ASSESMENT OF WATER QUALITY OF HAND-DUG WELLS IN NORTH-WESTERN PART OF BOSSO LOCAL GOVERNMENT AREA IN MINNA, NIGER STATE.

BY

OJONUBA, MOSES OJOAGO

2006/24118EA

DEPARTMENT OF AGRICULTURAL & BIORESOURCES ENGINEERING

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

FEBRUARY 2012

ASSESMENT OF WATER QUALITY OF HAND-DUG WELLS IN NORTH-WESTERN PART OF BOSSO LOCAL GOVERNMENT AREA IN MINNA, NIGER STATE.

BY

OJONUBA, MOSES OJOAGO

2006/24118EA

BEING A FINAL YEAR POJECT REPORT SUBMITTED IN PARTIAL FUFILMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING (B. ENG.) DEGREE IN AGRICULTURAL & BIORESOURCES ENGINEERING, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE

FEBRUARY 2012

DECLARATION

I hereby declare that this project work is a record of a research work that was undertaken and written by me. It has not been presented before for any degree or diploma or certificate at any university or institution. Information derived from personal communications, published and unpublished work were duly referenced in the text.

__________________________ ________________________

Ojonuba, Moses Ojoago date

CERTIFICATION

This is to certify that the project entitled "Assessment of Water Quality of Hand-dug Wells in North - western part of Bosso Local Government Area, Niger State" by Ojonuba, Moses Ojoago meets the regulations governing the award of the degree of Bachelor of Engineering (B. ENG.) of the Federal University of Technology, Minna, and it is approved for its contribution to scientific knowledge and literary presentation.

27-02-2012

Engr. Dr. N. A. Egharevba
Supervisor

Date

27/02/2012

Engr. Dr. P. A. Idah
Head of Department

Date

22-02-2012

External Examiner

Date

DEDICATION

I dedicate this work to all those that have lost loved ones as a result of consuming contaminated water.

ACKNOWLEDGEMENTS

First of all, I thank God for His goodness, mercies, favour and love throughout the period I spent on this campus, He is the one that has kept me and I give Him all the glory.

I also want to appreciate the effort of my able supervisor Engr. Dr. N.A. Egharevba for his tremendous contribution to see that this work was done. Thank you sir for taking out time from your busy schedule to go through this work page to page, God bless you sir.

I will not forget to appreciate the project coordinator of this department Engr.Dr.O. Chukwu for taking out time to explain to me what writing a project report means and how to go about it. I also want to appreciate the effort of the Head of Department Engr. Dr. P.A. Idah and the entire lecturers that have contributed to my life in one way or the other, God bless you all.

I also want to appreciate my wonderful parent Chief and Mrs. J.U Ojonuba for all the love and care you showed me during the period I spent in school and also for your counsels. You will surely live long to enjoy the fruits of your labour. I also want to appreciate my siblings for your support and your prayers for me. May God grant you all your heart desires.

I also want to appreciate Mr. A.J Peters and Mr. Bode Badaki for your support in various ways when it was needed most. God will never forget your labour of love.

The acknowledgements will not be complete without appreciating the Fellowship of Christian Students and my friends, through you; God has made me what I am today. God bless you all.

ABSTRACT

The well water is one of the major sources of drinking water to the inhabitants of Bosso Local Government Area; most especially when there is power failure and lack of electricity supply. Pollution of well water, either from point or non-point sources, has become a thing of health concern. This study aim at assessing the quality of well water by sampling some shallow wells at Maikunkele, Kampani and Mararaba all within Bosso Local Government Area in Minna, Niger state. Field investigation was carried out at the locations to determine the depth, age, sanitory conditions and purpose of the well. The distance of the well from residence, dumpsite and septic tank were also measured. Three samples were collected using screw-capped bottles that have been sterilized. Collected samples were taken to the laboratory and analyzed for water quality parameters using standard procedures. The parameters analyzed were: color, turbidity, temperature, Electrical Conductivity (EC), pH, Total Dissolved Solids (TDS) Total Suspended Solids (TSS), Total Solids (TS), total hardness, cations {Calcium (Ca), magnesium (mg), Manganese (Mn),}, anions Chloride (Cl), Nitrate (NO3), Sulphate (SO4)}, heavy metals {Nickel, Copper (Cu)} and microbiological parameters {Bacteria count and Total Coliform count (TC)}. The mean values of turbidity (6.33mg/l), colour (32.00ptCo), Electrical conductivity (343.33us/cm), E-coli (195.00) and total coliform count (353.33) were all higher than World Health Organization maximum permissible standards for drinking water. Elevated values of these parameters are of great concern to public health when the water from these wells is consumed by people without treatment.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABREVIATIONS

FAO	Food and Agriculture Organization
NSDWQ	Nigeria Standard for Drinking Water Quality
USEPA	U.S. Environmental Protection Agency
WHO	World Health Organization

