ASSESSMENT OF QUALITY OF DRINKING WATER IN BOSSO TOWN, NIGER STATE

BY

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DECLARATION

I declare that the work in the thesis entitled 'Assessment of Quality of Drinking Water in Bosso town, Niger state' has been performed by me in the Department of Community Medicine under the supervision of Dr. C.L Ejembi of the Department of Community Medicine, Ahmadu Bello University Zaria in the year 2011.

The information derived from literature has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at any university.

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CERTIFICATION

This thesis entitled **"ASSESSMENT OF QUALITY OF DRINKING WATER IN BOSSO TOWN, NIGER STATE" by GIMBA, Patrick Bidi** meets the regulations governing the award of the degree of Master in Public Health of Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This thesis is dedicated to the Almighty God for His mercy upon my life and to my God – given family: Lucinda S. Gimba (wife) and my wonderful sons Onomsokehnyi Gimba and Onomsereh Gimba for their love, support and affection.

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SUMMARY

Water is an important ingredient for life and it is an effective vehicle for the transmission of diseases when contaminated. Therefore every responsive and responsible government of any country strive to make safe water available and accessible to its populace throughout the year.

The study aimed to assess the quality of drinking water in Bosso town of Niger state, Nigeria.

Forty samples of water from different sources (Bosso pond, wells, borehole, tap and sachet water) were analyzed for faecal coliform (Escherichia. coli), total coliform, PH, residual chlorine, total dissolved solids, turbidity, colour, chloride, nitrate, nitrite, iron, and fluorine using membrane filtration method, PH meter, HACH digital titrator, Total dissolved solids/Conductivity meter, and DR 2000 (HACH) spectrophotometer.

Selection of water samples was carried out using proportionate allocation, equal allocation, simple random sampling and systematic sampling methods depending on the stage.

Four hundred and twenty-two household heads were interviewed to determine their common sources of drinking water in dry and in raining seasons, perception on the physical quality (colour, odour and taste) of water and availability and accessibility of water. Selection of households to be interviewed was done using household selection grid, simple random sample and systematic sample methods.

Finally, all the one hundred and fifteen wells in Bosso were inspected to determine their sanitary condition based on WHO standard for improved (protected) well.

The study revealed that less than 30% of households had access to tap water within their residences.

Of all the wells inspected in Bosso town, only 20% (23) of the wells can be considered improved/ protected**.** There was high bacterial contamination of most (80%) of the water samples. The faecal coliform (Escherichia coli count) varies from 0 to 436 cfc/100ml.

Similarly, all treated water samples (tap and sachet) failed to the meet WHO guideline value for residual chlorine which is 0.5mg/l and above.

The study also showed that 33.3% and 11.1% of well water samples had nitrate (NO_3) nitrite (NO_2) contents above the guideline level respectively. All samples of water from other sources had nitrate and nitrite content within the recommended values.

Majority (93.75%) of the tap water samples met the WHO guideline for fluoride while 56.25% showed compliance for iron content.

The single water sample from borehole failed to meet the guideline value for both fluoride and iron.

Finally, the study showed that despite the high contamination of drinking water in Bosso town, only 30.1% of households treat their water before consumption.

There is an urgent need to improve on the quality of drinking water in Bosso town coupled with mass health education to the community on the dangers of contaminated water and importance of personal hygiene.

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ACRONYMS

ADPs	Agricultural Development Projects
cfc	Coliform count
DFRRI	Directorate of Food, Road, and Rural Infrastructure
FMWR	Federal Ministry of Water Resources
ISO	International Organization for Standardization
MDGs	Millennium Development Goals
NAFDAC	National Agency for Food and Drug Administration Control
NWRI	National Water Resources Institute
RADWQ	Rapid assessment of drinking water quality
RBDA	River Basin Development Authority
RC	Residual Chlorine
SON	Standard Organization of Nigeria
TDS	Total Dissolved Solids
UN	United Nations
UNEP	United Nations Environment Programme
UNGA	United Nations General Assembly
UNICEF	United Nations Children's Fund
WHO	World Health Organization
^{o}C	Degrees Celsius

CHAPTER ONE

INTRODUCTION

1.1 Background

Water is a common natural chemical substance containing two atoms of Hydrogen and an atom of Oxygen. Its common usage refers to liquid form, though has other forms: solid water- ice and gaseous forms - water vapour and steam.

Water is indispensable for life and socioeconomic development of any society. It is used in domestic activities (cooking, drinking, washing, bathing etc), agricultural activities (e.g irrigation, gardening), generation of power (hydroelectric power plants), running industries, recreational activities etc. It is very essential for human existence and sustenance of life. Water constitutes 60%-70% of the total body weight. A man can live for several days without food but will only survive for few days without water. Therefore, water is indispensable for normal physiological function of plants and animals.[1] In spite of its importance in sustenance of live and livelihood, it is the major cause of morbidity and mortality because of limitations in access and quality [2,3].

The basic physiological requirement for drinking water has been estimated at about 2 litres per capita per day which is just enough for survival [4,5] .World Health Organization (WHO) states that domestic water consumption of 30-35 liters per capita per day is the minimum requirement for maintaining good health [6]. However, the amount of water required by individuals varies depending on climate, standard of living, habit of the people and even age and sex.

One factor that impinges more on the accessibility to enough quality drinking water is the distance of the source from house. This condition forces the individual most especially

the women and children (especially girls) to transverse many kilometers to get safe drinking water (which deprives them from engaging in productive ventures or going to school like their male counterparts). In addition to this, in order to reduce the hardship in getting water, they may resort to reducing the quantity of water used in the house far below the recommended volume and also they may resort to fetching water from unimproved sources e.g. unprotected well, pond, stream etc[7].

Safe (quality) drinking water is that which does not present any significant health risk over a life time consumption, including any sensitivities that may occur in different stages of life.[8] It is water which is free from pathogenic microbes, hazardous chemicals/substance and aesthetically acceptable (i.e. pleasing to sight, odourless and good taste). It is important that this type of water should not only be available, but also be available in enough quantity all the time [4] i.e. twenty-four hours a day, seven days a week ("24/7")

In assessing quality of drinking water, physical, chemical and bacteriological parameters must be considered. Although water from a source may not pose any health threat to consumers, they may abhor it due to its colour, odour, or taste [8]. Physical parameters include colour, smell, temperature, PH, turbidity etc. There are myriad of chemical substances which may be naturally present or introduced (even chemicals used for water treatment) into water; those that are naturally present seldom pose risk to health. However, chemicals released due to anthropogenic activities (fertilizer, pesticides, herbicides, industrial effluents and byproducts etc) carry more health risk to consumers. Fortunately, whether chemical naturally present or introduced into water, there are maximum allowable concentration (limit) of most of them proposed by World Health

Organization (WHO) which serves as guide. Some of the chemical substances include residual chlorine (RC), Iron (Fe), Fluoride (Fl), Nitrate/Nitrite, Lead (Pb), Mercury (Hg)[8,9,10] etc.

Bacteriological (microbial) parameter is used to assess drinking water quality using the index /indicator concept as advocated by Waite (1991) [9]. The infectious risks associated with drinking water are primarily those posed by faecal pollution and their control depends on being able to assess the risk from any water source and applying suitable treatment to eliminate the risk. Rather than trying to detect the presence of pathogens at which time the consumer is being exposed to possible infection, it is better practice to look for organisms, while not pathogenic themselves, that show the presence of faecal pollution and therefore the potential for the presence of pathogens. For this reason, Escherichia coli (E.coli) is universally used as an indicator organism to assess water treatment and widely preferred as index organism for faecal contamination.[9] Thermotolerant coliform count (Faecal coliform) is acceptable where E.coli detection is not possible[8,9] .

The presence of other microbes may indicate faecal contamination as well e.g. faecal streptococci indicate recent contamination of water sources with faeces.[9,10]

While planet earth is made up of predominantly water, only 3% is fresh water, and of this, 99% is trapped in icecaps and glaciers. Even the 1% of the fresh water available for human use is not evenly distributed[11].

According to WHO and UNICEF report (2006), safe water which is a basic necessity is still a luxury for many poor developing countries of the world today. It has been estimated that over 1.1 billion people do not have access to drinking water from

improved sources. Eighty percent of the unserved populations live in these three regions – Sub-Saharan Africa, Eastern Asia and Southern Asia. Eighty- four percent of these people are the rural dwellers [7]. In 2004, 83% of the world population (5.3 billion) had access to drinking water from improved sources. This seemingly high global statistics hide a critical situation in some developing countries. In sub-Saharan Africa and Oceania only 54% and 50% of their populations respectively are served with improved sources of drinking water in 2004. Whereas at the same period, the population that had access to water from improved sources is over 90% in the Caribbean, Northern Africa and Western Asia.

Although over 80% of the developing world population has access to some type of improved drinking water source, only 44% have access through household connection from piped system. There are large disparities between regions. While access to drinking water through household connection is as low as 16% in Sub-Saharan Africa, 20% in South-Eastern and 21% in Oceania; it is much higher in Eastern Asia 70%, Northern Africa 76%, and 80% in Latin America and the Caribbean [7].

There is also urban / rural disparity in access to drinking water. Access to drinking water from an improved source is significantly higher in urban than in rural areas. In rural areas, in virtually the entire developing world, drinking water coverage from an improved source remains unacceptably low. Urban drinking water coverage is 95% from 1990 to 2004, whereas in rural areas coverage increased to 73% in 2004 from 64% in 1990 [7,12]. In 27 developing countries (Nigeria inclusive), less than 50% of the rural population have access to improved drinking water [7].

The situation of access to improved water in Nigeria is not different from her counterparts in the sub-Saharan African region. In fact in some cases the situations may be worse. In 1990, 49% of Nigerian population have access to improved water but this figure dropped to 48% in 2004 [7]. According to WHO/UNICEF estimates that in 2006, 65% of Nigerian urban population have access to improved drinking water sources (a decline from 80% urban drinking water coverage in 1990)[13] but only 7% of the population have their houses connected to tap borne water supply and at the same period, 30% of Nigerian rural population have access to improved drinking water sources and 2% of the rural households are connected to tap borne water supply [14].

Over 50% of the water supplies are intermittent and some of the sources of improved drinking water are seasonal i.e. some run out of water during the dry season [12].

Water treatment plants are poorly maintained, some have become obsolete and urgently need upgrading which seldom occur despite the population increase (due to increase in birth and rural-urban migration). Pipes laid to convey water to houses hardly get to their destination because they are shabbily done with substandard materials. Evidences of water being pumped from the water treatment plants to a community are broken pipes gushing out water all over the places and gutters but no water in houses.

Poor quality of drinking water is responsible for the spread of deadly diseases such as cholera, typhoid, dysentery, shigellosis, hepatitis A, poliomyelitis, Escherichia coli diarrhoea etc[13]. Every year unsafe water, coupled with poor basic sanitation, kills about 1.6 million children under 5years which is more than eight times the number of people who died as a result of Asian Tsunamis in 2004 [7] and most of this occur in poor /economically disadvantaged countries of the world. According to WHO,

80% of ill- health in developing countries can be traced to lack of access to safe drinking water and poor sanitation. About 37% of all diarrhoeal cases in the world occur in the Sub-Saharan Africa [2]. Four million under 5 children die annually in developing nations from diarrhoeal diseases which place a heavy burden on the health services. Although diarrhoea is less frequent in adult, it is also an important cause of mortality [3] most especially in the aged and immuno-compromised [15].

Mortality resulting from the consumption of contaminated food and water in Africa is around 700,000 annually. The incidence of diarrhoea caused by consumption of contaminated food and water was estimated at up to five episodes per child per year. The Disability Adjusted Life Years (DALY) lost to food and water borne diarrhoea in Africa region was 4.1 per 1000 globally as compared to 5.7-7.1 per 1000 in Africa by Dr. Daniel Kertesz, (2009, WHO Country Representative for Ghana). Diarrhoea diseases and worm infestations account for 10% of the total disease burden in developing / economically disadvantaged countries [4] .

In Nigeria, 315,000 under 5 children die annually due to diarrhoea which is 23 times more than under 14 years mortality in Europe caused by the same [13]. Federal Ministry of Health's (Nigeria) data rate diarrhoea second after malaria as a disease of high prevalence. It accounts for 16% of under 5 mortality [16]. Worm infestation is still having its toll on the people especially the vulnerable (children and women).Schistosoma haematobium and mansoni are the causes of schistosomiasis with prevalence in communities that patronize ponds and other artificial reservoirs where snails breed. The incidence in different parts of the country ranges from 10-18% in Gumau, Bauchi State, 50.4% in Admin community, Cross River State to 71.8% in Oyan reservoir area, Ogun

State [13]. Generally, children and women are more prone to water borne and water related diseases; this could be because children (especially under 5 years) require twice the amount of water consumed by adults per day and women consume 20% more than men which means, children and women are 100% and 20% respectively more exposed than men [13].

