THE EFFECT OF COMMUNITY SANITATION PRACTICE ON WATER QUALITY IN SELECTED COMMUNITIES IN JALINGO, TARABA STATE, NIGERIA

BY

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A DISSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES AHMADU BELLO UNIVERSITY, ZARIA NIGERIA IN PARTIAL FULFILLMENT FOR THE AWARD OF MSC. WATER RESOURCES AND ENVIRONMENTAL ENGINEERING

DEPARTMENT OF WATER RESOURCES AND ENVIRONMENTAL ENGINEERING AHMADU BELLO UNIVERSITY,

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DECLARATION

I declare that the work in this dissertation entitled: "**The Effect of Community Sanitation Practices on Water Qualityin Selected Communities in Jalingo, Taraba State, Nigeria"** has been carried out by me in the Department of Water Resources and Environmental Engineering under the supervision of Prof D. B. Adieand Dr (Mr**s)** F. B. Ibrahim. The information derived from literaturehas been duly acknowledged in the text and a list of references provided. No part of this dissertation was previously presented for another degree or diploma at any other institution.

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CERTIFICATION

This dissertation entitled: "**The Effect of Community Sanitation Practices on Water Quality in Selected Communities in Jalingo, Taraba State, Nigeria" by Emmanuel RIKA** meets the regulations governing the award of the degree of Master of Science of the Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This research study is dedicated to the blessed memory of my late younger brother DanielRIKA

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GLOSSARY

Abbreviations and Acronyms

ANOVA	Analysis of variance
BH	Hand pump borehole
CL	Confidence level
CFU	Coliform forming unit
DO	Dissolved oxygen
DP	Dry season
GIS	Global positioning system model
GPS	Global information system
G.V	Guideline value
MDG	Millennium development goal
MLSB	Membrane lauryl sulphate broth
NTU	Nephelometric turbidity unit
TDS	Total dissolved solid
TW	Tube well
UNICEF	United children development fund
WHO	World health organization
WP	Wet season
WW	Dug well

ABSTRACT

The study was conducted on communities along Lamurde floodplain between Latitude 8˚52'0" and 8˚56'6" and Longitude11˚19'0" and 11˚22'8". The study areaoverlain the shallow well fieldswhere public water supply system and main private water vending were extracted to service the entire Jalingo city. Sample points were selected among the few available functional water points during the month of April when dry season was at its peak. Seventeen water points were randomly sampled,assessed and quantified for sanitary risk using standardized checklists. Biophysicochemical constituentsof the water samples were also conducted using international standard methods of water samplings and analytical application principles. The sanitary inspection identified different degree of sanitary risk factor at the sample points, with a common practice at the dug wellsource where fetching tools were left in pools of stagnant water. All the sample points quantifiedwith high sanitary risk were noted with faecal coliforms. There were significant differences between faecal coliform counts ($F_{2,14}$= 17.31; p = 1.64 x 10^{-4}) in the dry season and ($F_{2,14}$= 5.39; p = 8.54 x 10^{-4}) in the wet season at 95% confidence level along borehole, tube well and dug well sources. Nitrate contaminations were localized to sources closed to either pit latrines or solid waste dumpsites. No effect between nitrate concentrations ($F_{2,14}$=1.75; p =0.21) in the dry season and ($F_{2,14}$ =1.65; p =0.23) in the wet season 95% confidence level along the boreholes, tube wells and dug wells. The summary of the analysis indicated that fecal and chloride contaminations were widespread over borehole, tube well and dug well water sources while all other chemical contaminations were localized.

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CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

The soil formation has the capacity of self-cleaning and equilibrium maintenance of groundwater quality to preserve its quality so that every generation finds it the same as the one before it (Bhatia, 2002). However, with man's expanded population and his quest to develop industrial and agricultural sectors to provide food and other basic amenities to the increasing population, there has been enormous amount of wastes generated and released with varying compositions onto the environment on a continuous basis. The contaminants arising from these wastes may be carried from the sources by infiltrating water through long distances to the groundwater table before natural processes such as adsorption, biodegradation, radioactive decay, ion exchange and dispersion could remove them. Studies have shown that Nigeria urban groundwater quality is influenced by geology and geochemistry of the environment, rate of urbanization, industrialization, landfill/dumpsite leachates and effect of seasons (Ocheri*et al.*, 2014).

In urban settings, the risk of groundwater contamination are likely to be most significant, due to the higher density of contaminant sources, issues of contaminant legacy and greater concentrations of anthropogenic activity (Sorensen and Pedly, 2015). Additionally, as the impervious and un-vegetated ground of urban developmental areas have little or no retention during rains, human and animal wastes are flushed into the river systems polluting urban water supplies, rivers and coastal waters (Mafuta*et al.*, 2011). Principal water contaminants arising from poor community sanitation practices include but not limited to faecal matters, nitrate and chloride. Faecal contamination may occur because there are no community facilities for waste disposal, because collection and treatment facilities are inadequate or improperly operated, or because on-site sanitation facilities (such as latrines) drain directly into aquifers (Bartram and Ballance, 1996). Ammonia in the environment mainly results from

feedlot and the use of manures in agriculture, or from on-site sanitation or leaking sewer. Ammonia in water could also be an indicator of sewage pollution (WHO, 2006). Chloride is abundant in human faeces; its presence in water is an indication of faecal contamination.

Of primary concern is the quality of groundwater exploited for drinking as well as other domestic purposes. Many human bacteria and virus are transmitted through faecal contaminated groundwater supply, making them waterborne. High prevalence of diarrhoea among children and infant can be traced to use of unsafe water and unhygienic practice (Bradford *et al.*, 2013). Heavy metals enter groundwater through natural leaching from the rock or runoff from industrial wastes and pollution fallout of pervious surface of roads, motors parks and commercial areas, which percolate down, into groundwater tables. They persist in the environments and tend to accumulate in soils, sediments and biota. Heavy metals can cause neurological disorder and any contact with water with highly polluted heavy metals can result in skin irritation (Davis and Susan, 2004).

This concern has attracted overwhelming studies on the quality status of groundwater abstracted from shallow wells and deep wells for human consumption in urban areas of the country (Ocheri *et al.*, 2014). Jalingo, which is one of the fast growing cities in Nigeria, is not exceptional. The urban abstraction wells are mainly within the informal congested city limit with wells and boreholes constructed close to pit latrines. The solid wastes management and pollution control within the city is characterized by insufficient methods of collection, transfer and storage, insufficient coverage of the collection system and uncontrolled disposal of the waste (Yavini and Musa, 2013).

1.2 Statement of the Research Problem

Although groundwater is not easily contaminated, once this occurs it is difficult to remediate, and in the developing world such as the Nigerian cities, such remediation may prove practically

impossible (Morris *et al.*, 2003).The communities in the study area are relying on shallow groundwater source for drinking water supply. The rising concerned of possible contamination of the water sources include but not limited to the following:

i. Its ground is becoming impervious and un-vegetateddue to expanding growth and development leading to flooding of the water points.
ii. Household dug wells and boreholesare either poorly designed and constructed or dilapidated, creating local pathways for pollution.
iii. Family latrines are often sited less than 10m away from functional water points due to lack of space or knowledge of its impact.
iv. Management and disposal of solid waste, faeces, and wastewater in and around the households are inadequate and incomplete and solid wasteare frequently dumped at the environments of water points or along floodplains where public water supply andprivate water vending are extracted.

In light of these,it become necessary to assess the community sanitation practices at the environments of the sample points and to identify which aquifer systems and settings are most vulnerable to degradation because the replacement cost of a failing local aquifer will be high and its loss may be fatal asthere is currently no substitute.

1.3 Aim and Objectives of the Study

The aim of the study is to assess the impact of sanitation practices on water quality in selected communities in Jalingo, Taraba State, Nigeria.

The specific objectives of the study were as follows:

i. The examinationof community sanitation practices at the environment of the existing drinking water points in Nukkai, Roadblock, MayoGwoi, Magami, AngwanSarki and old abattoir

ii. The analyses of biophysicochemical quality parameters of the drinking water qualities, which are peculiar to the closest contamination sources

iii. The use of statistical tools to investigate the results ofbiophysicochemical quality parameters to establish whether or not contaminations are localised or widespread, and the indicators that help interpret the scale of contaminations

1.4 Significance of the Study

i. The study wouldcreate awareness for the communities to ensure theenvironments of the water fetching points are protected from contamination threat.

ii. The results of the findings will serve as a guide to water managers, policy makers and the public who might desire to carry out further studies or to government and stakeholders in decision making.

iii. It would provide groundwater quality data for the communities.

1.5 Limitation of the Research

i. The study was limited to some parts of the urban development areas along the River Lamurde and Mayogwoifloodplains where major city's aquifers underlie and on those water sources that were not seasonal.

ii. The investigations of the sanitary survey relied on observations made at the sites at the time of the study and on information provided by owners and users of the water facilities.

iii. The analyses of water quality parameters were limited to those parameters that were peculiar to the observed contamination sources close to water sample points.

1.6 Description,Existing Water Supply and Sanitary Practices in the Study Area

1.6.1 Description

The study area is located at North-Eastern Nigeria between Latitude of $8^{o}52''$N and $8^{o}56''$N and Longitude$11^{o}19''$E and $11^{o}23''$E. The area is drainedRiverMayogwoiandRiverLamurde (Figure

1.1), which took their sources from the mountain ranges in Yorro Local Government Area, formed a confluence at Nukkai and emptied into the Benue river system at Tau Village (Oruonye, 2015). The relief of the study area consists of undulating plains. Its wavelike topography according to Morris *et al*, (2003) may produce thin mantle of weathered materials with the infiltrating water from high ground discharging to springs forming on the lower slopes. The streams are seen overflowing with almost all the wells being filled to brim during the raining season. Dry season begins in month of November and lasts until March, leading to dryness of almost all the dug wells, except some few ones, which might be sited on deep weathered zone or along fractured pathways that lead to deep weathered zone.

1.6.2 Existing water supply system

River Lamurde has extensive floodplain on both sides with large groundwater reservoirs (evidences of water farm at Magami and Nukkai). The existing public water supply system and a distribution network was extracted from the floodplain was installed with a capacity of 6,500m^3 per day, which was reduced to 2,735m^3 per day, and additionally increased to 4,900m^3 per day in 2007, while the population of the city has already overwhelmed the public water facilities (Siam,2002). The rapid growth and development in the City has put the existing public water supply under pressure, compelling the populace to rely on hand pump boreholes, tube wells and open dug wells for drinking water sources.

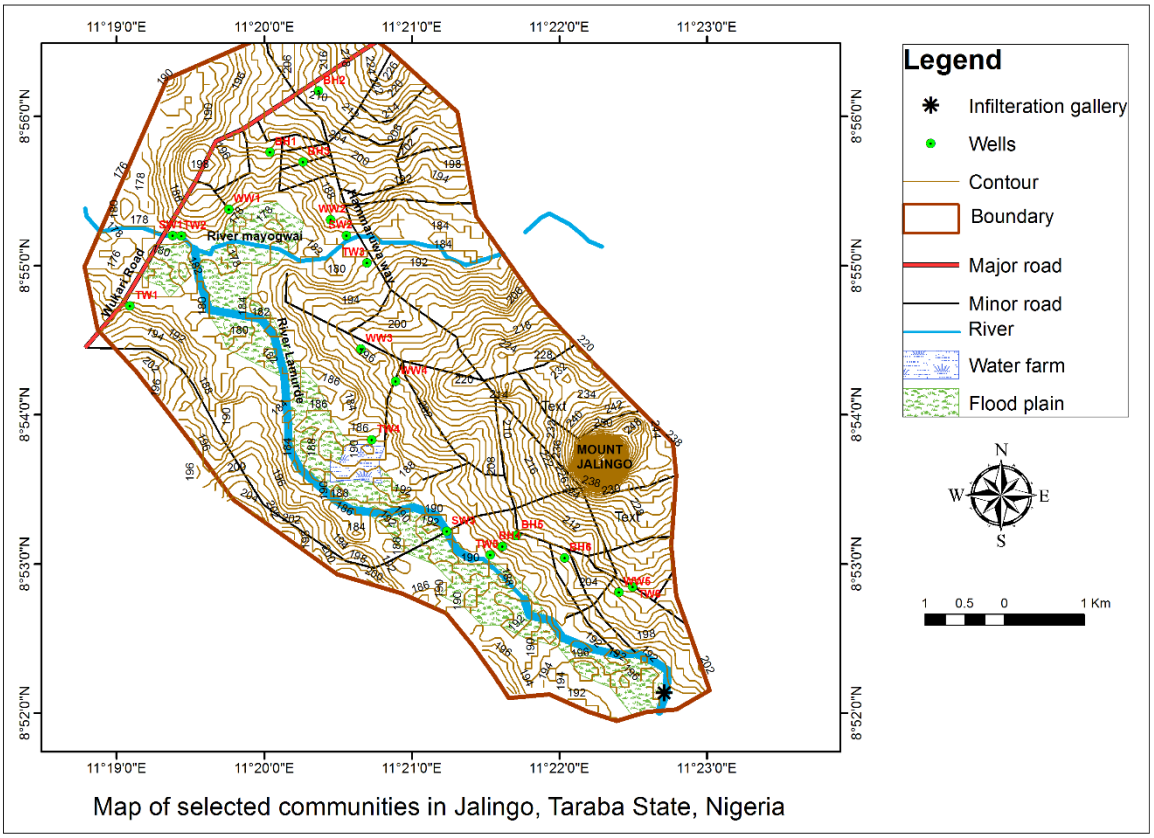


Figure1.1: Topographical map of the study area (Modified from Google Earth Image)

1.6.3 The sanitation status

The northern bank of River Lamurde is heavily occupied by family household compounds despite the increasing devastating effects of recent floods in the area, while the southern bank is intensively cultivatedwith continual application of fertilizers (Oruonye, 2011). There are other anthropogenic activities such as cemetery, laundries and free-range animals within the watershed. The Valley of Lamurde River is dotted with ox-bow lakes, resulting from depositional activities (Kwesaba*et al.*, 2014). The residents are living in unplanned settlements; while the solid waste management and pollution control are characterized by insufficient methods of collection, transfer and storage; insufficient coverage of the collection systems and uncontrolled disposal of the solid waste (Yavini and Musa, 2013). Many household compounds have private family dug wells and tube wells which are constructed very close to family pit latrines and garbage pits due to lack of space or the knowledge of its impact; a common practice in many parts of world (UNICEF, 2008). Most of the water and on-site sanitation facilities are poorly constructed and are rarely well sealed. Pujari *et al.* (2011) suggested that on-site sanitation programme in hard rock areas with shallow water tablessuch as Jalingo City should be discouraged due to presence of fractured in the underlying rocks that might render the water source vulnerable to pollution from the on-site sanitation systems.

CHAPTER TWO

LITERATURE REVIEW

2.1 Sources of Water

Freshwater is indispensable for all forms of life and is needed, in large quantities, in almost all human activities (Bates, *et al.*, 2008). While about 67% of Earth's surface is covered by water, only about 2.7%of the global water is freshwater and out of this,2.2% is locked up in polar ice caps and glacial. A meager of 0.5% is distributed in groundwater, 0.02% in inland lakes and 0.0001% in rivers (Khublaryan, 2009; Narayanan, 2007). The two major sources of freshwater could be broadly classified into surface and groundwater.