LIST OF APPENDICES

CHAPTER ONE

1.0 Introduction

1.1 Background to the study

Ground water constitutes the largest source of hand dug-well water. It is found below the soil surface and largely contained in interstices of bedrocks, sands, gravels, and other interspaces through which precipitation infiltrates and percolates into the underground aquifers due to gravity (Ogedengbe, 2004). The water quality of hand dug wells is largely dependent on the concentration of biological, chemical and physical contaminants as much as environmental and human activities in such respects (Schewab *et al.,* 1992). Chemicals pollute water supply through industrial process and agrochemical applications while physical contaminants result from erosion and disposal of solid wastes. These sources of contaminants contribute to degradation of drinking water quality standards thereby degenerating into prohibitive water pollution situations. Consequently, water borne diseases such as typhoid, cholera, diarrhea and dysentery become potentially communicable (Musa, 1996). Drinking water quality must be within tolerable use-limits for human consumption as stipulated by the World Health Organization. Water taste, color, odour, pH and salinity status must satisfy recommended drinking water standards (Schewab *et al.,* 1992). Hand dug well water is not only useful to man for consumption, it is also useful for irrigation of crops during dry season, but its quality must also be within acceptable standard for irrigation water. Poor quality water may affect irrigated crops by causing accumulation of salts in the root zone, by causing loss of permeability of the soil due to excess sodium or calcium leaching, or by containing pathogens or contaminants which are directly toxic to plants or to those consuming them. Contaminants in irrigation water may accumulate in the soil and, after a period of years, render the soil unfit for agriculture. Even when the presence of pesticides or pathogenic organisms in irrigation water does not directly affect plant growth, it may potentially affect the acceptability of the agricultural product for sale or consumption.

1.2 Statement of the problem

Water is a very essential component of our environment which man cannot do without. One of the major sources of water for man is the groundwater which is accessed through hand dug wells. However, due to pollution and contamination of hand dug wells today, the water is most at times unsuitable for consumption and domestic use. This has in turn resulted to the outbreak of various water borne diseases and negative effect on the economic wellbeing. Furthermore, data from the study can assist in the management and policy formulation on water quality in Niger State.

1.3 Aim and Objectives of the study

The aim of this project work is to assess the water quality of hand dug wells in North-western part of Bosso local Government area in Minna, Niger state.

The specific objectives of this project includes the following,

a) To assess the physical and chemical parameters of the water sample from selected hand dug wells
b) To assess the biological parameters of water sample from selected hand dug wells
c) To compare observed results with water quality standards and proffer recommendations where necessary

1.6 Justification of the study

Due to its economical nature, hand dug wells are most available source of water for human consumption and for irrigation purposes. In our society today, this source of water has become a source of all manners of water borne diseases which has resulted to the loss of lives in some cases and also the poor yield of crops. This work will attempt to bring to the awareness of the society the various sources of contaminations, measures that can be taken to minimize the contamination of hand dug well water, and also localized and cost effective ways of improving the water quality of hand dug well water. Data from the study will facilitate the management and policy formulation of water quality in Niger state.

1.7 Scope of the study

This scope of this project covers the field investigation, collection of water samples from selected hand dug wells, and the laboratory analysis of the collected samples, in 2011 only.

CHAPTER TWO

2.0 Literature Review

2.1 Water and Man

The surpassing importance of water, or lack of it, has made it a lively topic of conversation and action throughout the historical period and probably since long before. The rising tide of human population in the twentieth century has accentuated this importance, not because water is scarce in general, but because use and conservation of it are poor.

2.2 Sources of Water for Man

Surface Water: Surface water is the easiest water to understand because we see it every day. It is any water that travels or is stored on top of the ground. This would be the water that is in rivers, lakes, streams, reservoirs, even the oceans. Snow can become surface and groundwater. An example of this is when it snows a few times on a mountain. The snow might not melt in between snows. When it warms up, there could be too much water for the earth to absorb. This causes the melted snow water to run down the mountains as surface water until it reaches a body of water. Surface water is treated before it becomes drinking water. This is done because things like leaves, fish, animal droppings, and boat fuel can easily get into lakes, streams, and rivers. Often times, groundwater is more preferred because it is cleaner.

Ground Water: Ground water is a little harder to understand than surface water because you can't actually see it. Any water that is underground is groundwater. In the water cycle, some of the precipitation sinks into the ground and goes into watersheds, aquifers and springs. The amount of water that seeps into the ground depends on how steep the land is and what is under ground. For example: places that have lots of sand underground will allow more water to sink in than ones that have lots of rock.(Library.thinkquest, 2011). When the water seeps down, it will reach a layer of ground that already has water in it. That is the saturated zone. The highest point in the saturated zone is called the water table. The water table can rise and fall depending on the seasons, rainfall amount a d soil intake characteristics. Groundwater flows through layers of sand, clay, rock, and gravel. This cleans the water. Since groundwater stays underground, things that fall into surface water can't fall into it. This means that groundwater stays cleaner than water on the surface. It has its problems, too. When farmers use fertilizers and insecticides, rain will wash them into the soil where they get into aquifers. Groundwater doesn't need as much treatment as surface water, but it usually gets some because of these problems.

2.3 Uses of water

The various uses of water can be categorized as consumptive and non-consumptive (the use of water is consumptive if that water is not immediately available for another use. Losses to sub-surface seepage and evaporation are considered consumptive. Water that can be treated and returned as surface water, such as sewage, is generally considered non-consumptive if that water can be put to additional use. Water use in power generation and industry is generally described using an alternate terminology, focusing on separate measurements of withdrawal and consumption. Withdrawal describes the removal of water from the environment, while consumption describes the conversion of fresh water into some other form, such as atmospheric water vapor or contaminated waste water (Wikipedia, 2011)

Agricultural: It is estimated that 69% of worldwide water use is for irrigation, with 15-35% of irrigation withdrawals being unsustainable. (WBCSD Water Facts & Trends, 2009). It takes around 3,000 litres of water, converted from liquid to vapour, to produce enough food to satisfy one person's daily dietary need. This is a considerable amount, when compared to that required for drinking, which is between two and five litres. To produce food for the 6.5 billion or so people who inhabit the planet today requires the water that would fill a canal ten metres deep, 100 metres wide and 7.1 million kilometres long.