Due to the recognition of the impact of water and sanitation, national and international strategies, goals etc have been developed and one of the recent declarations on the global front is the Millennium Development Goals (MDGs). This is the product of United Nations General Assembly (UNGA) in 2000. MDG 7, target number 10 is to "halve by 2015 the proportion of people without sustainable access to safe drinking water and sanitation" and the health indicator which will be used to monitor success of this target is indicator number 30 "proportion of population with sustainable access to an improved water sources, urban and rural " [17]. In addition, the UN Millennium project task force on water and sanitation recently recognized that integrated development and management of water resources is crucial to the success or failure of all the MDGs as water is the centre to livelihood of all individuals [8]

Outcomes of many international conferences and fora on health, water and sanitation led to co-operations and collaborations between international organizations and nations to provide improved sources of water, provision of technical assistance to governments, monitoring etc. For example there is a global WHO/UNEP network for air and water quality monitoring which is operational in more than 60 countries. Surface and groundwater quality are monitored in 350 cities worldwide.[4]

Despite the declining water coverage rate in Nigeria, various successive governments had made efforts both on the federal and state levels to increase access to improved drinking. In the 1960s Niger and Chad river Basins were commissioned to produce hydrological map of Nigeria's water resources. Subsequently from 1973-1976 eleven river basin development authority were established to develop the country's water resources to meet domestic need, agriculture etc. Creation of dams in various part of the nation for hydroelectric power generation, agriculture and domestic uses, establishment of Water Boards and Corporations at regional and state level for distribution of potable water to urban and semi-urban areas. To extend this service to rural communities, the government created Directorate of Food, Road, and Rural Infrastructure (DFRRI), Agricultural Development Projects (ADPs) and co-opting of some non-governmental organizations such as UNICEF and recently World Bank to partner with government in developing Nigeria's water resources. Establishment of Federal Ministry of Water Resources (FMWR), River Basin Development Authority (RBDA) in 1976, National Water Resources Institute (NWRI) in 1977 saddled with responsibilities in training, formulation of policies, monitoring etc[13].

In the 1980s, government of Nigeria made concerted effort to attain the target of UN International Drinking water Supply and sanitation which was to provide potable water for all by the year 1990 [4,13]. Although Nigeria fell short of the target, it was able to provide 25 litres and 60 litres of potable to rural and urban dwellers respectively.

A national water supply and sanitation policy was adopted in January, 2000. The policy made adequate water supply and sanitation a right of all Nigerians and gives responsibility to all the three tiers of government, private sectors and the beneficiary[13].

On16th April, 2007, Nigerian Standard of Drinking Water Quality (final draft) was submitted to the Standard Organization of Nigeria (SON) and was accordingly approved [10].

Although a lot has been done to increase access to improved source of drinking water, more still need to be done in term of translating policy to action, monitoring water quality regularly in order to nip any outbreak in the bud, monitoring and controlling activities of water vendors (hawkers, mai ruwas) and "pure water" producers to ensure safety of their products. In addition to these, concerted efforts should be made to maintain present equipment and upgrade them when necessary to cope with teeming and growing population of the nation.

1.2 Problem statement

Water is not only essential for life but also an indispensable factor in socio- economic development of any community. Ancient civilizations are traceable to availability of source(s) of water which propelled agricultural, industrial, and economic development.

Globalization and population growth have placed enormous demand on industry and commerce, it has also affected the availability and quality of consumable waters. Waste / toxic substances from agricultural chemicals, animals (including human) and industries have combined to increase the level of toxic contamination in both surface and underground waters.

MDG target 10 aims to halve by 2015 the proportion of people without sustainable access to safe drinking water and sanitation. Nigeria being a member of the UN Security Council need to double her efforts to realize this target.

In spite of the decade on water and sanitation and all the different efforts, the water situation in Nigeria appears to be deteriorating. Only 48% of Nigerians in 2004 had access to improved drinking water, a decline in coverage as at 1990 when the access to improved water was placed at 49%. Even these low figure could be an over representation: Proliferation of water vendors (mai ruwas) who get their water from unimproved sources and the "pure water" business which various researches have proved them to be unsafe for drinking e.g. Aliyu and Victor [18,19] . There are taps without water and such taps may have worked last many months or years ago. Some treatment plants pump raw water to their communities due to the fact that they lack chemicals for treatment.

These point to the fact that Nigeria is not on the track to achieving Millennium Development Goal 7 target 10 except it redoubles its effort and intensifies the present reforms on water and sanitation.[7,13]

1.3 Justifications for the study

The quality and quantity of drinking water supply to human population is a topical global issue. That is why of recent the UN General Assembly at its 58th session declared the years 2005-2015 as International Decade for Action "Water for life". This is to reduce by half the population of people without access to sustainable improved drinking water. Previous studies on quality of drinking water in different parts of Nigeria revealed high contamination in the various samples of drinking water : Aliu in his study of bacteriological quality of water in Dutsin-Ma, Katsina State, shows that most non-tapped sources of drinking water were heavily

contaminated whereas tap water were only slightly contaminated and about 36% cases of diarrhoea were caused by contaminated water [20]. Similarly, a study in Zaria, Kaduna State on quality of "pure water" (packaged water) by Aliyu, equally reveals that all samples failed to meet the WHO recommendation of coliform count for drinking water. [18]

While studies in various parts of Nigeria have documented the failure of the water supply to meet minimum WHO quality standards, no similar study has been conducted in Niger State. This study will aim to provide empirical evidence on the quality of water available to residents in a section of the Niger State capital, that hopefully will guide water policy makers in actions to improve water supply quality in the state.

1.4 Aims and Objectives

Aim of the study is to assess the quality of dinking water in Bosso town, Niger State.

Specific objectives are

1. To determine the source(s) and availability of drinking water available to residents in Bosso town.
2. To assess the physical, chemical and bacteriological quality of the drinking water from the different sources.
3. To compare the physical, chemical, and bacteriological characteristics of drinking water in Bosso town with WHO standard of quality of drinking water in developing countries.

CHAPTER TWO

LITERATURE REVIEW

2.1 Sources of Water Supply

Water is a factor of production in virtually all enterprises and its importance in disease control has long been recognized and most water related diseases occur in large number i.e. epidemic proportion: a classical example is the Broad Street cholera epidemic in London in 1886 [21,22] .

Though it is enshrined as human rights, the provision of adequate potable water remains a problem in most developing countries[21] which have huge debt burden and low governmental commitment.

Globally, 1.1 billion of the world's population has no access to safe drinking water and 80% of that population live in Sub-Saharan Africa, Eastern Asia and Southern Asia. Eighty- four percent of these people are the rural dwellers [7].

Most urban communities in developing countries depend on municipal treatment plants as their secured source for pipe borne potable water. Often, these treatment facilities fail to deliver or/and fail to meet the water requirement of the communities due to mis-management, corruption or increase in population. The scarcity of pipe borne safe water has made communities to find alternative sources of drinking water [22]. These include rain water which is the purest natural water, surface waters e.g. rivers, streams, ponds, dams and lakes and underground water such as wells, borehole and springs. These alternatives are the only sources of drinking water available to most rural communities. One of the short falls of these traditional supplies of water apart from being unsafe is that they are season dependent i.e. the sources fill up in raining seasons and dry up in dry seasons.[23]

2.2 Properties of Water

Water is the most essential chemical substance for survival of all forms of life. It is one of the very few substances to be found naturally in all three states on earth: solid water as ice, liquid form is called water and gaseous water is known as vapour.

Water in its natural form has many unique properties. It is a clear, transparent, tasteless, and odourless fluid [4]. In small quantity, it is colourless but appears pale blue through a deep column [18].

It freezes at 0 ^{o}C and boils at 100 ^{o}C under standard atmospheric pressure of 760 mmHg. Water can dissolve many substances, giving it different tastes and odours. In fact all substances dissolve in water and hence it is referred as universal solvent.

2.3 Quality of Drinking Water and Drinking Water Quality Guidelines

Water quality refers to suitability of water for a certain purpose. Hence quality of drinking is the suitability of water for drinking and domestic uses including personal hygiene. A good quality (safe) drinking water is that which is aesthetically acceptable and does not contain pathogenic agents and dangerous chemical substances [4,8,10].

The consequences of contaminated water are so all pervasive that they defy effort to draw up global balance sheet. The cost of dirty water includes not only loss of lives but also loss of socioeconomic momentum. For instance, World Bank estimated that Peru loss due to reduction in agricultural exports and tourism was about $1000 million (US dollars) in the first 10 weeks after cholera outbreak in January 1991[24]. Due to the importance of water for sustenance of life and livelihood, WHO in 1983-84 published the first guideline for drinking water quality and subsequent editions were published in order

to update previous publications [8]. It is a UN document for member states to either adopt or adapt in their own countries based on their local situations.

WHO guideline defined safe (quality) drinking as water that "does no represent any significant risk to health over a lifetime of consumption, including different sensitivities that may occur between life stages." [8]

Assessing quality of drinking water is a rigorous task which entails assessing the physical, chemical and bacteriological parameters of water. There are myriad of chemical / radioactive substances, bacteriological agents and physical properties of water that need to be considered in order to determine its quality (safety) for drinking. However, the greatest risk to human health especially in developing countries is from faecal contamination of water sources [8]. For that reason, bacteriological analysis is the most important analysis and E. coli count is the most appropriate indicator of faecal pollution in assessing quality of drinking water.

Below are some of the parameters to be considered in assessing quality of drinking water.

I. Total coliforms count and Escherichia coli (E. coli) count

Total coliforms are not index of faecal pollution or of any health risk, but can provide basic information on the source water quality. Total coliforms have long been utilized as a microbial measure of drinking water quality, largely because they are easy to detect and enumerate in water.

In general, definitions have been based around the following characteristics: Gram negative, non spore forming rod-shaped bacteria capable of growth in the presence of bile salts or other surface-active agents with similar growth- inhibiting properties, oxidase- negative, fermenting lactose at 35-37 ^{o}C with production of acids, gas and

aldehyde within 24-48 hours. Traditionally, total coliforms are regarded as belonging to genera Escherichia, Citrobacter, Enterobacter and Klesiella. However, regardless of the definition adopted, the group is heterogenous. Many of the bacteria can be found in both faeces and the environment (nutrient-rich waters, soil, decaying plant materials) as well as in drinking water containing relatively high concentration of nutrients. It also includes members of genera such as Budvicia Rahnella, which are never found in mammalian faeces [9].

Because total coliforms of non-faecal origin can exist in natural waters, their presence can occasionally be tolerated in untreated water in the absence of more specific index [9]. Standard guideline stipulates that total coliform count of water leaving treatment plant should be zero per 100ml [8].

E. coli is taxomically well defined member of Enterobacteriaceae possesses the enzymes ß- galactosidase and ß- glucuronidase. It grows at 44-45 ^{o}C on a complex media. However, some strains grow at 37 ^{o}C and not at 44-45 ^{o}C. Complete identification of E. coli is complicated for routine use, but a number of tests have been developed for rapid and reliable identification with an acceptable degree of accuracy.

E. coli is abundant in human and animal faeces and a fresh faeces, it may attain concentration of 10^{9} per gram [8,9].

E. coli is universally used as an index of faecal contamination and also widely used as an indicator of treatment effectiveness.

The reasons for using E. coli and to some extent faecal coliform as an indicator or and index bacteria are as follows [8,9]:

a) They are not pathogens themselves.

b) They are universally present in faeces of human and animals in large numbers.

c) They are present in higher numbers than faecal pathogens.

d) They do not readily multiply in natural waters but persist in water in a similar manner to faecal pathogens.

e) They can readily be detected by relatively simple and inexpensive methods.