2.1.1 Surface water sources

Water sources that occur permanently or intermittently on the land surface in the form of different water bodies: rivers, streams and temporary watercourses, reservoirs, lakes, swamps, mires, glaciers, and snow cover are called surface water. A river is a watercourse flowing in a self-developed bed augmented by surface waters and groundwater (Khublaryan, 2009). Lakes and ponds are inland depressions that hold standing freshwaters (Corcoran *et al.*, 2010).Khublaryan (2009) defines a lake as a natural reservoir filled with water within a lake basin not directly linked with the sea. Basins are subdivided according to their origin into tectonic, glacial, fluvial, coastal, sinkhole (in karst and thermokarst), volcanic, and dammed (artificial reservoirs and ponds). A water reservoir is an artificial water basin, usually formed in a river valley by water supply lines that regulate its use for purposes of the natural economy.

With reasonably reliable rainfall the collection and storage of runoff from roofs can give a quite satisfactory source of water provided that the first flush of water from a storm, which is likely to be contaminated by bird droppings, etc., can be diverted away from the storage tank (Tebbutt, 1998).For instances, in Port Harcourt water supplies have been diminishing due to limited capacity by the central government. This has spurred house-owners to invest in rainwater harvesting for household consumption. The increased use of rainwater harvesting provides additional water supply and reduces pressures of demand on surrounding surface water and groundwater resources (Mafuta *et al.*, 2011).

2.1.2 Groundwater or subsurface water Source

The term groundwater refers to water in the Earth's crust in all physical states, in the sedimentary rock layers and massive-crystallized rock fractures(Khublaryan, 2009).Groundwater acts as a large reservoir of freshwater, providing "buffer storage" during periods of drought. Much groundwater is of good quality because of natural purification processes. The typically modest treatment requirements make groundwater a valuable source of potable water, which can be developed cheaply and easily, if necessary in a piecemeal fashion (Morris *et al.,*2003).In many parts of the world groundwater sourceis the single most important water supply for the production of drinking water, particularly in areas with limited or polluted surface water sourcesthrough boreholes is widespread but largely unmonitored in Africa (Mafuta *et al.*, 2011).

Although groundwater is not easily contaminated, once this occurs it is difficult to remediate, and in the developing world, such remediation may prove practically impossible. For this reason it is important to identify which aquifer systems and settings are most vulnerable to degradation because the replacement cost of a failing local aquifer will be high and its loss may stress other water resources looked to as substitutes (Morris *et al.*, 2003). Moreover, like any other natural resources, groundwater is not unlimited and must be wisely managed and protected against undue exploitation and contamination by pollutants or saltwater intrusion (Reddy, 2008). Some of major threats to groundwater sustainability, arise from the steady increase in demand for water (from rising population and per capita use, increasing need for irrigation etc.) and from the increasing use and disposal of chemicals to the land surface (Morris *et al*., 2003).

Groundwater and surface waters are often closely interrelated;their interconnection is characterized by two opposite processes: augmentation of surface streams and reservoirs and groundwater recharge from surface water. A combination of these two processes is possible

within one river basin both in time and space but the processes are considerably affected by groundwater exploitation (Khublaryan, 2009). Apart from the provisionofwater supply to meet the growing demand for water for drinking and domestic use, crop irrigation and industry; groundwater sourcecan also benefit the environment by naturally maintaining and sustaining river flows, springs and wetlands (Morris *et al*., 2003).

2.2 Water Quality, Standard and Health Implication

Health is rarely the only motive for people wanting improved water and sanitation in the developing countries (ARGOSS, 2001). However, safe water is simply not available and people rely on unimproved and contaminated water sources where treatment is carried out at home (UNICEF, 2008).

A greater majority of the Nigerian populationdepends on self-efforts in meeting their daily wat er and sanitation needs (Akpabio, 2012).Water is often sourcedfrom rivers and streams, rain, household and public dug wells and boreholes and water vending usually supply to customers by truck pushers and tankers.Studied have shown that water from these sources are often unsafe for drinking (Ocheri*et al.*, 2012).

2.2.1 Water quality

Clean drinking water is essential to humans and other life forms but when water is once contaminated, it is difficult to restore its quality especially groundwater (Karija*et al.,* 2013).The provision of drinking water that is not only safe but also acceptable in appearance, taste and odour is of high priority. Water of poor physical qualitydoes not directly cause disease, but it may be aesthetically unacceptable to consumers, and may force them to use less safe source (UNICEF, 2008). Therefore, drinking water supply must obviously be of potable quality and aesthetically attractive. In addition, as far as feasible, public water supplies, should be suitable for other domestic uses such as clothes washing and so on (Tebbutt, 1998).

As water travels through the hydrological system from the mountain summit to the sea, the activities of human society capture, divert and extract, treat and reuse water to sustain communities and economies throughout the watershed. However, these activities do not return the water in the same condition (Corcoran, *et al*., 2010). More obvious are the polluting activities, such as the discharge of domestic, industrial, urban and other wastewaters into the watercourse (whether intentional or accidental) and the spreading of chemicals on agricultural land in the drainage basin (Bartram and Ballance, 1996). The steady growth in world population coupled with extension in irrigated agriculture and accelerated industrial development and other economic activities have put tremendous stress on the quality and quantity aspects of groundwater resources the world over (Reddy, 2008). All pollutants, atmospheric, and land-based invariably enter water bodies, by direct discharge, precipitation and runoffs (Narayanan, 2007).

The quality of water may be described in terms of the concentration and state (dissolved or particulate) of some or all of the organic and inorganic material present in the water, together with certain physical characteristics of the water. One purpose of a monitoring program is, therefore, to gather sufficient data (by means of regular or intensive sampling and analysis) to assess spatial and/or temporal variations in water quality. Complete assessment of the quality of the aquatic environment, therefore, requires that water quality, biological life, particulate matter and the physical characteristics of the water body be investigated and evaluated (Bartram and Ballance, 1996). However, Water quality testing gives information about the quality at the time of sampling, but it says nothing on either the causes of pollution or possible future trends. Combining the results of a sanitary inspection with water quality data can be useful to identify the most important causes of contamination and actions to be taken to improve the situation (CAWST, 2013).

2.2.2 Water quality standards

Because of the negative public health impacts of unsafe water, national government agencies have established drinking-water quality standards that public and private sources must meet (UNICEF, 2008). Effective control of drinking-water quality should be supported ideally by adequate legislation, standards and codes and their enforcement. Standards and codes should normally specify the quality of the water to be supplied to the consumer, the practices to be followed in selecting and developing water sources and in treatment processes and distribution or household storage systems, and procedures for approving water systems in terms of water quality (WHO, 2008). In most cases, private water supplies are not subjected to national drinking-water standards (UNICEF, 2008). The third world take advantage, of inadequate or poorly policed, environmental legislation to extract the maximum financial benefit from their operations, disregarding the environment in the process (Morris *et al.*, 2003).

An assessment of public water supply quality management in Nigeria reveals major inadequacies, notable among which are ineffective and uncoordinated regulation, inadequate resources, low priorities of water quality issues and poor data management (Habila and Kehinde, 2003). The lack of awareness, poverty, poor planning, poor funding, and poor implementation of hygiene programs by different agencies also hamper efforts to expand sanitation access (Water Aid, 2006). Community- based surveillance systems are important in two ways: they extend the reach of national surveillance systems to poor and rural areas, and they directly involve the primary stakeholders in communities, thus helping to raise awareness on water quality. Improved local awareness and surveillance leads ultimately to safer water supplies (UNICEF, 2008).

2.2.3 Health implication

Water, although an absolute necessity for life can be a carrier of many diseases (Bartram and Ballance, 1996). There exists a linear connection between dirt, water and disease- covering personal and domestic hygiene such as vector control,

food cleanliness, drinking water storage (Kpabio, 2012).Half of the diseases that affect the world's population are transmitted by or through water (Morris *et al.*, 2003).Many bacteria, viruses, protozoa and parasites can cause disease when ingested. Infectious water-related diseases can be categorized as waterborne (typhoid, cholera and infectious hepatitis), water-washed (diarrhoea, dysentery, trachoma and cholera), water-based (guinea worm and schistosomiasis) and water-habitat vector diseases (malaria, dengue fever and onchocerciasis) (UNICEF, 2008). Most of the pathogens involved are derived from human faeces, and the diseases transmitted by consumption of faecal contaminated water are called 'faecal-oral' diseases. The diseases can also be transmitted through media other than water, for example faecal contaminated food, fingers or utensils. The principal faecal-oral diseases are cholera, typhoid, shigellosis, amoebic dysentery, hepatitis A and various types of diarrhoea (Bartram and Ballance, 1996).

While microbiological contamination is the largest public health threat, chemical contamination can be a major health concern in some cases. Water can be chemically contaminated through natural causes (arsenic, fluoride) or through human activity (nitrate, heavy metals and pesticides) (UNICEF, 2008). Drinking water may contain many chemicals; however, only a few are of immediate health concern in any given circumstance (WHO, 2008). Infant methaemoglobinaemia, caused by the consumption of water with a high nitrate concentration by infants (usually those which are bottle-fed), is an example. The occurrence of this disease is usually related to nitrate (often in ground waters) which has been derived from extensive use of nitrate fertilizers or from leaching of wastewater or other organic wastes into surface water and groundwater (Bartram and Ballance, 1996;WHO, 2008). Fluorosis, damage to the teeth and bones, can result from long-term consumption of water containing high concentration of fluorides thatoften come from natural sources (Uriah*et al.*, 2014).In areas

with aggressive or acidic waters, the use of lead pipes and fittings or solder can result in elevated lead levels in drinking water, which cause adverse neurological effects (WHO, 2008).

2.3 Community Impact, Water Supply and Sanitation

Water pollution is caused by the presence of undesirable and hazardous materials and pathogens beyond certain limits. Much of the pollution is due to anthropogenic activities like discharge of sewage, effluents and wastes from domestic and industrial activities, particulate matters and metals and their compounds due to mining and metallurgy and fertilizer and pesticide runoffs from agricultural activities (Narayanan, 2007).

2.3.1 Community impact

Early civilizations often drank from the rivers in which they bathed and deposited their wastes, yet the impact of such use was relatively slight as natural cleansing mechanisms easily restored the water quality. Only as early peoples began to gather together in larger, more or less stable groupings did their impact upon their local environments begin to be significant. Natural and manufactured wastes are generated and released into the environment by these increased numbers of human beings, have upset the natural equilibrium (Howard*et al.*, 1985) resulting in pollution of rivers, lakes, and oceans on a large scale these days. Water pollution has also resulted from the disposal of solid urban wastes, such as plastics, metals, untreated wastewaters and sewage, and so on (Garg, 2006). The introduction of pollutants from human activity has seriously degraded the water quality, even to the extent of turning pristine trout streams into foul open sewers with few life forms and fewer beneficial uses (Davis and Susan, 2004).

Water is the ultimate source and conduit for accumulation and dispersal of environmental pollutants. Therefore, the wellbeing and quality of vegetation and living organisms on this planet are intimately connected with the quality of water bodies (Narayanan, 2007). Failure to ensure drinking-water safety may expose the community to the risk of outbreaks of intestinal

and other infectious diseases. Those at greatest risk of waterborne disease are infants and young children, people who are debilitated or living under unsanitary conditions and the elderly. Current knowledge on disease transmission indicates that disease is fully attributable to risks associated with unsafe water, sanitation and hygiene (Fewtrell, *et al.*, 2007). Drinking-water-borne outbreaks are particularly to be avoided because of their capacity to result in the simultaneous infection of a large number of persons and potentially a high proportion of the community. The community represents a resource that can be drawn upon for local knowledge and experience. They are people who are likely to first notice problems in the drinking-water supply and therefore can provide an indication of the source when immediate remedial action is required (WHO, 2008).

Water and sanitation are fundamental to human development and well-being. Access to safe water and sanitation is also a human right, as recognized in 2010 by the United Nations General Assembly (JMP, 2015). One of the common features in Nigeria and indeed in many developing countries is that the impacts of community water and sanitation programmes are limited, because many of them are ill-conceived and are abandoned prematurely due to numerous attitudinal, institutional and economic factors (Ademiluyi and Odugbesan,2008).Improvement in quality of water supply and sanitation services lead to improvement in people's health and quality of their livelihoods (Dan-Hassan *et al.*, 2015). According to JMP (2015), more than one billion people lack access to good water supply and sanitation globally, and seven out of ten of the 159 million people relying on water taken directly from rivers, lakes and other surface waters live in Sub-Saharan Africa, eight times more than other regions.

2.3.2 Water supply

Access to safe water is now regarded as a universal human right. However, the world is facing increasing problems in providing water services, particularly in developing countries (Bates *et al.,* 2008).Safe drinking water, as defined by the WHO (2008) guidelines, does not represent

any significant risk to health over a lifetime of consumption, including different sensitivities that may occur between life stages.A lack of available water, a higher and more uneven water demand resulting from population growth in concentrated areas, an increase in urbanisation and more intense use of water to improve general well-being (Bates*et al.*, 2008)

Community drinking-water supplies worldwide are more frequently contaminated than larger drinking-water supplies, may be more prone to operating discontinuously (or intermittently) and frequently break down.Drinking water supplies vary from very large urban systems servicing populations with tens of millions to small community systems providing water to very small populations. Vendors selling water to households or at collection points are common in many parts of the world where scarcity of water or faults in or lack of infrastructure limits access to suitable quantities of drinking water. Water vendors use a range of modes of transport to carry drinking water for sale directly to the consumer, including tanker-trucks and wheelbarrows/trolleys. There are a number of health concerns associated with water supplied to consumers by water vendors.Even fully protected sources and well-managed systems do not guarantee that safe water is delivered to households. Studies show that the water collected from safe source is likely to become faecal contaminated during transportation and storage. Safe water sources are important, but it is only with improved hygiene, better water storage and handling, improved sanitation and in some cases, household water treatment, that the quality of water consumed by people can be assured. Other reason why water is unsafe is that in many countries, safe water is simply not available and people rely on unimproved and contaminatedwater sources where treatment is carried out at home (UNICEF, 2008).

In Nigeria, for instances, provision of safe drinking water and its quality management is a herculean task especially in the light of pollution threats from urbanization, domestic, commercial and industrial activities. This is due largely to failed public or municipal water supply. Nigeria's water infrastructure has suffered from years of poor operation and

maintenance, and the very low access to improved sanitation constitutes a serious public-health problem. Weak and inefficient institutions, unsustainable public sector spending, and persistent implementation failures have also contributed to poor access rates and sustainability (Water Aid, 2006).

To meet the community need of water supply, some states in the country namely Lagos, Cross River, Kaduna, Ogunand Taraba State Water Agencies are undergoing reforms by introducing service public-private participation (PPP -mostly service contracts). Generally, each Water Supply Agency is established under an edict to develop and manage water supply facilities within its respective state and to meet sound financial objectives. However, the operational efficiency of most of the Water Supply Agencies is low and unaccounted-for-water often exceeds 50%. The Agencies often find it difficult to be operationally autonomous from the state government. Rate increases may be proposed by utilities, but are typically approved by the state - and political imperatives often keep rates unreasonably low. Urban areas are often water-scarce due to environmental and capacity issues and technical losses. Residents in these areas must buy water from private vendors at high prices (Water Aid, 2006).

2.3.3 Sanitation

Karija*et al*. (2013) defines sanitation as the provision of facilities and services for the safe disposal of human waste in toilets, or versions of toilets such as latrines. Sanitation and hygiene can act as transmission barriers on all of these pathways (UNICEF, 2008). The sanitary disposal of human excreta is more important in healthy context than the provision of water supply. Even in the presence of good-quality water, direct faecal-oral contact can maintain high levels of incidence of diseases such as typhoid and cholera (UNICEF, 2008; Tebbutt, 1998). A report revealed that shared facilities and open defecation remained widespread in some region of the world and led to increase attention to these issues within the sector (JMP, 2015). According to the call to action on sanitation issued by the Deputy Secretary-General of the United Nations in March 2013, open defecation perpetuates the vicious cycle of disease and

poverty and is an affront to personal dignity. Those countries where open defecation is most widely practiced have the highest numbers of deaths of children under the age of five, as well as high levels of malnutrition, high levels of poverty and large disparities between the rich and poor. Those without an education are also more likely to defecate in the open, percentage of the population practicing open defecation appears to decline with increasing levels of education. Eliminating open defecation, a practice strongly associated with poverty and exclusion, is critical to accelerating progress towardsMDG sanitation target (JMP, 2014).