Increasing water scarcity: Fifty years ago, the common perception was that water was an infinite resource. At this time, there were fewer than half the current numbers of people on the planet. People were not as wealthy as today, consumed fewer calories and ate less meat, so less water was needed to produce their food. They required a third of the volume of water we presently take from rivers. Today, the competition for water resources is much more intense. This is because there are now nearly seven billion people on the planet, their consumption of water-thirsty meat and vegetables is rising, and there is increasing competition for water from industry, urbanization and biofuel crops. In future, even more water will be needed to produce food because the Earth's population is forecast to rise to 9 billion by 2050. (United Nations Press Release, 2007) An additional 2.5 or 3 billion people, choosing to eat fewer cereals and more meat and vegetables could add an additional five million kilometres to the virtual canal mentioned above.

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

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

As global populations grow, and as demand for food increases in a world with a fixed water supply, there are efforts under way to learn how to produce more food with less water, through improvements in irrigation methods(FAO Water Unit | Water News: water scarcity) and technologies, agricultural water management, crop types, and water monitoring. Aquaculture is a small but growing agricultural use of water. Freshwater commercial fisheries may also be considered as agricultural uses of water, but have generally been assigned a lower priority than irrigation.

Industrial: It is estimated that 22% of worldwide water use is industrial. (WBCSD Water Facts & Trends, 2009). Major industrial users include hydroelectric dams, thermoelectric power plants, which use water for cooling, ore and oil refineries, which use water in chemical processes, and manufacturing plants, which use water as a solvent. Water withdrawal can be very high for certain industries, but consumption is generally much lower than that of agriculture. Water is used in renewable power generation. Hydroelectric power derives energy from the force of water flowing downhill, driving a turbine connected to a generator. This hydroelectricity is a low-cost, non-polluting, renewable energy source. Significantly, hydroelectric power can also be used for load following unlike most renewable energy sources which are intermittent. Ultimately, the energy in a hydroelectric powerplant is supplied by the sun. Heat from the sun evaporates water, which condenses as rain in higher altitudes and flows downhill. Pumped-storage hydroelectric plants also exist, which use grid electricity to pump water uphill when demand is low, and use to stored water to produce electricity when demand is high.

Hydroelectric power plants generally require the creation of a large artificial lake. Evaporation from this lake is higher than evaporation from a river due to the larger surface area exposed to the elements, resulting in much higher water consumption. The process of driving water through the turbine and tunnels or pipes also briefly removes this water from the natural environment, creating water withdrawal. The impact of this withdrawal on wildlife varies greatly depending on the design of the power plant. Pressurized water is used in water blasting and water jet cutters. Also, very high pressure water guns are used for precise cutting. It works very well, is relatively safe, and is not harmful to the environment. It is also used in the cooling of machinery to prevent over-heating, or prevent saw blades from over-heating. This is generally a very small source of water consumption relative to other uses. Water is also used in many large scale industrial processes, such as thermoelectric power production, oil refining, fertilizer production and other chemical plant use, and natural gas extraction from shale rock. Discharge of untreated water from industrial uses is pollution. Pollution includes discharged solutes (chemical pollution) and increased water temperature (thermal pollution). Industry requires pure water for many applications and utilizes a variety of purification techniques both in water supply and discharge. Most of this pure water is generated on site, either from natural freshwater or from municipal grey water. Industrial consumption of water is generally much lower than withdrawal, due to laws requiring industrial grey water to be treated and returned to the environment. Thermoelectric power plants using cooling towers have high consumption, nearly equal to their withdrawal, as most of the withdrawn water is evaporated as part of the cooling process. The withdrawal, however, is lower than in once-through cooling systems.

Household: It is estimated that 8% of worldwide water use is for household purposes.(WBCSD Water Facts & Trends, 2009) These include drinking water, bathing, cooking, sanitation, and gardening. Basic household water requirements have been estimated by Peter Gleick (Wikipedia, 2011) at around 50 liters per person per day, excluding water for gardens. Drinking water is water that is of sufficiently high quality so that it can be consumed or used without risk of immediate or long term harm. Such water is commonly called potable water. In most developed countries, the water supplied to households, commerce and industry is all of drinking water standard even though only a very small proportion is actually consumed or used in food preparation.

Recreation: Recreational water use is usually a very small but growing percentage of total water use. Recreational water use is mostly tied to reservoirs. If a reservoir is kept fuller than it would otherwise be for recreation, then the water retained could be categorized as recreational usage. Release of water from a few reservoirs is also timed to enhance whitewater boating, which also could be considered a recreational usage. Other examples are anglers, water skiers, nature enthusiasts and swimmers.

Environmental: Explicit environmental water use is also a very small but growing percentage of total water use. Environmental water usage includes artificial wetlands, artificial lakes intended to create wildlife habitat, fish ladders , and water releases from reservoirs timed to help fish spawn, or to restore more natural flow regimes.(silkroadintelligencer.2010).