The WHO guideline states that there should be no E. coli or faecal coliform per 100ml of water meant for drinking while untreated or unpiped water should not contain more than 10 cfc/100ml [8, 10]. However, people in some rural and suburban areas of Nigeria drink water with E. coli count of 500 cc/100ml and above. [22, 25]

II. PH

PH refers to determination of H ion concentration in any liquid using a PH meter. One of the main objectives in controlling the PH is to minimize corrosion and incrustation in the distribution system. PH levels below 7 may cause severe corrosion of metals in the distribution level while at levels above 8, there is a progressive decrease in the efficiency of the chlorine disinfection process. The acceptable PH for drinking Water ranges from 6.5-8.5. [8]

III. Colour

Colour of water per se has no safety consequence on drinking water but aesthetically, it is very important because water even though safe for drinking may be abhorred by people if it is not pleasant to sight (colourless). Drinking water should ideally have no visible colour. Colour in drinking water is usually due to the presence of coloured organic matter associated with the humus fraction of soil. Colour is also strongly influenced by the presence of iron and other metals, either as natural impurities or as corrosion products.

Most people can detect colours above 15 true colour units (TCU) or 15 platinum cobalt (Pt. Co) in a glass of water. Levels of colour below 15 TCU or 15 Pt. Co are usually acceptable to consumers. No health-based guideline value is proposed for colour [8,10].

IV. Turbidity

Turbidity is that property which interferes with the distinctiveness with which the outline of object is seen through water. It is a function of particulate matter which interferes with disinfection and could affect colour, taste and even odour of water. The levels that is likely to give rise to consumer complaints above 15 nephlometric turbidity unit (NTU)[4,8,10]

V. Total Dissolved Solids (TDS)

TDS comprise inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulphates) and small amounts of organic matter that are dissolved in water. TDS can affect the taste of drinking water. Water becomes increasingly unpalatable and objectionable at level greater than1000 - 1200mg/l which is the recommended value of TDS in drinking water. There is no health based proposed value for TDS [8].

VI. Chloride

Chloride in the form of chloride ions is one of the major inorganic anions in water. Salty taste is produced by chlorides and the concentration varies depending on the chemical composition of the water. Up to 250mg/litre of chlorine may have a detectable salty taste if the cation is sodium. On the other hand, if the cation is calcium, the salty taste may be absent even at chlorine concentration of 1000mg/litre.

Chloride in drinking water may originate from natural sources, sewage and industrial affluent etc. No health based guideline value was proposed. However, chloride in excess of about 250mg/litre can give rise to detectable taste in water [8].

VII. Residual chlorine (RC)

Water treated by chlorination usually contains some amount of chlorine which provides a margin of safety against subsequent microbial contamination such as may occur during storage and distribution. The minimum recommended concentration of free chlorine (residual chlorine) is 0.5mg/litre [8]. In water related epidemic e.g. cholera outbreak, it is advisable to increase the RC level [4,8,10]

VIII. Iron (Fe)

Iron is one of the most abundant metals in the Earth's crust. It is found in natural fresh waters at levels ranging from 0.5 to 50 mg/litre. Iron may also be present in drinking water as a result of the use of iron coagulants or the corrosion of steel and cast iron pipes during water distribution. Iron is required in human nutrition and the minimum daily requirement depends on the sex, age, physiological status and iron bioavailability.

Although no health based-guideline value for drinking water was proposed, for aesthetic reason, WHO guideline fixed the value of iron at 0.3mg/litre (values above this level stain laundry) [8]

IX. Nitrate/Nitrite (NO_3/NO_2)

Nitrate and nitrite are naturally occurring ions that is part of nitrogen cycle. Nitrate is used mainly in inorganic fertilizers and sodium nitrite is used as a food preservative, especially in cured meats. The nitrate concentration in groundwater and surface water is normally low but can reach high levels as a result of leaching or runoff from agricultural

land or contamination from human or animal wastes as a consequence of the oxidation of ammonia and similar sources. Nitrate is reduced to nitrite in the stomach of infants, and nitrite is able to oxidize haemoglobin (Hb) to methaemaglobin (metHb), which is unable to transport oxygen around the body. Excess nitrate in drinking water could lead to formation of methaemaglobin and subsequently causing methaemaglobinaemia most especially in infant i.e. "blue baby syndrome" WHO Guideline value (maximum allowable limits) for nitrate 50mg/litre and nitrite 3mg/litre. [8]

X. Fluoride

Fluoride accounts for about 0.3 g/kg of the Earth's crust and exists in the form of fluorides in a number of minerals. The most important source of fluoride in drinking water is naturally occurring. Fluorides can be released to the environment from the phosphate-containing rock used to produce phosphate fertilizers; these phosphate deposits contain about 4% fluorine.

In areas with relatively high concentrations, particularly in groundwater, drinking water becomes increasingly important as a source of fluoride. Guideline value which the maximum allowable limit is 1.5mg/litre. Occurrence in groundwater, concentrations vary with the type of rock the water

Epidemiological evidence have shown that concentrations above this value carry an increasing risk of dental fluorosis, and progressively higher concentrations lead to increasing risks of skeletal fluorosis [8,10].

Maximum allowable limits are maximum concentration of bacteriological, chemical and organic constituents / contamination allowed in drinking water. These are base on WHO value for which no adverse health effect is noticed [16]

The most undesirable constituents of drinking water are those that are capable of having adverse effect on public health. Many of these in the guideline have established guideline values (maximum allowable limits).

To a large extent, consumers have no means of judging the safety of their drinking water themselves but their attitudes towards their drinking water supply and their drinking water suppliers will be affected to a considerable extent by the aspect of water quality that they perceived with their own senses. It is natural for consumers to regard with suspicion water that appears dirty or discoloured or that has unpleasant taste or smell even though these characteristics may not themselves be a direct consequence to health. Therefore, drinking water that is aesthetically unacceptable will undermine the confidence of the consumers, leads to complaints and more importantly, possibly leads to the use of water from sources that are less safe.

The acceptability of drinking water based on aesthetical consideration is dependent on individual and local factors including the quality of drinking water to which the community is accustomed and a variety of social, environmental, and traditional considerations [8].

As regards constituents of drinking water that are of aesthetic importance, WHO guideline values have not been established only references are made on values that are likely to cause complaints. These are not precise values because problems may occur at a lower or higher value depending on individual and other circumstances.

2.4 Water Pollution / Contamination

Polluted water is one that is aesthetically unacceptable (colour, taste and odour) to consumers which may or may not contain dangerous micro-organisms and chemical

agents whereas contaminated water is one that contains dangerous micro-organisms and chemical agents, though may or may not be aesthetically unacceptable. [26,]

Pure uncontaminated water does not exist in nature; even rain water which is the purest water nature provides contains some impurities of various kinds. Rain is runoff of the air atmosphere therefore may contain dust, dissolved nitrogen, carbondioxide, hydrogen sulphide etc. Natural impurities are no essentially dangerous. However, a more serious aspect of water pollution is caused by human activity- urbanization and industrialization[4].

The sources of water pollution / contamination include a) sewage, which contains decomposed organic matter and pathogenic agents; b) industrial and trade waste which ranging from metal salts to complex synthetic organic chemicals and c) agricultural pollutants like fertilizers and pesticides d) physical pollutants, viz thermal pollution and radioactive substances.

In practice protecting drinking water source from contamination is dependent on improving excreta and solid waste management and changing of behaviour. [2]

In most developing countries, much of the water available for drinking is not only short in supply, but also unsafe for drinking due to contamination mostly with human and animal faeces as a result of poor sanitation i.e. lack improved excreta and solid waste disposal. According to WHO/UNICEF, 2.6 billion, more than 40% of the world population do not use toilet, but defaecate in the open or in unsanitary place [7, 26]. Unfortunately, majority of this population is found in the developing nations.

Even if water sources and its treatment are of high standard, water pollution may still occur between the source and consumer due to leaky distribution pipes, corrosion and cross connection between supply pipes and sewage drainage pipes. Though, ground

water such as those obtained from deep wells are said to be protected from bacterial contamination by impervious strata and therefore do not need disinfections, such protection depends on the geographic nature of the strata. In shallow wells however, this protection is usually not adequate. [27,] Contamination is believed to occur mostly in shallow wells that are not sanitary (unprotected wells) [7] i.e. uncovered, located close to pit latrine, not having concrete lining, parapet and permanent fetcher.

Various studies on assessment of the quality of drinking show different results ranging from satisfactory (mostly in developed countries) to unsatisfactory (highly unacceptable level of pollution) water quality (in developing countries):Rapid assessment of drinking water quality (RADWQ) of the Republic of Tajikistan, (Dushanbe 2006) shows that 87.2% of sampled sites compiled with the WHO coliforms count guideline value with utility piped supplies showing slightly better result than protected springs (88.6% versus 82.0%), for fluoride, 99.7% compliance with WHO guideline value of 1.5mg/l.

The overall compliance of water sources in Tajikistan was 86.9% [28]. This statistic is very high compared to the ones in Sub-saharan region.

Assessment of quality of well water in Saudi Arabia by Nabil Alla El-din shows that 18.6% and 7.0%, of the wells sampled had TDS and nitrates respectively above the WHO guideline values. Also 21.4% of the wells had faecal Coliforms. [29,]

In Nigeria, studies revealed higher level of non compliance to WHO guideline values (higher level of contamination): Adekunle studies on well in Asa dam estate shows high coliform count (1600-1800cfc/100ml) and presence of E. coli in all the wells examined [22].

Similarly, Olabisi studies on well water in Abeokuta shows that all the wells sampled (40) were highly contaminated with faecal coliforms and other faecal microorganisms [25].

In a study in Dutsin-Ma town, Katsina State on bacteriological studies to assess water safety supplies to the residents of the town shows that coliform count of tap water ranges from 2-8/100ml and for wells 98-192cfc/100ml. This inadvertently means that they all fail to meet the WHO standard [20].

Also, a study in Zaria on packaged water - "How pure is 'pure' water?" shows high coliform counts up to 58 cfc/100ml in the samples examined [18].

From the review of studies above, it will not be incorrect to conclude that most of the water sources available to many Nigerian communities are contaminated.

2.5 Water Treatment

Purification of water is of great importance in community medicine and it is aimed at producing water that is safe and wholesome. The need and methods of purification depend on the source of water or nature of the raw water and the desired standard of water quality. Generally, water from deep wells (boreholes), protected wells and springs may need no treatment except disinfection; however, unprotected wells, springs and other surface water e.g. rivers, lakes, ponds, dams may require extensive treatment.

Basically, treatment of water in a municipal water treatment plant comprises the following processes: aeration, coagulation, sedimentation, filtration and disinfection (chlorination) [4].

The purification of water can be achieved by the combination of some of these measures e.g. protection of water source; storage; coagulation and sedimentation using alum and disinfection water via boiling or chlorination [20].

Disinfection is the only treatment needed in many small water supplies where the physical and chemical quality of the water is satisfactory. Since the prime objective of water treatment is health protection, it follows that the destruction of pathogens is of major importance. Ozone is the disinfectant widely used in some industrialized countries [4,8] but required a degree of technical supervision beyond the means of most developing countries. In such developing countries, chlorine in one form or the other is the most common disinfectant (chlorination).

Chlorine destroys the enzymes essential for the existence of micro-organisms. In addition to its germicidal ability, chlorine oxidizes iron, manganese and hydrogen sulphide; it destroys taste- and- colour producing constituents; it controls algae and slime; and aids coagulation.

Despite germicidal properties of chlorine, it cannot destroy spores, protozoa cyst, helminthes and organisms embedded in solid matters. [30,]

The correct chlorine dose to be applied for water chlorination is the sum of the chlorine demand and the residual chlorine (RC) level of that water [4].

CHAPTER THREE

METHODOLOGY

3.1 Study Area

Bosso is one of the largest towns in Bosso Local Government Area of Niger State. The projected population of the town is 41, 930 (2009), which is spread over two political wards: Bosso Central I and Bosso Central II. The socio-economic activities of majority of the population are peasant farming, petty trading and a good number of them are government employees. The major ethnic groups are Gbagyi, Nupe, Kadara, Hausa-Fulani, Yoruba, and Igbo with Christianity and Islam as their main religions.

Geographically, Bosso lies in the north central area of Nigeria approximately latitude 9^0 40' N longitude 6^0 33 E'. It is bounded by Minna (the capital of Niger State) on the south , Maikunkele (Headquarters of Bosso Local Government) and Minna International airport on the north – west, Nautikoo on the north and Gbaiko and Kobio villages on the west and east respectively. The topography of the town is rocky and it is surrounded by hills; this makes construction of deep and shallow wells extremely difficult and most of the shallow wells that have been constructed dry up easily during dry season. As such people tend to look for other sources of drinking water that are usually unsafe for consumption e.g. ponds.

Annual rainy season spans from April to October with peak downpours in August. The drainage system of the town is very poor with poor sanitation. Settlements are mainly squatters, some made of mud houses with farming activities around the

town which occasionally leads to flooding and contamination of sources of drinking water during heavy downpour.

