well, stream and river water for domestic use. The bacterial qualities of groundwater, pipe borne water and other natural water supplies in Nigeria, have been reported to be unsatisfactory, with coliform counts and chemicals far exceeding the level recommendation by W.H.O (Dada *et al*., 1999a, 1999b, Edema *et al*., 2001). The reason for elucidation of important parameters in water quality assessment may be attributed to the fact that in the overall portability of water, such parameters should not be ignored (Osuinde and Enuezie 1999).

In the whole Africa nearly 80% of the population relies on surface water as the main source of water (Venter, 2001). Natural surface water bodies often have impurities from various sources. The impurities may besuspended particles, colloidal materials and may also be dissolved cationic and anionicsubstances. Various natural and human activities, like industrial, domestic, agricultural activitiesand others create water pollution particularly in surface and ground water system (Gardiner andMance, 1984). The rapid growth of urban areas has further affected groundwater quality due tooverexploitation of resources and improper waste disposal practices. Landfills and other solidwastes disposal sites are major targets of pollution because rainfall and ground water leach thesehighly contaminated substances into rivers and streams which are in advertently used by peopleresiding in such areas (Asnoye *et al*., 2007). Even the most commonly

used tap water in cities may be contaminated due to poor maintenance of broken and leaking pipes, especially those close to gutter and drainages.

Water becomes contaminated by pathogens such as coliforms i.e. salmonella and dysentery causing bacilli. The waste products of human (faeces) carried in sewages is mostly dumped into water bodies such as lakes, rivers etc. which eventually contaminates the water (Elizavet *et al.,* 2007). Ground water which is the major source of drinking water in almost all areas (i.e. rural and urban), can easily be polluted through discharge of industrial effluents, domestic sewage and refuse (Desai, 2012).

Water of good quality is of importance to human physiology. According to Gupta and Sharma (2008), only 1% part of the world's water is available on land for drinking, agriculture, domestic power generation, transportation and waste disposal. Water quality means, the chemical, physical and biological characteristics of water (Diersing, 2009, Yadav *et al.,* 2011).

Ground water contains high amount of ions & salts. If such type of water is used as potable water, it may lead to various water-borne diseases (Mishra *et al.,* 2010). Unsafe drinking water contributed to numerous health problems in developing countries and according to World Health Organization (WHO), there were estimated 4 billion cases of diarrhea and 2.2 million deaths.

Parihar *et al.,* (2012) reported that about 1% of ground water is threatened by pollution. Non-pathogenic faecal organisms are best indicators of faecal pollution. However, in all cases, faecal coliform content & E. coli are used as major tools in the assessment of the health risk borne by pathogens in water (Parihar *et al.,* 2012).

Bacteria of health concern in contaminated water include the following bacterial agent of diarrhea and gastro-enteritis namely *Salmonella* spp*., Shigella* spp*., Escherichia coli* and *Vibrio*

cholarae (Birmingham *et al.,* 1997). Protozoan agent of diarrhea includes *Entamoeba histolitica, Giardia lamblia, Balantidium coli* (Jawetz *et al.,* 1997).

Presence of faecal coliforms or *E. coli* is used as an indicator of the presence of any of these water borne pathogens (Chukwurah, 2001; Okafor, 1985; Okpokwasili and Akujobi, 1996.) WHO recommends that no faecal coliform should be present in drinking water.Major factors affecting the microbiological quality of surface water are discharges from sewage works and run off from informal settlements. High total and faecal coliform counts in water are usually manifested in the form of diarrhoea, fever and other secondary complications (Fatoki *et al.,* 2001).

Chemical composition of water may affect the safety, taste and appearance, bacterial contamination cannot be detected by appearance, taste or smell. This can only be detected by testing the water for the presence of indicator organisms and determining the *E. coli* and total coliform organisms present (Gomes and Martinis, 2004). Water samples that contain any coliform bacteria are generally reported as total coliform positive. Federal regulations now require that public drinking water found to be total coliform positive must be analysed with a faecal coliform or *E. coli* test. These faecal bacteria when present in any concentration in water supply are unaccepted (Kathleen, 1998).

Water can be polluted in two major ways, namely; point source pollution- which occurs as a result of release of harmful substances directly into the body of water, and non-point source pollution- which occurs as a result of indirect introduction of pollution into water bodies/sources from the environment (Kerker, 2003). Water pollution in Nigeria occurs both in rural and urban areas. Estimate suggests that nearly 1.5 million people lack safe drinking water. Raw sewage, garbage and oil spill all serve as sources for contamination (Ladeji, 2002). World Health

Organization (WHO, 1995) informed that contaminated water, inadequate sanitation, and poor hygiene cause over 80% of diseases in developing countries.

A good knowledge of the chemical qualities of raw water is necessary so as to guide its suitability for use. Thus, regular physicochemical analysis of water at source must be carried out to determine or check the effectiveness of treatment process. Thus, this research was conducted to evaluate the different sources of drinking water, water used for domestic purposes and irrigation water in Katsina town so as to.Compare it with microbiological and physicochemical standards for treated water samples. Also, to identify possible pathogens which could be responsible for such contamination and to stress the public health implication of consumption of such contaminated water.

1.1 AIM AND OBJECTIVES

Aim:

The aim of the research work is to determine the microbiological quality and physico-chemical parameters of water from various sources used for different purposes in Katsina metropolis.

Objectives:

1. To determine the microbial load of water from various sources of water in Katsina.
2. To determine the physicochemical parameters of the water sample used in the study area.
3. To detect some specific organisms of public health concern in water source used in the area.

1.2 STATEMENT OF RESEARCH PROBLEM

Water quality has always been a major issue in many countries, especially in developing countries (Moe and Rheingans, 2006).Unfortunately, the quality of water used for various purposes by the public in many places in Nigeria may not be wholesome (Mendie, 2004).

Reports from various places in the country shows high contamination of water sources used by many communities both in the case of microorganisms and undesirable chemicals (Ashaye *et al.*, 2001; Egwari, 2002; Ajewole, 2005; Garba *et al.,* 2010 and Adegoke *et al.,* 2012).

1.3 JUSTIFICATION OF THE STUDY

There are many sources of water in Katsina such as tap, boreholes, wells as well as jerrycan water sold by water vendors. The quality of the sources may not be wholesome. The provision of town water supply is however inadequate and this inadequacy leads the proliferation of water vendors in jerry cans. Due to water scarcity, many urban dwellers resorted to using water from sources either than the town water supply. But there is an apparent lack of quality control in the distribution of water by vendors and this may result in the infection of humans and their livestock with pathogenic microorganisms and may also be the source of associating irrigated food products with harmful microorganisms (WHO, 2004). For this reason, this work is therefore set up to assess the water quality and make recommendations based on the results obtained.

1.4 HYPOTHESIS

Water used from various sources in Katsina contain microorganism of public health importance.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Water Quality Assessment and Monitoring

Much of the current concern with regards to environmental quality is focused on water because of its importance in maintaining the human health and health of the ecosystem. Water is the principal need of all life on earth, and is an essential component for all forms of lives, from microorganisms to man (Priyanka *et al.,* 2010). It is an essential substance for the maintenance of all life processes. It is abundant in nature, yet most people lack adequate and safe drinking water due to increase in human population, coupled with human activities which lead to pollution of drinking water sources and failure from government to provide potable water to its citizens, more especially in developing countries. Water is indispensible for life, since it is essential part of human nutrition and it is also required for maintenance of personal hygiene, food production and prevention of diseases (Adenkunle *et al.,* 2004, Oparaocha *et al.,* 2010, Edema *et al*., 2011, Adegoke *et al*., 2012).

Water quality has always been a major issue in many countries, especially in developing countries (Moe and Rheingans, 2006). Throughout the world, about 2-3 billion people suffer from disease that are linked to water related problems (WHO, 1997), which will continue to kill millions of people yearly, debilitate billions, thereby undermining developmental efforts (Nash,1993; Olshansky *et al*., 1997). Diseases contacted through drinking water kill about 5 million children annually and make one-sixth of the world population sick (WHO, 2004).

Natural surface water bodies often have impurities from various sources. The impurities may besuspended particles, colloidal materials and may also be dissolved cationic and anionicsubstances. Various natural and human activities, like industrial, domestic, agricultural

activitiesand others create water pollution particularly in surface and ground water system (Gardiner andMance, 1984). The rapid growth of urban areas has further affected groundwater quality due tooverexploitation of resources and improper waste disposal practices. Landfills and other solidwastes disposal sites are major targets of pollution because rainfall and ground water leach thesehighly contaminated substances into rivers and streams which are in advertently used by peopleresiding in such areas (Asnoye *et al*., 2007). Water is vital to our existence in life and itsimportance in our daily life makes it imperative that thorough microbiological andphysicochemical examinations be conducted on water.

Water quality reflects the composition of water as affected by natural causes and man's cultural activities expressed in terms of measurable quantities and related to intended water use. The composition of surface and groundwater is dependent on natural factors (geological, topographical, meteorological, hydrological and biological) in the drainage basin and varies with seasonal difference in runoff volumes, weather conditions and water levels (Muller, 2001).

2.2 Quality of Surface and Ground Water Bodies

Nigeria has adequate surface and ground water resources to meet current demands for potable water but variation in geographical climatic condition has lead to scarcity in some locations especially in the North (USAID, 1990). The Nigerian government held the role of provision of water and sanitation services to its citizens but after fifty-four years of water supply development in Nigeria, it is regrettable that only few number of the population has no access to safe drinking water (FMWR, 2000). However, the public sector has not been successful in meeting more than a small portion of the demand for water and sanitation of residential and commercial users. Services are in critically short supply in many communities in Nigeria (FMWR, 2000). Many households often end up purchasing water from private vendors much more expensively than

from the public supply. Water supply services where they exist, are unreliable and of low quality and are not sustainable because of difficulties in management. Many water supply systems show extensive deterioration and poor utilization of existing capacities, due to under maintenance and lack of funds for operation. Rural people in the country still depend very much on rivers, streams, ponds, and shallow wells for their water needs.

2.2.1 Ground WaterPollution

Groundwater is an increasingly important resource all over the world. The term groundwater is usually reserved for the subsurface water that occurs beneath the water table in soils and geologic formation that are fully saturated (Biswas, 2003). In Nigeria, groundwater is an important source of water and dominant source for domestic supply in many areas, especially in the dry areas where surface waters are scarce and seasonal (e.g. Afar north and Somali region in the east).

Groundwater is generally less susceptible to contamination and pollution when compared to surface water bodies (Zaman, 2002). Also the natural impurities in rainwater, which replenishes groundwater systems, get removed while infiltrating through soil strata (Veslind, 1993). Importantly, groundwater can also be contaminated by naturally occurring sources. Soil and geologic formation containing high levels of heavy metals can leach those metals into groundwater. This can be aggravated by over-pumping wells, particularly for agriculture (Gay and Proop, 1993). Pollution caused by fertilizers and pesticides used in Agriculture, often dispersed over large areas, is a great threat to fresh groundwater ecosystems. Pollution of groundwater due to industrial effluents and municipal waste in water bodies is another major concern in many cities and industrial clusters in Nigeria.

Several contaminants have been known for years to be harmful to human, animal health and plantlife (Emeric, 1974). The very common source of contamination to wells is surface water runoff intoshallow, poorly ceased wells, direct disposal of industrial wastes and agricultural drain water torivers. Nitrates and nitrites are soluble and if added to the soil may move to the ground. In mostcases higher level of toxicity effect of nitrite is more pronounced than nitrate (FAO, 1988).

2.2.2 Surface WaterPollution

Direct contamination of surface water with metals in discharges from mining, smelting and industrial manufacturing, is a long-standing phenomenon. Today there is trace contamination not only of surface water but also of groundwater bodies, which are susceptible to leaching from waste dumps, mine tailings and industrial production sites (Daniel *et al*., 1998). Several human activities in Nigeria that may result to water pollution include agriculture, irrigation, urbanization, mining and industrialization.

2.3 Causes and Effects of Water Pollution

Water pollution refers to the changes in the physical, biological, and chemical conditions of any body of water which harmfully disrupts the balance of the ecosystem. The effects of pollution in the water are myriad. In rivers, oceans and seas, the water pollution can be lethal, killing the fish and plant life (Goel, 2006). This in turn can kill the birds and other animals that eat this contaminated food supply. The effects of water pollution have also been considered the leading cause of human deaths worldwide. Almost every type of contamination found in water has a detrimental effect on humans. Blood diseases, heart disease and nervous system disorders are commonly linked to the effects of water pollution (Andrew and Julie, 1996). Many of the toxins found in polluted water are carcinogenic, which means they can cause cancer. Some substances

can even effect generations to come by changing the body's chromosomal makeup. Less severe effects of water pollution can include diarrhea, skin lesions, and vomiting (Walten and Stanley, 1980).