Environmental usage is non-consumptive but may reduce the availability of water for other users at specific times and places. For example, water release from a reservoir to help fish spawn may not be available to farms upstream.

2.4 Ground Water

Groundwater is water located beneath the ground surface in soil pore spaces and in the fractures of rock formations. A unit of rock or an unconsolidated deposit is called an aquifer when it can yield a usable quantity of water. The depth at which soil pore spaces or fractures and voids in rock become completely saturated with water is called the water table. Groundwater is recharged from, and eventually flows to, the surface naturally; natural discharge often occurs at springs and seeps, and can form oases or wetlands. Groundwater is also often withdrawn for agricultural, municipal and industrial use by constructing and operating extraction wells. The study of the distribution and movement of groundwater is hydrogeology, also called groundwater hydrology. (Wikipedia, 2011)

2.4.1 The Occurrence of Groundwater

The Hydrological Cycle: The hydrological cycle, also known as the water cycle, is the constantly-occurring process whereby, in simplified terms, water falls to the ground as rain, or other precipitation, runs along the ground under the force of gravity or percolates down to an impermeable layer of soil or rock, appears again at the surface, eventually reaches the sea or a lake and evaporates to form clouds which produce rain. In its use of water for various activities, the world's population intervenes in this cycle at a number of points. When water flows through shallow aquifers, it is referred to as groundwater. (Seamus, 2000)

2.4.2 Types of Aquifer

Aquifers may be classified broadly in three categories, namely,

Confined aquifers are water-bearing strata which lie between two impermeable layers. Water in these aquifers is often under pressure and, if the upper impermeable layer is breached by a borehole, the water from the aquifer will rise to its piezometric level. Where this piezometric level is above ground level, water will emerge from the borehole under pressure and will gush up into the air. This is referred to as an artesian well. In a case where the piezometric level is below ground level, but above the level of the top of the confined aquifer, this is known as a sub-artesian well. Note that the piezometric pressure line refers only to the water in the confined aquifer.

Unconfined aquifers occur when the waterbearing stratum is not covered by an impermeable layer. In this situation, the water in the aquifer is not under pressure, and will not rise in a borehole or well which reaches the level of the aquifer. The level of water in this aquifer will fluctuate with the seasons, and care must be taken when exploiting such an aquifer for water supply purposes.

Perched aquifers are a special case of unconfined aquifers. These occur where water, as it percolates down from the surface, is trapped by an isolated impermeable layer, of limited extent, within otherwise permeable strata. Unless the impermeable stratum is very extensive, a perched aquifer is recharged only by locally-occurring rainfall and will provide at best a seasonal supply of water. (Seamus, 2000)

2.5 Water Wells

Water well is an excavation or structure created in the ground by digging, driving, boring or drilling to access groundwater in underground aquifers. The well water is drawn by an electric submersible pump, a trash pump, a vertical turbine pump, a hand pump or a mechanical pump (e.g. from a water-pumping windmill). It can also be drawn up using containers, such as buckets that are raised mechanically or by hand. (Wikipedia)

Hand Dug Wells: The traditional method of obtaining groundwater in rural areas of the developing world, and still the most common, is by means of hand-dug wells. However, because they are dug by hand their use is restricted to suitable types of ground, such as clays, sands, gravels and mixed soils where only small boulders are encountered. Some communities use the skill and knowledge of local well-diggers, but often the excavation is carried out, under supervision, by the villagers themselves.

Hand-dug wells are excavations with diameters large enough to accommodate one or more men with shovels digging down to below the water table. They can be lined with laid stones or brick; extending this lining upwards above the ground surface into a wall around the well serves to reduce both contamination and injuries by falling into the well. A more modern method called caissoning uses reinforced concrete or plain concrete pre-cast well rings that are lowered into the hole. A well-digging team digs under a cutting ring and the well column slowly sinks into the aquifer, whilst protecting the team from collapse of the well bore.

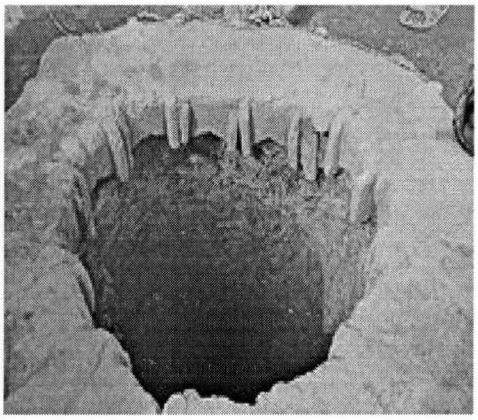


Fig 2.1: Hand dug well

Hand dug wells provide a cheap and low-tech solution to accessing groundwater in rural locations in developing countries, and may be built with a high degree of community participation, or by local entrepreneurs who specialize in hand-dug wells. Hand dug wells have been successfully excavated to 60m. Hand dug wells are inexpensive and low tech (compared to drilling) as they use mostly hand labour for construction. Hand dug wells have low operational and maintenance costs, in part because water can be extracted by hand bailing, without a pump. Hand dug wells can be easily deepened, which may be necessary if the ground water level drops, by telescoping the lining further down into the aquifer. The yield of existing hand dug wells may be improved by deepening or introducing vertical tunnels or perforated pipes. (Wateraid, 2011).