The sources of drinking water available to residents of Bosso town are taps / pipe borne water, wells and boreholes which may be publicly located or sited within private residence / yard, rain water, pond, and sachet water commonly called "pure water". According to a pilot study conducted by the researcher and his research assistants on the 10th of October, 2009, the proportion of the population served by each source is as follows: taps inside residence / yard-28.4%, well in residence / yard-23.7%, borehole in residence / yard-0%, public tap -18.7%, public wells-2.4 %, public boreholes -26.8%. It is important to note that over 43.6%, 18.7% and 0.23% of the households interviewed use sachet water, rain water and Bosso pond respectively in addition to the other sources mentioned above.

Bosso water treatment plant was constructed in 1947 by the colonial imperialists to serve the then inhabitants of Bosso village. Since then, a series of expansion projects were done and of recent in June, 2009 the plant was upgraded from one million litres per day to three million litres per day capacity. Despite this, epileptic power supply and drying up of the dam often make the utilization of the plant facilities to its fullest impossible. These, coupled with increase in population, have made scavenging for drinking water in ponds, shallow wells etc a common sight.

3.2 Study Design

This study was a cross-sectional descriptive study

3.3 Study Population

The study population includes all sources of drinking water available to residents in Bosso and the population of people residing in Bosso town.

3.3.1 Exclusion criteria

Due to difficulty in accessing some areas of Bosso town, they were excluded in the study. Thus, the following places were excluded

- Population of Federal University of Technology Minna, Bosso campus and Mariam Babangida Girls Science College, Bosso.
- Sources of drinking water available in Federal University Technology Minna, Bosso campus and Mariam Babangida Girls Science College, Bosso.

3.4 Sample Size Determination

The sample size for determining the source(s) of drinking water available in Bosso town was determined using

$$n = \frac{Z^2 p^1 q^1}{d^2}$$

Where n = Sample size

Z = Probability distribution (1.96)

P^1 = National prevalence of households with improved water supply = 48%

$q^1 = 1 - p^1 = 52\%$ (0.52)

d = Precision at 5% (0.05)

Therefore,

$$\frac{(1.96)^2 \text{ x } 0.48 \text{ x } 0.52}{(0.05)^2} \approx 383.55$$

Thus, the minimum sample size was 384 households. Ten per cent of the calculated minimum sample size was added to take care of non response. i.e. 0.1x 384 = 38.4 was added to 384 to make it approximately 422.

The total number of households in Bosso was 2927 [31]. Therefore, sample size of 422 constitutes approximately 14% of the estimated number of households.

Forty samples of water from different sources of drinking water were taken and were apportioned thus: 20 samples were taken from public sources of drinking water and the remaining 20 samples from private sources.

Sampling Techniques

For analysis of water, the sample frame consisted of all the different sources of drinking water at different locations within the two political wards of Bosso town.

A seven- man research team headed by the researcher carried out a survey on the 10th June, 2009 to determine the number and distribution of public sources of water available in Bosso. From the findings of the study, the distribution pattern of public sources of water in 'Bosso as at 10th June, 2009 is as depicted in Table 1 below.

Table 1: Distribution of public sources of water in Bosso town, Niger State, 2009

Source of water / Wards	Wells	Boreholes	Taps	Total
Bosso Central I	39	6	39	84
Bosso Central II	34	2	21	57
Total	73	8	60	141

There were 73 functional wells, 8 functional public boreholes and 60 functional public stand taps and a pond. A total of 20 water samples were collected; by proportionate allocation which means, 10 samples were collected from wells, 8 samples from public stand taps and 1 sample each from Bosso pond site and borehole.

From the findings of the research team on the 10th of October, 2009, the number of wells within residence /yard in Bosso Central I and II were 28 and 14 respectively and the number of households/ yards connected to tap (Water Board) in Bosso Central I and II were 440 and 431 respectively. There were no boreholes in residence / yard only public boreholes were available as shown in Table 2.

Table 2: Distribution of sources of water within residence / yard in Bosso town, Niger State, 2009

Source of water / Wards	private Wells	private Boreholes	Household/yard Taps	Total
Bosso Central I	28	0	440	468
Bosso Central II	14	0	431	445
Total	42	0	871	913

A total of forty samples of water were collected: twenty were from public sources of water and remaining twenty from private sources of water (sources within residence / yard and sachet water)

The number and the selection of water samples for assessment of its quality was done using proportionate or equal allocation, simple random, and systematic sampling methods depending on the stages as described below.

Twenty samples from the public sources of water were collected and the following steps were taken in their selection.

(I) The geographical area under study was identified which was Bosso town (Bosso Central I & Bosso Central II)

(II) Number of sources of drinking water available to public in both Bosso Central I and II were identified and numbered.

(III) Proportionate allocation method was used to allocate the sample size to the different categories of water sources and the numbers to be allocated to each ward.

There were one hundred and forty-one public sources of drinking water available to residents of Bosso town and its distribution was as shown in Table 1 . A pond was also used as a source of drinking water by few residents of Bosso. Thus, a sample was taken from it and the remaining 19 samples were proportionately allocated as shown in Table 3.

Table 3 : Number of samples of water taken from public sources of water in Bosso town, Niger State.

Wards / Sources	Bosso Central I	Bosso Central II
Wells	5	5
Boreholes	1	0
Tap water	5	3
Total	11	8

(IV) Systematic sampling method was used to select the water samples from both wards after the first sample has been selected.

The first sample from any source of water was determined by using the simple random sampling (SRS) with the aid of a random number table after which systematic method of

sampling was applied using the appropriate sample interval to get the remaining number of samples.

The appropriate sample intervals used:

Bosso Central I	Bosso Central II	:
Wells: 39 / 5 = 7.8 (8)	34 / 5 = 6.8 (7)	
Tap: 39 / 5 = 7.8 (8)	21 / 3 = 7	

In selection of twenty samples of water from private sources of drinking water, since about 90% of water sources within residence /yard are tap, equal allocation of number of samples was adopted i.e. irrespective of the number of sources (4 samples of water was collected from each source and from each ward) as shown in Table 4 below.

Table 4 : Number of samples of water taken from private water sources in Bosso town, Niger State.

Wards / Sources	Bosso Central I	Bosso Central II
Wells	4	4
Boreholes	0	0
Tap water	4	4
Total	8	8

Four samples of different sachet water were taken for analysis from Bosso market.

The selection of these samples was done the same way as that of selection of samples from public source of water except for sachet of water i.e. geographic area was considered and SRS and systematic sampling methods were applied.

The first sample was selected randomly using random number table and subsequent samples were selected by using appropriate sample interval.

	Bosso Central I	Bosso Central II
Wells inside residence/yard :	28 / 4 = 7	14 / 4 = 3.5 (4)
Tap inside residence/yard :	440 / 4 = 110	431 / 4 = 107.75 (108)

For selection of sample of sachet water, a market survey on the different types of sachet water so called “pure water” in Bosso market was conducted by the researcher which revealed that there were six different types. Each was given a number from 1 to 6 written on a small squeezed paper and four were picked randomly by closing the eyes.

In determining the sources of drinking water available to residents of Bosso town, the sample frame was all the households in Bosso. Bosso town was divided into six sectors. One interviewer administered one sector. All questionnaires were coded alphabetically from A to K (excluding letter I) and distributed among the interviewers. A SRS and systematic sampling methods was used and the structured questionnaires were administered (face- to- face) to 422 household heads or their representatives (who were not less than 18 years old) out of the estimated 2927 households in Bosso town by the trained interviewers.

Determination of the household to visit was done by selecting the first household using SRS: first, the dwelling structure was determined using the day’s date and applying the left hand rule i.e. the dwelling structure that corresponds to the date or the

sum of digits of the date on the left side was considered the first to start with. When the dwelling structure comprises more than one household, the first household visited was selected by using the household selection grid (Appendix III). The earlier assigned alphabetical code on the questionnaires was used by tracing them along side the number of households in a dwelling structure where the two intersect (i.e. the alphabet on the row, and the number on the column) was the household where the interview started. The household selection grid was used only once in each sector. Subsequently, systematic sampling method was applied such that, every seventh household was visited because the sampling interval is approximately seven ($2927 / 422 \approx 7$).

3.5 Procedure

One litre capacity sample bottles (Pyrex ®) were used for collection of water samples. The bottles and their covers were washed properly and sterilized using dry air oven set at 170 ^{o}C for one hour. When collecting water sample, the sterile bottle was rinsed with the water to be sampled three times before finally collecting the sample.

Water samples from taps, boreholes, well and pond were collected using the one litre sterile bottles fitted with its cover.

0.2ml of Sodium Thiosulphate was added to each bottle before sterilization to stop the action of residual Chlorine on Escherichia Coli (E.coli) in the water sample for bacteriological analysis. The nozzles of the taps were disinfected using ethanol and flame and allowed to cool by running water to waste for some few seconds. The sample bottles were filled with water by a gentle flow from the tap. The bottles were then covered and labeled for easy identification.

Water sample from the pond was collected by simply dipping the neck of the of bottle downwards about 30 cm below the water surface and then tilted upwards till the water fills it. The cover of the bottle was replaced and the bottle labeled appropriately.

Water samples from wells were also collected using the bottles by tying them on a rope above metal weight. The cover of the bottles were aseptically removed and lowered into wells to the depth of about 1 metre and raised out of the well and their covers were carefully replaced and bottles labeled.

All water samples were stored in a cooler containing ice packs and were transported immediately within some few hours to the Department of Water Quality Control, Minna, Niger Sate Ministry of Agriculture and Water Resources for immediate microbial, chemical and physical analysis. Analysis of the water samples were carried out by the Head of the Department of Water Quality Control and his able lieutenants. Quality assurance was guaranteed by taking a few samples of the sampled water to the Regional Water Quality Laboratory of Federal Ministry of Agriculture and Water Resources, Minna for similar analysis and their results were compared with that of the former for reliability. Lastly, but not the least, the origin of the source of sampled water was not disclosed to the laboratory scientists.

3.5.1 PH

PH refers to determination of H ion concentration in any liquid using a PH meter. In obtaining the PH of sampled water, a digital PH meter was used. Prior to using, it was standardized using a buffer solutions: starting with acidic, neutral and lastly alkaline. After standardization, the sample was poured into a test tube and placed in PH meter

where the reading was taken and recorded immediately for each sample [32]. The acceptable PH for drinking Water ranges from 6.5-8.5 -9.5 [2]

3.5.2 Turbidity

Turbidity was measured using DR 2000(HACH) spectrophotometer. Freshly prepared distilled water was filled into 25ml sample cell and another containing sampled water to be analyzed. The knob of the spectrophotometer was turned to a programmed number of turbidity which was 750 and wavelength 450nm.The distilled water was inserted first into the cell holder and the lid (cover) closed, the knob for zero was pressed to standardize the instrument. After that, the sample was inserted into the cell holder and the "Read" button was pressed and the result was displayed on the display screen in Formazine Turbidity Unit (FTU=NTU) [33]. The maximum acceptable value for turbidity of drinking water is 5NTU.

3.5.3 Colour

Using DR 2000 (HACH) Spectrophotometer, colour of the water samples was determined using the same procedure as in turbidity measurement except that the spectrophotometer was programmed at number 120 and wavelength 450nm, the colour of water sample was determined. The unit of colour displayed was Platinium Cobalt (Pt Co) [33].

3.5.4 Total Dissolved Solids (TDS)

In determining TDS, 200mls of distilled water and 200mls of water sample were poured into two separate beakers. The TDS / Conductivity meter was switched on, and its sensor rod was dipped into the beaker containing distilled water which gave a reading 0.00 mg/litre TDS. After that, the sensor rod was dipped into the second beaker

containing water sample; the TDS / Conductivity then displayed the TDS value in mg/litre.[33]

3.5.5 Chloride

Spectrophotometric method was used with the aid of spectrophotometer DR 2000 (HACH). A sample cell was filled with 25ml of freshly prepared distilled water, second cell with sample water. Setting the spectrophotometer at programme number 70 and dialed to wavelength 455; 2ml of mercury thiocyanate was added into each sample swirled to mix. 1ml of ferric ion solution was pipetted into each sample and swirled to mix and let to stand for 2 minutes reaction time. Then the first solution (reference) was inserted first into the cell holder and lid closed, the knob for is pressed to give 0.00mg/litre reading. After that, the second solution was inserted into the cell holder and the "Read" pressed to give chloride value in mg/litre.[33]

3.5.7 Residual Chlorine (RC)

Residual chlorine of sampled tap water was determined by taking 25mls of the water sample, add DPD total chlorine. Using 0.00564 N ferrous ethylene diammonium sulphate (FES) catridge , titrate with 0.00564N FES to a colourless end point. [32]

$$[\ RC\ ] = \frac{\text{Digital reading}}{100}\ \text{mg/litre}$$

3.5.8 Nitrate/Nitrite

The spectrophotometric analysis method was used: DR 2000 (HACH) spectrophotometer was programmed at number 355 and dialed to wavelength 500nm. 25ml sample cell was filled with water sample, and Nitraver 5 Nitrate reagent was added to the water sample, stoppered and shaked for at least 60 seconds to dissolve. The sample

cell was kept undisturbed for a reaction time of 5 minutes. The timer on the DR 2000 was used which beeped immediately the time elapses. Another empty sample cell was filled with the same sample to be analyzed to serve as reference; the reference was inserted into the cell holder and lid closed, reference button pressed to record 0.00mg of nitrate. The prepared sample was then inserted into the cell holder lid closed and "Read" pressed to give the concentration nitrate in sampled water in mg/litre.