Menstrual hygiene management is also identified as a priority for improving the health, welfare and dignity of women and girls. Several essential elements are required, including clean materials to absorb or collect menstrual blood, a private place to change these materials as often as necessary, soap and water for washing the body as required, and access to safe and convenient facilities to dispose of used materials. Further, women and girls need access to have basic information about the menstrual cycle and how to manage it with dignity and without discomfort or fear. Globally, there is very little comparable information available on menstrual hygiene management. However, the lack of basic sanitation and drinking water facilities, as documented earlier in this report, suggests that many women lack a suitable place for managing menstruation. Assuming at least half of the 946 million people globally who lack any kind of facility and defecate in the open are female, a conservative estimate would suggest that at least 500 million women and girls lack adequate facilities for menstrual hygiene management (JMP, 2015).

The relationships between a considerable number of water-related diseases and the presence in the environment of excreta from people suffering from these diseases are well established (Tebbutt, 1998). During the Millennium Development Goals period, the use of improved sanitation facilities was estimatedto have risen from 54 per cent to 68 per cent globally. However, in Sub-Saharan Africa sanitation has not kept up with population growth since last 25 years, with only 36% of the additional population gaining access (JMP, 2015). In Nigeria, for

instance, piped sewerage is almost non-existent. Except for Abuja and limited areas of Lagos, no urban community has a sewerage system, until a more focused public approach is developed, sanitation will remain primarily a responsibility of individual households (Water Aid, 2008).

2.4 Sources and Pathway of Water Pollution

There has always been a balance between natural sources and sinks to water pollution, but human and industrial activities have created pollution that overburden the natural removal systems (Narayanan, 2007). Preventing contamination of water supplies through the protection of water resources is the first step in any programme to provide safe water to consumers (UNICEF, 2008). Poor design and construction of the borehole, well or spring supply can also lead to groundwater contamination (Morris *et al.*, 2003). There are two sources of pollution:point and non-point sources.

2.4.1 Point sources of pollution

Specific locations where pollution resulting from human populations and human activities occurs such as discharges from sewage treatment works, industrial wastewater outlets, solid waste disposal sites, animal feedlots and quarries, can be described as point sources (Narayanan, 2007). The effect of a point on the receiving water body is dependent on the population, or size and type of activity, discharging waste, capacity of the water body to dilute the discharge, ecological sensitivity of the receiving water body, andthe uses to which the water may be put (Bartram and Ballance, 1996). Pollution, especially point source pollution can be prevented, as it is easier to identify and isolate (UNICEF, 2008).

2.4.2 Non-point sources of pollution

Pollutants may also be derived from diffuse and multi-point sources. Diffuse sources are often of agricultural origin that enter surface waters with run-off or infiltrate into ground waters (particularly pesticides and fertilizers). Multi-point sources, such as latrines and septic tanks in rural and urban areas may be treated as diffuse sources for the purposes of monitoring and assessment because it is not possible to monitor each source individually (Bartram and Ballance, 1996). Wastewater disposal or sanitation practices can introduce pollutants into water used for bathing, washing or fishing (Irish Aid (nd)). Failure to a proper sanitary seal between the well casings in boreholes or lining in dug wells and the ground can provide a ready and rapid pathway for contaminants to migrate from the land surface close to the wellhead down casing annulus in borehole and from the cracked wall of the dug well to the water table. Such pathways will rapidly bypass the unsaturated zone; providing little opportunity for contaminants alteration (Morris *et al.*, 2003).

2.5 Groundwater Pollution

Pit latrine has become one of the most common human excreta disposal systems in low-income countries like Nigeria, and its use is on the rise as countries aim to meet the sanitation-related target of the Millennium Development Goals. Contaminants from pit-latrine excreta may potentially leach into groundwater, thereby threatening human health through well-water contamination.The safety of water from hand-dug wells especially for drinking is doubtful because of pollution threats arising from anthropogenic activities and environmental factors (Graham and Polizzotto, 2013).

Fertilizers or soil amendments containing sewage sludge or "bio-solids" are potential sources of hazardous trace elements, including lead, cadmium and zinc (Zubair *et al.*, 2008).Pesticides are intentionally applied in order to protect crops in agriculture as well as to control pests and unwanted vegetation in gardens, buildings, railway tracks, forests and roadsides or they may be accidentally released from production sites or, transported away from their sites of application in water, air or dust. Pesticides can reach groundwater after accidental spills or

excessive application. Though some organochlorine insecticides have been banned or are subject to severe restrictions in many countries, in several developing countries production and use of, for example, DDT has continued because of its relatively inexpensive production and its high efficacy against mosquitoes in malaria control. However, the newer work has shown that pesticides, especially insecticides, are also reaching water resources in urban and suburban areas, including residential sources (WHO, 2006). Similarly, poultry manure often contains arsenic that is in drugs administered to chickens for disease management. Pig manure usually has elevated level of copper (Zubair *et al.*, 2008).

The term municipal solid wastes, refers to solid wastes from houses, streets and public places, shops, hospitals and offices, which are very often the responsibility of municipal and other government authorities. Solid and liquid waste generated by modern society is often spread over the land surface, and moisture from the waste and from rainfall may percolate down through the underlying soil. Depending on the type of waste, the resulting leachate may be highly acidic, have a large organic load or contain a high concentration of ammonia, toxic metals or various organic compounds, all of which may contaminate underlying groundwater (Morris*et al.*, 2003). The quantities of solid waste generated in Jalingo have been increasing due to rise in the population rate. It has increased from 28 tons/day in 1998 to 54 tons/day in 2011. Household wastes together with the hazardous waste, such as paints, used batteries, and pesticides containers, are not collected separately (Yavini and Musa, 2013).The rate of uncontrolled and un-scientific dumping of municipal solid wastes has brought about a rising number of incidents of hazards to human health; contamination of both surface and ground water, which is in turn a serious human health risk (Karija*et al.*, 2013).

2.6 Groundwater Pollution due to Seasonal Changes

The water cycle is driven by solar energy, which is one of the climatic processes that contribute to our weather (Narayanan, 2007). The climate, which affects the quality and quantity of Nigeria water resources, results from the influence of two main wind systems: the moist,

relatively cool, monsoon wind blows from the south-west across the Atlantic Ocean towards the country and brings rainfall. The hot, dry, dust-laden *Harmattan* wind blows from the North East across the Sahara desert with its accompanying dry weather and dust-laden air. The mean temperature is generally between 25°C and 30°C, although because of the moderating influence of the sea the mean daily and annual maximum temperatures increase from the coast towards the interior. In the dry season, the temperatures are extreme, ranging between 20°C and 30°C (Anukam, 1997).

Season is believed to influence the concentration level of the physic-chemical and bacteriological loading in water sources. The study carried out by Ocheri *et al.* (2014) shows total dissolved solids was lower in the dry season. Seasonal variation in nitrate level in Makurdi Metropolis was carried out and 80% of the wells had nitrate concentrations above the WHO allowable limit for drinking water for wet season. Other parameters whose concentrations were higher in the wet season are pH, turbidity, electrical conductivity, chloride, iron, calcium, chromium, biochemical oxygen demand and faecal coliform bacteria (Ocheri and Michael, 2010).

2.7 Related Studies on Sanitation Practices and Groundwater Pollution

In developing countries, water is often sourced from rivers and streams, rain, household and public dug wells and boreholes and water vending usually supply to customers by truck pushers and tankers. Studied have shown that water from these sources are often unsafe for drinking (Ocheri *et al.*, 2012).A study carried out by Ocheri and Ona (2015), revealed that water from open dug wells in Makurdi town is not safe for drinking.Tse and Adamu (2012) in their studies on chemical and bacteriological analyses of open dug wells in the same town notes that the well water is slightly acidic, moderately hard, with low total dissolved solids. Heavy metals such as iron, zinc, copper, lead and cadmium occur in traces, while high concentration of coliform is noted in all the wells. Physicochemical and bacteriological analyses

carried by Mgbemena, (2016) indicated that borehole water source used for drinking and other domestic purposes in Owerri North Local Government Area were unsafe.

Seasonal variation in nitrate level in Makurdi metropolis carried out by Ocheri and Michael (2010) indicated that 80% of the wells had nitrate concentrations above the WHO allowable limit for drinking water during wet season.Other parameters whose concentrations were higher in the wet season are pH, turbidity, electrical conductivity, chloride, iron, calcium, chromium, biochemical oxygen demand and faecal coliforms (Makwe and Chup, 2013; Ocheri*et al.*, 2012).In Ibadan Metropolis, (Ayantobo*et al.*, 2012) assessed the quality of water from dug wells and noted nitrate, faecal coliforms and total coliforms at objectionable level and were pronounced in wells located close to domestic wastes, abattoir, pit latrine and stagnant water and drainages. The study carried by Rania *et al*., (2012) indicated widespread access to improve sources of drinking water and toilet facilitiesin Egypt; however, service quality remains a significant problem in many parts of the country.In Botswana, high nitrate concentrations in some drinking water wells have been linked to the proximity to large numbers of cattle at nearby stock watering points (ARGOSS, 2001).

The study conducted by Asnakew *et al.*, (2017), revealed that the prevalence of under-five diarrhoea in model households was relatively high and the availability of latrine, water source of the households, number of children in the households, hand-washing methods of the mothers/care takers and sharing a house with animals were significant predictors. The analysis of impact of water and sanitation in Nigeria indicated that children under 5 years old in households with access to both unimproved water sources and sanitation facilities had increased risk of neonatal, post-neonatal, and child death than those with access to improved water sources and sanitationfacilities (Osita *et al.*, 2014).

2.8 Parameters for Drinking Water Quality

The quality of water is characterized by its biological, physical and chemical (biophysicochemical) parameters (Narayanan, 2007).

2.8.1 Physical parameters

Physical parameters define those characteristics of water that respond to the sense of sight, touch, or smell. Suspended and dissolved solids, turbidity, electrical conductivity, colour, taste and odour, and temperature fall into this category. Solids suspended in water may consist of inorganic and organic particles immiscible in water. Because of the filtering capacity of the soil, suspended material is seldom a constituent of groundwater (Narayanan, 2007). Turbidity is a measure of the extent to which light is either absorbed or scattered by suspended material in water. Water that is highly turbid is highly coloured or has an objectionable taste or odour may be regarded by consumers as unsafe and may be rejected. In extreme cases, consumers may avoid aesthetically unacceptable but otherwise safe drinking water in favour of more pleasant but potentially unsafe sources (WHO, 2008).

One of the problems with the measurement of turbidity (especially in low values in filtered effluent or clear water) is the high degree of variability observed, depending on the light source and the method of measurement. Another problem often encountered is the light-absorbing properties of the suspended materials. Colloidal matter will scatter or absorb light and prevent its transmission; for example, turbidity of a solution of lampblack will essentially be equal to zero. As a result, it is difficult to compare turbidity values reported in the literatures. However, turbidity reading at a facility can be used for process control (Tchobanoglous*et al.*, 2004). It is also recommended when assessing faecal contamination, since pathogens can sorbs onto suspended particles and to some extent be shielded from disinfection (UNICEF, 2008).

(a) Electrical conductivity

The electrical conductivity (EC) of water is a measure of the ability of a solution to conduct an electric current. Because the electric current is transported by the ions in solution, the conductivity increases as the concentrations of the ions increases. In effect, the measured of electrical conductivity value is used as a surrogate measure of total dissolved solids concentration (TDS) (Tchobanoglous*et al.*, 2004). It has been reported that drinking water with extremely low concentration of TDS may be unacceptable because of its flat insipid taste (WQA, 2013).

(b) Taste and odour

Sources of taste and odour in waters are minerals, metals, and salts from the soil, end products from biological reactions, and constituents of wastewater. Inorganic substances are more likely to produce tastes unaccompanied by odour while organic material is likely to produce both taste and odour (Howard *et al.*, 1985). Safe water that does not taste, look or smell good could lead people to reject the water and use other sources that are less safe (WHO, 2011).

(c) Temperature

Temperature can affect other properties of water pollutants such as speeding up chemical reactions, reduction in solubility of gases, amplification of tastes and odours, and so on (Tebbutt, 1998). The source,water temperature, treatment, chemical and biological processes taking place in the distribution system is influenced by dissolved oxygen content of water (WHO, 2011). Consumers often tend to prefer cool water over warm water(UNICEF, 2008). However, temperature does not carry any significance in terms of contamination(CAWST, 2013).

2.8.2 Bacteriological parameters

Water can be the vehicle for the transmission of many different types of pathogenic microorganism: some being natural aquatic organisms and some introduced into the water from an infected host. Overall, the pathogens in water that are the main concern to public health originate in the faeces of humans and animals, and establish an infection when a susceptible host consumes contaminated water (WHO, 2006). Microbiological quality is usually the main concern since infectious diseases caused by pathogenic bacteria, viruses, protozoa and helminths; are most common and widespread health risk associated with drinking water (CAWST, 2013).

The soil or media through which storm water infiltrated can filter infiltrated pathogens and suspended solids. This may not be true of viruses, which are currently a concern in drinking water aquifers due to leakage from sanitary sewers and septic tanks (Nieber*et al.*, 2014). Faecal pollution may occur because there are no community facilities for waste disposal, because collection and treatment facilities are inadequate or improperly operated, or because on-site sanitation facilities (such as latrines) drain directly into aquifers (Bartram and Ballance, 1996). While water can be a very significant source of infectious organisms, other routes, including person-to-person contact, droplets and aerosols and food intake, may also transmit many of the diseases that may be waterborne. Depending on circumstance and in the absence of waterborne outbreaks, these routes may be more important than waterborne transmission (WHO, 2008).

The effects of faecal pollution vary. In developing countries, intestinal disease is the main problem (Bartram and Ballance, 1996). Consumption of water contaminated by disease-causing agents (pathogens) or toxic chemicals can cause health problems such as diarrhoea, cholera, typhoid, dysentery, and cancer. In addition, inadequate amounts of water for basic hygiene can contribute to poor hygiene practices, which in turn can lead to skin and eye diseases, and act as a key factor in the transmission of many diarrhoea diseases (JMP, 2015). Microorganisms can be useful in wastewater treatment and in raw water treatment, but they

are usually considered as sources of nuisance and hazard in relation to drinking water (Tebbutt, 1998).

2.8.3 Chemical parameters

Water has been called the universal solvent, and chemicals in water are related to the solvent capabilities of water. Alkalinity, hardness, fluoride, metals, organics and nutrients are chemical parameters of concern in water quality management (Howard*et al*, 1985). Unlike microbe contaminations, most chemicals in drinking water pose a health concern only after years of exposure. Often chemical contamination goes unnoticed until disease occurs due to chronic exposure. The severity of health effects depends upon the chemical and its concentration, as well as the length of exposure. Only a few chemicals that can lead to health problems after short-term exposure, such as nitrate, unless there is a massive contamination of a drinking water supply (CAWST, 2013).

(a) Total dissolved solid

Total dissolved solids (TDS) is a measure of the combined content of all inorganic and organic substances contained in a liquid in molecular, ionized or micro granular suspended form (Gichuki and Gichumbi, 2012). An isolated report, a summary of Russian studies available through the World Health Organization, has recommended that fluid and electrolytes are better replaced with water containing a minimum of 100 mg/L of TDS (WQA, 2013). A close approximation of its value may be obtained by the measurement of electrical conductivity (Bartram and Ballance, 1996). The straining action of soil and rocks as water percolates through them is normally sufficient to remove suspended impurities from contaminated infiltration flows. Soluble impurities may be removed by the ion-exchange properties of some soils and rocks, but this is by no mean the case with contaminants (Tebbutt, 1998).