Drawbacks to hand-dug wells are numerous. It can be impractical to hand dig wells in areas where hard rock is present, and they can be time-consuming to dig and line even in favorable areas. Because they exploit shallow aquifers, the well may be susceptible to yield fluctuations and possible contamination from surface water, including sewage. Hand dug well construction generally requires the use of a trained well construction team, and the capital investment for equipment such as concrete ring moulds, heavy lifting equipment, well shaft formwork, motorized de-watering pumps, and fuel can be large for people in developing countries. Construction of hand dug wells can be dangerous due to collapse of the well bore, falling objects and asphyxiation, including from dewatering pump exhaust fumes. (Wikipedia, 2011)

Principles of Hand-Dug Wells

The fundamental principle of any water supply system is to gather water in a location from which it can either be collected by the consumers or transported to a point of use. In the case of water supply systems with a distribution network, water is first stored at central storage tanks before being released into the distribution system. This system may bring water directly to households or to public standpipes. With individual waterpoints such as boreholes and hand-dug wells, water is collected by the consumers directly from the point of exploitation of the aquifer. The purpose of the well is to provide a safe and reliable means of accessing the water in the aquifer.

To make the construction of a hand-dug well viable, water in sufficient quantities must be found at a depth which will allow safe excavation and economically feasible exploitation of the water resource (this will depend, of course, on a range of specific local conditions), but at a depth which does not allow easy pollution of the groundwater in the aquifer. The quantity of water made available by a well will depend on the soil type at the particular location and will also be influenced by the diameter of the hole made to extract the water and by the depth of penetration into the water-bearing stratum.

Soil conditions

Groundwater is normally found occupying the spaces between the particles of an aquifer. The type of material which constitutes the aquifer is important in that, while some soil types retain water quite well, the relative size of the pores between the soil particles may not be conducive to allowing the water to flow along the aquifer – an important consideration in the recharge of waterpoints. Strata which have large pores will allow water to flow more freely, and as a result, layers of sand and gravel tend to provide good locations for wells and boreholes. Other good locations are in weathered rock in granite areas, along the edges of valleys in mountainous areas or in a river valley where there may be sandy deposits under the banks.

The limiting factor is, of course, that the bulk of the excavation must take place in material which allows work by hand. As a result, hand-dug wells are normally located where there are unconfined aquifers in alluvial deposits or in the weathered zone above a consolidated or crystalline basement rock. Hand-dug wells are usually constructed in unconfined aquifers.

Well diameter

For a given thickness and type of aquifer, and considering equal depths of penetration, a larger diameter hole will expose a greater area for filtration, and therefore give a faster recharge, than a smaller hole. For example, for an aquifer of 2m depth, a 1.3m diameter well will expose $8.17m^2$ of the aquifer for infiltration of water while a 150mm diameter borehole will expose only $0.94m^2$, as shown in fig 2.2

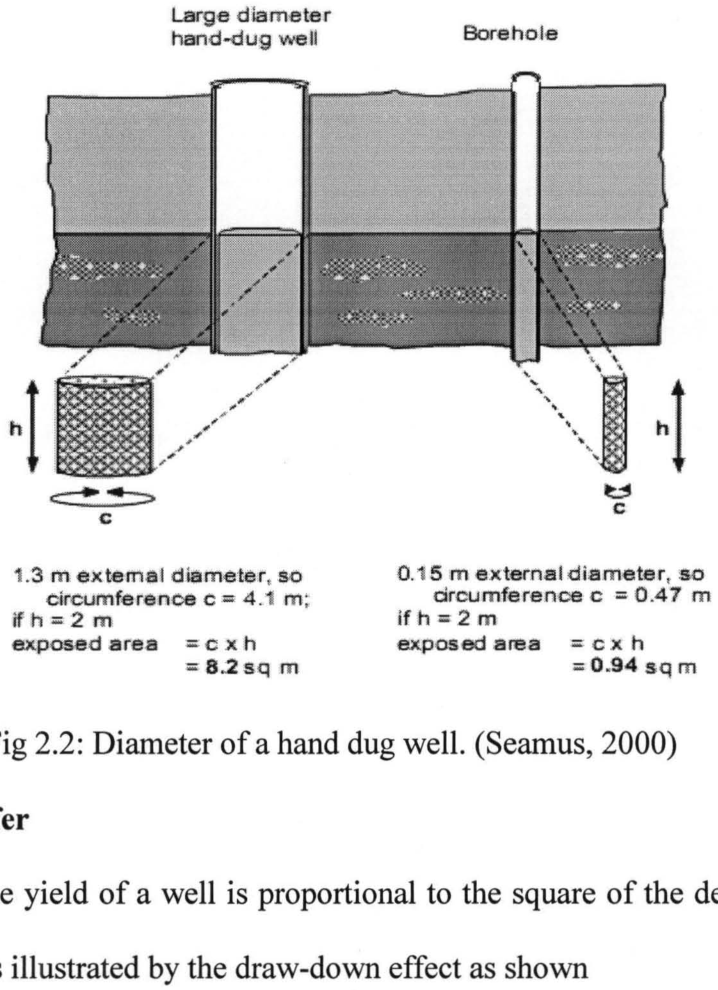


Fig 2.2: Diameter of a hand dug well. (Seamus, 2000)

Depth of well in aquifer

For a given aquifer, the yield of a well is proportional to the square of the depth of penetration into the aquifer. This is illustrated by the draw-down effect as shown