The same procedure was applied for determining nitrite in drinking water except that the Spectrophotometer DR 2000 was programmed at number 371, dialed to wavelength 507nm, Nitriver 3 Nitrite was used as reagent, shaking time of 20 seconds and 15 minutes reaction time [33]

3.5.9 Fluoride

Using DR 2000 (HACH) spectrometer, Fluoride content of the water samples was determined. A 25ml sample cell was filled with distilled water and another one with sample water to be analyzed. Pipeted 5ml of SPADNS reagent (sulpho phenyl azo dihydroxy naphthalene disulfonic acid) into each cell and waited for 1 minute reaction time. Spectrophotometer was set at programmed number 190 and dialed to wavelength 580nm .[33]

3.5.10 Iron (Fe)

Fe content in sample of water collected was analyzed using spectrophotometer DR 2000 (HACH) using the same procedure as in nitrate content determination, only with difference in programme number 260, dialed wave length 562 and Ferrozine iron reagent.[33]

3.5.11 Faecal Coliform Count and Total coliform count

Sampled water was taken immediately for faecal coliform analysis. However, if this was not possible, the samples were stored in refrigerator for not more than 4 hours before taking for analysis.

WHO Guideline value for faecal coliform is 0 count /100ml.[8]

Membrane filter technique was used for the microbial coliform analysis of all the samples. Each sample was filtered through a membrane which consists of cellulose compound with a uniform pore of 0.45μm; the bacteria were retained on the surface of the membrane filter. The membrane was placed in a Petri dish containing "m- faecal coliform broth (PARK Scientific Limited)" and was incubated at 44 ^{o}C for 24hours.[30] The bacterial colonies were then counted using magnifying lens or colony counter when necessary and expressed as numbers per 100mls of water.

Total coliform count was determined using the same procedure but the medium used was membrane Lauryl Sulphate broth and incubated at 37^{o}C.[34]

3.6 Data Collection Technique

A structured questionnaire was administered by trained research assistants (interviewers) to respondents who were heads of household or their representatives (whose ages were not less than 18 years). The respondents were selected by selecting the first household to visit using SRS and then systematic sampling method was applied for subsequent households to visit. Information on their source(s) of drinking water, perception on the quality and supply of drinking water, and whether they treat their drinking water or not were collected.

The questionnaire comprises two sections as shown in Appendix I. From the questions in section one, respondent's socio-demographic data were be obtained. Section two of the questionnaire helped in collecting information on the source(s) of drinking water, and whether water meant for drinking was treated before consumption or not.

Sampling of water sources was done as described in subsection 3.5 i.e. sampling technique.

A seven-man research team was constituted with the researcher as the head of the team: three university degree/ HND holders, two advanced level certificates holders and one senior secondary school certificate holder. The research assistants had two days training to enable them assist in administering questionnaires and inspecting wells to assess their sanitary conditions.

To ensure quality of data collected, the researcher supervised the administration of the questionnaires and checked the questionnaires administered with the view to identifying any inconsistency. These steps were taken to achieve that- (a) Pre-briefing and selection of reliable interviewers. (b) Piloting and modifying the questionnaire for clarity, language problems etc. (c) The researcher reviewed completed questionnaire for legibility, accuracy and consistency (d) The Researcher monitored the accuracy of interview and conducted spot checks to eliminate fraud, inaccurate form filling.

Prior to administration of questionnaires, the interviewers did a pre-test of the questionnaires by administering few to their various sectors. During the pre-testing, members of the research team had opportunity to learn how to work in a coordinated

manner and how to use research tools. Difficulties encountered in executing the protocol during this period were discussed and rectified.

Questionnaires were administered by interviewers (research assistants) in English or Pidgin. However, Hausa, Nupe or Gbagyi languages were used when necessary.

All research assistants and the researcher converged in a place and data collected by each member of the research team (seven) were pooled and analyzed using Statistical Package for Social Sciences (SPSS 10.0)

3.7 Data Analysis

Data obtained from this research was analyzed using simple tables and other statistical methods applicable with the aid of SPSS software (version 10.0).

Based on the results of the questionnaires, the descriptive frequency of the respondents was depicted in terms of their sex, age, educational status and occupation. The common (main) sources of drinking water during raining season and dry seasons were presented vis-a- vis educational qualification. Summary indices that were used in analyzing data obtained were

- Proportion of inspected wells that were located at least 30meters from pit latrine, had water tied cover, and permanent fetcher attached to them, parapet and concrete lining of about 6 metres from the surface down (protected wells)
- Proportion of households connected to tap borne water.
- Proportion of households that were using different sources of drinking water.
- Proportion of households with reliable (regular) source of drinking water.
- Proportion of households that were located more than 200 meters from their source of drinking water.

- Proportion of households that treat their water before consumption.

The physical, chemical and bacteriological results obtained from the laboratory were compared with the WHO Guidelines on Quality of Drinking Water, 2006, Third Edition[8]

Analysis of proxy parameters was done on selected parameters (turbidity vs faecal coliform count and colour vs faecal coliform count) to determine whether one parameter could be used as a proxy indicator for the other. Pearson's coefficient of linear correlation "r" was used to measure the strength of the association at 5% (α= 0.05) significance level.[28]

3.8 Limitation

I. The difficulty in getting access to some areas in Bosso town made the coverage limited.

II. Due to high financial cost involved, the number of samples and the parameters that have been included for testing were limited. A general chemical analysis would have included as much as fifteen parameters.

III. This study did not include virology, parasitology, heavy metals and radiological examination because of financial limitations and difficulty in accessing a standard laboratory that could carry out the examinations.

3.9 Ethical Consideration

In collecting data, the nature of the study was explained to the respondents and their verbal consent was obtained. To ensure confidentiality, the names of the respondents were excluded in the questionnaire and only household number and address

was used for identification. In addition, the questionnaires were administered one-on-one basis.

CHAPTER FOUR

RESULTS

The study aimed at assessing the quality of drinking water in Bosso, Niger State. To achieve this, 422 household heads were interviewed using structured questionnaires (Appendix I). The questionnaires provided information about the socio-demography of the respondents, their common source(s) of drinking water in the dry and during raining seasons, their perceptions of physical quality of water (colour, odour, taste), availability and accessibility of water. In addition to this, all (115) wells in Bosso were inspected to determine whether they conform to WHO criteria for improved/protected well.

Forty samples of water from different sources (18 wells, 16 taps, 4 sachet, 1 pond water sample, and 1 borehole water sample) were analyzed for total coliform and faecal coliform counts (E.coli), PH, RC, NO_2, NO_3, turbidity, colour, Fl, Fe, and TDS. The values obtained from the laboratory analysis of water samples were compared with WHO guideline values for drinking water.

The results of the study were presented in tables and figures which can be divided into two components: First, the data which include socio-demographic characteristics of respondents, common sources of water, availability, accessibility and physical quality of drinking water obtained from 422 respondents who were Heads of households or their representatives. Second, the data obtained from laboratory analysis of 40 water samples from different sources.

All the respondents co-operated and answered all the questions on the questionnaires except six of them who refused to specify their household size based on traditional belief.

4.1 Background characteristics of respondents

Table 5 shows some socio-demographic characteristics of the respondents (household Heads or their representatives)

Table 5: Distribution of respondents according to age, sex, educational attainment and occupation

	Male		**Female**		**Total**	
	No	(%)	No	(%)	No	(%)
Age (years)						
<20	43	(16.3)	43	(27.2)	86	(20.4)
20-29	29	(11)	41	(25.9)	70	(16.6)
30-39	66	(25)	47	(29.7)	113	(26.8)
40-49	75	(28.4)	16	(10.1)	91	(21.6)
50-59	28	(10.6)	8	(5.1)	36	(8.5)
60-69	17	(6.4)	3	(1.9)	20	(4.7)
≥70	6	(2.3)	0	(0)	6	(1.4)
Total	264	(100)	158	(99.9)	422	(100)
Education						
Tertiary	101	(38.3)	55	(34.8)	156	(37.0)
secondary	87	(33)	57	(36.1)	144	(34.1)
No formal	59	(22.3)	35	(22.2)	94	(22.3)
Primary	17	(6.4)	11	(7)	28	(6.6)
Total	264	(100)	158	(100)	422	(100)
Occupation						
Civil service	93	(35.2)	45	(28.5)	138	(32.7)
Trading	46	(17.4)	50	(31.6)	96	(22.7)
Farming	61	(23.1)	28	(17.7)	89	(21.1)
Others	64	(24.3)	35	(22.2)	99	(23.5)
Total	264	(100)	158	(100)	422	(100)

The Table 5 above shows that 264 (62.6%) respondents were males and 158 (37.4%) were females. The mean ages of females and males were 33 and 39.5 years respectively while their SD were 10.8 and 12.6 respectively. The majority of the respondents were within 30 to 39 years age bracket representing 26.8% (113) of the respondents.

Bosso community was a literate one only 94 (22.3%) respondents had no formal education while 156 respondents (37%) had tertiary level education. Similarly, this study

shows that majority 32.7% (138) of the respondents were civil servants (federal, state or local establishments) while 99 (23.5%) represented occupations other than farming, petty trading and civil service e.g. Mechanics, plumbers, vulcanizers, carpenters, taxi / vehicle drivers and Motor cycle riders " okada riders"

The distribution of household size of the respondents in Bosso town showed a wide range of household size: minimum size of 1 person and maximum of 27 persons. The mean household size was 7.1 with a standard deviation (SD) of 3.8

Six respondents refused to disclose the number of persons in their households with the explanation that, it was a taboo in their tradition to count the members of their family.

4.2 Sources of drinking water

The study attempts to determine the sources of drinking water available to residents of Bosso in both dry season and rainy seasons. This finding reveals that both improved and unimproved sources of water were used for consumption.

Table 6: Household sources of water in dry and rainy seasons

Sources of water	Dry season		Rainy season	
	Frequency	**%**	**Frequency**	**%**
Tap water in residence	121	28.7	115	27.3
Public borehole	113	26.8	112	26.5
Well in residence	95	22.5	96	22.7
Public tap	77	18.2	75	17.8
Public well	9	2.1	8	1.9
Pond	7	1.7	4	1.0
Rain water	0	0	12	2.8
Total	**422**	**100**	**422**	**100**

The common source of drinking water in both dry and rainy seasons was tap water within residence as shown in Table 6; 28.7% (121) of respondents used tap borne water located within their residence during dry season while 27.3% (115) respondents used it in rainy season.

The use of boreholes during the two seasons did not change significantly (26.8% in dry season and 26.5% in rainy season). Ninety-five (22.5%) and 96 (22.7%) respondents used well located within residence in dry and rainy seasons respectively.

During the rainy season, 2.8% of the respondents used rain water for drinking. Four (1%) respondents used pond as source of drinking water in rainy season and the value increased to 1.7% (7) during dry season. This was probably because many wells might have gone dry and rain which is a source of water would have gone.

4.3 Accessibility and availability of drinking water

About seventy-one percent (71.3 %) of the respondents had their drinking water source located within 200 meters from their houses while 28.7 % (121) had theirs located more than 200 meters.

Table 7: Frequency of water supply

Water supply	Frequency	%
Few hours a day	139	32.9
All the time	138	32.7
Every other day	88	20.9
Twice a week	41	9.7
Weekly	8	1.9
Unpredictable	8	1.9
Total	**422**	**100**

From Table 7 above, only 32.7% (138) of the respondents had water supply all the time. However, 9.7% (41) respondents had water supply twice a week whereas only 1.9% of the respondents either got their water supply once weekly or had unpredictable water supply.