There are many sources of the water pollution. Mining, chemical waste, solid waste, liquid waste, coal, industrial effluents (waste), detergents, metal plating, natural geological source, corrosion and industrial effluents are the most dangerous sources of water pollution (Walten and Stanley, 1980). It is through these sources that hazardous chemicals enter into the water and cause disease like cancer. Organic pollutants like dyes, salts, cyanides, suspended solids, greases, and oils are included in the industrial effluents.

The mono-methyl mercury carried along with the industrial effluents enters human body with water and causes brain damage. Sometimes even direct deaths are being reported by drinking the water mixed with such industrial effluents (Walten and Stanley, 1980).

Silt is the source of pollution that pollutes the water at very initial stage. During silt, the soil or silt from the mountains gets carried along with the rain water and mixes with the ground water. This also happens during the process of deforestation. This generally is not so hazardous because once the water gets deep these soil particles get deposited at the bottom and you get to drink clean water. In some cases only infecting microorganisms are observed in silt (Goel, 2006).

Nowadays the modern concept of agriculture is being utilized everywhere. This includes the usage of the many chemical pesticides and fertilizers. The crop yield is surely increased by it, but when these pesticides and fertilizers get incorporated in the water bodies through irrigation, rainfall, and drainage can cause water pollution. Primarily they destroy the aquatic life (Andrew and Julie, 1996).

Many causes of pollution including sewage and fertilizers contain nutrients such as nitrates and phosphates. In excess levels, nutrients over stimulate the growth of aquatic plants and algae. Excessive growth of these types of organisms consequently clogs our waterways, use up dissolved oxygen as they decompose, and block light to deeper water (Drever, 1997). This, in turn, proves very harmful to aquatic organisms as it affects the respiration ability of fish and other invertebrates that reside in water. No fishes are able to survive in this polluted water.

The consumption of this polluted water may cause nerve disorders, leukemia, and cancer. Power plants use water to cool their machineries, and due to heat exchange, the temperature of water can increase to the level it kills the aquatic animals (Goel, 2006).

2.4 Physico-chemical Pollutionof Water

Most chemicals arising in drinking water are of health concern. A few chemical contaminants have been shown to cause adverse health effects in humans as a consequence of prolonged exposure through drinking water. Some substances of health concern have effects on the acceptability of drinking-water that would normally lead to rejection of the water at concentrations significantly lower than those of health concern. Several research findings such as those of Egwari and Aboaba (2002) showed that water from several boreholes and wells in some urban centers in Nigeria were heavily contaminated with toxic organic wastes.

Some of the physicochemical contaminants of concerns in drinking water are discussed below:

2.4.1 Colour

Drinking-water should ideally have no visible colour. Colour in drinking-water is usually due to the presence of coloured organic matter (primarily humic and fulvic acids) associated with the humus fraction of soil. Colour is also strongly influenced by the presence of iron and other metals, either as natural impurities or as corrosion products (WHO, 2011). It may also result

from the contamination of the water source with industrial effluents and may be the first indication of a hazardous situation (WHO, 2011). Most people can detect colour above 15 True Colour Units (TCU) in a glass of water. Levels of colour below 15 TCU are often acceptable to consumers (CAWST, 2009). High colour from natural organic carbon (e.g. humics) could also indicate a high propensity to produce by products from disinfection processes.

2.4.2 Odour

Odour in water is usually caused by volatile substances associated with organic and inorganic chemical materials such as algae and hydrogen, respectively. In many cases, aesthetic problems will be prevented by optimizing conventional treatment processes such as coagulation, sedimentation and chlorination (WHO, 2008). However, if specific treatment is deemed necessary, aeration, granular or powdered activated carbon and ozonation are generally effective techniques in removing organic chemicals and some inorganic chemicals, such as hydrogen sulphide, that cause tastes and odours (WHO, 2010)

2.4.3 pH

pH is the measure of acidity or alkalinity of a substance. Careful attention to pH control is necessary at all stages of water treatment to ensure satisfactory water clarification and disinfection (WHO, 1997). The optimum pH required will vary in different supplies according to the composition of the water and the nature of the construction materials used in the distribution system, but it is usually in the range 6.5–8.5 (WHO, 2011). Many enzymes and other proteins are denatured by low pH which differs much from pH 7, which disrupt the functioning of the organism and may eventually kill it. Low pH's also increase the release of metals, some toxic, from soils and sediments. Alkalinity is an important parameter because it measures the water's ability to resist acidification, for instance, to acid rain. The significant environmental impact of

pH involves synergistic effects. That is, the pH value of the water may influence levels at which certain chemical substances become toxic.

2.4.4Total Dissolved Solids (TDS)

Total Dissolved Solids are correlated fairly well to the total mineral content of the water (deposits left after evaporation of a water sample), primarily salts, carbonates and metals. Organic compounds may also be dissolved solids. A high concentration of TDS is an indicator of possibly high volume contamination(WHO, 2011).

2.4.5 Turbidity

Solids particles suspended in water absorb or reflect light and cause the water to appear “cloudy”. These particles are suspended inorganic minerals or organic matter picked up over or under the ground. Since the earth acts as an excellent filter, the water from deep well is usually clear without significant amounts of turbidity. This problem is more common in the water from surface supplies. The major problem with turbidity is aesthetic, but in some cases suspended matter can carry pathogens with it. Large amounts of organic matter can also produce stains on sinks, fixtures, and laundry (WHO, 1985).

2.4.6Dissolved Oxygen

Dissolved oxygen (DO) levels in natural and wastewaters depend on the physical, chemical,and biochemical activities in the water body (APHA, 2005). The analysis for DO is a key test in water pollutionand waste treatment process control. Dissolved oxygen is important for the survival of aquatic microbes.

2.4.7 Biochemical Oxygen Demand

The biochemical oxygen demand (BOD) is the relative oxygen requirements by microorganisms to decompose waste materials in wastewaters, effluents, and polluted waters. High BOD in water indicate high water pollution and possibly high microbial load (WHO, 2010)

2.4.8 Nitrate

The Nitrate anion (NO_3^-) is not adsorbed by soil and moves with infiltrating water. Nitrates are present in water particularly in regions where agriculture fertilization is intense. Other important routes of entry of nitrogen into bodies of water are municipal and industrial wastewater, septic tanks, feedlot discharges from car exhausts. The nitrate level in drinking water is extremely important with infants, because of their high intake of water with respect to body weight. Nitrates in the infant are converted by the body to nitrites that oxidize blood haemoglobin to methaemoglobin. The altered blood cells can no longer carry oxygen, which can result in brain damage or suffocation. Water with nitrite levels exceeding 1.0 mg/l should not be used for feeding babies. Epidemiological studies show a correlation between high nitrate levels and gastric and stomach cancers in humans (WHO, 1993).

2.5 Microbiological Pollution of Water

The most common and widespread health risk associated with drinking water is contamination; whether directly or indirectly, by human or animal excreta, particularly faeces. If such contamination is recent, and if those responsible for it include carriers of communicable enteric disease, some of the pathogenic microorganisms that cause these diseases may be present in the water. Drinking the water, or using it for food preparation, may then result in new cases of infection. They are usually considered as sources of potential nuisance and hazard in relation to drinking water (WHO, 1993). The pathogenic agents involved include bacteria, viruses, and

protozoa, which may cause diseases that vary in severity from mild gastroenteritis to severe and sometimes fatal diarrhea, dysentery, hepatitis, or typhoid fever, most of them are widely distributed throughout the world. Fecal contamination of drinking water can be transmitted from one person to another or, in some cases, from animals to people. Other pathogens cause infection when water containing them is used for bathing of for recreation involving water contact, rather than by the oral route (Olstadt, 2007).

The microbiological quality of drinking water is of serious concern to consumers and public health authorities. Certain microorganisms, including various bacteria, viruses, fungi and parasites, are well-known water contaminants, of which several may lead to waterborne disease and epidemics (Hageskal *et al.,* 2009). Bacteria are probably the most frequently studied group of microorganisms with respect to the quality of drinking water. Pathogenic viruses in water are also of great importance as viruses are the most common cause of gastrointestinal infection worldwide (Mara and Horan, 2006). The level of microorganisms in drinking water generally dependent on good manufacturing practices. The presence of microorganisms in processed water can deteriorate and the potability of the water before it reaches the consumer(Mara and Horan, 2006). To ensure that the microbiological characteristic of drinking water is safe for human consumption the Nigeria base National Agency for Food and Drugs Administration and Control in association with World Health Organisation recommended that potable water for human consumption should not contain any microorganism that is known to be pathogenic (WHO, 1984).

2.5.1 Bacteria associated with drinking water

The bacteriological quality of drinking water is of paramount importance and monitoring must be given highest priority, this is so because studies have reveal several disease outbreak

associated with untreated or poorly treated water containing bacteria pathogen that have been isolated from sachet water. The water contamination with fecal bacteria is a common and persistent problem that has a direct impact on the public health, and in economic and social aspects (Stewart *et al.* 2007). *Coliform* in water, though harmless to human health had been shown to portend the most probable presence of other pathogenic microorganisms like *Salmonella typhi*, *E. coli*, *Pseudomonas*, *Vibrio* species,*Shigella* species, *Aeromonas hydrophilia* among others (Egwari and Aboaba, 2002).

Assin *et al*. (2006) evaluated bacteriological water quality and its relation to human health in Gaza Governorate, Gaza Strip. They reported that total and faecal coliform contamination in both water wells and networks generally exceeded that of WHO limit in Gaza Governorate. However, the level of contamination in networks was higher than that in wells, and it seems to occur mainly in winter and summer seasons. This may contribute to the prevalence of water-related diseases. Self-reported diseases among interview sees in Gaza City were associated with source of drinking water, intermittent water supply, sewage flooding and age of water, and wastewater networks.

Bacillus species are often detected in drinking-water supplies, even supplies treated and disinfected by acceptable procedures. This is largely due to the resistance of spores to disinfection processes (WHO, 2011). *E. coli* are enteric organisms, and humans and animals are the major reservoir.. Waterborne transmission of pathogenic *E. coli* has been well documented for recreational waters and contaminated drinking-water (WHO, 2011).There is no indication that the response of enteropathogenic strains of *E. coli* to water treatment and disinfection procedures differs from that of other *E. coli*.

Worldwide the most common bacterial diseases transmitted through water are caused by *Shigella, Salmonella*, Enterotoxigenic *Escherichia coli, Campylobacter jejuni* and *Vibrio cholera* (Mitchell, 1972). Members of the genus *Campylobacter* are important and frequently cause diarrhea. These bacteria occur in the excrements of birds, and thereby enter water. A gram of bird faeces contains up to 107 *Campylobacter* cells. Often *Mycobacterium tuberculosis* also occurs. Presence of the spores of pathogenic *Clostridia*, particularly those causing gas gangrene like *Clostridium perfringens*, *C. novyi* and *C. Septicum*, can nearly always be demonstrated in sewage loaded water (Seltzer, 1991). The spores of the causative agent of anthrax (*Bacillus anthracis*) are also very resistant to common procedures of water treatment (Rheinheimer, 1991).

2.5.2 Fungi associated with drinking water

Fungi are eukaryotic, heterotrophic and many fungal species can survive in oligotrophic environments (DEFRA, 2011). Some fungi are primarily adapted to aquatic environments and are naturally found in water. These fungi are zoosporic, and many belong in phyla Chytridiomycota while the rest of the phyla are primarily adapted to terrestrial environments (Hageskal *et al.,* 2009).

In 1980s and 1990s, more cases of health problems caused by fungal contaminated drinking water were reported from Finland and Sweden (Muittari *et al.,* 1980; Aslund, 1984). In the last decade, several studies conducted in several countries on drinking water had results which indicated that the recovery of fungi varied between 7.5–89 % positive samples, and that the levels of fungi in the samples varied considerably in the various investigations (Kelley *et al.,* 2003; Hapcioglu *et al*., 2005; Kanzler *et al*., 2007; Kennedy and Williams, 2007). In addition, results from studies of taste and odour problems in drinking water indicated the occurrence of fungi as an important causative factor for these sensoric changes (Nystrom *et al.,* 1992; Montiel

et al., 1999). Statistically, it has been established that the odds for fungal recovery are three times higher in surfaces sourced water compared with ground-sourced water and fungi are more commonly recovered from cold water than from hot tap water (Hageskal *et al.,* 2007). Fungi have been reported from all types of water which include bottled and sachet drinking water (Mirian *et al*., 2007). The most commonly isolated genera from drinking water are *Penicillium*, *Cladosporium*, *Aspergillus*, *Phialophora* and *Acremonium* (DEFRA, 2011).