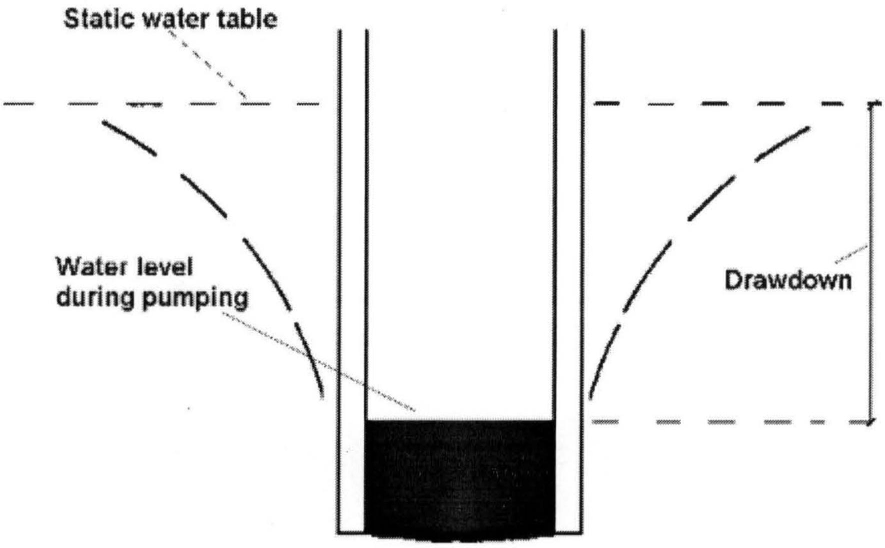


Fig 2.3: Depth of well in aquifer. (Seamus, 2000)

Water flows into the well through the porous areas of the intake until water levels inside and outside the well are equal. When water is extracted by pumping or by bucket, the water level inside the well drops relative to the water level in the aquifer, causing a pressure difference. This results in an inward flow of water through the intake pores. The amount of drawdown depends on the yield of the aquifer, the rate of removal of water from the well and the depth into the aquifer at which water is being extracted. This principle is especially important in tube wells, but will also apply to hand-dug wells constructed in weak aquifers, or in strata which do not allow a free flow of water. (Seamus, 2000)

Elements of a Hand Dug Well

The three main elements are:

Well Head - this is the part of the well which is visible above the ground. It generally consists of a protective apron and a superstructure which depends on the type of extraction system in use.

Well Shaft-this is the part of the well that connect the well head and the intake

Intake - this is the part of the well in contact with the aquifer. It is constructed in such a way that water flows from the aquifer into the well, from where it can be extracted using a bucket, a pump or another method.

Each of these elements is now considered in turn.

Well Head

The design of the well head will vary with local conditions and with the type of water extraction system to be used. It is important that the well head be constructed in such a way as to contribute to the overall hygiene and cleanliness of the water point. This will normally involve an impervious apron around the well, with a method of removing spilt water from around the well, to a soakpit or to a planted area.

Shaft

This is the section of the well between the head and the intake. As with all elements of the well lining, it must be constructed of a strong, durable material which can easily be kept clean and which will not in itself constitute a health hazard. Well shafts are normally circular in shape. There are two important considerations. Firstly, the size of the shaft must be sufficient to allow excavation work to continue within it. The minimum space for one person to work is 80cm. For two people, this should be 1.2m. Secondly, the initial diameter of a well shaft should allow for possible future deepening of the well, for example if the water table drops or if there is increased demand. It will not always be feasible to construct such an extension, but normally a well should be built first with a shaft of internal diameter 1.2-1.3m, to allow the later insertion of smaller diameter lining rings.

Intake

This is the part of the well which is in contact with the aquifer. The walls of the intake are constructed in such a way as to allow water to pass from the aquifer into the well, thus creating a storage area which can be accessed by bucket or pump, while at the same time ensuring that this part of the well does not cave in. Depending on the type of soil in the aquifer, infiltration may occur through the sides of the intake, through the bottom or through a combination of the two. Local conditions and experience will indicate the best strategy to adopt, but the following points may act as general guidelines:

1. For a **highly permeable aquifer**, with water travelling at a high velocity through it, allow infiltration only though a filter layer placed on the bottom of the well.

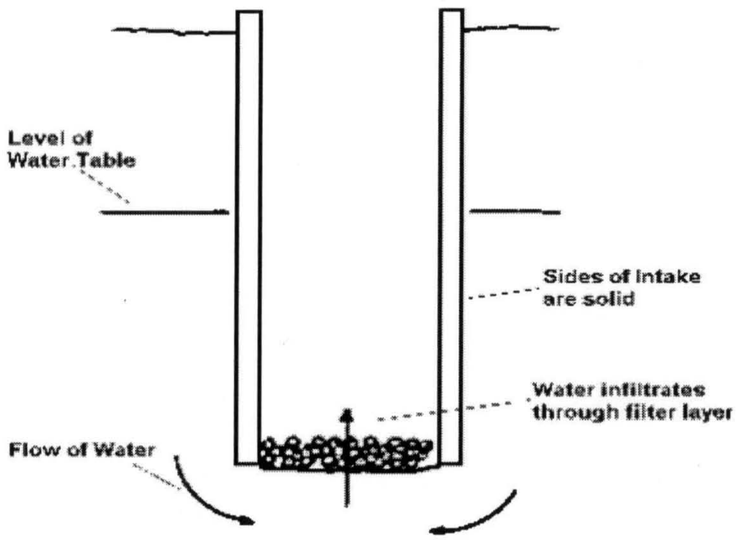


Fig 2.4: Water traveling through a highly permeable aquifer. (Seamus, 2000)

2. For a **less permeable aquifer** (water travelling at a lower velocity), allowing infiltration through the sides of the well only is a better option.