4.4 Physical quality of drinking water

The physical quality (colour, taste and odour) of drinking water based on the perceptions of the respondents is depicted in the table below.

Table 8: Perceptions of physical characteristics of drinking water

Characteristics	Frequency	%
Colourless	389	92.2
Odourless	375	88.9
Tasteless	313	74.2

Table 8 reveals that 389 (92.2%) respondents had the opinion that their water was colourless and 375 (88.9%) said their water was odourless whereas 313 (74.2%) of respondents were of the view that their water for drinking water was tasteless**.**

4.5 Association between sources of drinking and educational attainment of respondents

Tables 9 and 10 present the different sources of drinking water in dry and rainy seasons with number of respondents in relation to their educational status.

Table 9: Relationship between sources of drinking water and educational status of respondents in dry season

Sources of water	Education qualification								Total	
	No formal education		Primary education		Secondary education		Tertiary education			
	(N)	(%)	(N)	(%)	(N)	(%)	(N)	(%)	(N)	(%)
Tap water in residence	15	**(12.4)**	3	**(2.5)**	39	**(32.2)**	64	**(52.9)**	**121**	**(100)**
Public borehole	34	**(30.1)**	14	**(12.4)**	34	**(30.1)**	31	**(27.4)**	**113**	**(100)**
Well in residence	32	**(33.7)**	4	**(4.2)**	32	**(33.7)**	27	**(28.4)**	**95**	**(100)**
Public tap	6	**(7.8)**	6	**(7.8)**	33	**(42.9)**	32	**(41.6)**	**77**	**(100.1)**
Public well	2	**(22.2)**	0	**(0)**	5	**(55.6)**	2	**(22.2)**	**9**	**(100)**
Pond	5	**(71.4)**	1	**(14.3)**	1	**(14.3)**	0	**(0)**	**7**	**(100)**
Total	**94**	**(22.4)**	**28**	**(6.6)**	**144**	**(34.1)**	**156**	**(37)**	**422**	**(100.1)**

$X^2 = 60.717$ df =15, $p<0.05$

Table 9 demonstrates that there was relationship between sources of drinking in dry season and educational status of respondents. It showed that 64 (52.9%) respondents who had tap water as their source of water within their residence had tertiary education while only 15 (12.4%) respondents who had no formal education had tap borne as their source of drinking water within residence. This finding was found to be statistically significant ($X^2 = 60.717$, df = 15, $p< 0.05$)

Table 10: Relationship between sources of drinking water and educational status of respondents during rainy season

Sources of water	Education qualification								Total	
	No formal education		Primary education		Secondary education		Tertiary education			
	N	(%)	N	(%)	N	(%)	N	(%)	N	(%)
Tap water in residence	15	**(13)**	3	**(2.6)**	35	**(30.4)**	62	**(53.9)**	**115**	**(99.9)**
Public borehole	33	**(29.5)**	14	**(12.5)**	34	**(30.4)**	31	**(27.7)**	**112**	**(100.1)**
Well in residence	33	**(34.4)**	3	**(3.1)**	31	**(32.3)**	29	**(30.2)**	**96**	**(100)**
Public tap	8	**(10.7)**	5	**(6.7)**	32	**(42.7)**	30	**(40)**	**75**	**(100.1)**
Rain water	3	**(25)**	1	**(8.3)**	6	**(50)**	2	**(16.7)**	**12**	**(100)**
Public well	1	**(12.5)**	0	**(0)**	5	**(62.5)**	2	**(25)**	**8**	**(100)**
Pond	1	**(25)**	2	**(50)**	1	**(25)**	0	**(0)**	**4**	**(100)**
Total	**94(22.4)**		**28(6.6)**		**144(34.1)**		**156(37)**		**422(100.1)**	

X^2 =62.102 df=18 p< 0.05

Similarly, Table 10 shows that there was also an association between sources of drinking water in rainy season and the educational attainment of respondents. This was also found to be statistically significant (X^2 = 62.102, df = 18, p < 0.05)

4.6 Sanitary conditions of the well

On inspection of 115 wells to assess whether they were protected wells as recommended by WHO, the findings were presented as in Table 11

Table 11: Sanitary conditions of the wells inspected

Characteristics	No of wells (N=115)	Percent
≥30m from pit latrine	87	75.7
Cover present	81	70.4
Fetcher present	71	61.7
Parapet present	57	49.6
Concrete lining present	48	41.7
All present	23	20.0

N is the total number of wells inspected

Table 11 above shows that 81 (70.4%) wells inspected had cover, 87 (75.7%) of the wells inspected were located at least 30 metres from pit latrine, 57 (49.6%) of the wells had parapet and 48 (41.7%) wells inspected had concrete lining. Only 23 wells which represented 20.0% of the 115 inspected wells had all the characteristics and can therefore be termed as sanitary (improved/protected).

4.7 Laboratory analysis of the quality of water

A total of forty water samples were taken for physico-chemical analysis (Colour, Turbidity, PH, TDS, Residual chlorine, Chlorides, Fluorides, Nitrates, Nitrites and Fe) and bacteriological analysis (E.coli count and Total coliform count). Results were depicted in Appendix IV. The methods used for collecting samples and their analysis were in accordance with American public health Association guidelines.

4.7.1 Laboratory analysis of physical quality of water

Laboratory analysis of forty samples of water from different sources revealed the following results as depicted in the below.

Table 12: Physical parameter of drinking water

	Colour	**PH**	**Turbidity**	**TDS**
WHO values	≤ 15 Pt.Co	6.5-8.5	5 NTU	≤ 1200mg/l
Normal	17 (42.5%)	26(65%)	20 (50%)	40 (100%)
Abnormal	23 (57.5%)	14 (35%)	20 (50%)	0 (0%)

Table 12 demonstrates that all the 40 (100%) samples of water met the WHO guideline values for TDS, 20 (50%) and 17 (42.5%) samples were within WHO recommended values for turbidity and colour respectively.

4.7.2 Chemical quality of water

All the water samples were analyzed for chloride (Cl), Nitrate (NO^3), Nitrite (NO^2), Fluoride (Fl) and Iron (Fe). For residual chlorine (RC), only water samples from tap and sachet were tested. Results of the analysis are shown in Table 13

Table 13: Chemical analysis of water samples

	Cl	**RC**	**NO_3**	**NO_2**	**Fl**	**Fe**
WHO values	≤ 250mg/l	≥0.5mg/l	50mg/l	3mg/l	≤ 1.5mg/l	0.3mg/l
Normal	40 (100%)	0	34 (85%)	38 (95%)	38 (95%)	32 (80%)
Abnormal	0 (0%)	20 (100%)	6 (15%)	2 (5%)	2 (5%)	8 (20%)

From the Table 13 above, all the 40 samples of water analyzed met the WHO requirements for chloride concentration. However, all the 20 samples of treated water failed to meet WHO standard for RC. Eighty-five percent of the sampled water had normal nitrate (NO_3) concentration and 38 (95%) samples of water were within WHO recommended value for nitrite (NO_2) and Fluoride (Fl), while 32 (80%) samples had normal Iron (Fe) concentration.

4.7.3 Bacteriological quality of water

Out of the forty samples of water taken for bacteriological examination, only 8 (20%) samples met the WHO recommended value for E. coli count which is 0 cfc/100ml for treated water; of which one was a sample from a well (lat. N 0966115, long. E 006.25854).

Twelve samples of water (untreated) met the WHO recommended value of E. coliform ≤ 10 cfc/100ml.

Although total coliform count is not an indicator of faecal contamination, it is primarily used for assessment of the general sanitary quality of finally water treated water and disinfected drinking water. WHO guideline stipulates that there should be no coliform bacteria per 100ml in either treated water entering distribution system or in the distribution system. Only one (2.5%) sample of water had no total coliform bacteria per 100ml.

4.5 Comparison of quality of water of the different sources of water

The quality of water samples of different sources was compared and the results depicted in the Table 14 below.

Table 14: Compliance of water samples with WHO guideline on physical and bacteriological qualities

Source of water	No of samples	Colour (%)	PH (%)	Turbidity (%)	TDS (%)	Coliform (%)	E.Coli (%)
Well	18	44.40	77.78	61.60	100.00	0.00	22.20
Tap	16	31.25	37.50	31.25	100.00	0.00	31.25
Sachet	4	100.00	100.00	100.00	100.00	50.00	50.00
Borehole	1	0.00	100.00	0.00	100.00	0.00	100.00
Pond	1	0.00	100.00	0.00	100.00	0.00	0.00
Total	**40**	**17**	**26**	**20**	**40**	**2**	**12**

Table 14 demonstrates that all samples of sachet water (100%) met the WHO recommendation except for coliform count which had 50% compliance to the recommendation. Samples from wells had 44.4%, 77.8%, 61.6% and 22.2% compliance on colour PH, turbidity and E. coliform count respectively.

Utility pipe water samples shows that 31.50% samples complied with WHO guideline for E. coli.count. Less than 40% of tap water samples are in keeping with the guideline values in terms of colour, PH, turbidity. This is possibly because there was no filter or filtration process is poorly done. The single borehole and pond water samples analyzed met the WHO requirements on PH and TDS; while the borehole water sample complied with WHO recommendation on faecal coliform, pond water sample did not.

Table 15: Compliance of water samples with WHO guideline on Chemical quality

Source of water	No of samples	Cl (%)	RC (%)	NO_3 (%)	NO_2 (%)	Fl (%)	Fe (%)
Well	18	100.00	-	66.70	88.90	100.00	100.00
Tap	16	100.00	0.00	100.00	100.00	93.75	56.25
Sachet	4	100.00	0.00	100.00	100.00	100.00	100.00
Borehole	1	100.00	-	100.00	100.00	0 (0)	0.00
Pond	1	100.00	-	100.00	100.00	100.00	100.00
Total	**40**	**40**	**0**	**34**	**38**	**38**	**32**

Table 15 shows that all samples of treated water failed to meet the WHO recommended value for RC. The finding of this study revealed that all sachet water samples complied with WHO guideline values for Cl, NO_3 NO_2, Fl and Fe. Similarly, tap water samples had compliance in all except Fl and Fe which had 93.75% and 56.25% compliance rate respectively.

Well water samples complied with WHO guideline on Cl, Fl and Fe but 66.70% and 88.90% compliance on NO_3 and NO_2 respectively.

Pond water Sample had 100% compliance on all chemical parameters while borehole water had Fe and Fl content above the recommended values

4.8 Analysis of proxy parameters

Analysis of proxy parameters was done on following selected parameters: turbidity vs total coliform count, turbidity vs total dissolved solids, and colour vs total coliform count. Pearson's coefficient of linear correlation "r" was used to measure the

strength of the association at 5% (α= 0.05) significance level. All the proxy parameter analysis showed no significant association.

4.9 METHODS OF TREATMENT OF HOUSEHOLD WATER

Despite the unsafe and unwholesome nature of most of the water samples, only a few percent of the households treat their water before drinking.

The study shows that majority of the households do not treat their water before drinking irrespective of the source of water

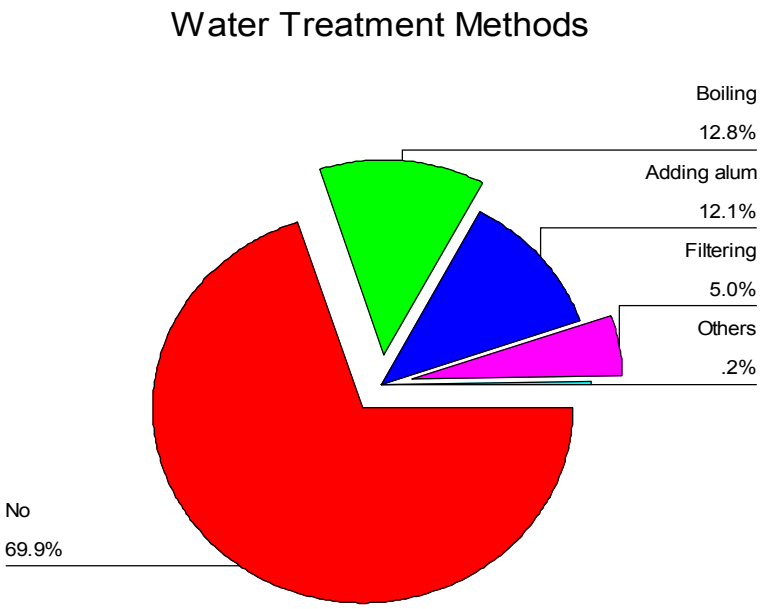


Figure 1: Household methods of water treatment

Figure 1 above, shows that 69.9% (295) respondents did not treat their water before drinking. However, among those that treated their water before drinking, 12.1% (51) used alum, 12.8% (54) of the respondents boil their water, 5.0% (21) used filter and 0.2% (1) used others means of treatment e.g. using sodium hypochlorite “Jik”

CHAPTER FIVE

5.1 Discussion

The socio-demographic profile of the respondents in Table 5 depicts that most of the respondents (62.6%) were male. This implies that as Head of households, male were the main bread winners of their households in Bosso town. About twenty-seven percent (26.8%) of the respondents fell within the 30 to 39 years age bracket. The mean ages of the female and male respondents were 33 and 39.5years respectively which means that majority of the respondents were young people.