Fungi can enter drinking water distribution systems through deficiencies in treated water storage facilities, cross-connections, mains breaks and intrusions, and during installation of water storage and distribution facilities (DEFRA, 2011). Purification procedures such as chlorination do not eliminate fungal spores, which implies that perhaps the treatment given to our sachet water is usually not effective enough to eliminate these microorganisms (DEFRA, 2011).

Studies established that fungi can survive treatment, and that most of the water treatment methods are not sufficient against fungi. Many of the taxa most frequently isolated from drinking water has the potential to secrete pigment called melanin which provide protection against range of stresses making them resistance to water treatment (Langfelder *et al.,* 2003). In a study by Kelley (2003) sand filtration was reported to give better removal of fungi than coagulation with iron. Chlorination used for disinfection of water was found to be insufficient (Frankova´ and Horecka, 1995), whereas the use of chlorine dioxide and ozone were reported as the most effective water treatment methods against fungal spores (Kelley *et al.,* 2003). A frequently used water treatment method in developed countries is ultra violet radiation. With respect to fungi in drinking water, ultra violet may have a positive effect (Kanzler *et al.,* 2007). However, as the ultra violet sensitivity of fungi often is related to pigmentation, fungi with pigmented spores, such as *Aspergillus* and *Penicillium*, have better protection against radiation and are less

sensitive to ultra violet (Waipara, 1998). The abiotic factors that influence fungal taxa isolated from drinking water are accumulation of organic and inorganic materials, water temperature, water flow rate and nutrient concentration while the biotic factors are interaction between fungi with bacteria, protozoa and viruses (DEFRA, 2011).

Penicillium species have been frequently recovered from water in the various studies performed. Several of the species in both genus *Penicillium* and *Aspergillus* are known to produce mycotoxins in food and beverages (Moreau, 1979; Pitt and Hocking, 1999). In a study by Kelley *et al.* (2003) concluded that mycotoxins and other metabolites can be produced by fungi in water. Mycotoxins produced in water will of course be extremely diluted, and are perhaps of minor concern. Nevertheless, water is occasionally stored in cisterns or reservoirs, or even in bottles, for prolonged periods. In such cases, the concentrations of mycotoxins may increase. Large amounts of water are consumed daily, and daily intake over many years of even small amounts of mycotoxins may be hazardous to human health. According to Nikaeen and Mirhendi (2008), *Aspergillus* species in drinking water are involved in the production of health risks while De-hoog *et al*. (2000) described that many species of *Aspergillus* are found in water and are causative agents of kidney and liver disorders, allergic sinusitis burns, otitis media and increase the risk of invasive infections.

2.6 Indicator Organisms

The microbiological quality of drinking water relies on the presence or absence of indicator organisms. The indicator organisms that are well known are the total coliforms, and thermotolerant coliforms or alternatively *E. coli*. Indicator bacteria are bacteria organisms which are always excreted in large numbers by warm- blooded animals, irrespective of whether they are healthy or sick. The presences of indicator organisms are the coliforms (Kool, 1988). The

concentration of any given indicator suggests the level of risk from associated pathogens. Bacterial indicators are thus valuable in short term monitoring, for instance bacteriological water quality testing (Ellis, 1986).

An effective indicator organism for inferring the presence of pathogenic microorganisms in drinking water should: always be present when pathogens of like origin are present; be present in relatively large numbers so that they can be detected after considerable dilution; not be present in the absence of contamination, be easy and quick to detect, survive in water as long as water-borne pathogens, and be of similar sensitivity to disinfection as pathogens (ADWG, 1996). Coliforms may sometimes be present when there is no faecal contamination in the water or, the absence of thermotolerant coliforms does not necessarily guarantee the absence of faecal contamination (ADWG, 1996; WHO, 2011).The coliform group of organisms is generally accepted as the most suitable set of organisms to indicate faecal contamination. Although as a group they may not be exclusively of faecal origin, they are present in very high numbers in the faeces of warm-blooded animals. These are the coliform bacteria which can survive better, longer and are easier to detect than other pathogens (Agunwamba, 2000). Coliform bacteria are commonly found in soil, on vegetation, and in surface water. They also live in the intestines of warm-blooded animals and humans. Some coliform bacteria strains can survive in soil and water for long periods of time. Coliform bacteria are not likely to cause illness. However, because coliform bacteria are most commonly associated with sewage or surface waters, the presence of coliform bacteria in drinking water indicates that the other disease-causing organisms (pathogens) may be present in the water system (ADWG, 1996).

Coliforms comprise *E. coli*, other thermotolerant coliforms such as*Citrobacter* and regrowth bacteria such as *Klebsiella*, and other related enterobacteria. They are the most sensitive but least

specific indicator group for faecal contamination (WHO, 2011). The total coliforms serve as an indicator because: as a group, they include thermotolerant coliforms which are a direct indicator of faecal contamination; their high numbers and their ability, along with some other more resilient faecal pathogens, to survive longer in natural water than *E. coli*enable them to indicate less recent or more remote incidents of faecal pollution; their detection can indicate that conditions may favour the presence of free living opportunistic pathogens such as *Aeromonas, Pseudomonas* and *Legionella*; their relative abundance and hardiness makes them a useful indicator of the efficiency of water treatment and disinfection processes, and their absence is a good indication of the absence of contamination and where coliforms are found in water supply systems they usually outnumber thermotolerant coliforms, and thus may be easier to detect (ADWG, 1996).

The desirable characteristics of indicator organisms have been summed by WHO (1997) as organisms that are harmless to humans especially laboratory workers, present in polluted waters when pathogens are or might be present, present in polluted water in number higher than those of the pathogens, are easy and quick to identify through relatively simple laboratory tests and are able to survive unfavourable environmental conditions longer than those pathogens.

2.7 Biology of Some Indicator Organisms

Escherichia coli

The concept of using *Escherichia coli* as indicators of feacal pollution is well established practice in the assessment of drinking water quality. *Bacillus coli* comminus was the name given by Theodor Escherich in 1885, but was later changed to *Escherichia coli* by Migula in 1895.

Escherichia coli is a gram negative, rod-shaped, facultative anaerobic bacterium commonly found in the lower intestine of warm-blooded organisms (endotherms) as normal flora. Most *E. coli* strains are harmless but some serotypes can cause serious food poisoning and water borne diseases in humans and are occasionally responsible for product recall due to food contaminations (Vogt *et al.,* 2005).*E. coli* becomes pathogenic by acquiring virulence factors through plasmids, transporons, bacteriophages etc. These pathogenic *E.coli* are categorized based on serogroups, pathogenicity mechanism, clinical, symptoms or virulence factors (Kaper *et al.,* 2004).

The harmless strains are part of the normal flora of the gut and can benefit their hosts by producing vitamin k and by preventing the establishment of pathogenic bacteria within the intestine (Feng *et al.,* 2002). E. coli and related bacteria constitute about 0.1% of gut flora and faecal-oral transmission is the major route through which pathogenic strains of the bacterium cause disease.

Pseudomonas aeruginosa

Pseudomonas aeruginosa is a common bacterium that can cause disease in animals including humans. It is found in soil, water, skin (which makes it a normal flora) and most man-made environments. It thrives not only in normal atmosphere but also in hypoxic atmospheres (partial pressure of oxygen is lower than that at the sea level).

The symptoms of *Pseudomonas* infections are generalized inflammation and sepsis. If colonization occur in critical body organs, such as lungs, urinary tract and kidneys, the result can be fatal because it thrives on most surfaces (Balcht *et al.,* 1994).

This bacterium can also be found on medical equipments including catheters, causing cross infections in hospitals and clinics (Iglewski *et al.,* 1996).

Salmonella typhii

Salmonella is a genus of rod-shaped, gram negative, non-spore forming, predominantly motile enterobacteria with diameter around 0.7-1.5um, length from 2-5um and flagella that grade in all directions (i.e. peritrichous). They are chemo-organotrophs obtaining their energy from oxidation and reduction reactions using organic sources and are facultative anaerobes. Most species produce hydrogen sulphide which can readily be detected by growing them on media containing ferrous sulphate. Most isolates exist in two phases: a motile phase I and a non-motile phase II (Clark *et al.,* 1987).

Salmonella are closely related to *Escherichia coli* and are found worldwide in cold and warm-blooded animals (including humans), and in the environment. They cause illness such as typhoid fever, paratyphoid fever and foodborne illnesses (Jantsech *et al.,* 2011).

Shigella species

Shigella organisms are a group of gram-negative pathogens which were initially recognized as the causal agents of shigellosis (also known as bacillary dysentery) in the 1890s and become an official genus in the 1950s. it is a non-spore forming negative bacterium which aids in facilitation of intracellular pathogens. It is able to survive the proteases and acids of the intestinal tract, which allows the bacteria to infect in very small amounts down to as few as 10 bacteria being necessary. With the penetration of colonic mucosa, it results in the degradation of the epithelium and acute inflammatory colitis in the lamina propria. This causes leakage of blood, inflammation in the colon and mucus into the intestinal lumen. Faeca-oral route transmission is

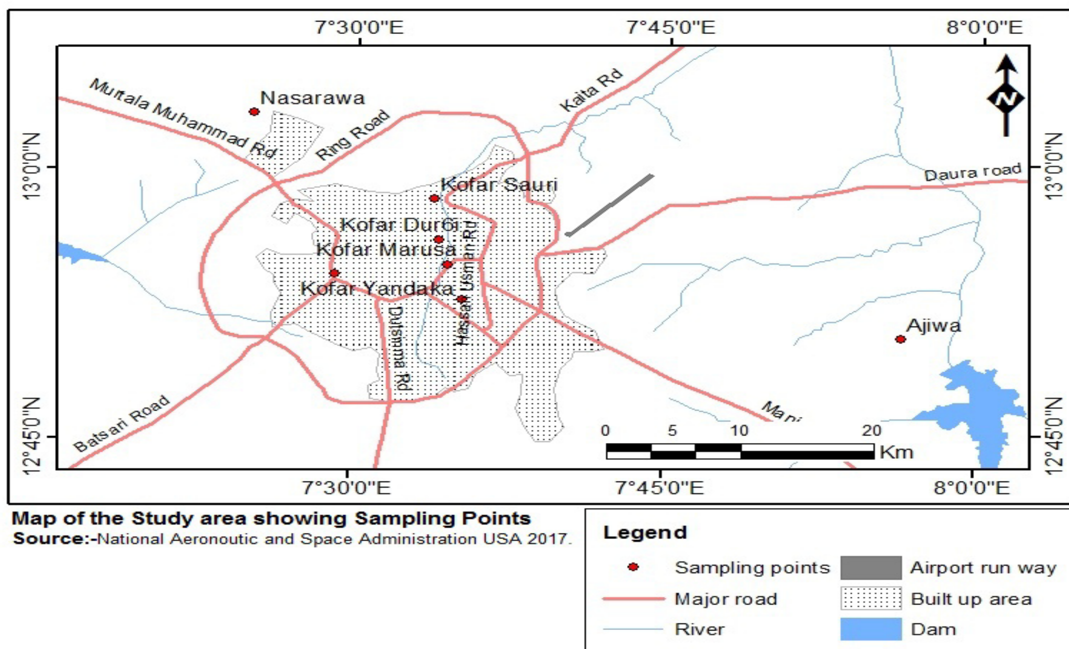
the main path of *Shigella* infection. Other mode of transmissions includes ingestion of contaminated food or water, contact with infected object objects or sexual contact. Outbreaks of shigella infection are common in places where sanitation is poor (Hale *et al.,* 1991).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

Katsina State covers land area of 23,938 sq. km., is located between latitudes 11Â°08'N and 13Â°22'N and longitudes 6Â°52'E and 9Â°20'E. The state is bounded by Niger Republic to the north, by Jigawa and Kano States to the east, by Kaduna State to the South and by Zamfara State to the West. Katsina State forms part of the extensive plains known as the High Plains of Hausa land. Katsina has a population of 6,483,429 people as according to the 2006 National Census and a Population Density of 160 km^{-2}.



Map of the Study area showing Sampling Points

Source:-National Aeronoutic and Space Administration USA 2017.