(b) Alkalinity and acidity

Alkalinity is a measure of the capacity of water to neutralize acids. The predominant chemicals present in natural waters are carbonates, bicarbonates and hydroxide compounds of calcium, sodium and potassium. The bicarbonate ion is usually prevalent. Because chemicals in the water can affect it characteristics, pH is an important indicator of water that is changing chemically. Groundwater, especially if acidic, in many places contains excessive amounts of iron (Gichuki and Gichumbi, 2012). Virtually, all water has some alkalinity; acidic water is not frequently encountered except in cases of severe pollution. Carbon dioxide is the main contributor of acidity in water, but sometime includes protein, fatty acid and hydrogen sulphide (Bhatia, 2002). Water with high pH is corrosive to materials and it increases hardness. Acidic pH, generally, enhances the mobility of chemicals (Narayanan, 2007). Basic water can form scale and for drinking water, a pH range of 6.5–8.5 is recommended (Gichuki and Gichumbi, 2012). Groundwater, especially if acidic, contains excessive amounts of iron. Shallow wells in carbonate-poor terrains for example, in granitic rocks, may give rise to health problems since waters are typically acidic and may contain harmful concentration of metals. Alkalinityvalue is an important wastewater characteristic that affects the performance of biological nitrification processes. It is produced in de-nitrification reactions and the pH is generally elevated, instead of being depressed (Tchobanoglous*et al.,*2004).

(c) Nitrogen

Nitrogen can exist in four main forms in the water cycle: organic nitrogen in the form of proteins, amino acids, and urea; ammonia; nitrite and nitrate (Tebbutt, 1998). Because of the health effects and solubility in groundwater, nitrate is often the most studied form of nitrogen groundwater pollution (Nieber*et al.*, 2014). Nitrate in the environment mainly results from feedlots and the use of manures in agriculture, or from on-site sanitation or leaking sewers. Nitrate in water could also be an indicator of sewage pollution (WHO, 2006). Evidence from the three study sites carried out by Nieber*et al.* (2014) indicates that nitrate contamination of infiltrating storm water is not a big concern.Study by Lindenbaum, (2012) also indicated that

nitrates in the soil is usually very small at any time because of rapid uptake by plants and microorganisms.

The predominance of nitrate nitrogen in water indicates that the waste has been stabilized with respect to oxygen demand. Dissolved oxygen can inhibit nitrate reduction by repressing the reduction enzyme (Tchobanoglous*et al.*, 2004). Nonetheless, anaerobic conditions (evidenced by negligible dissolved oxygen and redox potential) favour de-nitrification and formations of ammonium, which is either volatilized to atmosphere as ammonia, absorbed to sediments or remains in the surface runoff (Morris *et al.*, 2003). Nieber*et al.* (2014) recommends that dissolved oxygen should always be included in water monitoring programs when an objective is to determine the vulnerability of an aquifer to nitrate contamination. In places where nitrate concentrations are lower than regulatory limits, the authors suggested that, unless nitrate loading is reduced, nitrate concentrations in the groundwater would continue to increase. Ayantobo*et al.* (2012) assessed the quality of water from dug wells and noted nitrate, faecal coliforms and total coliforms at objectionable level and were pronounced in wells located close to domestic wastes, abattoir, pit latrine and stagnant water and drainages.The toxicity of nitrate to humans is mainly attributable to its reduction to nitrite. Nitrite, or nitrate converted to nitrite in the body, causes a chemical reaction that can lead to the induction of methaemoglobinaemia, especially in bottle-fed infants (WHO, 2006).

(d) Fluoride

Fluoride occurs naturally in some waters and its presence in drinking water has been shown to be inhibitory to tooth decay, particularly when young children are exposed (Tebbutt, 1998). The source of fluoride in groundwater is from the crystalline metamorphic basement and igneous rocks and rarely by anthropogenic processes(Uriah *et al.*, 2014). Excessively high fluoride groundwater concentrations are from crystalline aquifer and this increases with depth (old water) where the water had considerable residence time. Excessively high fluoride groundwater concentrations are from crystalline aquifer and this increases with depth (old

water) and along groundwater flow length due to rock-water interaction (UNICEF, 2008). Higher fluoride values from spring water, which originated from great depth, go to assert that fluoride concentration increases with depth and of course the residence time. The higher the fluoride level, the lower is that of Calcium. This may be because of the substitution of sodium ions by Caesium ions during the circulation of water in an aquifer or through carbonate precipitation. The higher the fluoride level, the lower is that of Calcium (Uriah *et al.*, 2014). However, its contribution from anthropogenic sources cannot be ruled out especially with phosphoric fertilizers where fluoride is contained as impurities. In addition, most pesticides contain high concentrations of fluorides; coal burning can also release large amounts of fluoride to the environment, and is a significant source of domestic exposure in China (UNICEF, 2008). Electronics waste can release fluoride in the environment (Tchobanoglous*et al.*, 2004).

Depending on the level in which fluoride is present in the water, it could be beneficial or detrimental to both bone and dental development in human beings. Like most chemical elements, fluorine is an essential element in the human diet. Lack of it has long been linked to tooth decay. For these reasons, fluoride has been recommended for pregnant women and children. The addition of fluorine to toothpaste is to supplement for the needed fluorine to reduce tooth decay. Moreover, like in most urban centres in Nigeria where there are controlled water supply systems, it is added to water supplies to boost the naturally low concentration (Uriah *et al.*, 2014).

Excess of fluoride in drinking water can cause mottling and staining of teeth (dental caries). High oral intake of fluoride results in physiological disorders, which is the hardening and calcification of bones and causes pain, stiffness, and irregular bone growth. More advanced manifestations are crippling skeletal fluorosis resulting in bone deformation and debilitation. Dental caries is endemic and epidemic spread over a large range of superficial area mainly the North Eastern half of Nigeria in both the crystalline basement and sedimentary areas. The few

data available on fluoride in drinking water clearly establishes the relationship between dental caries and environmental fluoride in drinking water (Uriah *et al.*, 2014).

(e) Chlorides

Chloride anions are usually present in natural waters. A high concentration occurs in waters that have been in contact with chloride-containing geological formations. High chloride content may also indicate pollution by sewage or industrial wastes or by the intrusion of seawater or saline water into a freshwater body or aquifer (Bartram and Ballance, 1996). As chloride is frequently associated with sewage, it is often incorporated into assessments as an indication of possible faecal contamination or as a measure of the extent of the dispersion of sewage discharges in water bodies (Chapman, 1996). Human excreta contain about 6 g of chlorides per person per day (Tchobanoglous*et al.*, 2004).

Therefore, an increase in the number of chloride content of water may indicate possible pollution from human sewage, animal manure or industrial wastes (WHO, 2011). Chlorides can travel a great distance in groundwater. They can get in groundwater from solid waste when it meets rainwater and then gain entrance into aquifer (Gichuki and Gichumbi, 2012). Chloride is a contaminant that has no known sinks in natural systems. Chloride is a concern for both groundwater and surface water (Nieber*et al.*, 2014). Although there are no known health risks from chloride in drinking water, the concentrations above 250mg/L may affect the taste and acceptability of water (Graham and Polizzotto, 2013). In excess, chloride salts give water a salty taste. A salty taste in water depends on the ions with which the chlorides are associated. With sodium ions, the taste is detectable at about 250mg/L but with calcium or magnesium, the taste may be undetectable at 1000mg/L. High chloride content has a corrosive effect on metal pipes and structures and is harmful to most trees and plants (Bartram and Ballance, 1996).

Chlorides have a chronic toxicity for aquatic biota at concentration of 300mg/L or higher (Nieber*et al.*, 2014).

(f) Sulphate

Sulphate is an abundant ion in the earth's crust and its concentration in water can range from a few milligrams to several thousand milligrams per litre. Industrial wastes and mine drainage may contain high concentrations of sulphate. Sulphate also results from the breakdown of sulphur-containing organic compounds (Bartram and Ballance, 1996; Chapman, 1996). Therefore, animal excreta and decomposition of plants and animals may contribute sulphate to the environment (Bhatia, 2002).Sulphate in drinking water can cause a noticeable taste above concentration of about 250 mg/L(UNICEF, 2008). Sulphate is one of the least toxic anions in drinking water does not have any recommended guideline value. However, catharsis, dehydration and gastrointestinal irritation have been observed at high concentrations and WHO therefore suggests that health authorities should be notified when concentrations of sulphate in drinking water exceed 500mg/L (WHO, 2011).

(g) Organic matters

Many organic compounds are naturally occurring, although many of concern in groundwater contamination investigations are man-made. Animal waste, vegetation, soil organisms are naturally occurring organic compounds while petroleum hydrocarbons, automobile tire particles are of anthropogenic origin. Sub-surface infiltration systems store water underground and allow the infiltration process to begin beneath the soil surface. This means that the retention of contaminants by organic compounds in the soil may not occur. Thus, metals and petroleum hydrocarbons are more likely to enter into groundwater from these infiltration systems (Nieber*et al.*, 2014). Reduction of oxygen by reactions with organic matter may give rise to an increased concentration of iron, arsenic and some other metals.

A major problem with groundwater pollution is the lack of significant self-purification capacity so that once polluted, an aquifer may become useless for water supply for the near future. Organic matters entering an aquifer is relatively easily oxidised under aerobic condition where much of the organic content are removed in the saturated zone. Whenever the oxygen demand for the degradation of organic matter exceeds supply, oxidation-reduction of the groundwater declines and further degradation of organic matter continues utilising other ions (electrons acceptors) that are progressively more difficult to reduce. This include in order of disappearance, nitrate, ammonium, ferric iron, and sulphate (Morris, 2003). The anaerobic conditions can also result in the production of unpleasant tasting and smelling compounds as well as causing the dissolution of iron from the surrounding rocks (Tebbutt, 1998). Studies on infiltrating storm carried out by Nieber*et al.* (2014), indicates that the bacteria surrounding plant roots will degrade captured petroleum hydrocarbons.

(h) Metals

Metals are naturally occurring substances, which are often present in the environment at low level but augmented by anthropogenic activities. Heavy metals are individual metals and metal compounds that have serious impact on human health (Ocheri*et al.*, 2014). Metals can also enter drinking water from pipes and fittings (UNICEF, 2008). Due to frequency of occurrence and toxicity, cadmium, copper, lead, and zinc are the primary metals of concern in urban storm water runoff (Nieber*et al.*, 2014; Ocheri*et al.*, 2014). Some of these metals are micronutrients needed by plants and may be accumulated into plant biomass as plants grow. Nonetheless, at sufficiently high concentrations, all metals are considered a threat to human health and the environment; different organisms have different tolerances to different metals (Nieber*et al.*, 2014). Dissolved metals may contribute to colour in drinking water, and can stain laundry and plumbing fixtures (UNICEF, 2008)

Most groundwater contains some iron because it is common in many aquifers and it is found in trace amounts in practically all sediments and rock formations (Gichuki and Gichumbi, 2012). Water collects iron in several ways. Even as it falls through the air, water acquires small amounts of the oxides of iron found in the atmospheric dust. Water rich in carbon dioxide, readily dissolves iron from the earth's plentiful deposits as it leaches these in its underground flow. Elevated levels of iron in storm water can be caused by rusting steel in constant contact with water (Ocheri*et al.*, 2014).

Zinc is an essential trace element found in almost all food hence, its source is diet (Tchobanoglous*et al.*, 2004). Zinc is found in motor oil where it forms a film that helps prevent the wearing of metal parts. Zinc is also found to occur mostly in dissolved form; roof runoff containing the highest concentrations (Nieber*et al.*, 2014). Manganese is essential trace element to plants and its pollution is mainly due to metallurgy, ferrous metal industry and industrial waste (Narayanan, 2007). Fertilizers or soil amendments containing sewage sludge or "bio-solids" are potential sources of hazardous trace elements, including lead, cadmium, and zinc.Poultry manure often contains arsenic that is in drugs administered to chickens for disease management. Pig manure usually has elevated level of copper (Zubair *et al.*, 2008). In waters containing ferrous and manganese salts, oxidation by iron bacteria (or by exposure to air) may cause rust-coloured deposits on the walls of tanks, pipes and channels and carry-over of deposits into the water. Anaerobic groundwater may contain ferrous iron of concentrations up to several milligrams per litre without discoloration or turbidity in the water when directly pumped from a well. On exposure to the atmosphere, however, it oxidizes to ferric iron, giving an objectionable reddish-brown colour to the water (Ocheri*et al.*, 2014). Iron can also promote the growth of “iron bacteria,” which derive their energy from the oxidation of ferrous iron to ferric iron and in the process deposit a slimy coating on the piping (WHO, 2011). Zinc level above 3 mg/Lcan impart an undesirable astringent taste to water (UNICEF, 2008).

Metals do not generally degrade to another element in the environment; however, when loading into storm water in the gardens with subsequent detention can result in metal accumulation (Nieber*et al.*, 2014). Impact of metals is bioaccumulation results from various physiological processes by which an organism accumulates a given substance (mercury and lead) from water or suspended particles. While bio-magnification is the increase in concentration of a given substance within a food chain: phytoplankton→zooplankton→microphage-fish →carnivorous fish→ carnivorous mammals (Bartram and Ballance, 1996).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials

Potable Wagtech test kit was used for on-site and laboratory analysis. The kit contained the following equipment and reagents and other instruments/materials:

3.1.1 Materials and equipment used at the field

i. Portable Horiba Water Quality Monitor with digital readout (Model);

ii. Wagtech Conductivity/TDS/ ^{0}C, turbidimeter and PH meter (Model);

iii. Geographic Positioning System (GPS) ;Global Information System (GIS)

iv. Camera, Masking tape, marker, tape rule, rope, screw-capped sterile plastic bottles, mentholated spirit and Cigarette lighter.

3.1.2 Equipment/Reagents used in the laboratory

a. Equipment

i. 20ml WagtechNitratesttube and 10ml round test tubes, forceps, Petri dish

ii. Wagtech Automatic Selection Photometer(Model) presented in plate 1(a).

iii. Rechargeable dual incubator(Mode), Membrane filter equip with pump(Model) presented in plate 11(A) and (B).

b. Reagents use in the laboratorypresented in plate 1(b) are as follow:

i. WagtechNitratest powder (zinc base) spoon pack and WagtechNitratest tablets (N-(1-napthyl)-ethylene diamine)

ii. Wagtech fluoride No. 1 tablets (Zirconyl Chloride) and Wagtech fluoride No. 2 tablets (Eriochrome Cyanine)

iii. Zinc Tablets (Zincon) and Zinc-Dechlor Tablets

iv. Media: Membrane Lauryl Sulphate Broth (MLSB)



A: Wagtech Photometer



B: Reagents in Tablet and powder forms



C: Potable Horiba Digital readout



D: Wagtech Turbidity and TDS Meters

Plate I(a-d): Equipment/Reagents for analysis of quality parameters



A: Rechargeable Dual Incubator



B: Membrane Filter equip with pump



C: Prepared samples arranged in Petri dish rack ready for incubation

Plate II (a-c): Equipment for analysis of faecal coliform count in the water sample

3.2 Methods

3.2.1 Sanitation survey

Sanitary inspection carried out in this study include baseline information about groundwater potential, identifying functional water points and sanitary practices of the communities, selecting the water sample points and designing the size of questionnaire to be administered.

a. Baseline information of groundwater potential in the study area

The researcher contacted Rural Water Supply and Sanitation Agency (RUWSSA) and Taraba State Water Supply Agency (TSWSA) to gather information about groundwater potential in the entire Jalingo Metropolis. It was discovered thatLamurde floodplain is the only location with extensive groundwater potential and the study was carried on those communities that settled along the floodplain.

b. Pre-visit inspection

The visual inspection was carried out to assess the type of settlement, the nature and state of water facilities and the community sanitation practices in the communities.The community leaders were officially informed of the purpose of the study and nature and extent of their participation. Their opinion formed part of the planning process.

i. The identification of communityboundaries and functional water points

A cluster of household settlements were identified at Nukkai(Yola- WukariRoad serving as a boundary); Roadblock [Taraba Agricultural Development Projects (TADP) and Taraba State Tractor Haring Unit (TSTHU) areas]; Mayogwoi; Magami (Angwanwater board to CRCN Magami area); AngwanSarki (AngwanBariya 1 and 2); and Old abattoir (Angwan Mayakkadown to Yelwa Market). Thesecommunities directly influencedthe contamination threats on the selected water sample points.