The educational levels of the respondents as indicated in the same table, shows that only 22.3% of the respondents had no any form of education; majority of the respondents which constituted 37% of the respondents had tertiary form of education and 34.1% had secondary education. From this study, one can conclude that Heads of households in Bosso town are highly literate because 71.1% of the respondents had some post primary education. This was not surprising, possibly because there were many schools including Federal University of Technology, Minna, Bosso campus located in Bosso town.

The Table also shows that large number 138 (32.7%) of the respondents were civil servants (local, state and federal governments and government parastatal) and 99 (23.5%) respondents represented occupations other than farming, petty trading and civil service.

The distribution of household size of the respondents in the study area showed a wide range of household size: minimum size of 1 person and maximum of 27 persons. The mean household size was 7.1 with a standard deviation (SD) of 3.8.

Six respondents refused to disclose the number of persons in their households with the explanation that, it was a taboo in their tradition to count the members of their family.

The common sources of drinking water during dry and raining seasons are shown in Table 6 shows that most respondents use tap borne water located within their residence in both seasons (28.7% and 27.3% in dry and rainy seasons respectively) and only few proportion of respondents used public wells and pond irrespective of the seasons. The proportion of people using pond water in dry season was significantly greater than that of rainy season because of the transient nature of well water.

Although proportion of people using tape water did not change much between seasons, the proportion of those using pond decreases during rainy from 1.7% in dry season to 1% during the rainy season. This is probably because; there was another alternative source of drinking water which is rain water (2.8% of the respondents used rain water for drinking.)

The study shows that about seventy-one (71.3 %) of the respondents had access to drinking water within 200 metres from their houses. This simply implies that there is a source of water located within 200 metres from their houses but that does not necessarily mean that the water is safe for consumption.

The study reveals in Table 7 that 65.6% of the respondents got water supply at least daily and only 1.9% had irregular supply (unpredictable water supply).

The physical quality of water based on the perception of the respondents as in Table 8 shows that about 74% of respondents opined that their water for drinking water was tasteless, 92.2% respondents had the opinion that their water was colourless and 88.9% of respondents claimed that their drinking water was odourless. Though taste, colour and smell of drinking water may not be a direct indication of unsafe water, they

are very important, for their presence may indicate the presence of a dangerous / injurious substance. Water that is colourful, odorous or has unpleasant taste may be objectionable even when it may not pose any danger to the health of the consumers. Ideally, safe drinking water is colourless, tasteless and odourless.

The common sources of drinking water in dry and in rainy seasons vis- a-vis educational levels of the respondents as shown in Tables 9 and 10 indicate that the proportion of respondents that used tap water was higher among those that had secondary or tertiary education. They constituted about 85% of the total respondents that had tap water within their residence in dry season which does not change much even in rainy season. About 71% of respondents that used pond water for drinking in dry season had no formal education. The proportion of respondents that used pond water for consumption was still high among the less educated in the rainy season. There is association between the educational level of respondents and the source of drinking water. This was statistically significant: X^2 =60.717, df= 15 in dry and X^2 =62.102, df= 18 in rainy season at $p < 0.05$

From these findings, it can be said that those with higher educational levels had more access to pipe borne water supply within their residence and also less likely to use unsafe alternative water source. Higher educational level may also mean improved income and increased awareness of the dangers of unsafe water sources while those with little or no formal education, had less access to improved water supply due to ignorance and / or poverty.

Inspection of all the wells (115) in Bosso town to determine their sanitary condition revealed that only 23 wells (20.0%) of the inspected wells could be termed as sanitary. Based on these findings, it can be concluded that about 80% of wells in Bosso town were unimproved (unsanitary) based on WHO criteria. Results are shown in Table 11. Thus, contamination of well water through seepage of faeces, water runoff and dirty fetchers are common.

The turbidity and PH of the water samples, Table 12 shows that 50% of the samples had turbidity above 5NTU and 35% samples had PH less than 6.5 as shown in Appendix IV (recommended PH value is 6.5-8.5). Turbidity and PH affect chlorination of water. The higher the turbidity and a PH above 7, the more the chlorine that is required and the longer the contact period before adequate disinfection.

About 58% of the samples had colour above the recommended value of less than 15Pt Co.

The study also shows that nitrate (NO_3) and nitrite (NO_2) contents were above the guideline level in 15% and 5% of the samples respectively as shown in Table 13. It should be noted that these chemicals could interfere with oxidation of haemoglobin by causing methaemaglobinaemia (“blue baby” syndrome) most especially in infant.

The same table shows that 5% of the samples had fluoride content more than the 1.5mg/l recommended value. This level of fluoride causes fluorosis of the bones and teeth.

The majority (80%) of the water samples had Fe content within the WHO recommended value of less than 0.3mg/l, however, 20% of the samples did not meet this standard; thus prone to be aesthetically unfit for drinking due to discoloration.

The chloride varies from 0.3 to 118.45mg/l (Appendix IV). This is in keeping with WHO guideline of ≤ 250mg/l for drinking water.

All the 20 samples of treated water fell short of WHO recommended chlorine value of not less than 0.5mg/l. This is probably due to lack of enough chlorine and or absence of proper equipments for chlorination (chlorinator) and monitoring the chlorine level. Thus, reducing margin of safety against microbial recontamination.

There was high bacterial contamination of most (80%) of the water samples The faecal coliform (E.coli) count varies from 0 to 436 cfc/100ml as depicted in Appendix IV. This signifies gross faecal contamination hence the general public are exposed to high risk of pathogenic bacteria which are important causes of water borne diseases. Only 20% samples met the WHO recommended value of E. coli count of 0 cfc/100ml for treated water; of which one was a sample from a well located lat. N 0966115, long. E 006.25854. Five (25%) of the untreated water samples met the WHO recommended value of E. coli count not greater than 10 cfc/100ml and only 2.5% sample of water had no total coliform bacteria per 100ml which means that the sanitary conditions of water sources were poor and the general sanitary quality of treated/disinfected water for drinking was equally poor.

Comparing the quality of water samples from different sources as demonstrated in Tables 14 and 15, sachet water samples complied in all parameters with the WHO guidelines except for faecal coliform (E. coli) counts which had 50% compliance. Results from other research works on quality of sachet water in Zaria and in Kaduna in 2000 and 2005 respectively showed that all sample of water did not meet WHO standard of 0 coliform count per 100ml of water sample [18,19]. The probable reason for improved

bacteriological quality of sachet water in Bosso might be due to the activities of National Agency for Food and Drug Administration Control (NAFDAC).

Tap water samples showed compliance rate of only 31.25% for E. coli count (ie 0cfc/100ml) while 68.75% had E. coli count ranging from 1 to 33 cfc/100ml and total coliform count of up to 240 cfc/100ml. The high total coliform count in tap implies that the sanitary quality of the water was very poor. This finding is at variant with results of a research on bacteriology of drinking water in Calabar in 2005 which showed that 100% of the sampled tap water complied with WHO recommendation on faecal coliform count of 0 per 100ml 0f sampled water [21]. Some of the reasons for this disparity may be due to ineffective chlorination (disinfection) of water supplied to the town. At the time of this study, there was no chlorimeter in Bosso Water Board (treatment plant). Bosso treatment plant sometimes pumps raw water to the community intended for something other than consumption and there are leaky pipes lied in gutters and dump grounds. Less than 40% of tap water samples met the WHO standard for PH, colour and turbidity. None of the treated water samples (sachet and tap water) had RC of 0.5mg/l and above.

The only borehole water sample analyzed was in keeping with the guideline except in Fluoride and Iron content which were more than the recommended values (Fl $\leq$1.5mg/l, and Fe< 0.3mg/l).

The water sample from pond had E.coli count of 59 cfc/100ml and total coliform of 460 cfc/100ml. This may be due to faecal contamination of the pond arising from unsanitary method of waste disposal. The PH, TDS, Cl, NO_3 , NO_2 , Fl and Fe contents of the pond sample water was within the guideline value.

From the analysis of well water, Most of the samples (77.8%) failed to meet the guideline for E.coli count of less than 10 cfc/100ml.The E.coli count varies from 0-436 cfc/100ml while the total coliform was as high as 1160 cfc/100ml. In a study to assess the bacteriological quality of well water in Abeokuta in 2007 showed that all the sampled water were contaminated with faecal coliforms [25]. Other studies of well water in other parts of Nigeria and other developing countries showed gross contamination of well water with faecal coliform over 2400 cfc/100ml [22,25,35].

This high contamination of well water is anthropogenic in origin. The increasing human concentration in Bosso enhances the use of pit latrines and septic soak away which are usually located too close to open wells. Coupled with this, free ranging of domestic animals and other domestic waste which are dumped indiscriminately around the houses were possible sources of bacteria contamination of wells. Contamination of well water is also as a result of unsanitary conditions of the wells [7,35]. The result of this study revealed that only about 20% of the inspected wells could be termed protected (sanitary).

The study shows that nitrate (NO_3) and nitrite (NO_2) contents were above the guideline level in 33.30% and 11.10% of well water samples respectively It should be noted that only the well water samples had these nitrogenous compounds above the WHO recommendations. These results were corroborated by findings in Pakistan and Saudi Arabia that showed higher values of nitrate above WHO recommended value in 15.6% and 7.7% of well sampled water [29,36]. There were potential reasons which might have contributed to these elevated values in Bosso. These include human and animal wastes, usage of nitrogenous fertilizer, organic manures and domestic wastes. Of all the sources mentioned above, it was expected that sources of high nitrate concentration was human

and animal waste due to construction of wells close to pit latrines and poor basic sanitation. This fact was supported by the presence of large concentration of faecal coliform in well water samples.

All the proxy parameter analysis using Pearson's coefficient of linear correlation "r" to measure the strength of the association at 5% (α= 0.05) were not significant.

From the study, it was found that only 30.1% of the respondents treated their water before consumption while 69.9% did not as shown in Figure 1.This means that even though 80% of the water samples were grossly contaminated with faecal bacteria, only few households treat their water before consumption. This therefore implies that many households were exposed to dangers of unsafe/unsanitary water.

Methods of household treatment of water applied before drinking include the use of alum 12.1%, boiling of water 12.8%, filtering 5.0% and the use of other means. These treatments may not be done properly. For instance duration at which water is allowed to boil, handling of filters used in filtering water, amount of jik to add in a particular quantity of water etc.

5.2 Conclusions

From this study, it can be concluded that water available to residents of Bosso town of Niger state was heavily contaminated with faecal bacteria and therefore, unsafe for consumption.

All the various sources of water were prone to contamination. However, sachet water and borehole were slightly contaminated and thus, safer for drinking compared to other sources of water. Only about 30% of tap water in Bosso was free from faecal contamination.

All the treated water failed to meet WHO recommendation in terms of RC. This is as a result of absence chlorine, chlorinator and other equipments in water treatment plants.

NO_3 and NO_2 contents were higher than the recommended values only in well water. These chemicals are more dangerous to the most susceptible group (infants)

It can be concluded also that despite gross faecal contamination of water in Bosso town, only 31.9% of household treated their water before consumption. Though the various treatment methods may not be effective due to lack of knowledge.

Majority of the wells in Bosso town can be considered unsanitary as only 20% of the wells met the WHO criteria for improved/protected well.

From this study, it can be concluded that Bosso town is not on track in attaining the MDG 7 target 10. Therefore, all stakeholders (Federal, Niger state and Bosso local government authorities) should work relentlessly in order to be on track to its attainment by 2015.

5.3 Recommendations

Based on the findings of this study, the following recommendations are made

1) Ministry of Health in collaboration with Ministry of Education should launch a continuous mass health education to communities, primary and secondary schools on the consequences of contaminated water and benefits of sanitation and personal hygiene.
2) Waste Management Board in conjunction with Urban Development Board and Ministry of Housing should provide tactical and logistic support for proper waste management and housing.