3.2 Collection of Sample

Twenty five (25) samples were collected from each of tap, well, borehole, jerry can and irrigation water making a total of 125 samples. Water samples were collected from each water sources using a sterile glass sample bottle (500ml). The well was sampled by connecting the bottles to ropes, both of which were previously disinfected with 70 % alcohol and dried in sterile air. The rope was lowered to immerse the bottle in the water to fill. When the bottle was filled, it was pulled out of the well and corked firmly. For the boreholes, the nozzles of the boreholes was swabbed with cotton wool soaked in 70% (V/V) ethanol. Tap water sample was collected using sterile glass sample bottle (500ml); the water was allowed to gush/run for about for 1-2 minutes before the collection is done. Water sample from the jerry can was aseptically collected directly after the cap and the outlet was sterilized with alcohol. Samples from irrigation water were aseptically collected by dipping the sampling bottle into the water source, after collection, the sample bottle is covered and transported to the laboratory for further analysis.

Some of the physicochemical parameters such as temperature and pH were conducted in-situ. All the samples were collected in replicates, they were covered with sterilized caps and transported to the Microbiology laboratory in sterile containers with ice pack for analyses (WHO, 2003; Greenberg *et al.* 1995).

3.3 Microbiological Analyses

3.3.1 Sample Preparation and Serial Dilution

Ten milliliter from the sample was transferred into a tube containing 90ml of buffered peptone water; this was labeled 10^{-1} dilution. From the 10^{-1} dilution, 1ml was transferred to another tube

containing 9ml of buffered peptone water and labeled 10^{-2}. The procedure was repeated to 10^{-5} dilution(Egboh and Emeshili, 2007).

3.3.2 Aerobic Plate Count (APC)

This was carried out by pour plating technique after serial dilution (Egboh and Emeshili, 2007, Godswill *et al.,* 2014). Using a fresh syringe, 1ml of sample from each dilution was transferred into appropriately labeled duplicate petridishes. This was followed by pouring cooled molten nutrient agar in each petridish, homogenized by swirling and allowed to solidify. Finally the plates were incubated at 37°C for 24-48 hours. Following incubation, plates that contain between 30-300 colonies were selected and average of the colonies from the two plates was multiplied by the inverse of the dilution factor to get cfu/ml.

3.4.3 Enumeration of Coliform Bacteria Using MPN Method

This was carried out using Multiple Tube Fermentation Technique (Egboh and Emeshili, 2007). About 10ml of each sample was inoculated into the first sets of test tube (5 tubes per set) each containing 10ml sterile double strength lactose broth with inverted durham tubes (ensuring that no air bubble is captured). Then 1ml of each sample was inoculated into 5 tubes each containing 5ml sterile single strength lactose broth with inverted durham tubes. Then 0.1ml was also inoculated into five test tubes each containing 5ml of sterile single strength lactose broth with inverted durham tubes. The tubes were incubated at 37°C for 24-48 hours. Following incubation, tubes showing gas production were counted and compared with the MPN table adopted for determination of most probable number (MPN) of coliforms.

3.4.4 Detection of *E. coli*

From the positive tubes showing lactose fermentation (gas production), a loopful of broth from the tube was streaked on the Eosine Methylene Blue (EMB) Agar plate and incubated for 24-48

hours at 45°C. Colonies that formed green metallic sheen on EMB are *E. coli* and those that form pink are suspected colour of *Enterobacter aerogens* (Cheesbrough, 2006).

3.4.5 Detection of *E. coli* O157:H7

Isolates that formed green metallic sheen on EMB were streaked on Sorbitol MacConkey Agar, and incubated at 37°C for 24hrs as stated by Ngwa *et al.,* (2013). After incubation, the plates were observed for the presence of colourless colonies.

3.4.6 Detection of *Salmonella*

This was carried out according to the method of Egboh and Emeshili, (2007). A loopful of inoculum from each of the serially diluted tubes was streaked on *Salmonella-shigella* (SS) Agar plate and labeled accordingly. The plates were incubated at 35-37°C for 24-48 hours. After incubation, the colonies were gram stained and tested for motility.

3.5 Biochemical Test

3.4.1 Catalase Test

Two drops of hydrogen peroxide were dropped on a clean grease free slide. An applicator stick was used to collect the test organism and then smeared on the drops of hydrogen peroxide and then observed for an immediate bubbling of gas which indicates a positive test (Cheesbrough, 2005).

3.5.2 Citrate Utilization Test

Simmon's citrate agar was prepared according to manufacturer's instruction and autoclaved at 121°C for 15 minutes. The autoclaved media was kept in a slanty position and allowed to solidify. Using a sterilized straight wire loop, the slope was streaked and the butt was stabbed

with a saline suspension of the test organism. This was Incubated at 37^0C for 48 hours and observed for colour change(Cheesbrough, 2005).

3.5.3 Indole Test

The test organism was inoculated into a tube containing tryptone water and incubated for 48 hours at 37^oC. Following 48 hours of incubation, 2 drops of kovac's reagent were added and observed for the formation of red ring at the surface of the medium which indicates positive test (Cheesbrough, 2005).

3.5.4 Triple sugar iron (TSI) Test

Triple sugar iron agar slant was streaked and stabbed (butt) with a saline suspension of the test organism and was incubated at 37^oC for 24 hours. Following 24 hours incubation, sugar fermentation, hydrogen sulphide production and gas formation will be observed. Yellow butt (acid production) and red pink slope indicate fermentation of glucose, cracks and bubbles in the medium indicates gas production from glucose fermentation. A yellow slope and a yellow butt indicate fermentation of lactose and glucose or lactose. Blackening along the stabbed line or throughout the medium indicate hydrogen sulphide production (Cheesbrough, 2005).

3.5.5 Methyl Red Voges Proskauer Test (MR-VP)

This will be carried out according to Fowale and Oso (1998). Two different tubes each containing MR-VP broth were inoculated with the suspended test organism, incubated at 37^oc for 2-3 days. Five drops of methyl red indicator were added to each tube. Red colour indicate negative (alkaline test). On the second tube of each organism, VP test was carried out by addition of 1ml napthol solution followed by 1ml of 40% KOH solution. This was agitated and allowed to

stand for about an hour and then observed. Pink to red colour indicates the presence of acetyl, methyl carbinol (VP-positive). A reddish brown colour indicates negative.

3.5 Enumeration of Fungi

This was carried out by pour plate technique and serial dilution (Egboh and Emeshili, 2007). Using fresh syringe, 1ml of sample from each of the dilution tubes was transferred into duplicate petridishes and labeled accordingly. This was followed by pouring cooled molten potato dextrose agar in each petridish, homogenized by swirling and allowed to solidify. Finally the plates were incubated at room temperature for 24-48 hours. Following incubation, plates that contain between 30-300 colonies were selected and average of the colonies from the two plates was multiplied by the inverse of the dilution factor to get cfu/ml.

3.6 Determination of physicochemical parameters

3.6.1 Physical analysis

a) **Odour:**The was determined using sensory evaluation (i.e. with nose) as carried out by (Ogundele, 2010).
b) **Colour:** This was also determined using sensory evaluation (Ogundele, 2010)
c) **pH:** This was determined using a digital pH meter. The sample was poured into 50ml beaker and the meter was dipped inside for a minute. The pH reading was taken directly from the meter.(Lawal and Lohdip, 2011)
d) **Temperature:** Temperature was determined using mercury-in-glass thermometer calibrated in degree centigrade (Lawal and Lohdip, 2011).
e) **Turbidity:** The turbidity of the sample was determined with a turbidity meter and the result obtained expressed in Nephelometric Turbidity Unit (NTU). Water sample was poured into

the tube and allowed to stand for some time, when mark disappeared; the value was taken and recorded in NTU(Lawal et al., 2011).

3.6.2 Chemical analysis

a) **Dissolved Oxygen (DO):** This was determined using dissolved oxygen meter as described by Aderomoti (1996). Zero oxygen solution was prepared by dissolving 2g of sodium sulphate in 100ml of sample. This was allowed to stand for 2-5 minutes. The 'CAL' key was pressed and the meter proof was inserted into prepared solution. This was allowed to stand for 30 seconds to calibrate, meter proof was also inserted into the sample, allowed to stand for a minute and the final reading was taken and recorded in mg/l.

b) **Nitrates (NO_3^{2-}):** This was carried out as described by Lawal and Lohdip (2013) with JENWAY 6305 UV/Vis spectrophotometre. A Nitrate Tests Standard Tablet was grinded and poured in spectrophotometric bottle containing 10ml of the sample. After about 10 minutes, the colour that developed was measured photometrically at 493nm against corresponding reagent blank (APHA, 2005).

c) **Phosphate (PO_4^{2-}):** This was carried out as describedby Lawal and Lohdip (2013) with JENWAY 6305 UV/Vis spectrophotometre. A Phosphate Tests Standard Tablet was grinded and poured in spectrophotometric bottle containing 10ml of the sample. After about 10 minutes, the colour that developed was measured photometrically at 690nm against corresponding reagent blank.

d) **Biochemical Oxygen Demand (BOD):** The Biochemical Oxygen Demand was determined using standard methods (APHA, 2005). The water sample in BOD bottle was thoroughly aerated after which it was seeded with 2ml diluted domestic waste water. The bottle was

sealed and incubated in the dark for 5 days at 20°C.. The BOD is the difference between the two determined DO levels as indicated below:

$$BODmg/l \quad = \quad (DO_0 - DO_5)$$

DO_O = Dissolved oxygen found in the sample on the initial day (initial day may be termed day Zero)

DO_5 = Dissolved oxygen found in the sample after incubation for 5 days.

e. Total Dissolved Solid (TDS): This was determined according to FAO procedures with a TDScan (Model A2352) meter. In each case, the waterproof meter was immersed into a beaker containing the collected samples. After about 5 minutes, the TDS reading on the meter was collected and recorded in mg/l (FAO, 1997).

CHAPTER FOUR

4.0 RESULTS

4.1 Microbiological Analyses of the Water Samples

Total plate counts (TPC) for aerobic Bacteria and Fungi in various water sources from various locations within Katsina Town shows high contamination especially in samples collected from irrigation, jerrycan and borehole sources.With the exception of water obtained from tap water, the analysis for the most probable number of coliform bacteriashows high contamination in water obtained from well, borehole, jerrycan and irrigation sources. This makes the water sources unfit for consumption without prior treatment. These analyses were presented in the tables below:

Table 4.1 Mean Microbial Counts (cfu/ml) from the Studied Locations

Water Source	Location	Mean APC (cfu/ml)	Mean CC (cfu/ml)	Mean FC (cfu/ml)	Detection of:		
					E. coli	*Salmonella*	*E. coli* 0157:H7
Tap Water	K/D	<1.0×10^1	0	<1.0×10^1	0	0`	0
	K/S	<3.0×10^1	0	<3.0×10^1	0	0	0
	K/M	<1.0×10^1	3±0.94	<1.0×10^1	0	0	0
	AJW	<1.0×10^1	0	<1.0×10^1	0	0	0
	K/KL	5.4×10^5	7±4.04	<1.0×10^1	0	0	0
Well Water	K/D	3.1×10^6	16±4.55	47.2×10^6	1	1	0
	K/S	2.6×10^5	29±15.27	3.0×10^5	3	2	0
	K/M	$3.6.2 \times 10^5$	74±59.99	3.09×10^5	4	2	0
	K/Y	3.38×10^6	9±3.04	8.7×10^5	1	2	0
	K/KL	9.5×10^3	21±6.73	4.23×10^4	2	1	0
	K/D	<3.0×10^1	8±1.47	<1.0×10^1	1	0	0
	K/S	2×10^1	8±2.73	8×10^1	0	0	0
Borehole Water	K/M	<1.0×10^1	13±3.49	<3.0×10^1	1	1	0
	K/Y	<3.0×10^1	7±1.66	<1.0×10^1	0	0	0
	K/KL	<3.0×10^1	6±2.33	<1.0×10^1	1	0	0
	K/D	9×10^4	9±2.39	2.0×10^6	1	1	0
	K/S	1.19×10^4	22±19.53	7.8×10^2	3	0	0
Jerrycan Water	K/M	4.9×10^5	18±3.81	5.0×10^6	2	2	0
	K/Y	6.1×10^5	21±36.9	4.8×10^6	2	0	0
	K/KL	5.4×10^5	7±4.04	8.4×10^3	1	1	0
	K/D	7.8×10^5	1600	1.11×10^7	5	4	0
	K/S	3.9×10^6	1316±635.4	10.02×10^5	5	5	0
Irrigation Water	K/M	5.9×10^6	9814±847.9	5.0×10^6	5	4	0
	AJW	<1.03×10^7	614483±290	5.7×10^4	5	5	0
	NSR	9.0×10^5	1600	2.63×10^5	5	5	0