The study began in the month of April when thedry season is at its peakin order to target the functional water points since only few water sources had water in them during this period. The identification of water sample point was done with the assistance of volunteer member of the communities. Water points within the household compounds were not included in the study due to its inaccessibility. Boreholes and sealed wells connected to the overhead tanks and reservoirs were excluded to avoid contaminations that mayarise from the storage.

ii. Sanitary conditions of the environments and selection of sample points

The water points were spread across the unplanned settlement with the solid wasteslittered at the environments ofwater points. Additionally, solid wastes were intentionally dumped along the ditches, streets, water drainages and alongthe floodplain.Family pit latrines were constructed less than 10m from most of the functioningwater points. A common practice was observed at all the dug well sites, where fetching tools such as bucket and rope were left in pools of stagnant water. A sanitary checklists in form of questions for borehole and dung well in Table 3.1 and Table 3.2 were used in assessing the sanitary risk of the water points.

The water sample points were systematically selected randomly from the water points at interval that would ensure fair distribution of sample across the communities. The following factors were considered in determining the number of water sample points to be selected from each of the communities:

I. The number of available functional water points at the time of study
II. The location and accessibility of the functional water points
III. The available functional water point mustbe unseasonal

Table 3.1: Sanitary inspection checklists for hand pump borehole water sources

S/no	Risk Assessment Checklists Question Statement	Observation
1	Is there any latrine within 10 m of the borehole/tube well?	Yes/No
2	Is there latrine or other source of faecal contamination uphill of the borehole and tube well?	Yes/No
3	Is there any source of within 10 m of the borehole/tube well (e.g., animals, agriculture, roads, industry etc.)?	Yes/No
4	Is the drainage channel absent or faulty allowing water to pool within 2 m of borehole and tube well?	Yes/No
5	Is the drainage channel absent, cracked, broken or in need of cleaning?	Yes/No
6	Is the wall or fence around the pump inadequate?	Yes/No
7	Is the well apron less than 2 m in diameter?	Yes/No
8	Does spilt water collect in the apron area?	Yes/No
9	Is the well apron or pump cover cracked or damaged?	Yes/No
10	Is the hand pump/tube well loose at the point of attachment?	Yes/No

'yes answers' add up to determine risk factor[Source: (Who, 2011)]

Table 3.2: Sanitary inspection checklists for open dug well water sources

S/no	Risk Assessment Checklists Question Statement	Observation
1	Is there any latrine within 10 m of the well?	Yes/No
2	Is there latrine or other source of faecal contamination uphill of the well?	Yes/No
3	Is there any source of within 10 m of the well (e.g., animals, agriculture, roads, industry etc.)?	Yes/No
4	Is the drainage channel absent or faulty allowing water pool within 2 m of the well?	Yes/No
5	Is the drainage channel absent, cracked, broken or in need of cleaning?	Yes/No
6	Is the wall around the top of the well inadequate, allowing surface water to enter the well?	Yes/No
7	Is the well apron less than 2 m in diameter?	Yes/No
8	Are the walls of the well inadequately sealed at any point for 3 m below ground?	Yes/No
9	Is the well apron cracked or damaged?	Yes/No
10	Are the rope and bucket left in such position that they may become	Yes/No

contaminated?

11	Is the wall or fence around the well inadequate?	Yes/No

'yes answers' add up to determine risk factor[Source: (Who, 2011

c. Sanitary inspection score risk factor

The standardized sanitary checklists for borehole and dug well water sources are presented in Table 3.1 and Table 3.2. The checklists were used for observations and interviews with a scoring system to quantify overall risk (CAWST, 2013). The questions were written so that 'Yes' score is assigned '1' and 'No' is assigned '0'. At the end of inspection '1' scores were added up to get the total contamination score risk. The overall sanitary score risk were interpreted based onthe following range of values.

- Score '0' to '2' indicates low risk of contamination
- Score '3' to '5' indicates medium risk of contamination
- Score '6' to '8' indicates high risk of contamination
- Score '9' to'10' indicates very high risk of contamination

The use of standard checklist serves as objective assessment, so that data obtained by different inspectors or in different areas can be compared directly (CAWST, 2013).

d. Some of the selected water points and the anthropogenic activities in the communities

Plate IIIA and IIIB show the tube well (TW5) located on the bed of Lamurde River at AngwanSarki where water is being abstracted all year run; the tube well is quantified to be of very high risk of contamination. Plate V and VI show a hand pump borehole (BH2) located at

the Ministry of Water Resources and Rural development and a tube well (TW2) located at Nukkai Riverbank, a few metres downstream of the Rivers Nukkai and Lamurde Confluence. These water sources were quantified to be of low risk of contamination. Plate VII shows riverbed dotted with depositional activities at the upstream of MayogwoiBridge along Hamaruwa-way and Plate VIII shows the solid waste dumpsite by urban storm water around A AKassai.



A: Tube well on 12/04/2016 (dry season) B: Tube well on 12/04/2016 (wet season)
Plate III: Tube well (TW5) quantified as high risk of contamination sited at AngwanSarki



Plate IV: Fetching point sited 100m away from TW5 taken on 12/04/2016



Plate V: Hand pump borehole (BH2) with low risk of contamination located at the premise of Ministry of Water Resources (12/04/2016)



Plate VI: Tube well (TW2) with low risk of contamination located at Nukkai old Bridge (12/04/2016)



Plate VII: The surface of River Mayogwoi dotted with depositional solid waste; some women were extracting water from sand shore around Mayogwoi Bridge (12/04/2016)



Plate VIII:Depositional activities around Lamurde River where TW3 is sited12/04/2016)

Table 3.3: Estimated number of households within the community's watershed influencingthe water sample points and administered questionnaires

S/no	Community	Number of Households	Number of questionnaire administered
1	Nukkai	108	32
2	Roadblock	65	19
3	Mayogwoi	55	16
4	Magami	125	37
5	AngwanSarki	85	25
6	Old Abattoir	71	21
Total		509	150

3.2.2 Administering of questionnaire

The estimated number of households within the community's watershed influencing the water sample points and number of questionnaires administeredis presented in Table 3.2. The number questionnaire administered to each community was based on proportional population (Abubakar2012).

$$n = (N * x) \,/\, (x + N - 1) \ldots\ldots\ldots\ldots\ldots \quad (3.1)$$

Where

$$\mathrm{x} = (\mathrm{Z} * \mathrm{p} * (1 - \mathrm{p}))/(\mathrm{e}^2) \ldots\ldots\ldots\ldots\ldots \quad (3.2)$$

Z is critical values of the normal distribution at 95% confidence level, p = 0.5(maximum sample proportion), e=0.05(error margin) and N is the population size of the community.

The questionnaire is administered tohousehold member not below 18 year of age and had lived in the community for at least 5 years and had knowledge about the community sanitation

practices. Face-to-face interviewer-administered structured questionnaires were used to collect field data, whichwere verified and analysed.

3.3 Water Sampling and Biophysicochemical Quality Analyses

The methods of water samplings and analytical testing adopted were based on international acceptable methods and analytical application principles(CAWST, 2013;Ryan *et al.,* 2005 and UNICEF, 2008).

3.3.1 Water sampling

Water sampling was carried out on the existing hand pump boreholes, dug wells and tube wells closed or on the pollution sources. Information on the depth of hand pump boreholes/tube wells, depth to the well screens, and length of the screens was obtained from the owners and operators of the water facilities. While in dug wells, a sterile metal was attached to the end of rope and lower into the well until it touched its bottom. The rope was then pulled out and measured with tape.

The samples were collected in 150ml properly labelled screw-capped sterile plastic bottles and placed inside a portable cooler box containing ice pack in order to maintain a low temperature before reaching the Laboratory. On reaching the laboratory, the analysis was carried out as quickly as possible. Where the immediate analysis was not possible, the sample was stored in a freezer as recommended by Ryan *et al.* (2005).

a. Well water sampling

The water sample was conducted in accordance with the procedures proscribed in (CAWST,2013). Only those well waters being patronized by the community on daily basis were considered.

i. A cup, sterilized with 2ml of methanol, was attached to a weight and string.

ii. The weighted cup was lowered into the well by unwinding the string slowly not allowing the bottle to touch the sides of the well to some distance below the water surface not letting the cup to touch the bottom of the well or disturb any sediment.

iii. It was then pulled up by rewinding the string around the stick.

iv. The water sample was transferred into the sterile sample bottle with small air space in the sample bottle to allow the sample to be mixed before analysis.

b. Borehole water sampling

Sampling depth of the borehole was taken from the water surface to the location of the well screen where water entered the well (Chapman, 1996 and UNICEF, 2008). Sampling from borehole source was strictly conducted in accordance with UNICEF POTALAB WE10016 instructions and other standard procedures (CAWST, 2013).

i. The inside of the tap was sprayed with mentholated spirit and ignited and left to cool after which it was flushed for few minutes.

ii. The open sample bottle was placed facing up the running tap until it was filled.

iii. The water sample was placed inside a portable cooler box containing ice pack, with air space in the bottle to allow for mixing.

c. Sampling from tube wells

i. The inside of the hose (pipe) was sprayed with sodium hypochlorite solution (bleach) with a wash bottle and flushed until all the bleach had been washed off and tested to be sure no residual chlorine remained.

ii. The pipe was placed inside the sample bottle running water until the bottle is filled. A slight air gap was left at the top of the sampling bottle to allow for mixing.

3.3.2 Analyses of biophysicochemical quality parameters

Water quality analyses were carried out at the Rural Water Supply and Sanitation Agency (RUWSSA) Jalingo, one of the approved UNICEF assisted Laboratories in North East Geopolitical

Zone. It was the policy of the Agency to assign a trained chemist in order to supervise the equipment and instrumentation used by outsider during field and laboratory analysis to ensure their safety. To this end, this analysis was carried out under the watch of Vincent Peter Kwakwa in the dry season and Timothy Akafa in the wet season.

The analytical methods adopted were based on international acceptable methods and analytical application principles (CAWST and 2013; UNICEF, 2008). Measurement of turbidity, temperature, pH, total dissolved solid (TDS) and demand oxygen (DO) were conducted at the site. Chemical and bacteriological parameters such as nitrate, fluoride, zinc, sulphates, chlorides, faecal coliform count were conducted in the laboratory. The detailed procedures used for testing each of the parameters are given below.

a. On-site determination of water quality parameters

i. Geographical coordinates

The measurements of latitude (^{0}N) and longitude (^{0}E) were carried out at each selected water sample point using a Global Positional System Meter (Garmin GPS MAP 76).

ii. pH

The pH measurement was conducted using Wagtech WE30200 pH meter. The pH meter electrodes were dipped into the water sample at about 2-3cm, stirred once, allowed the reading to stabilize and the reading was noted.

iii. Electrical conductivity and total dissolved solids

Electrical conductivity and total dissolved solids were determined using Wagtech WE30120 Conductivity/TDS Meter. The measurements were conducted by submerging the meter probe into the water sample in a plastic beaker to minimize any electromagnetic interference, stirred once, allowed reading to stabilize and recorded the readings.

iv. Dissolved oxygen and temperature

Horiba Water Quality Monitor meter was used in measuring the value of dissolved oxygen and temperature of the water sample. The measurements were carried out by dipping the probe of the instrument into the water sample at about 2-3cm in a plastic beaker to minimize any electromagnetic interference, stirred once and reading allowed to stabilize and the reading of dissolved oxygen and temperature were noted.

v. Turbidity

Turbidity was measured using Wagtech WE30140 PotalabTurbidimeter. The turbidity measurement was conducted by placing the meter on a flat surface, filling a clean sample vial to mark, placing in a sample well and covering the vial with light shield cap. The display reading was recorded as sample turbidity.

b. Laboratory determinations of water quality parameters

i. Faecal coliform counts

Experimental Procedure

I. A growth pad was dispensed onto sterilized Petri dish and saturated with prepared Membrane Lauryl Sulphate Broth (MLSB); excess of MLSB was poured off.

II. Sterilized membrane was placed onto the bronze membrane support until the filter funnel firmly hold down into position using sterilized forceps and 100 ml water sample was poured into the filter funnel with hand pump connected to filtration unit bases to suck out the water sample through the membrane and leaving out the trapped coliform bacteria.

III. The membrane was then transferred onto the top of pad that has already saturated with MLSB using sterilized forceps.

IV. The Petri dish lid was replaced, labelled and placed onto Petri dish rack and the rack was placed into the incubator at 44 ^{0}C for 18 hours.

V. At the end of incubation, the temperature of the incubator was noted, the lid was removed and all the yellow colonies were counted irrespective of size.

VI. The value obtained from the count equalled to the number of coliforms per 100 ml. The sample that was incubated at 37 ^{0}C was Total Coliforms while the one incubated at 44 ^{0}C was faecal coliforms.

ii. Nitrate

Experimental Procedures

I. Water sample was filled into the Nitratest Tube to the 20 ml mark. One level spoonful of Nitratest power and one Nitratest tablet were added to the Tube with the screw cap in placed and vigorous shaken for one minute.

II. The Tube was allowed to stand for about one minute and then gently inverted four times to aid flocculation and allowed to stand for further three minutes until the content were completely settled out.

III. The screw cap was removed and the top of the tube was cleaned and the clear solution was carefully decanted into the Round Test Tube to the 10 ml mark.

IV. One tablet of Nitratest was grinded and mixed to the solution in round test tube with shaken until complete dissolution.

V. After the mixture had allowed standing for 10 minutes, reddish dye colour was developed.

VI. Wavelength of 570 nm on Photometer (Phot. 23) was selected and the test tube was placed in a sample well.

VII. The reading of the transmittance was noted and the percentage of transmittance obtained was converted to concentration with aid of Nitratest calibration chart and mg/L nitrate is obtained by multiplying the result by a factor of 4.43.

b. Fluoride

Experimental Procedures

I. The test tube was filled with water sample to 10 ml mark.

II. One tablet of fluoride No. 1 was grinded and mixed thoroughly in test tube until complete dissolution.

III. One tablet of fluoride No. 2 was also grinded and mixed thoroughly in test tube until complete dissolution.

IV. The test tube content was allowed standing for five minutes with pale yellow colour of the solution formed.

V. Wavelength of 570 nm on photometer (Phot. 14) was selected and the reading of the transmittance was noted.

VI. The percentage of transmittance obtained was converted to concentration in milligram per litre with aid of fluoride calibration chart.

c. Zinc

Experimental procedures

I. The test tube was filled with water sample to 10 ml mark.

II. One tablet of zinc was grinded and mixed thoroughly in a test tube until complete dissolution.

III. The test tube was allowed standing for five minutes until intensive blue colour of the solution was observed.

IV. The sample tube was placed in the test chamber; Phot. 35 was selected and the reading was displaced as milligrams per litre (mg/L) Zinc on the photometer

3.4 Data Analyses

Statistical toolswere used to analyse the results of water quality parameters in order to determine whether the contaminations of the water sources were localised or widespread and the indicators that helped interpreting the scale of contamination. The statistical tools used include one-way analysis of variance (ANOVA), linear regression and Pearson correlation.