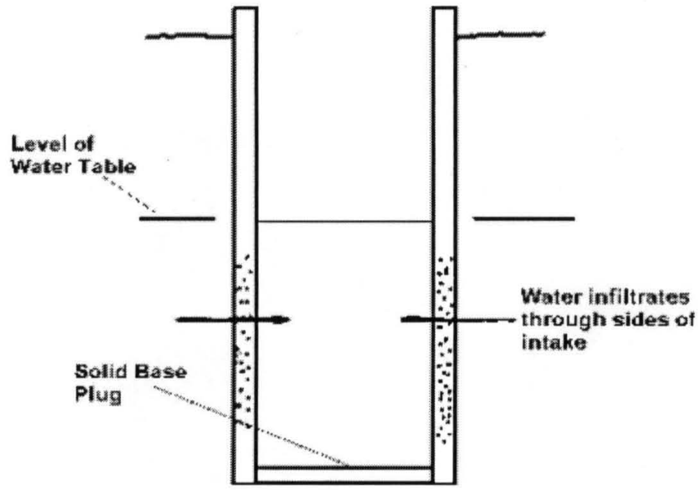


Fig 2.5: Water traveling through a less permeable aquifer. (Seamus, 2000)

3. In each of the above cases, the bottom of the well is located still within the water bearing stratum. When the well can be extended down to an impermeable layer, it is not necessary to put either a plug or a filter layer at the bottom, and infiltration takes place only at the part of the well which is in contact with the aquifer.

2.5.1 Guidelines for the location of water point

Even if a particular site gives very positive indications for the presence of shallow groundwater, certain conditions must be fulfilled before continuing with the construction of the well. Internationally accepted guidelines for the location of a waterpoint may be summarized under two sets of criteria, one general and one relating to the proximity of other structures or facilities, as follows.

General points

The proposed water point or source should:

a) Be above the flood level of any nearby river or lake;

b) Be in a location which allows the free access of all users all year round. This refers to physical access (i.e. that the pathway is passable) but also to legal access. A right of way must exist to the well.

c) Be within the specified distance from the intended users;

d) Be in an area which will allow the rapid dispersal of spilt water;

e) Be in a location where the level of the water table is at a depth of at least 2m all year round.

f) Not be located in any other area liable to seasonal flooding;

g) Not be located in any area where pesticides or fertilizers are spread on crops;

h) Not be in an area liable to erosion;

i) Not be in an area where the fluctuating fresh water table is influenced by a saltwater table;

j) Not be in an area where the sinking of a well will pierce the saltwater table;

k) Not be below, in terms of the direction of groundwater flow, any source of pollution such as a pit latrine, abattoir, dumping site, fertilizer or pesticide store etc. In addition, the minimum distances, in any other direction, to such sources of pollution, are given in the next list.

Recommended Specific distances

Table 2.1: Recommended specific distance of various facilities from dug wells.

Facility, Location or building	Minimum distance from water point (m)
1. Communal dumping site	100
2. Store for pesticides, fertilizers or fuel	100
3. Cemetery	50
4. Abattoir	50
5. Dwelling house	10
6. Pit latrine	30
7. Animal pen	30
8. Private (domestic)dumping site	30
9. Large trees or any tree with extensive root system	20
10. Roads, airstrips, railway lines	20
11. River or lake	20
12. Laundry or washing slab	20

(Seamus, 2000)

If these guidelines cannot be fulfilled, either by choosing an already-appropriate site or by making the necessary adjustments (for example, by the closing down of a communal or private dumping ground or of a pit latrine), then another site should be chosen. In the case where a dump, pit latrine or pesticide/fertilizer store is to be relocated to make way for a water point, sufficient time must be allowed for the existing pollutants to dissipate in the ground, before beginning to use the water for human consumption. The water quality should be tested to ensure that all pollutants have been dispersed. In certain specific circumstances, the distance from a pit latrine may be reduced, but if there is any uncertainty about fulfilling these conditions, it is advisable to comply with the 30m criterion given (Fig 2.5). Where pit latrines are in use, the bottom of the latrine pit should be normally no less than 1m above the top of the aquifer. In all cases, the local community must be fully involved in the decision about the location of water points. (Seamus, 2000)