KEY

APC - Aerobic Plate Count

CC - Coliform Count

FC - Fungal Count

K/D - Kofar Durbi

K/S - Kofar Sauri

K/M - Kofar Marusa

AJW - Ajiwa

K/KL - Kofar Kaura Layout

NSR - Nasarawa

4.2 Physicochemical Analyses of Water Samples from Various Water Sources in Katsina Town

The physicochemical Analyses of different water sources within Katsina Town showed that the samples colourless, odourless, tasteless but higher BOD, TDS and Nitrates were observed in some water sources in a level that is beyond the level specified by WHO for drinking water and FAO in case of water used for irrigation purpose. This information is presented in Table 4.4 as below

Table 4.2. Physico-chemical Parameters of the Water Samples Collected

	Location	Colour	Odour	pH (Mg/L)	Temp. (°C)	TDS (mg/L)	DO (mg/L)	BOD (mg/L)	NO_3 (mg/L)
Tap Water	K/D	Colourless	Odorless	6.9±0.75	19.8±1.64	51.2±13.31	0.84±0.11	0.144±0.11	0.008±0.01
	K/S	Colourless	Odorless	6.99±0.81	20.6±1.51	63.6±14.01	0.98±0.40	0.34±0.05	0.04±0.05
	K/M	Colourless	Odorless	7.0±0.85	20.8±2.51	39.6±8.32	1.18±0.13	0.74±0.11	0.006±0.01
	AJW	Colourless	Odorless	6.96±0.94	20.4±2.20	25.4±12.93	0.56±0.21	0.104±0.02	0.002±0.004
	K/KL	Colourless	Odorless	6.98.±0.76	22.2±1.81	20.4±1.70	1.04±0.11	0.406±0.41	0.002±0.004
Well Water	K/D	Colourless	Odorless	7.4±0.98	21.8±2.39	187.2±17.54	3.14±1.03	1.74±0.73	2.03±1.55
	K/S	Colourless	Odorless	6.79±1.02	22.2±1.92	152.8±34.02	1.84±0.36	0.76±0.18	0.93±0.68
	K/M	Colourless	Odorless	7.19±0.68	21.8±3.60	268.2±46.06	1.64±0.54	0.36±0.21	3.06±0.87
	K/Y	Colourless	Odorless	8.06±0.12	20.2±2.61	156.6±12.97	2.4±0.45	0.68±0.30	1.282±0.67
	K/KL	Colourless	Odorless	7.51±0.01	21±2.92	149.4±21.96	3.16±0.7	0.78±0.40	0.66±0.43
Borehole Water	K/D	Colourless	Odorless	7.69±1.32	22.8±2.30	339.6±65.81	1.78±0.33	0.28±0.11	0.432±0.14
	K/S	Colourless	Odorless	7.13±1.03	25±3.08	271.8±54.13	2.68±0.38	0.2±0.14	0.73±0.17
	K/M	Colourless	Odorless	8.04±1.23	21.4±2.3	127.4±28.53	2.08±0.41	0.98±0.26	0.37±0.04
	K/Y	Colourless	Odorless	8.16±1.31	19.2±1.30	173.8±55.01	2.68±0.41	2.32±0.8	0.92±0.21
	K/KL	Colourless	Odorless	7±0.64	23±1.41	247.6±44.7	1.8±0.32	0.4±0.2	0.81±0,18
Jerrycan Water	K/D	Colourless	Odorless	7.46±0.71	21.2±1.64	282.6±24.43	2.52±0.36	0.66±0.21	0.41±0.08
	K/S	Colourless	Odorless	7.22±0.61	22.2±2.8	164.4±36.53	2.88±0.31	1.28±0.13	1.678±0.36
	K/M	Colourless	Odorless	6.90±0.81	19.6±2.1	200.8±24.41	2.96±0.7	1.4±0.51	1.51±0.51
	K/Y	Colourless	Odorless	7.40±0.72	18.8±2.21	123.4±36.6	2.06±0.31	0.78±0.12	0.61±0.32
	K/KL	Colourless	Odorless	7.74±1.33	20.4±2.97	226.6±50.1	1.76±0.53	2.06±0.41	1.222±0.33
Irrigation Water	K/D	Turbid	Smelly	7.85±1.27	20±1.60	711.06±193.5	4.32±0.74	49.86±6.1	30.02±2.21
	K/S	Turbid	Smelly	7.81±1.2	24.2±3.6	719.22±95.42	2.94±0.55	54.08±1.84	29±3.9
	K/M	Turbid	Smelly	8.61±0.53	17.8±0.83	651.4±221.50	5.68±1.43	43.36±6.02	32.3±7.41
	AJW	Turbid	Smelly	8.30±0.91	22.4±3.64	389.24±56.93	5.9±2.20	18.52±1.04	17±3.2
	NSR	Turbid	Smelly	7.82±0.65	19.2±2.58	458.6±125.12	2.96±0.18	15.32±1.82	19.48±3.73

KEY

TDS-Total Dissolved Solid
DO-Dissolved Oxygen
BOD-Biochemical Oxygen Demand

CHAPTER FIVE

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 DISCUSSION

Results of the total bacteriological and fungal analysis of the various water samples from Katsina are presented in Tables 4.1. The result showed high bacterial and fungal loads in well water, borehole water, jerryacan and irrigation water sources. The total viable counts of bacteria for all water samples were quite high ranging from 9.5×10^3 in Kofar Kaura Layout to 3.9×10^6 in Kofar Sauri from water collected from wells. Bacterial counts from tap and borehole water sources are quite low, this may be due to the fact that tap water sources are effectively treated before they are released to the town and the boreholes are underground and hence contamination in them mostly occurs as a result of unhygienic behaviors at the surface as reported by (KEBS, 2005).

Very high bacterial counts were obtained in water from irrigation sources; the counts (cfu/ml) here was recorded as 7.8×10^6, 2.6×10^5, 4.9×10^5, 1.03×10^7 and 9.0×10^5 for Kofar Durbi, kofar Sauri, Kofar Marusa, Ajiwa and Nasarawa respectively. Analysis of variance shows significant differences between the bacterial counts of these locations. Previous studies in other parts of the country reported similar bacterial load indicative of poor water quality (Olayemi, 2005).

Similar result was also reported by Germs *et al.,* (2004) in their study of chemical and microbial water quality of the Chunies Water Sources – Limpopo. Therefore a potential health risk exists due to presence of high microbial counts some of which can be pathogens in water. The potential health effects that may be caused by these bacterial species include abscesses, ulcers, food poisoning, inflammation of breast and conjunctivitis in new born, nausea, vomiting, diarrhea,

urinary tract infections, appendicitis, meningitis, abdominal pain , pneumonia and bacteraemia (Cheesbrough, 2005;WHO, 2011).

Similarly, high fungal counts were also observed in well water, jerrycan and irrigation sources but are quite very low in water from tap and borehole sources. This varied count of fungal colony could be attributed to variation in level of treatment (for tap water), hygiene practices, sources of water and unhygienic environment.

The presence of fungal species in all the five water sources is probably due to contamination from one way or the other Similar observation was made by (Hageskal, 2006; Okpako, *et al.,* 2009; Tanveer, *et al*., 2011). However, the standard for drinking water by World Health Organization and Standards Organisation of Nigeria did not provide information about the occurrence and implication of fungi on human health in drinking water (SON, 2007 and WHO, 2011). The occurrence of these fungi may however lead to diverse effects on human health as they have the potential of producing mycotoxins.

5.1.2 Most Probable Number of Coliforms from the Different Water Sources

Most Probable Number of Coliforms results from the Different Water Sources is as shown in the tables. The most probable number of coliforms (MPN) per 100 ml in tap water was recorded as 0, 0, 3±0.94, 0 and 0 in Kofar Durbi, Kofar Sauri, Kofar Marusa, Kofar Kaura Layout and Ajiwa respectively. Based on a one way ANOVA test, it was found that there was no significant difference (>0.05) in the MPN of coliforms from tap water from all the five different sampling points. The most probable number which defined the degree of contamination and the microbiological quality of drinking water, going by the zero tolerance levels stipulated by regulatory agency for coliforms in drinking water, none of the tap water, well, borehole or

irrigation samples meet the existing standards. Previous studies in other parts of the country reported bacterial load indicative of poor water quality (Olayemi, 2005).

The most probable number of coliforms per 100 ml in well water ranges from 9±3.04 in wells from Kofar Yandaka to 74±59.99 in wells from Kofar Marusa. Statistical analysis observed shows significant difference (<0.05) between the MPN of coliforms in various wells from the study area. The presence of faecal coliform bacteria indicates that the water is contaminated with faecal human or animal waste. The well water is therefore not recommended for use without prior treatment (ANON, 2000).

Similar reports were obtained from borehole and jerrycan water sources. Lack proper environmental hygiene is one of the contributing factors in the contamination of underground water sources such as boreholes and in most cases the boreholes are constructed very near to the latrine systems of the communities, hence the presence of coliforms in larger amount (Sueiro *et al.,* 2001). High MPN counts for coliform were found in the water used for irrigation purposes, this however, is expected because the use for irrigation along Kofar Marusa, Kofar Durbi and Kofar Sauri mostly come from domestic sources and therefore higher coliform could be present. What was reported by this research corresponds to the findings of Yassin *et al*., (2006) were they evaluated microbiological water quality and its relation to human health in Gaza Governorate, Gaza Strip. They reported that total and coliform contamination in both, boreholes, water wells and networks generally exceeded that of WHO limit in Gaza Governorate. However, the level of contamination in networks was higher than that in wells, and it seems to occur mainly in winter and summer seasons. This may contribute to the prevalence of water-related diseases.

5.1.3 Distribution of *E. coli and Salmonella spp.* in the Different Water Sources

The Distribution of *E. coli and Salmonella spp.* in different water sources from different locations in Katsina was shown in Table 4.1. Neither *E. coli* nor *Salmonella* were isolated from tap water samples collected from each of the five locations. This is in agreement with the findings of Dada *et al.,* (1990) who detected *E. coli* in the water distribution system of Zaria Nigeria *E. coli* is generally considered an indicator organism whose presence reveals that fecal contamination has occurred and that enteric pathogens are likely to be present in the water (Garba *et al.,* 2010). However, they are both present in most of the locations in various water sources studied. As fecal coliforms, *E. coli and Salmonella* should not be detected in potable water (should record zero cfu per 100 ml of water) (WHO, 2004), Hence the presence of *E. coli and Salmonella* in all categories of water sources except tap water, confirms that most of the water sources are not fit for human consumption. This therefore means that the direct use of natural water sources in Katsina metropolis poses a health risk to the consumers. Under normal circumstances, water from boreholes supposed to be coliform free, but the fact that there is no proper sanitation close to where the boreholes are, may lead to the contamination of the water with enteric microbes as reported by Thornton (1987). According to Sueiro *et al*., (2001), *E.coli* count of particularly unprotected water sources can be explained by poor sanitation habit and hygiene education of the people. Since they dispose house hold wastes and defecate in an open field which can be washed and enter to the collecting chamber or open wells as a result it can cause contamination of the source and cause water related diseases. The result of this study was in line with earlier studies by (Worku.*et al*, 2000; Shewaye, *et. al*, 1999) which they reported that *E. coli* was identified in their studied water samples.

Presence of *Salmonella* in the irrigation water samples collected is not in agreement with EPA water standard for recreational use which states that this pathogenic organism must not be present in water, because they are of public health significance, having been associated with gastrointestinal infections such as diarrhoea, dysentery, typhoid fever and other form of infection (EPA, 2003). The presence of *E. coli, Salmonella spp* as well as *Shigella spp and Vibrio spp* have been documented as national primary drinking water regulations (NPDWRs) or primary standards which protect public health by limiting the levels of contaminants in drinking water (EPA, 2002).

5.1.4 Frequency of Occurrence of *E. coli* and *Salmonella spp.* in the Collected Water Samples

The frequency of occurrence of *E .coli* and *Salmonella spp* in water from the different sources varied widely. The highest occurrence was among the irrigation water. With the exception of tap water sources, *E. coli* was isolated in all the water sources with the highest frequency obtained from water used for irrigation purposes (100%) and only in few places *E. coli* was isolated from borehole sources. Ideally, borehole sources are *E. coli*-free but due to lack of proper sanitation, they too can be contaminated. Similar case was observed from the isolation of *Salmonella spp*, *Salmonella spp* was isolated from 88% of all water samples used for irrigation purposes and only in few places *Salmonella spp* was isolated from borehole sources. This result corresponds to the findings ofJeophita, (2010) in his study physico-chemical and bacteriological quality of water, and antimicrobial susceptibility of pathogenic isolates from selected water sources in Samburu South, Kenya.