3.4.1 **One-way analysis of variance**

The analysis of variance was carried out using a statistical tool packs built into Microsoft Excel. One-way analysis compared the means data of the water quality parameters along the three water sources and along each water quality parameter to determine whether there are statistical significant difference between the determinants.

3.4.2 Regression analysis

The regression analysis was carried out to establish whether the regression lines of either distances of contamination sources from the water sample points or the depth of water sources approximate the real data. Microsoft Excel package was used to calculate the predicted value, which was related to change in response variables. A large P-value suggested that changes in predicted values were not associated with changes in the response.

3.4.3 Analysis of dependence (proxy) parameters

The strength in association between total dissolved solids and chloride; total dissolved solids and fluoride and turbidity and faecal coliform counts in each of the water sources was determined by calculating Pearson's r, a linear correlation coefficient. To interpret the field data, the following ranges of values for r were used to define the strength of dependence between data pairs (WHO/UNICEF, 2010):

- -1.0 to -0.7 strong negative association;
- -0.7 to -0.3 weak negative association;
- -0.3 to +0.3 little or no association;
- +0.3 to +0.7 weak positive association;
- +0.7 to +1.0 strong positive association

Hence, this study attempted to determine the extent to which the chloride and fluoride concentrations are dependent on total dissolved solids. The study also investigated a statistical linear correlation between faecal coliform count and the turbidity of the water samples.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Water Facilities, Pollution Sources and Sanitary Risk Factors

4.1.1 Types of water facilities and pollution sources

The sanitary risk obtained at each of the water sample points was presented in Table 4.1. The types of water sources identified in the study area include hand pump boreholes, dug wells, tube wells and surface waters, and the source of contaminations observed in and around water-sources include on-site sanitations, municipal solid wastes and abattoir wastes. Although, other water sources such as public water piping systems and family household tube wells existed, these facilities were not included in the examination because the study was intended primarily to determine the effect of community sanitation status on water coming out directly from the sources.

Table 4.1:Sanitary risk obtained at each of the water sample points

Risk of Contamination	Very High Risk	High Risk	Medium Risk	Low Risk
Score matrix for ranking risk	9-10 or 11	6-8	3-5	0-2
Water Sample Point	TW3, TW5	BH1, BH4, WW3, WW5, TW4	BH3, BH5, BH6, WW1, WW2, WW4, TW6	BH2, TW1, TW2

Modified from WHO (2011)

4.1.2 Quantifying sanitary risk factors at the sample points

Sanitary risk obtained at each of the water sample points is presented in Table 4.1.TW3 and TW5 were quantified with very high sanitary risk factor because of the unsanitary conditions at the environment of the wells. TW3 is located along Mayogwoifloodplain beside A. A. Kassai where the waste generated within Mayogwoicommunity has been deposited over years by storm water coupling with poor design and absence of drainage round the tube well. TW5 was sited right in the middle of Lamurde Riverbed and water is being abstracted from the well all year round.

TW4, BH1, BH4, WW3 and WW5 in Table 4.2 were ranked with high risk of contamination. TW4 is located at the floodplain along River Lamurde where the main drainage coming from Central Market and passed through dense settlements around the upstream to Water Farm terminated. Deposit of waste by storm water could be seen around the well with pool of stagnant water with the drainage completely block.

BH1, which was situated at less than 10m downstream of the on-site sanitation, had cracked apron while the apron of BH4 was partly damaged with no drainage, leaving water pools. Parapet around the top of the walls of WW3 and WW5 were observed to be inadequate with absence of drainage, allowing pool of stagnant water to seep into the wells. Moreover, the two wells were surrounded by multiple on-site sanitation structures with WW5 situated at less than 100 metres downhill of the old Abattoir. TW1 and TW2 had good structural facilities and

minimal sanitary risks, thus making the wells to be rated with low risk of contamination. Although, BH2 had good structural facilities and minimal sanitary risks, the location of chicken dung dumpsite in the neighbour compound, less than 10m uphill could place the source to sanitary risks.

Although, the sanitary risk factors of WW1, WW2 and WW4 were ranked among medium risk, the mode at whichwater were being fetched could pose additional source of contamination in the wells. For instance, fetching tools such as rope and bucket either were usually left in pool of stagnant waters during the time of fetching or after water had been fetched. In most cases, little children were often sent to fetch water and in the process, wash off spilt dirt water from their feet onto the wells in attempt to pull out the water cans with their foot rested on the parapet. Sanitation status and water quality parameters from river sources were not included in the statistical analyses because they were not used as drinking water supply.

Table 4.2: Opinions of the respondents on questionnaires administered

S/no	Question statement	Frequency	Percentage
1.	How many years have you lived in the community?		
(a)	Less than 6 years	35	23.33
(b)	Between 6 and 25 years	69	46.00
(c)	More than 25 years	46	30.67
2	How many households do you have?		
(a)	Less than 6 members	36	24.00
(b)	Between 6 and 10 members	72	48.00
(c)	10 above members	42	28.00
3	How do you dispose the waste generated within your household?		
(a)	At collection centre	44	29.33
(b)	By roadside or in drainage	70	46.67
(c)	Burn or buried behind backyard	36	24.00
4	What type of toilet do you use in your household?		
(a)	VIP or pit latrine with slab	124	82.67
(b)	Pit latrine without slab or composing toilet	23	15.33
(c)	Share with neighbour or open field	3	2.00
5	Main source of drinking water used in your household?		
(a)	Pipe water into dwelling or public tap	22	14.67
(b)	Tube well or borehole or protected dug well	65	43.33
(c)	Rainwater or Sacket/bottle water	13	8.67
(d)	Unprotected dug well or surface water	50	33.33
6	What do you do to your water to make safe for drinking?		
(a)	Boil or strain it through cloth	56	37.33
(b)	Add chlorine or use water filter	45	30.00
(c)	No any form of treatment	49	32.67
7	What method do you use in preserving drinking water?		
(a)	Store in cistern	91	60.67
(b)	Store in refrigerator	20	13.33

(c)	Store in open basin	39	26.00

4.2 Analysis of Questionnaire

Summary of the respondents' opinions on questionnaires administered was presented in Table 4.2. Public building such as Church, Mosques, offices and stores were excluded. One hundred and fifty (150) questionnaires were determined at 95% CL using population proportion shown in equation 3.1 and 3.2. Questionnaire was self-administered by random selection of the households. 59% ofrespondents represented female and 88% had attended a minimum of secondary education.

Theanalysis of the respondents' opinions were summarised in Table 4.4. From the results of the analyses, it could be said that:

I. Jalingo city is a low density with about 72% of the households had population of less ten members and fast growing city with about 69% of the respondents, which have lived in there within the space of 25 years.

II. About 29.33% of the population representing the respondents often dumped their solid waste generated within the households in designated dumpsites.

III. about 78% of the residents relied on open dug well, hand pump borehole and tube well water sources for drinking and other domestic purposes, in spite of all the aforementioned environmental degradation,.

IV. The anthropogenic loadings will continue to arise with the trend of increasing population; thereby leading to more contamination of the water sources, unless measures are taking to control the environmental pollution.

Table 4.3: Faecal coliform counts and turbidity of the water samples

Water sample point	Closest sanitation	Distance sanitation site	Depth of sample point	Water quality parameter			
				Turbidity(NTU)		Faecal coliform (CFU/100 ml)	
				DP	WP	DP	WP
BH1	Pit Latrine	12.35	26.90	1.60	2.30	0.0	1.0
BH2	Chicken dung	8.89	23.50	2.20	1.20	0.0	0.0
BH3	Pit Latrine	9.50	24.60	1.70	0.43	0.0	0.0
BH4	Pit Latrine	9.25	27.30	18.70	3.62	5.0	3.0
BH5	Pit Latrine	6.50	25.70	1.70	0.86	0.0	0.0
BH6	Pit Latrine	7.79	22.35	4.20	1.04	0.0	0.0
TW1	Farming	1.50	7.00	0.74	1.74	0.0	0.0
TW2	Farming	3.50	6.00	1.84	1.84	0.0	0.0
TW3	Waste dump	0.50	7.00	2.60	3.60	0.0	4.0
TW4	Waste dump	0.50	6.00	1.50	1.80	0.0	0.0
TW5	Waste dump	0.01	6.00	18.50	16.40	3.0	16.0
TW6	Animal waste	3.50	27.00	1.60	1.25	0.0	3.0
WW1	Pit Latrine	8.50	5.50	16.60	2.00	8.0	7.0
WW2	Pit Latrine	3.50	4.20	9.90	3.40	2.0	5.0
WW3	Pit Latrine	8.50	4.80	30.20	5.17	10.0	12.0
WW4	cemetery	8.00	3.90	43.70	6.40	10.0	13.0
WW5	Pit Latrine	6.10	3.80	28.50	8.80	11.0	15.0
WHO Standard				5.0		0.0	

4.3 Contamination of Sample Points by Faecal Coliforms and Turbidity

4.3.1 Impact of faecal coliforms and turbidity

The results of faecal coliform counts and turbidity were presented Table 4.5.

All water sample points (Table 4.4) with high risk of contaminations were detected with faecal coliforms, which confirmed with Ocheri*et al.* (2014) that high faecal coliform is often associated with the sanitary condition of the environment of the wells.

BH4, TW5 and all dug wells which were quantified as high risk also detected with faecal coliforms. In wet season, BH1, TW3, TW6and TW5 were also tested positive, which might be attributable to unsanitary conditions of the well leading to infiltration of stagnant water through the head or the side of the well casing not tightly sealed (Lindenbaum, 2012). Such local pathway would allow the contaminants to bypass the unsaturated zones, thereby providing little opportunity for contaminants attenuation (Morris *et al.*, 2003).

Although, TW4 and BH2 water sources show compliance with the WHO guidelines of zero faecal coliform counts for drinking water quality, high concentration of ammonia in TW4 (0.8mg/L) and BH2 (2.0mg/L) during the dry season could be indicator of possible bacterial, sewage and animal waste pollution (CASWT, 2013). UNICEF (2008) stated in it manual that membrane filtration method does not usually detect stressed and injured coliform bacteria, which mean that water sources presume to be of zero faecal coliform counts may actually be contaminated by faecal coliforms.

Table 4.4: Variances in faecal coliform counts and turbidity values along the borehole, tube well and dug well sources

Water quality		F	p-value at 95% confidence level	
Faecal coliform counts	17.31	6.82	0.000164	0.000854
Turbidity	9.50	1.36	0.00248	0.288

Table 4.5: Variation between distance of sanitation site and depth of sample point

	F	p-value at 95% confidence level
Distance/depth	8.81	5.63×10^{-4}

4.3.2 Localised contamination of faecal coliforms

a. Variation of mean faecal coliform counts among the three water sources

One-way analysis of variance presented in Table 4.6 was aimed at determine if statistical significant difference exists between faecal coliform counts data obtained from the three water sources and the results. The results, (F=17.31, P= 1.64 x 10^{-4}) and (F=5.39, P=8.54 x 10^{-4}) during dry and wet seasons respectively indicated that at least one pairs of means in the two seasons had statistical significant differences. The post hoc test further revealed that the differences lied between hand pump borehole and tube well water sources during both seasons probably because these two sources were sealed against ingress of contaminated surface water (Ocheri*et al.*, 2014).

The statistical insignificant differences between open dug wells with either borehole or tube well water sources arises possibly because of its shallowness, inadequate parapets around the top of wells, poor sanitary conditions surrounding the wells and unsanitary method at which waters were been fetched from the dug well source (ARGOSS, 2001).

b. Variation of mean turbidity values among the three water sources

One-way analysis of mean values of turbidity from the three water sources is presented in Table 4.7. F=9.50, P= 2.48*10^{-4} in dry season had statistical significant difference between boreholes and dug wells probably because of theturbulence arising as a result of a very low yield of the water sources and over exploited during the dry seasonwhen compared with tube wells having very high yield with enough volume to withstand turbulence during pumping. No significant difference exist between the mean values of turbidity (F=1.36, P= 0.29) from the three water sources during wet season.A significant difference exist between distance and depth of sanitation site ($F_{3, 15}$ = 8.81; P = 5.63 x 10^{-4}) at 95% confidence levels in Table 4.5.

Table 4.6: Responses of faecal coliforms with distance of sanitation site

Water sample point	Number of source	Response of faecal coliform count (CFU) with distance (m) of closet contamination sources from water sample points					
		Gradient		R^2-coefficient		P-value at 95% C.L	
		DP	WP	DP	WP	DP	WP
BH	6	0.0488	0.53364	0.00258	0.10849	0.92391	0.52379
TW	6	-0.6300	-0.12340	0.24446	0.24113	0.31879	0.51504
WW	5	0.4428	0.028019	0.55876	0.16291	0.14640	0.50040

Table 4.7: Responses of faecal coliforms with depth of sample point

Water sample point	Number of source	Response of faecal coliform count (cfu) with the depth (m) of water source					
		Gradient		R^2-coefficient		P-value at 95% C.L	
		DP	WP	DP	WP	DP	WP
BH	6	0.538	1.168	0.32071	0.53225	0.24134	0.09982
TW	6	-1.533	-0.110	0.04969	0.00655	0.67115	0.87889
WW	5	-0.016	-0.085	0.00664	0.25805	0.89635	0.38222

4.3.3 Spatial literal variation of faecal coliform counts along borehole, tube well and dug well sources

(i) Linear regression analysis of faecal coliforms to the distance of closest contamination source from its water sample point

Responses of faecal coliforms with distance of sample point from its closest contamination source were presented in Table 4.8. Positive slopes negated the argument that faecal coli form counts decrease with distance of contamination source from sample point. Only tube well sources in dry and wet seasons had negative gradients with R^2-coefficient of determinations 0.244 and 0.241 respectively. Nonetheless, P-values (0.32 and 0.52) in each case was greater than 0.05 confidence level, leading to the rejection of any statistical linear correlation between faecal coliforms and distances of closest contamination sources.

(ii) Response faecal coliform bacteria with the depth of sample points

The response of faecal coliform counts with depth of sample point is presented in Table4.9. The depth of tube well and dug well sources had negative gradients with faecal coliform counts during both seasons. However, R^2- determinants were very low in tube wells (0.050, 0.007) and in dug wells (0.007, 0.258) in dry and wet seasons respectively. Moreover, p-values in tube wells (0.67, 0.88) and in dug wells (0.90, 0.38) in dry and wet seasons respectively are far greater than 0.05 significant levels.

These insignificant differences are indications that there could be other factors affecting the faecal coliform count, apart from distance of contamination source from its water sample point and the depth of water sources. This result tends to support Bartram and Ballance (1996) and Morris *et al.* (2003) that aquifers in hard rock were usually small, localised and not very productive where the pollutants are unpredictable.

Table 4.8: Proxy correlations between faecal coliform counts and turbidity values

Season	Hand pump borehole	Hand dug well	Tube well
Dry season	0.989	0.779	0.996
Wet season	-0.960	0.903	0.972

Table 4.9: Seasonal variation in faecal coliform counts and turbidity of water samples

Water quality parameter	F	P-value at 95% confidence level
Turbidity	4.87	0.00346
Faecal coli form counts	1.04	0.316

4.3.4 Proxy correlation and seasonal variation in turbidity and faecal coliforms

a. Proxy correlation between turbidity and faecal coliform counts

When assessing faecal contamination, it is recommended to measure turbidity along with faecal coliforms, since pathogens can be absorbed onto suspended particles and to some extent be shielded from disinfection (UNICEF, 2008). Pearson correlation coefficient (r) was also investigated to establish the strength in relationship between turbidity and faecal coliform counts among the three water sources is presented in Table 4.10.