3) The state government should upgrade all water treatment plants with necessary equipments, chemicals and personnel.
4) State and local governments should embark on continuous monitoring of water quality and undertake repairs of leaking / rusted pipes.
5) Local government should construct new public wells and reconstruct old ones in line with the WHO criteria.
6) State and local governments should construct more boreholes.

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APPENDIX I

Questionnaire on Assessment of Quality of Drinking Water in Bosso town, Niger state

This questionnaire is strictly designed for the above named study, so all responses will be treated for that purpose and with utmost confidentiality.

In an attempt to assess the quality of drinking water available to the residents of Bosso town, Niger State, the questionnaire below will be administered through face –to- face interview to respondents who are heads of households or their representatives (who must be at least 18years old) .

The purpose of the questionnaire is to determine-

1. different sources of drinking water in Bosso
2. the main source of drinking water
3. the distance of sources of drinking water from the households
4. quality and quantity of water in Bosso based on the views of the respondents.
5. sanitary conditions of wells in Bosso by inspecting them.

In collecting data, the nature of the study will be explained to the respondents and their verbal consent obtained. To ensure confidentiality, the name of the respondents shall be excluded (anonymously) from the questionnaire and only household number and address shall be used for identification. In addition to these measures, the questionnaire will be administered one-on- one basis.

SECTION 1. Personal Data/Profile

Respondent: Feel free to complete the form appropriately as all information shall not be divulged to anybody.

1.1 Respondent
Head of household
- Female
- Male

Representative of head of household (He/she should be aged 18years and above)
- Female
- Male

1.2 How old are you at your last birthday anniversary?----------
1.3 What is your household No----------
1.4 What is the address of your household? ----------
1.5 How many are you in your household ?----------

1.6 What tribe /nationality are you? (tick one that is applicable)
- Gbagyi
- Nupe
- Hausa/Fulani
- Yoruba
- Kadara
- Others

1.7 What is your educational qualifications
- Primary education
- Secondary education
- Tertiary education

- None

1.8 What is your occupation?
- Farming
- Petty trading
- Civil service
- Others----------(specify)

SECTION 2. Sources of Drinking Water

Please select by ticking appropriately:

2.1 What are the sources of water that you use for drinking in your household?
- tap water inside house
- public tap water
- Borehole inside house
- Public Borehole
- Well inside house
- Public well
- Sachet water
- Pond
- Others---------- (specify)

2.2 What is the commonest source of drinking water in your household during the drying season?
- tap water inside house
- public tap water
- Borehole inside house
- Public Borehole
- Well inside house
- Public well
- Sachet water
- Pond
- Others---------- (specify)

2.3 What is the commonest source of drinking water in your household during the raining season?
- tap water inside house
- public tap water
- Borehole inside house

- Public Borehole
- Well inside house
- Public well
- Sachet water
- Pond
- Rain water
- Others---------- (specify)

2.4 What is the distance of the source of water from your household?

- within 200metres
- more than 200metres

2.5 How regular is the water supply?

- 24hours in day
- Daily
- Every other day
- Twice a week
- Weekly
- irregular

2.6 What is your perception of the quality of water available?

Taste

- Tasteless
- Has taste

Colour

- Colourless
- has colour

Smell

- odourless
- has odour

2.7 Sanitary conditions of wells by inspection

Distance from pit latrine

- less than 30m
- more than 30m

Does the well have water tied cover?

- No
- Yes

Is there a permanent fetcher attached to the well?

- No
- Yes

Is there a parapet

- No
- Yes

Is there a concrete lining about 6 m long from the surface down?

- No
- Yes

2.8 Do you treat your water before drinking?

- No
- Yes

2.9 If your answer to 2.8 is yes, which treatment methods do you use?

- Boiling
- Adding Alum
- Filtering
- Others---------- (specify)

APPENDIX II

GUIDELINE FOR WATER SAMPLE ANALYSIS

This appendix guides you into analyzing the water samples.

1. Household No

2. Address of household----------

3. Source of water sample

- tap water inside house
- public tap water
- Borehole inside house
- Public Borehole
- Well inside house
- Public well
- Sachet water
- Pond

4 Colour of sampled water

5 Turbidity of sampled water

6 Total Dissolved Solids of sampled water (TDS)

7 PH of sampled water

8 Nitrate/Nitrite of sampled water

9 Iron concentration

10 Residual chlorine of sampled tap water

11 Chloride

12 Fluoride

13 Faecal coliform count and Total coliform count

APPENDIX III

Household selection Grid

Number of Rooms/households in dwelling structures (floors)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21+
A	1	2	3	2	4	5	6	3	6	3	10	8	3	7	2	1	4	4	7	14	7
B	1	1	1	2	2	5	1	1	6	7	5	12	1	3	4	12	3	3	4	8	10
C	1	2	2	3	4	5	2	5	9	1	1	7	1	3	4	12	4	1	12	3	18
D	1	2	3	3	5	2	1	3	9	6	1	8	7	14	4	12	10	3	17	19	21+
E	1	2	1	1	5	3	2	6	4	10	1	8	6	3	3	4	11	5	17	3	10
F	1	2	1	2	3	4	2	3	3	2	10	11	5	7	8	14	6	17	15	10	14
G	1	1	3	4	1	1	2	7	1	3	2	7	10	6	3	3	15	17	4	15	21+
H	1	2	1	3	5	3	5	7	8	3	4	5	1	3	7	6	15	2	3	13	19
J	1	2	2	4	3	2	7	2	9	4	1	12	8	9	8	16	2	10	16	4	21+
K	1	1	1	4	3	6	6	7	5	7	9	3	8	5	7	15	12	8	4	6	10
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21+

Table adopted from Sterling Business Research & Consulting Ltd, Lagos, Nigeria

Appendix IV

Table 20: PHysico-chemical and Bacteriological analysis of Drinking water in Bosso Town, Niger State

	Latitude (N)	Longitude (E)	Source of water	Address	Colour (Pt. Co)	PH	Turbidity (NTU)	Suspended solids (mg/litre)	Total dissolved solids (mg/litre)	Chlorides (mg/litre)	Residual chlorine (mg/litre)	Nitrates (mg/litre)	Nitrites (mg/litre)	Fluorides (mg/litre)	Iron (mg/litre)	Total coliform count (cfc/100ml)	Escherichia coli count (cc/100ml)
1			sachet water	Bosso market	9	7.00	2	0	50	.30	.04	5.304	.0143	.21	.0110	0	0
2			sachet water	Bosso market	8	8.10	2	1	40	.90	.03	4.862	.0124	.23	.0220	9	1
3			sachet water	Bosso market	6	6.71	4	0	50	.70	.08	4.420	.0132	.19	.0070	11	5
4			sachet water	Bosso market	3	6.94	5	0	50	.30	.06	4.420	.0197	.14	.0280	11	0
5	N 09.66115	E 006.25854	public well	Bosso 2	57	7.54	9	8	300	10.10	.	3.536	.0049	.19	.0460	19	0
6	N 09.66050	E 006.52934	public well	Bosso 2	260	6.86	45	44	150	13.20	.	29.614	1.4268	.71	.0640	240	54
7	N 09.65973	E 006.53414	public well	Bosso 2	33	6.87	4	3	170	9.87	.	4.420	.0067	.43	.0520	120	36
8	N 09.65993	E 006.53751	Bosso pond	Bosso 2	78	7.19	14	3	70	38.50	.	3.536	.0066	.47	.0452	460	59
9	N 09.65411	E 006.53615	public well	Bosso 2	8	6.92	3	1	490	47.00	.	170.170	.5050	.30	.0560	120	48
10	N 09.65042	E 006.54238	public well	Bosso 2	436	6.92	80	39	20	3.50	.	.000	.0328	.36	.0410	1160	70
11	N 09.66067	E 006.52929	private tap	Bosso 2	15	5.70	4	3	60	4.10	.05	3.978	.0200	.19	.0930	19	0
12	N 09.66084	E 006.52909	private tap	Bosso 2	228	6.20	44	22	40	11.00	.07	3.979	.0000	.00	1.2380	48	15
13	N 09.65794	E 006.52948	private tap	Bosso 2	430	4.20	73	45	90	30.50	.34	.000	.0000	.00	1.4300	48	0
14	N 09.66211	E 006.52910	private well	Bosso 2	60	6.40	9	8	170	10.90	.	4.862	.0070	.35	.0290	120	38
15	N 09.65714	E 006.53002	private well	Bosso 2	20	6.70	4	5	400	28.50	.	136.136	.1870	.38	.0240	210	160
16	N 09.65314	E 006.53474	private well	Bosso 2	103	6.70	20	16	570	13.20	.	174.148	1.3120	.33	.1120	460	200
17	N 09.66147	E 006.53045	public tap	Bosso 2	85	5.50	15	7	30	5.98	.04	4.862	.0131	.05	.2910	45	8
18	N 09.64968	E 006.52189	public tap	Bosso I	3	6.10	0	0	110	6.96	.05	4.420	.0660	.86	.0050	50	5
19	N 09.65335	E 006.52054	public tap	Bosso I	3	7.00	1	0	170	13.49	.04	10.610	.0200	.39	.0370	120	28
20	N 09.65242	E 006.51369	public well	Bosso I	15	6.90	3	2	160	23.49	.	60.112	.0131	.08	.0390	210	36
21	N 09.65894	E 006.53759	private well	Bosso 2	5	5.70	2	1	130	26.97	.	48.180	.1150	.21	.0080	1160	210
22	N 09.65314	E 006.50987	public well	Bosso I	1	6.50	3	2	130	24.95	.	27.846	.0459	.14	.0270	460	7
23	N 09.64755	E 006.52546	private well	Bosso I	16	6.50	2	3	130	22.92	.	21.220	.0328	.15	.0150	210	24
24	N 09.65078	E 006.53265	public well	Bosso I	15	6.50	3	2	720	118.45	.	278.460	10.1024	.29	.0080	460	62
25	N 09.65144	E 006.53230	public well	Bosso I	13	6.40	4	1	640	82.46	.	80.444	7.6424	.27	.0270	120	5
26	N 09.65609	E 006.50858	private well	Bosso I	1	6.50	3	2	130	24.95	.	27.846	.0459	.14	.0270	460	62
27	N 09.66096	E 006.52955	private tap	Bosso 2	97	6.50	17	5	40	4.00	.03	6.188	.0722	.23	.4380	120	33
28	N 09.66232	E 006.52932	public tap	Bosso 2	93	5.80	18	6	40	4.00	.03	6.630	.0590	.19	.6440	24	17
29	N 09.66309	E 006.53013	public tap	Bosso 2	90	6.00	17	5	40	3.50	.04	6.630	.0033	.32	.5490	20	6
30	N 09.65298	E 006.53104	public borehole	Bosso I	75	7.20	13	4	240	49.98	.	26.078	.0620	1.67	1.5900	34	2
31	N 09.64729	E 006.52500	public well	Bosso I	180	7.40	3	33	260	40.49	.	17.238	.0295	.05	.0310	240	82
32	N 09.64778	E 006.52500	private tap	Bosso I	7	6.40	2	1	50	6.50	.02	3.536	.0130	.07	.0380	240	10
33	N 09.65165	E 006.51402	private well	Bosso I	15	7.60	34	0	130	8.00	.	6.188	.0066	1.09	.0624	120	5
34	N 09.65357	E 006.51520	private tap	Bosso I	12	6.50	2	0	60	10.50	.03	4.420	.0130	.43	.0750	120	0
35	N 09.64969	E 006.52419	private well	Bosso I	52	6.20	9	11	90	22.99	.	39.340	.0164	.35	.0490	1160	436
36	N 09.65655	E 006.52947	public tap	Bosso I	100	6.70	20	7	40	6.00	.02	19.450	.0131	.19	.0330	15	0
37	N 09.65788	E 006.52942	public tap	Bosso I	59	5.80	13	2	40	7.50	.02	12.380	.0492	.36	.0405	9	0
38	N 09.66235	E 006.52961	private tap	Bosso I	114	7.00	21	9	40	6.00	.02	1.770	.0426	.53	1.0570	9	1
39	N 09.66320	E 006.52737	public tap	Bosso I	94	6.70	17	5	40	6.00	.02	3.090	.0390	.09	.0831	24	7
40	N 09.66124	E 006.52727	private tap	Bosso I	103	6.40	19	7	40	8.00	.05	44.200	.0131	6.40	.6360	120	29
Total N	40	40	40	40	40	40	40	40	40	40	20	40	40	40	40	40	40