5.1.5 Physico-chemical Parameters of Different Water Samples Collected

The physico-chemical parameters of different water samples collected from different locations within Katsina Town was shown in Table 4.2. The content were discussed as below:

Test for pH of water was carried out to determine the hydrogen ion concentration. The test reveals the pH values of tap water to range from 6.9±0.75 mg/l in Kofar Durbi to 7.0±0.85 mg/l in Kofar Marusa. From the well water, the pH values ranges from 6.79±1.02 mg/l in Kofar Sauri to 8.06±0.12 mg/l in Kofar Yandaka. The pH values obtained in borehole, jerrycan and irrigation water samples was found to range from 7±0.64mg/l to 8.16±1.31mg/l, 6.90±0.81 to 7.74±1.33mg/l and 7.81±1.2 to 8.61±0.53mg/l respectively. The mean values obtained for the five water sources are in most cases slightly above 6.5-7.0mg/l limit as recommended by WHO (2008) for drinking water. However, the water from irrigation sources are within the range of 6.0-8.5 as recommended by FAO (1997) for irrigation water. The findings also indicates there is no significant difference ($p>0.05$) between the calculated pH values between the five locations in all the five water sources. Although, the values indicate that the water samples are weakly acidic, this is in agreement with what was reported by other researchers in similar study that the samples they analyzed were also weakly acidic (Edimeh *et al.*, 2011; Aremu *et al.*, 2011; Igwemmar *et al.*, 2013).

The mean of the temperature of the water samples in tap water ranges from 19.8±1.64 to 22.2±1.81 in Kofar Durbi and Kofar Kaura Layout respectively, while in the well water from the five different locations it ranges from 20.2±2.61 in Kofar Kaura Layout and 22.2±1.92 in Kofar Sauri. In borehole, jerrycan and irrigation water, the temperature ranges from 19.2±1.30 to 25±3.08, 18.8±2.21 to 22.2±2.8 and 17.8±0.83 to 24.2±3.6 in the five studied location respectively. The temperature values fall within the acceptable temperature limit for drinking

water set by WHO (31.2-32°C). The findings also indicated that at 95% confidence level, there is significant difference between the calculated temperatures between the studied locations in each water sample (<0.05). Similar result was reported by Adeyemi and Ipinjolu, (1997). Temperature values are known to be dependent on climatic conditions at a particular geographical area and period of the day and therefore can be different from the ones reported.

In the present study, the values for TDS for tap water was recorded as 51.2±13.31, 63.6±14.01,39 .6±8.32, 25.4±12.93 and 20.4±1.70mg/l for Kofar Durbi, Kofar Sauri, Kofar Marusa, Ajiwa and Kofar Kaura Layout respectively. While the values for TDS in the well water ranges from 149.4±21.96 in Kofar Kaura Layout to 268.2±46.06 in Kofar Yandaka. TDS values in Borehole, jerrycan and irrigation water ranges from 127.4±28.53 to 339.6±65.81, 123.4±36.6 to 282.6±24.43 and 389.24±56.93 to 719.22±95.42 respectively. Higher TDS was observed in water use for irrigation as reported by other researchers in related studies (Amahmid *et al.,* 1999; Rattan *et al*., 2005). With the exception of the irrigation water, the values recorded for TDS are within the maximum permissible limits of WHO for drinking purpose. The water use for irrigation is lower than the TDS limit given by FAO for irrigation water (FAO, 1997; WHO, 2008). Significant differences between the five locations in all the five water sources were observed at 95% confidence level. Similar results for TDS were reported by other researchers (Aremu *et al.,* 2008; Jabbo *et al.,* 2012). Higher TDS can be toxic to aquatic life through increase in salinity or changes in the composition of the water and can harbor the growth of harmful microorganism rendering the source of water unfit for consumption. Primary sources for higher TDS in the dams might be due to agricultural runoff, discharge of domestic waste from the town and other human activities (Annalakshmi and Amsath, 2012).

Dissolved oxygen is essential for aquatic life, it plays the most important role in determining the potential biological quality of water (FAO, 1997). Decomposing organic matter, dissolved gases, industrial waste, mineral waste and agricultural runoff results to get higher lower DO levels (Srivastava *et al*., 2011; Addo *et al*., 2013). Concentration levels of DO below 5.0 mg/L adversely affect aquatic life (Sinha and Biswas, 2011). DO values in the present study were found to range from 0.84±0.11, 0.98±0.40, 1.18±0.13, 0.56±0.21 and 1.04±0.11mg/l from Kofar Durbi, Kofar Sauri, Kofar Marusa, Ajiwa and Kofar Kaura Layout respectively in samples collected from tap water. DO values obtained from well, borehole, jerrycan and irrigation water were found to range from 1.64±0.54 mg/l in Kofar marusa to 3.16±0.7 mg/l in Kofar Kaura Layout, 1.78±0.33 mg/l in Kofar Durbi to 2.68±0.41 mg/l in Kofar Yandaka, 1.76±0.53 mg/l in Kofar Kaura Layout to 2.88±0.31mg/l in Kofar Sauri and 2.94±0.55mg/l in Kofar Sauri to 2.96±0.18 mg/l in Nasarawa respectively. The value of DO in all the water samples collected are within the permissible limit of DO in drinking water as prescribed by (WHO, 2008). Based on a one way ANOVA test, it was found that there was a significant difference in DO value between the five locations in all the water sources (<0.05).

There is significant difference (P<0.05) between the BOD values of the five locations in all the five water sources. With the exception of water use for irrigation, all the other water sources had their BOD within the 2.0-5.0mg/l limit as prescribed by the WHO. The values of BOD for irrigation water are well above permissible limits for drinking water set by WHO and FAO standard for irrigation water (FAO, 1997; WHO, 2008). Mustapha, (2008) made similar observations in Oyun Reservoir, Offa. High BOD might be as the result of organic matter brought by runoff. High BOD also encourages the growth of harmful microorganisms.

The concentration of nitrates in water samples depends on the nitrification activities of micro-organisms (Igwemmar *et al.*, 2013). The result of nitrate from tap water was recorded as 0.008±0.01, 0.04±0.05, 0.006±0.01, 0.002±0.004 and 0.002±0.004 in Kofar Durbi, Kofar Sauri, Kofar Marusa, Ajiwa and Kofar Kaura Layout respectively. For well water, the value ranges from 0.66±0.43 to 3.06±0.87 while for borehole, jerrycan and irrigation water the values ranges from 0.92±0.21 to 0.81±0,18, 0.61±0.32 to 1.678±0.36 and 17±3.2 to 32.3±7.41 respectively. The highest nitrate values from irrigation water indicate contamination from agricultural sources. Except water from irrigation sources, the values for nitrate are well below the permissible limit for drinking water set by WHO (0.30 - 4.60 mg/l). However, water from irrigation sources are also below the 50mg/l permissible level set by FAO for irrigation water (FAO, 1997; WHO, 2008). The findings also indicated that at 95% confidence level, there is significant difference between the calculated nitrates of the locations in all the five water sources (<0.05). In general, vegetables are the main source of nitrates intake when level in drinking water is below 10 mg/l. Makhijani and Manoharan (1999) reported high level of nitrates in drinking water due to excessive use of agricultural fertilizers, decayed vegetable water, domestic effluents, sewage disposal industrial discharges, leachable from refuse dumps, and atmospheric precipitation has become a serious problem.

The lowest phosphate values were as expected obtained from tap water samples while highest Phosphate values were obtained from irrigation sources, the values for phosphate from tap, well, borehole and jerrycan water were below the WHO standard while the values of phosphates from irrigation water were higher than the WHO standard but well below the FAO standards for irrigation water (FAO, 1997; WHO, 2008). The findings also indicate that at 95% confidence level, significant differences exists between the calculated phosphates of the five locations in

each water source (<0.05). The observation is also in agreement with the findings of Aremu *et al.*, (2008).

Water from tap, borehole and Jerrycan were clear with turbidy readings of less than 5NTU. Turbidity readings from the well sources ranges from 11.4±5.41 NTU in Kofar Kaura Layout to 51.4±23.23 NTU from Kofar Sauri while from irrigation sources it ranges from 27.8±3.03 NTU in Kofar Durbi to 440±8944 NTU in Nasarawa. The turbity from well water and irrigation water are higher than the WHO standards for drinking water.

5.2 Conclusion

With the exception of water from tap water and borehole sources, high bacterial and fungal counts were observed from well, jerrycan and irrigation sources. The presences of these fungal and bacterial species could have significantly affected the quality of the water. High MPN coliform counts were also observed in well, jerrycan and irrigation water sources. This indicates fecal contamination in this sources which may arise from lack of proper environmental hygiene which contributes to the contamination of underground water sources. Indicator organisms such as *E. coli* and *Salmonella spp.* were also isolated from most of the water sources analyzed. Isolation of indicator organisms suggests the level of risk from associated pathogens and this is the reason why World Health Organization suggests that no indicator organism should be presented in drinking water sources. The physico-chemical properties of water from most sources in Katsina Town meet the recommended standards for portabilityas set by WHO except in the case of water use for irrigation purposes where it's TDS, DO, BOD, Nitrates and Phosphates contents went above the WHO prescribed level. However, the level of these parameters in water for irrigation purpose was within the required level for agricultural activities as prescribed by FAO (1997).

5.3 Recommendations

Base on the research carried out, the following recommendations were given:

i. Appropriate and affordable water disinfection techniques such as boiling and filtration should be carried out in the study area.

ii. Furthermore, to safeguard the health of the people there is need for regular monitoring of the quality of the water sources and environment in Katsina Town.

iii. Monitoring should be continuous to capture seasonal variability with more replication of samples to increase the precision margin.

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Appendix

Appendix 1

Biochemical Tests of the Water Samples Collected

Gram Staining	Motility	Colonies Morphology	Catalase	Citrate Utilization	Gas Formation	H_2S	Colour	MR	VP
Gram –ve		Metallic green sheen on EMB	Positive	Negative	Positive	Negative	A/A	Positive	Negative
Gram –ve	Positive	Pale Colonies with black dot at the centre on SSA	Positive	Positive	Positive	Positive	K/A	Positive	Negative

Appendix 2: Statistical Analyses of Physico-chemical Parameters

TAP WATER

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ONEWAY pH Temp TDS DO BOD Nitrate Phosphate Turbidity BY Group
  /MISSING ANALYSIS
  /POSTHOC=DUNCAN ALPHA(0.05).
```

Oneway

ANOVA

		Sum of Squares	Df	Mean Square	F	Sig.
pH	Between Groups	.996	4	.249	.373	.825
	Within Groups	13.339	20	.667		
	Total	14.335	24			
Temp	Between Groups	15.760	4	3.940	1.026	.418
	Within Groups	76.800	20	3.840		
	Total	92.560	24			
TDS	Between Groups	6399.360	4	1599.840	13.051	.000
	Within Groups	2451.600	20	122.580		
	Total	8850.960	24			
DO	Between Groups	1.108	4	.277	5.700	.003
	Within Groups	.972	20	.049		
	Total	2.080	24			
BOD	Between Groups	1.291	4	.323	8.365	.000
	Within Groups	.772	20	.039		
	Total	2.063	24			
Nitrate	Between Groups	.005	4	.001	2.888	.049
	Within Groups	.009	20	.000		
	Total	.014	24			
Phosphate	Between Groups	.004	4	.001	5.989	.002
	Within Groups	.004	20	.000		
	Total	.008	24			
Turbidity	Between Groups	.000	4	.000	.	.
	Within Groups	.000	20	.000		
	Total	.000	24			

Post Hoc Tests DUNCAN

Homogeneous Subsets

Ph

Duncan

Group	N	Subset for alpha = 0.05
		1
Kofar Durbi	5	6.9040
Ajiwa	5	6.9600
Kofar Sauri	5	6.9980
Kofar Kaura Layout	5	7.3100
Kofar Marusa	5	7.3960
Sig.		.403

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

Temp

Duncan

Group	N	Subset for alpha = 0.05
		1
Kofar Durbi	5	19.8000
Ajiwa	5	20.4000
Kofar Sauri	5	20.6000
Kofar Marusa	5	20.8000
Kofar Kaura LAyout	5	22.2000
Sig.		.096

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

TDS

Duncan

Group	N	Subset for alpha = 0.05			
		1	2	3	4
Kofar Kaura LAyout	5	20.4000			
Ajiwa	5	25.4000	25.4000		
Kofar Marusa	5		39.6000	39.6000	
Kofar Durbi	5			51.2000	51.2000
Kofar Sauri	5				63.6000
Sig.		.483	.056	.113	.092

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

DO

Duncan

Group	N	Subset for alpha = 0.05		
		1	2	3
Ajiwa	5	.5600		
Kofar Durbi	5	.8400	.8400	
Kofar Sauri	5		.9800	.9800
Kofar Kaura LAyout	5		1.0400	1.0400
Kofar Marusa	5			1.1800
Sig.		.058	.189	.189

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

BOD

Duncan

Group	N	Subset for alpha = 0.05		
		1	2	3
Ajiwa	5	.1040		
Kofar Durbi	5	.1440	.1440	
Kofar Sauri	5	.3400	.3400	
Kofar Kaura LAyout	5		.4060	
Kofar Marusa	5			.7400
Sig.		.086	.058	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

Nitrate

Duncan

Group	N	Subset for alpha = 0.05	
		1	2
Ajiwa	5	.0020	
Kofar Kaura LAyout	5	.0020	
Kofar Marusa	5	.0060	
Kofar Durbi	5	.0080	
Kofar Sauri	5		.0400
Sig.		.687	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

Phosphate

Group	N	Subset for alpha = 0.05	
		1	2
Kofar Durbi	5	.0020	
Ajiwa	5	.0060	
Kofar Kaura LAyout	5	.0140	
Kofar Marusa	5	.0200	
Kofar Sauri	5		.0400
Sig.		.068	1.000
Means for groups in homogeneous subsets are displayed.			
a. Uses Harmonic Mean Sample Size = 5.000.			

BOREHOLE