The turbidity was highly correlated with faecal coliform counts in hand pump boreholes (r=0.989, n=6) and tube wells (r=0.996, n=6) and to less extent in open dug wells (r=0.779, n=5) during the dry season. This result implies that the turbidity is acting as direct indicator of possible source of microbial contamination; the lower value in dug well source during the dry season could be due to high patronage.

b. Seasonal variations in turbidity and faecal coliform counts

A seasonal variation in turbidity and faecal coliform counts among the three water sources is presented in Table 4.11.

The turbidity (F=4.87, P= 3.46 x 10^{-2}) in dry and wet seasons was lower than 0.05 significant levels, an indication of statistical significant difference. Season had insignificant difference on faecal coliform counts (F=1.04, P= 0.316) probably because of coliform bacteria load due to storm water infiltration into shallow aquifer during raining season and die off during dry period due to dryness of the aquifers.

Table 4.10: Temperature, pH, DO, nitrate, nitrite and ammoniavalues

Water Sample Point	Water Quality Parameter					
	Temperature	pH Value	DO (mg/L)	Nitrate	Nitrite	Ammonia

	(°C)						(mg/L)		(mg/L)		(mg/L)	
	DP	WP	DP	WP	DP	WP	DP	WP	DP	WP	DP	WP
BH1	32.17	28.60	6.33	7.12	1.24	4.27	5.25	6.20	0.08	0.01	1.00	0.17
BH2	31.60	29.79	6.36	6.27	1.40	11.50	1.23	3.99	0.02	0.08	2.00	0.11
BH3	32.06	30.00	6.40	6.50	5.47	12.31	3.43	4.01	0.01	0.00	0.10	0.01
BH4	30.04	28.00	6.29	7.12	2.25	3.00	2.11	1.82	0.01	0.07	0.20	0.09
BH5	29.77	27.70	6.23	7.30	0.98	3.00	1.45	1.48	0.03	0.01	0.10	0.17
BH6	29.95	28.50	6.42	7.20	4.04	10.20	2.22	3.29	0.01	0.01	0.30	0.20
WW1	31.96	29.90	5.38	6.73	4.54	8.00	8.89	9.75	0.05	0.00	0.50	0.18
WW2	31.07	28.00	6.56	6.60	3.25	6.60	2.61	3.57	0.01	0.00	3.00	0.11
WW3	30.95	27.90	5.84	6.20	6.70	7.10	2.22	4.30	0.08	0.01	0.50	0.13
WW4	29.67	28.80	6.44	6.80	8.86	11.20	1.07	1.76	0.03	0.01	0.90	0.17
WW5	28.97	28.30	6.05	6.70	8.76	9.20	12.98	14.80	0.90	0.01	3.50	0.26
TW1	33.40	29.00	7.02	7.20	1.11	12.00	0.84	0.85	0.44	0.01	0.00	0.00
TW2	33.40	29.10	6.84	6.68	1.21	8.30	1.90	1.82	0.03	0.08	0.00	0.16
TW3	30.70	28.00	5.57	6.70	1.27	6.70	6.54	8.28	0.07	0.01	1.80	0.13
TW4	29.45	28.80	5.77	6.50	1.19	11.31	2.01	3.21	0.70	0.02	0.80	0.10
TW5	28.54	27.80	5.55	7.40	4.24	12.60	1.25	4.13	0.90	0.01	0.30	0.12
TW6	29.22	28.90	6.29	7.58	3.77	7.20	0.77	3.46	0.09	0.01	0.10	0.15
G.V			**6.5-8.5**		**-**		**50.0**		**3.0**		**1.5**	

4.4 Nitrate, Nitrite and Ammonia Contaminations

4.4.1 Impact of nitrogen compounds, pH and DO concentrations

Concentrations of nitrate, pH, DO, nitrite, ammonia are presented in Table 4.12. The borehole water source had nitrate concentrations ranging between 3.43 to 1.22 mg/L except BH1 that recorded 5.25mg/L during the dry season. BH1 and BH2 had high ammonia contents of 1.0 and 2.0mg/L respectively in dry season while other borehole sources had their values ranged between 0.3 and 0.1 mg/L, indicating that nitrogen contaminations of these wells is of recent. The results could be indication of possible aquifer pathway either between BH1 and pit latrine or between BH2 and chicken dung dumpsite. According to ARGOSS (2001), pathways will nearly always exist in the subsurface that will provide a link between the sources of contamination and the receptor (groundwater supply).

WW5 and WW1were noted with high nitrate values of 12.82 and 8.89mg/L when compared with other dug wells with values ranging between 2.26 and 1.07mg/L. The contribution of nitrate in WW5 could be traced to the waste generated at abattoir and WW1to accumulation of waste dumped. Although, TW1 and TW2 were sited at the floodplains where rice and vegetation cultivation are intensive with heavy application of fertilizer, very low nitrate values (0.84 and 1.82mg/L) were noted. This result together with evidence from literatures might be the consequence of poorly drained and anaerobic condition of groundwater beneath paddy (rice) cultivated area favouring the conversion of nitrates to ammonium which is either volatilised to the atmosphere as ammonia, sorbs to the sediments or remained in surface runoff (Morris *et al.*, 2003). Furthermore, the vegetation covered might also be playing

significant role in contamination attenuation in these wells. According to Nieber *et al.* (2014), the vegetation can filter particulate contaminants and increase infiltration.

Table 4.11: Variance in nitrate, nitrite and ammonia values along borehole tube well and dug well sources

Water quality parameter	F		P-value	
	DP	WP	DP	WP
Nitrate	1.75	1.65	0.21	0.23
Nitrite	1.97	1.12	0.18	0.35
Ammonia	2.27	1.33	0.14	0.29

Table 4.12: Seasonal variations in nitrate, nitrite, ammonia, DO, pH and temperature

Water quality parameter	F	P-value
Nitrate	0.99	0.327
Nitrite	5.54	0.0249
Ammonia	8.46	0.0066
DO	24.58	0.00002
pH	20.47	0.00008
Temperature	27.35	0.00001

4.4.2 Localised contamination of nitrate along borehole, tube well and dug well sources

One-way analysis of variance for mean nitrate, nitrite and ammonia concentrations among the three water sources is presented in Table 4.11. Therewere no significant difference in nitrate (F=1.75; P=0.21 and F=1.65; P=0.23), in nitrite (F=1.97, P=0.18 and F=1.12, P=0.35) and in ammonia (F=2.27, P=0.14 and F=1.33, P=0.29) in dry and wet season respectively, implying that contaminants were localised.

4.4.3 Seasonal variations in nitrate, nitrite, ammonia, DO, pH and temperature

One-way ANOVA for mean concentrations of nitrate, nitrite and ammonia and mean values for DO, pH and temperature is presented in Table 4.12.

Period had significant differencesin nitrite (F=5.54; P=0.025), in ammonia (F=8.46; P=0.0066), in DO (F=24.58; P=0.00002), in pH (F=20.47; P=0.00008) and in temperature (F=27.35; P=0.00001)at 95% confidence levels during the dry and wet seasons respectively. Theseasonal variations these contaminants with change in season may be due to the anaerobic conditions arising from low pH and dissolved oxygen concentration of the groundwater, promoting the microbial activities. During the wet season, however, water level of the unconfined aquifers increases resulting in dissolution of more oxygen that aid in oxidizing ammonia and nitrite to nitrate. However, there was no significant different between nitrate in the dry and wet seasons (F= 0.99;P= 0.327) at 95% confidence levels, which could be the result of high fluctuation in reduction-oxidation of nitrate potential of the shallow groundwater between wet and dry seasons. Under such reducing conditions one would expect that infiltrating nitrate might either be lost as nitrogen gas due to de-nitrification or converted ammonium (Lindenbaum, 2012).

Table 4.13: Responses of nitrate concentration with distance of sanitation site

Water	No of	Response of Nitrate concentrations with distance (m) sanitation site

source	source	Gradient		R^2-coefficient		P-value at 95% C.L	
		DP	WP	DP	WP	DP	WP
BH	6	1.120	0.960	0.73627	0.70520	0.02879	0.03646
TW	6	-0.261	-0.270	0.13305	0.19807	0.47713	0.37650
WW	5	-0.008	-0.002	0.00078	0.00003	0.97530	0.99322

Table 4.14: Responses of nitrate concentration with the depth of water sample point

Water source	No of source	Responses of nitrate concentration with the depth of water sample point					
		Gradient		R^2-coefficient		P-value at 95% C.L	
		DP	WP	DP	WP	DP	WP
BH	6	0.516	-0.035	0.15994	0.00097	0.43210	0.95330
TW	6	-1.156	-0.048	0.08953	0.00021	0.56458	0.97806
TW	5	0.007	0.005	0.00237	0.00158	0.93807	0.94942

4.4.4 Spatial variation between nitrate concentrations along borehole, tube well and dug well sources

Linear analyses of nitrate with either distance of sanitation site or the depth of water source analysed at 95% confidence levels are presented in Table 4.13 and in Table 4.14.

(i) Variation of nitrate with distance of sanitation site

The slopes of statistical linear regression analysis in dug wells (-0.008 and -0.002) and in tube wells (-0.261 and -0.270) during dry and wet seasons respectively supported the argument that nitrate concentration decreases with distance of sanitation site. However, the R^2-coefficient of determinations in dug wells (0.001 and 0.000) and tube wells (0.133 and 0.198) in dry and wet seasons respectively were so small to establish any relationship. The correlation could further be rejected on the account that the p-values (0.975 and 0.993) in dug wells and (0.477 and 0.379) in the tube wells in dry and wet seasons respectively were above 95% confidence intervals.

(ii) Variation of nitrate concentration with depth of the water samples points

The dug well water source during both season and hand pump borehole during dry season had positive linear regression correlation between nitrate concentrations and the depth of water sample points, contradicting the argument that nitrate concentration decreases with the depth of water source. In borehole source during dry season and tube well source during both season,the slope of depth of water sample points with nitrate concentrations were negative but the R^2-coefficient of determinantsinsignificant and the p-values (0.57 and 0.98) too large (insignificant) to establish any linear uncorrelated between nitrate concentrations and the depth of water sample points. These results imply that there are other factors responsible for the contamination of the water source by nitrate apart from the closest distance of the sanitation site and the depth of the water source.

Table 4.15: Chemical water quality parameters of sample points

Water Sample point	Water quality parameter											
	TDS (mg/L)		Hardness (mg/L)		Chloride (mg/L)		Fluoride (mg/L)		Sulphate (mg/L)		Zinc (mg/L)	
	DP	WP	DP	WP	DP	WP	DP	WP	DP	WP	DP	WP
BH1	256.0	128.0	110.0	129.0	115.2	105.3	1.03	1.20	3.0	9.0	0.80	0.25
BH2	223.0	200.0	25.0	110.0	105.6	111.9	1.27	0.80	4.0	5.9	1.30	1.50
BH3	217.0	219.0	100.0	120.0	90.5	100.0	1.20	1.15	8.0	10.0	0.30	0.21
BH4	383.0	507.0	105.0	130.0	119.0	91.2	2.70	2.51	0.0	33.0	0.27	0.40
BH5	457.0	475.0	175.0	210.0	131.6	99.8	2.50	2.55	1.0	26.0	0.00	0.37
BH6	302.0	315.0	115.0	145.0	114.2	112.9	1.41	1.90	3.0	42.0	0.11	0.55
WW1	422.0	260.0	105.0	109.0	174.8	188.9	0.20	0.28	14.0	23.0	0.91	0.36
WW2	208.0	210.0	25.0	81.0	190.0	191.5	1.14	0.80	1.0	39.0	0.30	0.43
WW3	484.0	495.0	85.0	81.0	176.4	188.1	0.21	0.30	40.0	38.0	0.01	0.40
WW4	259.0	160.0	105.0	107.0	96.5	100.2	0.23	0.30	8.0	4.0	0.30	0.32
WW5	265.0	329.0	60.0	105.0	180.0	177.6	1.96	1.50	26.0	18.0	1.14	0.32
TW1	123.0	130.0	30.0	35.0	87.6	89.2	0.09	0.08	3.0	4.0	0.03	0.05
TW2	63.3	75.0	5.0	5.0	10.3	11.4	0.09	0.10	3.0	0.0	0.00	0.46
TW3	308.0	320.0	23.0	30.0	156.0	171.7	0.21	0.40	10.0	39.0	0.26	0.68
TW4	418.0	430.0	115.0	122.0	111.6	130.3	1.08	1.00	104	130	0.31	1.40
TW5	103.0	96.0	10.0	50.0	37.8	34.9	1.11	0.90	2.5	13.0	0.00	0.56
TW6	166.0	144.0	60.0	90.0	95.2	106.4	2.10	2.00	0.9	10.0	3.00	0.32
G.V	500.0		100.0 – 300.0		250.0		1.50		250.0		4.00	

4.5 Chloride, Fluoride, Sulphate and Zinc Contaminations

4.5.1 Impact of chlorides, fluoride, sulphates and Zinc

Elevated concentrations of chloride, fluoride, sulphates and Zinc in the water samples presented in Table 4.15 were localised to some particular water sample points. Chloride concentrations were noted in TW3 (156 and 172mg/L) and in TW4 (112 and 130mg/L) when compared with TW2 (10 and 11mg/L) in dry and wet seasons respectively due to enormous waste dump close to these sample points. Dug wells and boreholes were noted with elevated chloride concentrations due to proximity to on-site sanitations.

Elevated concentrations of Zinc were noted in BH2 (1.30mg/L) located at the uphill of chicken dung and in TW6 (3.00mg/L) and WW5 (1.14 mg/L) located at the abattoir premise.While other sample points were below 1mg/L, conforming with literatures that Zinc being an essential traced element is often associated with food and meat (Tchobanoglous*et al.*, 2004; WHO, 2011).Fluoride concentrations were generally high in boreholes than in dug wells and tube wells.All water sources at AngwanSarki,BH4 (2.61mg/L),BH5 (2.53mg/L), and abattoirpremise WW5 (1.70mg/L), BH6 (1.66 mg/L), TW6 (2.05mg/L)had mean fluoride concentrations from the dry and wet seasonslightly above the WHO guidelines for drinking water quality.

Almost all water samples from hand pump borehole fall within the taste threshold of calcium ion (100–300 mg/L). However, water samples from tube wells recorded taste threshold of calcium ion below 100 mg/L hardness except TW4, which recorded 115 and 122mg/L hardness in dry and wet seasons respectively. This might lead to low buffering capacity and so be more corrosive for water pipes (WHO, 2011).