```
ONEWAY pH Temp TDS DO BOD Nitrate Phosphate Turbidity BY Group
  /MISSING ANALYSIS
  /POSTHOC=DUNCAN ALPHA(0.05).
```

Oneway

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
pH	Between Groups	5.475	4	1.369	1.056	.404
	Within Groups	25.914	20	1.296		
	Total	31.389	24			
Temp	Between Groups	92.240	4	23.060	4.865	.007
	Within Groups	94.800	20	4.740		
	Total	187.040	24			
TDS	Between Groups	138667.760	4	34666.940	13.287	.000
	Within Groups	52183.200	20	2609.160		
	Total	190850.960	24			
DO	Between Groups	4.058	4	1.014	7.319	.001
	Within Groups	2.772	20	.139		
	Total	6.830	24			
BOD	Between Groups	15.634	4	3.908	25.346	.000
	Within Groups	3.084	20	.154		
	Total	18.718	24			
Nitrate	Between Groups	1.158	4	.289	11.132	.000
	Within Groups	.520	20	.026		
	Total	1.678	24			
Phosphate	Between Groups	.852	4	.213	1.081	.392
	Within Groups	3.940	20	.197		
	Total	4.792	24			
Turbidity	Between Groups	.000	4	.000	.	.
	Within Groups	.000	20	.000		
	Total	.000	24			

Post Hoc Tests DUNCAN

Homogeneous Subsets

pH

Duncan

Group	N	Subset for alpha = 0.05
		1
Kofar Kaura Layout	5	7.0000
Kofar Sauri	5	7.1280
Kofar Durbi	5	7.6880
Kofar Marusa	5	8.0420
Kofar Yandaka	5	8.1560
Sig.		.164

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

Temp

Duncan

Group	N	Subset for alpha = 0.05		
		1	2	3
Kofar Yandaka	5	19.2000		
Kofar Marusa	5	21.4000	21.4000	
Kofar Durbi	5		22.8000	22.8000
Kofar Kaura Layout	5		23.0000	23.0000
Kofar Sauri	5			25.0000
Sig.		.126	.285	.145

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

\

TDS

Duncan

Group	N	Subset for alpha = 0.05		
		1	2	3
Kofar Marusa	5	127.4000		
Kofar Yandaka	5	173.8000		
Kofar Kaura Layout	5		247.6000	
Kofar Sauri	5		271.8000	
Kofar Durbi	5			339.6000
Sig.		.166	.463	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

DO

Duncan

Group	N	Subset for alpha = 0.05	
		1	2
Kofar Durbi	5	1.7800	
Kofar Kaura Layout	5	1.8000	
Kofar Marusa	5	2.0800	
Kofar Yandaka	5		2.6800
Kofar Sauri	5		2.6800
Sig.		.242	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

BOD

Duncan

Group	N	Subset for alpha = 0.05		
		1	2	3
Kofar Sauri	5	.2000		
Kofar Durbi	5	.2800		
Kofar Kaura Layout	5	.4000		
Kofar Marusa	5		.9800	
Kofar Yandaka	5			2.3200
Sig.		.456	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

Nitrate

Duncan

Group	N	Subset for alpha = 0.05	
		1	2
Kofar Marusa	5	.3700	
Kofar Durbi	5	.4320	
Kofar Sauri	5		.7280
Kofar Kaura Layout	5		.8100
Kofar Yandaka	5		.9220
Sig.		.550	.086

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

Phosphate

Duncan

Group	N	Subset for alpha = 0.05
		1
Kofar Marusa	5	1.0960
Kofar Kaura Layout	5	1.1040
Kofar Yandaka	5	1.3500
Kofar Durbi	5	1.4480
Kofar Sauri	5	1.5580
Sig.		.154

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

JERRYCAN

```
ONEWAY pH Temp TDS DO BOD Nitrate Phosphate Turbidity BY Group
  /MISSING ANALYSIS
  /POSTHOC=DUNCAN ALPHA(0.05).
```

Oneway

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
pH	Between Groups	1.924	4	.481	.643	.638
	Within Groups	14.953	20	.748		
	Total	16.877	24			
Temp	Between Groups	35.360	4	8.840	1.567	.222
	Within Groups	112.800	20	5.640		
	Total	148.160	24			
TDS	Between Groups	73324.560	4	18331.140	14.385	.000
	Within Groups	25485.600	20	1274.280		
	Total	98810.160	24			
DO	Between Groups	5.386	4	1.346	6.188	.002
	Within Groups	4.352	20	.218		
	Total	9.738	24			
BOD	Between Groups	6.238	4	1.559	16.980	.000
	Within Groups	1.837	20	.092		
	Total	8.074	24			
Nitrate	Between Groups	6.166	4	1.541	13.393	.000
	Within Groups	2.302	20	.115		
	Total	8.468	24			
Phosphate	Between Groups	15.366	4	3.841	14.030	.000
	Within Groups	5.476	20	.274		
	Total	20.842	24			
Turbidity	Between Groups	.000	4	.000	.	.
	Within Groups	.000	20	.000		
	Total	.000	24			

Post Hoc Tests

Homogeneous Subsets

pH

Duncan

Group	N	Subset for alpha = 0.05
		1
Kofar Marusa	5	6.9020
Kofar Sauri	5	7.2180
Kofar Yandaka	5	7.4020
Kofar Durbi	5	7.4600
Kofar Kaura Layout	5	7.7400
Sig.		.183

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

Temp

Duncan

Group	N	Subset for alpha = 0.05
		1
Kofar Yandaka	5	18.8000
Kofar Marusa	5	19.6000
Kofar Kaura Layout	5	20.4000
Kofar Durbi	5	21.2000
Kofar Sauri	5	22.2000
Sig.		.054

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

TDS

Duncan

Group	N	Subset for alpha = 0.05			
		1	2	3	4
Kofar Yandaka	5	123.4000			
Kofar Sauri	5	164.4000	164.4000		
Kofar Marusa	5		200.8000	200.8000	
Kofar Kaura Layout	5			226.6000	
Kofar Durbi	5				282.6000
Sig.		.084	.123	.267	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

DO

Duncan

Group	N	Subset for alpha = 0.05		
		1	2	3
Kofar Kaura Layout	5	1.7600		
Kofar Yandaka	5	2.0600	2.0600	
Kofar Durbi	5		2.5200	2.5200
Kofar Sauri	5			2.8800
Kofar Marusa	5			2.9600
Sig.		.321	.135	.173

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

BOD

Duncan

Group	N	Subset for alpha = 0.05		
		1	2	3
Kofar Durbi	5	.6600		
Kofar Yandaka	5	.7800		
Kofar Sauri	5		1.2800	
Kofar Marusa	5		1.4000	
Kofar Kaura Layout	5			2.0600
Sig.		.538	.538	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

Nitrate

Duncan

Group	N	Subset for alpha = 0.05	
		1	2
Kofar Durbi	5	.4120	
Kofar Yandaka	5	.6080	
Kofar Kaura Layout	5		1.2220
Kofar Marusa	5		1.5120
Kofar Sauri	5		1.6780
Sig.		.372	.057

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

Phosphate

Duncan

Group	N	Subset for alpha = 0.05		
		1	2	3
Kofar Kaura Layout	5	.6900		
Kofar Yandaka	5	1.0600	1.0600	
Kofar Durbi	5		1.4440	
Kofar Marusa	5			2.3720
Kofar Sauri	5			2.7640
Sig.		.277	.260	.250

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

WELL WATER

```
ONEWAY pH Temp TDS DO BOD Nitrate Phosphate Turbidity BY Group
  /MISSING ANALYSIS
  /POSTHOC=DUNCAN ALPHA(0.05).
```

Oneway

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
pH	Between Groups	4.361	4	1.090	1.152	.361
	Within Groups	18.924	20	.946		
	Total	23.284	24			
Temp	Between Groups	12.800	4	3.200	.429	.786
	Within Groups	149.200	20	7.460		
	Total	162.000	24			
TDS	Between Groups	50072.560	4	12518.140	14.770	.000
	Within Groups	16950.800	20	847.540		
	Total	67023.360	24			
DO	Between Groups	10.034	4	2.508	5.756	.003
	Within Groups	8.716	20	.436		
	Total	18.750	24			
BOD	Between Groups	5.366	4	1.341	8.004	.001
	Within Groups	3.352	20	.168		
	Total	8.718	24			
Nitrate	Between Groups	18.768	4	4.692	5.500	.004
	Within Groups	17.062	20	.853		
	Total	35.830	24			
Phosphate	Between Groups	.500	4	.125	6.523	.002
	Within Groups	.383	20	.019		
	Total	.883	24			
Turbidity	Between Groups	4455.440	4	1113.860	5.934	.003
	Within Groups	3754.400	20	187.720		
	Total	8209.840	24			

Post Hoc Tests

Homogeneous Subsets

pH

Duncan

Group	N	Subset for alpha = 0.05
		1
Kofar Sauri	5	6.7920
Kofar Marusa	5	7.1880
Kofar Durbi	5	7.4740
Kofar Kaura Layout	5	7.5060
Kofar Yandaka	5	8.0640
Sig.		.076

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

Temp

Duncan

Group	N	Subset for alpha = 0.05
		1
Kofar Yandaka	5	20.2000
Kofar Kaura Layout	5	21.0000
Kofar Durbi	5	21.8000
Kofar Marusa	5	21.8000
Kofar Sauri	5	22.2000
Sig.		.311

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

TDS

Duncan

Group	N	Subset for alpha = 0.05	
		1	2
Kofar Kaura Layout	5	149.4000	
Kofar Sauri	5	152.8000	
Kofar Yandaka	5	156.6000	
Kofar Durbi	5	187.2000	
Kofar Marusa	5		268.2000
Sig.		.073	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

\

DO

Duncan

Group	N	Subset for alpha = 0.05	
		1	2
Kofar Marusa	5	1.6420	
Kofar Sauri	5	1.8400	
Kofar Yandaka	5	2.4000	2.4000
Kofar Durbi	5		3.1400
Kofar Kaura Layout	5		3.1600
Sig.		.100	.099

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

BOD

Duncan

Group	N	Subset for alpha = 0.05	
		1	2
Kofar Marusa	5	.3600	
Kofar Yandaka	5	.6800	
Kofar Sauri	5	.7600	
Kofar Kaura Layout	5	.7800	
Kofar Durbi	5		1.7400
Sig.		.152	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

Nitrate

Duncan

Group	N	Subset for alpha = 0.05		
		1	2	3
Kofar Kaura Layout	5	.6580		
Kofar Sauri	5	.9300	.9300	
Kofar Yandaka	5	1.2820	1.2820	
Kofar Durbi	5		2.0300	2.0300
Kofar Marusa	5			3.0600
Sig.		.325	.089	.093

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

Phosphate

Group	N	Subset for alpha = 0.05	
		1	2
Kofar Kaura Layout	5	.5300	
Kofar Yandaka	5		.7540
Kofar Durbi	5		.8200
Kofar Sauri	5		.9100
Kofar Marusa	5		.9160
Sig.		1.000	.104

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

Turbidity

Duncan

Group	N	Subset for alpha = 0.05	
		1	2
Kofar Kaura Layout	5	11.4000	
Kofar Yandaka	5	20.0000	
Kofar Durbi	5	25.2000	
Kofar Marusa	5	26.6000	
Kofar Sauri	5		51.4000
Sig.		.122	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

IRRIGATION WATER

Oneway

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
pH	Between Groups	2.487	4	.622	.706	.597
	Within Groups	17.610	20	.881		
	Total	20.097	24			
Temp	Between Groups	131.440	4	32.860	4.577	.009
	Within Groups	143.600	20	7.180		
	Total	275.040	24			
TDS	Between Groups	463049.718	4	115762.429	5.055	.006
	Within Groups	457976.112	20	22898.806		
	Total	921025.830	24			
DO	Between Groups	40.460	4	10.115	6.488	.002
	Within Groups	31.180	20	1.559		
	Total	71.640	24			
BOD	Between Groups	6530.542	4	1632.636	100.971	.000
	Within Groups	323.388	20	16.169		
	Total	6853.930	24			
Nitrate	Between Groups	936.964	4	234.241	11.869	.000
	Within Groups	394.696	20	19.735		
	Total	1331.660	24			
Phosphate	Between Groups	165909.290	4	41477.322	17.410	.000
	Within Groups	47646.388	20	2382.319		
	Total	213555.678	24			
Turbidity	Between Groups	882717.360	4	220679.340	96.493	.000
	Within Groups	45740.000	20	2287.000		
	Total	928457.360	24			

Post Hoc Tests

Homogeneous Subsets

pH

Duncan

Group	N	Subset for alpha = 0.05
		1
Nasarawa	5	7.8220
Kofar Durbi	5	7.8480
Kofar Sauri	5	7.8580
Ajiwa	5	8.3020
Kofar Marusa	5	8.6080
Sig.		.248

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

Temp

Duncan

Group	N	Subset for alpha = 0.05		
		1	2	3
Kofar Marusa	5	17.8000		
Nasarawa	5	19.2000	19.2000	
Kofar Durbi	5	20.0000	20.0000	
Ajiwa	5		22.4000	22.4000
Kofar Sauri	5			24.2000
Sig.		.234	.088	.301

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

TDS

Duncan

Group	N	Subset for alpha = 0.05		
		1	2	3
Ajiwa	5	389.2400		
Nasarawa	5	458.6000	458.6000	
Kofar Marusa	5		651.4000	651.4000
Kofar Durbi	5			711.0600
Kofar Sauri	5			719.2200
Sig.		.477	.058	.511

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

DO

Duncan

Group	N	Subset for alpha = 0.05	
		1	2
Kofar Sauri	5	2.9400	
Nasarawa	5	2.9600	
Kofar Durbi	5	4.3200	4.3200
Kofar Marusa	5		5.6800
Ajiwa	5		5.9000
Sig.		.113	.072

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

BOD

Duncan

Group	N	Subset for alpha = 0.05		
		1	2	3
Nasarawa	5	15.3200		
Ajiwa	5	18.5200		
Kofar Marusa	5		43.3600	
Kofar Durbi	5			49.8600
Kofar Sauri	5			54.0800
Sig.		.223	1.000	.113

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

Nitrate

Duncan

Group	N	Subset for alpha = 0.05	
		1	2
Ajiwa	5	17.0000	
Nasarawa	5	19.4800	
Kofar Sauri	5		29.0000
Kofar Durbi	5		30.0200
Kofar Marusa	5		32.3000
Sig.		.388	.280

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

Phosphate

Duncan

Group	N	Subset for alpha = 0.05		
		1	2	3
Ajiwa	5	143.0000		
Nasarawa	5	166.0000		
Kofar Durbi	5		232.0800	
Kofar Marusa	5			325.3000
Kofar Sauri	5			344.8000
Sig.		.465	1.000	.535

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

Turbidity

Duncan

Group	N	Subset for alpha = 0.05	
		1	2
Kofar Durbi	5	27.8000	
Kofar Sauri	5	65.4000	
Kofar Marusa	5	81.0000	
Ajiwa	5		440.0000
Nasarawa	5		440.0000
Sig.		.111	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

Appendix 3: Statistical Analyses for Microbial Analysis

Tap Water

```
ONEWAY APC FC MPN BY Group
  /MISSING ANALYSIS
  /POSTHOC=DUNCAN ALPHA(0.05).
```

Oneway

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
APC	Between Groups	16.000	4	4.000	1.026	.418
	Within Groups	78.000	20	3.900		
	Total	94.000	24			
FC	Between Groups	16.000	4	4.000	2.105	.118
	Within Groups	38.000	20	1.900		
	Total	54.000	24			
MPN	Between Groups	14.234	4	3.558	24.989	.000
	Within Groups	2.848	20	.142		
	Total	17.082	24			

Post Hoc Tests

Homogeneous Subsets

APC

Duncan

Group	N	Subset for alpha = 0.05
		1
Kofar Durbi	5	.8000
Kofar Marusa	5	.8000
Kofar Kaura Layout	5	.8000
Ajiwa	5	.8000
Kofar Sauri	5	2.8000
Sig.		.165

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

FC

Duncan

Group	N	Subset for alpha = 0.05
		1
Kofar Durbi	5	.8000
Kofar Marusa	5	.8000
Kofar Kaura Layout	5	.8000
Ajiwa	5	.8000
Kofar Sauri	5	2.8000
Sig.		.051

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

MPN

Duncan

Group	N	Subset for alpha = 0.05		
		1	2	3
Kofar Durbi	5	.0000		
Kofar Sauri	5	.0000		
Kofar Kaura Layout	5	.0000		
Kofar Marusa	5		.8000	
Ajiwa	5			1.9200
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

Borehole

```
ONEWAY APC FC MPN BY Group
  /MISSING ANALYSIS
  /POSTHOC=DUNCAN ALPHA(0.05).
```

Oneway

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
APC	Between Groups	1280.560	4	320.140	4.315	.011
	Within Groups	1484.000	20	74.200		
	Total	2764.560	24			
FC	Between Groups	37082.560	4	9270.640	2.132	.114
	Within Groups	86964.800	20	4348.240		
	Total	124047.360	24			
MPN	Between Groups	395.578	4	98.894	20.868	.000
	Within Groups	94.780	20	4.739		
	Total	490.358	24			

Post Hoc Tests

Homogeneous Subsets

APC

Duncan

Group	N	Subset for alpha = 0.05	
		1	2
Kofar Marusa	5	.8000	
Kofar Kaura Layout	5	2.6000	
Kofar Yandaka	5	2.6000	
Kofar Durbi	5	2.8000	
Kofar Sauri	5		20.0000
Sig.		.741	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

FC

Duncan

Group	N	Subset for alpha = 0.05
		1
Kofar Yandaka	5	.6000
Kofar Kaura Layout	5	.8000
Kofar Marusa	5	2.8000
Kofar Durbi	5	80.0000
Kofar Sauri	5	80.0000
Sig.		.101

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

MPN

Duncan

Group	N	Subset for alpha = 0.05		
		1	2	3
Kofar Durbi	5	.8000		
Kofar Kaura Layout	5		6.1800	
Kofar Yandaka	5		7.4000	
Kofar Sauri	5		8.2400	
Kofar Marusa	5			13.2000
Sig.		1.000	.172	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

Well Water

```
ONEWAY APC FC MPN BY Group
  /MISSING ANALYSIS
  /POSTHOC=DUNCAN ALPHA(0.05).
```

Oneway

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
APC	Between Groups	37060779532256.000	4	9265194883064.000	.958	.452
	Within Groups	193457645769480.000	20	9672882288474.000		
	Total	230518425301736.000	24			
FC	Between Groups	73163778849744.020	4	18290944712436.004	6.447	.002
	Within Groups	56746170938720.000	20	2837308546936.000		
	Total	129909949788464.020	24			
MPN	Between Groups	13292.738	4	3323.184	4.254	.012
	Within Groups	15623.728	20	781.186		
	Total	28916.466	24			

Post Hoc Tests

Homogeneous Subsets

APC

Duncan

Group	N	Subset for alpha = 0.05
		1
Kofar Marusa	5	362052.0000
Kofar Kaura Layout	5	952100.0000
Kofar Sauri	5	2634000.0000
Kofar Durbi	5	3176000.0000
Kofar Yandaka	5	3377140.0000
Sig.		.183

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

FC

Duncan

Group	N	Subset for alpha = 0.05	
		1	2
Kofar Sauri	5	300000.0000	
Kofar Marusa	5	308506.0000	
Kofar Kaura Layout	5	423000.0000	
Kofar Yandaka	5	874300.0000	
Kofar Durbi	5		4720900.0000
Sig.		.628	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

MPN

Duncan

Group	N	Subset for alpha = 0.05	
		1	2
Kofar Yandaka	5	9.3800	
Kofar Durbi	5	16.2000	
Kofar Kaura Layout	5	20.6000	
Kofar Sauri	5	29.0000	
Kofar Marusa	5		74.2000
Sig.		.322	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

Jerrycan

```
ONEWAY APC FC MPN BY Group
  /MISSING ANALYSIS
  /POSTHOC=DUNCAN ALPHA(0.05).
```

Oneway

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
APC	Between Groups	79545793542784.000	4	19886448385696.000	2.221	.103
	Within Groups	179086178234720.000	20	8954308911736.000		
	Total	258631971777504.000	24			
FC	Between Groups	120806955080375.840	4	30201738770093.960	.788	.546
	Within Groups	766384484811562.000	20	38319224240578.100		
	Total	887191439891937.900	24			
MPN	Between Groups	2349531.184	4	587382.796	612.562	.000
	Within Groups	19177.916	20	958.896		
	Total	2368709.100	24			

Post Hoc Tests

Homogeneous Subsets

APC

Duncan

Group	N	Subset for alpha = 0.05	
		1	2
Kofar Durbi	5	90840.0000	
Kofar Kaura Layout	5	546000.0000	
Kofar Yandaka	5	619456.0000	
Kofar Sauri	5	1191740.0000	1191740.0000
Kofar Marusa	5		4984800.0000
Sig.		.601	.059

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

FC

Duncan

Group	N	Subset for alpha = 0.05
		1
Kofar Sauri	5	22.8000
Kofar Kaura Layout	5	8402.6000
Kofar Durbi	5	2079320.0000
Kofar Yandaka	5	4806070.0000
Kofar Marusa	5	5006100.0000
Sig.		.264

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

MPN

Duncan

Group	N	Subset for alpha = 0.05	
		1	2
Kofar Kaura Layout	5	7.0800	
Kofar Durbi	5	9.0000	
Kofar Marusa	5	18.0000	
Kofar Yandaka	5	20.7200	
Kofar Sauri	5		780.0000
Sig.		.532	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

Irrigation

```
ONEWAY APC FC MPN BY Group
  /MISSING ANALYSIS
  /POSTHOC=DUNCAN ALPHA(0.05).
```

Oneway

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
APC	Between Groups	595581399688249.000	4	148895349922062.250	2.576	.069
	Within Groups	1156035874732722.800	20	57801793736636.140		
	Total	1751617274420971.800	24			
FC	Between Groups	2324551905329687.500	4	581137976332421.900	.842	.515
	Within Groups	13811879321846588.000	20	690593966092329.400		
	Total	16136431227176276.000	24			
MPN	Between Groups	294394104.000	4	73598526.000	5.079	.005
	Within Groups	289843318.000	20	14492165.900		
	Total	584237422.000	24			

Post Hoc Tests

Homogeneous Subsets

APC

Duncan

Group	N	Subset for alpha = 0.05	
		1	2
Kofar Sauri	5	394574.8000	
Kofar Marusa	5	594672.0000	
Nasarawa	5	908200.0000	
Kofar Durbi	5	7888840.0000	7888840.0000
Ajiwa	5		12414720.0000
Sig.		.168	.358

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

FC

Duncan

Group	N	Subset for alpha = 0.05
		1
Ajiwa	5	68959.6000
Kofar Sauri	5	102000.0000
Kofar Marusa	5	8208341.2000
Kofar Durbi	5	11199800.0000
Nasarawa	5	26340000.0000
Sig.		.170

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.

MPN

Duncan

Group	N	Subset for alpha = 0.05	
		1	2
Nasarawa	5	614.0000	
Kofar Sauri	5	1316.0000	
Kofar Durbi	5	1600.0000	
Ajiwa	5	1600.0000	
Kofar Marusa	5		9814.0000
Sig.		.712	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 5.000.