Table 4.16: Variation between chloride, fluoride, sulphate and Zinc alongborehole, tube

well, dug well sources

Quality parameter	F		P-value	
	DP	WP	DP	WP
Chloride	6.137	5.460	0.012	0.018
Fluoride	2.769	4.093	0.097	0.040
Sulphate	0.769	0.211	0.482	0.812
Zinc	0.043	0.440	0.958	0.653

Table 4.17: Variations betweenall water quality parameters along the borehole, tube well and dug well sources

Water source	F		p-value	
	DP	WP	DP	WP
Borehole	51.94	24.89	1.00×10^{-30}	3.49×10^{-21}
Tube well	9.78	9.00	3.13×10^{-11}	1.70×10^{-10}
Dug well				

Table 4.18: Seasonal variation along chloride, fluoride, sulphate and Zinc

Water quality parameter	F	P-value
Chloride	0.0042	0.9488
Fluoride	0.6247	0.8760
Sulphate	1.6918	0.2027
Zinc	0.0173	0.8963

4.5.2 Spatial and seasonal variation in chloride, fluoride, sulphate and Zinc

a. Spatial variation in chloride, fluoride, sulphate and Zinc

One-way analysis of mean values of chloride, fluoride, sulphate and Zinc from the three water sources is presented in Table 4.16. Thevariance in all the water quality parameters along different borehole, tube well and dug well sources is presented in Table 4.19. Chloride (F=0.14, P= 0.012 and F=5.46, P= 0.018) in dry and wet seasons and fluoride (F=4.09, P= 0.04) in wet season hadeffect along borehole, tube well and dug well sources. The widespread contamination of chloride could mean the study area had rock-bearing chloride, which is also contributing chloride in the water sources. However, fluoride (F=2.77, P= 0.097) in dry season and sulphate(F=0.769, P=0.48 and F=0.21, P= 0.482) and Zinc(F=0.04, P= 0.958 and F=0.44, P=0.653) in dry and wet seasonsrespectively had no effect. The insignificant differenceswere indication of localised contamination.

There were significant differences on all the water quality parameter ($F_{13,70} = 51.94$, $p = 1 \times 10^{-30}$) in the dry season and ($F_{13,70} = 24.89$, $p = 3.49 \times 10^{-21}$) in the wet season along the borehole source. There were significant differences on all the water quality parameter ($F_{13,70} = 9.78$, $p = 3.13 \times 10^{-11}$) in the dry season and ($F_{13,70} = 9.0$; $p = 1.7 \times 10^{-10}$) in the wet season along the tube well source. And there were significant differences on all the water quality parameter ($F_{13,56} = 34.56$, $p = 6 \times 10^{-22}$) in the dry season and ($F_{13,56} = 26.8$, $p = 2 \times 10^{-19}$) in the wet season along the tube well source.

b. Seasonal variations in chloride, fluoride, sulphate and zinc

Seasonal variations in mean concentration of chloride, fluoride, sulphate and zinc among three water sources are presented in Table 4.18. Period had no significant difference on chloride (F=0.0042, P= 0.9488), fluoride (F=0.6247, P= 0.8760), sulphate(F=1.6918, P= 0.9488) and Zinc (F=0.0173, P= 0.8963) in dry and wet seasons respectively at 95% confidence level, probably due to high fluctuation in redox potential between the seasons.

Table 4.19: Proxy correlations between TDS and chloride; TDS and fluoride

Water Source	TDS verse Chloride		TDS verse Fluoride	
	Dry season	Wet season	Dry season	Wet season
Hand pump Borehole	0.873	-0.615	0.902	0.938
Tube well	0.771	0.794	0.135	0.112
Dug well	0.375	0.532	-0.597	0.022

4.5.3 Strength of association between TDS with chloride and fluoride

Strength of associations between TDS andchloride; TDS and fluoride is presented in Table 4.19

a. The strength of association between TDS and chloride

In hand pump boreholes, a strong positive correlation existed between TDS and chloride (r=0.87) in dry season and weak negative correlation (r=-0.62) in wet season. In the tube wells, however, strong correlations were observed between TDS and chloride (r=0.77) in dry season and (r=0.79) in wet weather. No correlation (r=0.38) between TDS and chloride in dug wells during the dry season and weak correlation (r=0.53) during the wet season.

b. The strength of association between TDS and fluoride

Strong positive correlations were seen in boreholes between TDS and fluoride in dry season (r=0.90) and in wet season (r=0.94). According to Uriah *et al.* (2014), high fluoride groundwater concentrations are from crystalline aquifer and increase with depth, which confirmed with the results obtained in this study. Open dug wells, which was within the unsaturated zone, showed no proxy correlation between TDS and fluoride (r = 0.02) during the wet season, probably because the water in the wells come from saturated zone which was no necessary pass through rocks. During the dry season, the infiltrating rainwater dried up due to low storage (Morris *et al.*, 2003), except dug wells which intersecting water bearing fracture, which tend to possess water. A moderate negative correlation (r = -0.60) between TDS and fluoride is an indication that water in the hand dug wells were actually flowing out of rock fracture.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

Summary of results obtained in this study and the statistical analyses are as follows;

a. Sanitary inspection

Different degree of deteriorating structural facilities, operational systems were identified with unsanitary practices at the dug wells, where fetching tools were left in pool of stagnant water.TW3 and TW5 were quantified as very high sanitary risk, while TW1, TW2 and BH2 with low with the other water sources falling in-between.

b. Faecal contamination and turbidity

All the sample points identified with very high sanitary risk were noted with faecal coliform counts. All the dug wells were also noted with faecal coliforms.There were significant differences betweenfaecal coliform counts ($F_{3,14}$= 17.31; p = 1.64 x 10^{-4}) in wet season and ($F_{3,14}$ = 5.39; p = 8.54 x 10^{-4}) in dry season at 95% CL along the borehole, tube well and dug well sources. No linear correlations existed between faecal coliform count with either the distance of closest sanitation site or the depth of water source. Period had no significant difference on faecal coliform counts in all the water sources (F = 1.04; p = 0.316) at 95% confidence levels.

A significant difference exist between distance and depth of sanitation site ($F_{3, 15}$ = 8.81; P = 5.63 x 10^{-4}) at 95% confidence levels. There was significant difference betweenturbidity (F= 4.87; P = 3.46 x 10^{-2}) in wet season across the boreholes, tube wells and dug wells at 95% confidence levels. Faecal coliform counts and turbidity had strong Pearson correlations in BH (0.989, -0.960), in TW (0.996, 0.972), and in WW (0.779, 0.903) during the dry and wet season respectively.

c. Physicochemical parameters

Chemical contaminations of water samples were localized to sources closed to either pit latrines or at the environment of solid waste piles. There was significant difference between chloride (F = 6.14; p =0.012) and (F = 5.46; p = 0.018)in the wet and dry seasons at 95% confidence levels along borehole, tube well and dug well water sources. Period had effect on nitrite (F=5.54, P=0.025); ammonia (F=8.46, P=0.007); DO (F=24.58, P=0.00002); pH (F=20.47, P=0.00008); and temperature (F=27.35, P=0.00001).

However, no seasonal effect exist between nitrate (F = 1.75; p =0.21) in the wet seasonsand (F = 1.65; p = 0.23) in the dry season; sulphate (F= 0.77; p =0.48) in the wet season and (F = 0.21; p = 0.81) in the dry season; Zinc (F=0.04; p =0.96) in the wet season and (F = 0.44; p = 0.65)in the dry season at 95% confidence levels along borehole, tube well and dug well water sources.

There were significant differences between all the water quality parameters, ($F_{13,70}$ = 51.94, p = 1 x 10^{-30}) in the dry season and ($F_{13,70}$ = 24.89, p = 3.49 x 10^{-21}) in the wet season along the borehole source. There were significant differences between all the water quality parameters, ($F_{13,70}$ = 9.78, p = 3.13 x 10^{-11}) in the dry season and ($F_{13,70}$ = 9.0; p = 1.7 x 10^{-10}) in the wet season along the tube well source. And there also were significant differences on all the water quality parameter ($F_{13,56}$ = 34.56, p = 6 x 10^{-22}) in the dry season and ($F_{13,56}$ = 26.8, p = 2 x 10^{-19}) in the wet season along the tube well source.

The mean fluoride concentrations for both seasonsat AngwanSarkin [BH4 (2.61 mg/L), BH5 (2.53 mg/L)] and at Abattoir [WW5 (1.73mg/L), TW6 (2.10 mg/L) and BH6 (1.66 mg/L)] were above WHO guidelines for drinking water quality.

5.2 Conclusion

The following conclusions are drawn from the results obtained at the field and inthe laboratory and fromstatistical analyses of the biophysicochemical parameters:

1. The sanitary inspection identified different degree of sanitary risk factors at the sample points with common unsanitary practice at the dug well source where fetching tools were left in pools of stagnant water.
2. Thecontamination of the water sources byfaecal coliforms and chloride were widespread (significant difference at 95% confidence level); while contaminations of nitrate, sulphate, zinc, fluoride ammonia and nitrite were localized (insignificant difference at 95% confidence level) to sources close to anthropogenic sources.
3. There were significant differences between all the water quality parameters along borehole, tube well and dug well water sources in the dry and wet seasons at 95% confidence levels. There was alsoa significant difference between distance of sanitation site and depth of water sample point.
4. No linear regression correction between both nitrate concentrations and faecal coliform counts with either distance of sanitation site and depth of water sample point.Period had no significant difference onbetween biochemical water quality parameters; while significant difference existbetween physical water quality parameters

5.3 Recommendations

1) Since the risk of faecal contamination is strongly associated with sanitary conditions of the environment of the water sources, it is central for governments to embark on regular

environmental sanitation exercises and to provide refuse dumping sites and disposal vehicles in order to lessen indiscriminate dumping of solid waste in the communities.

2) It is also necessary to educate the community on the need to disinfect the water to make it safe for both drinking and domestic use. Municipal water supply should be made available and connected households in order to reduce the dependence on water from unsafe sources.

3) The activities of water vendors and owners of private wells and boreholes should be monitored to ensure compliance with drinking water quality standard. This will improve the general healthcare and wellbeing of the community.

4) The decline in oxidation-reduction potential during the dry season could lead to increase in solubility of toxic compounds such as arsenic and manganese. Hence, a further study should be carried out to ascertain the concentrations of these compounds.

5) Since Lamurde floodplain is known to be a reservoir of groundwater, state government should fence it against encroachment and invest on tree plantation to preserve its natural ecosystems.

CONTRIBUTION TO KNOWLEDGE

1. There were no significant differences in mean nitrate concentrations ($F_{2,14}$= 1.75; p = 0.21) in the dry season and ($F_{2,14}$= 1.65; p = 0.23) in the wet season at 95% confidence interval along the Borehole, Tube well and dug well water sources.

2. There were significant differences in mean faecal coliform counts ($F_{2,14}$= 17.31; p = 1.64 x 10^{-4}) in the dry season and ($F_{2,14}$= 5.39; p = 8.54 x 10^{-4}) in the wet season at 95% confidence interval along the Borehole, Tube well and dug water sources.
3. There was a significant difference between distance and depth of sanitation site ($F_{1,32}$ = 8.81; p = 5.63 x 10^{-4}) at 95% confidence interval.
4. The concentrations of fluoride in water sources at Angwan Sarki and abattoir were above the WHO guidelines for drinking water.

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APPENDICES

Appendix 1: Sample of Questionnaire

Name of community:- ……

Gender:- ……

Education status:- ……..

Instructions: Tick the option that is applicable to you.

1. How many years have you live in Jalingo City? (a) 1 - 5 years (b) 6 - 25 years (c) 26 years or more

2 How many household members do you have? (a) 1-4 persons (b) 5-9 persons (c) 10 persons or more

3 How do you dispose the waste generated within your household? (a) At the collection centre (b) By roadside (c) Along the drainage (d) Burned or buried behind the backyard

4 What type of toilet facility do you use in your household?(a) Ventilated improved pit latrine (b) Pit latrine with slab (c) Pit latrine without slab (d) Composting toilet (e) No facilities or field.

5 What is the main source of drinking water used by members of your households?
(a) Piped water into dwelling (b) Public tap (c) Tube well/borehole (d) Protected dug well (e) Unprotected dug well (f) Rainwater collection (g) Bottled/sachet water (h) Surface water (river, dam, lake, pond, stream, canal)

6 What do you usually do to your water to make it safer for drinking? (a) Boil (b) Add bleach/chlorine (c) Strain it through a cloth (d) Use a water filter (ceramic, sand, composite, etc.) (e) Let it stand to settle

7 How do you preserve your drinking water? (a) Store in cistern (b) store in refrigerator (c) store in open basin (d) others

Appendix 2: Location, source of contamination and GPS coordinates at hand pump borehole water source

S/n	Location	No	Pollution source	North (N)	East (E)
1	Beside TADP	BH1	VIP Latrine	O8°56’10.4”	011°20’26.7”
2	MWR, Roadblock	BH2	Poultry dung	O8°55’46.0”	011°20’04.7”

3	Investment Quarters	BH3	Solid wastes	O8°55’40.4”	011°20’19.3”
4	AngwanBaraya 1	BH4	Latrine	O8°53’03.2”	011°21’42.9”
5	AngwanBaraya 2	BH5	latrine/waste	O8°53’06.7”	011°21’47.6”
6	Yelwa Market	BH6	latrine/waste	O8°53’01.4”	011°22’03.0”
7	ATC downstream	TWI	Solid waste/waste [c]	O8°54’51.0”	011°19’13.5”
8	Nukkai bridge	TW2	Waste [c]/Fertilizers	O8°55’09.7”	011°19’24.3”
9	MayoGwoi bridge	TW3	Solid waste /waste [c]	O8°55’04.1”	011°20’41.2”
10	Beside Water Farm	TW4	Solid waste /waste [c]	O8°53’46.7”	011°20’43.1”
11	AngwanSarkin	TW5	Solid waste /waste [c]	O8°52’59.9”	011°21’36.”
12	Abattoir premise	TW6	latrine/animal waste	O8°52’48.0”	011°22’29.5”
13	Star nur/prisch)	WW1	Latrine /waste [c]	O8°55’22.1”	011°19’47.3”
14	Mid-land Hotels	WW2	VIP Latrine	O8°55’18.3”	011°20’26.9”
15	Behind CRCN Magami	WW3	Latrine with cover	O8°54’21.0”	011°20’41.4”
16	Beside Water-Farm	WW4	Cemetery/Latrine	O8°54’09.9”	011°20’52.9”
17	Abattoir Downhill	WW5	latrine/animal dung	O8°52’47.0”	011°22’24.0”
18	Nukkai bridge	SWI	Solid waste /waste [c]	O8°55’09.4”	011°19’30.2”
19	MayoGwoi Bridge	SW2	Solid waste /waste [c]	O8°55’11.8”	011°20’38.3”
20	KogiSarkin	SW3	Solid waste /waste [c]	08°53’13.2”	011°21’16.2”

[c]→ solid waste dumped by city’s storm water

Appendix 3: Bacteriological/chemical water quality parameter of surface (river) water

Water Source / Unit	Nukkai River		MayogwoiRiver		Lamurde River		WHO
	DP	WP	DP	WP	DP	WP	Standard

Temperature	◦C	31.26	29.00	29.38	29.00	30.01	28.60	Ambient
pH	-	5.77	7.66	6.80	7.70	6.89	7.44	6.5-8.5
TDS	mg/L	106.0	269.0	363.0	237.0	392.0	167.5	500.0
Turbidity	NTU	14.1	16.6	28.0	111.0	35.1	16.5	5.0
Hardness	mg/L	25.0	99.0	93.0	80.0	115.0	15.0	100-300
Chloride	mg/L	21.5	9.4	141.3	15.3	135.2	14.5	250.0
Fluoride	mg/L	0.11	0.40	1.07	0.80	1.11	0.80	1.50
Sulphate	mg/L	0.00	18.00	6.00	91.00	5.00	21.00	250.0
Nitrate	mg/L	1.46	0.50	4.90	1.02	3.95	1.11	50.00
Nitrite	mg/L	0.90	0.08	0.09	0.00	0.14	0.03	3.00
Ammonia	mg/L	3.85	0.09	2.50	0.13	2.00	0.23	1.50
DO	mg/L	10.40	10.20	6.82	7.35	9.03	9.20	-
Zinc	mg/L	0.20	0.46	0.91	0.48	2.00	0.42	4.00
F. coliform	Cfu	1.0	11.0	5.0	8.0	6.0	9.0	0.0