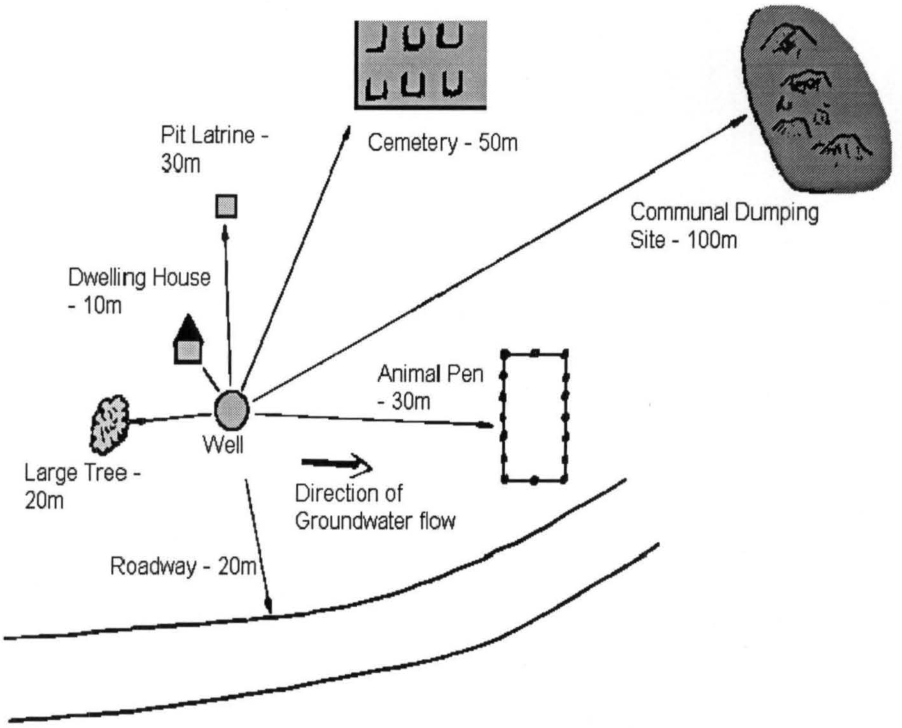


Fig 2.6: Recommended distance of facilities from well. (Seamus, 2000)

2.5.2 Advantages and Disadvantages of Hand-Dug Wells

Each of the different technologies available for the installation of rural water supplies will provide the optimum solution in a given specific case, while it will prove quite inappropriate in another case. No single technology is universally applicable. As far as hand-dug wells are concerned, the advantages and disadvantages are as follows:

Advantages

1. The community of users can become involved from the very beginning of the process. This can lead from an information campaign to the submission of a request by the community, to the planning and construction steps, and to preparation for the operation and maintenance phase. The relatively slow pace of hand-dug well preparation and construction allows plenty of time for valuable contact with the community.

2. The technology provides a perfect opportunity for community participation in contributing unskilled labour to the preparation of the construction site and the excavation of the well. Depending on the arrangements in a particular case, villagers may also assist in the prefabrication of lining rings or bricks, or in the mixing of concrete for in-situ placement.

3. In most cases where hand-dug wells are an option, excavation is relatively easy and does not require sophisticated equipment.

4. Construction and maintenance do not require very sophisticated equipment. Routine groundlevel maintenance such as the repair of cracks in the apron can be done by somebody within the community, thus eliminating the need for an extensive, centrally-controlled corrective maintenance network.

5. Construction teams require minimal technical and logistical support in comparison to other methods. However, this is not intended to diminish the importance of having competent field and supervisory staff.

6. Given the relative simplicity of the technology, the involvement of the private sector at local level is encouraged.

7. Apart from cement, the materials needed for construction are normally available locally. The provision of these materials from nearby sources is another opportunity to increase community involvement in the construction phase.

8. When construction takes account of local soil conditions and proper construction standards are applied, the well will rarely require any down the-hole structural maintenance.

9. A number of options are available to increase the yield of the well if the need arises.

10. Depending on the water-lifting device installed, it can provide years of trouble-free water supply.

11. If a hand pump is installed, the quality of water supplied can be brought to a high level.

12. Where technical conditions permit, and in a situation where the construction of water supply infrastructure is demand-driven, it is a good midrange option between traditional sources and mechanised systems, to offer a community. A positive experience with a low-technology, easyto-manage system will encourage the community to develop its water supply system as demand and economic capacity increase.

13. Wells can be excavated in harder soils where hand-drilling is difficult.

14. A large-diameter, hand-dug well exposes more of the aquifer, thereby allowing a greater volume of water to flow into the well, and creates a larger reservoir for water storage.

15. While the construction phase may be longer than with other technologies, the longer time will be useful in assuring the acceptance of the new system by the villagers since the community will have more time to witness the development and "arrival" of the new system.

16. Hand-dug wells are in many cases very similar in form to traditional water collection systems. As such, the technology can be readily accepted by the community, and provides an

ideal basis for future development of the system (for example, from an open well to a covered well with a hand pump, and from there to a system with A motorised pump).

Disadvantages

1. Community participation may be difficult due to safety considerations. Excavating a well is a hazardous undertaking, even in ideal conditions, and the work cannot be passed lightly to inexperienced workers. If, on the other hand, the work is given to a private contractor, he or she may not wish to be dependent on a supply of voluntary labour over which there is very little control, given the many demands on the time of rural farming and fishing families.

2. Excavation can be dangerous for a number of reasons. At depths of over 2 metres, access to the well by those doing the excavation must be subject to strict safety controls. Also, in some areas, the process of excavation may release harmful gases.

3. During excavation, a method of keeping the well pumped dry after reaching the water table is required. This will normally involve a motorised pump, which in turn will require a power source. The capacity to dewater the well will limit the extent to which excavation can continue below the top of the water table.

4. The lowering of lining rings weighing up to 900kg can be a dangerous operation.

5. Supply is greatly influenced by water table fluctuations.

6. Since most hand-dug wells exploit shallow aquifers, water in the well may be susceptible to pollutants infiltrating from the surface.

7. In open hand-dug wells, the water can be contaminated by mud, vegetation, bird and animal droppings or even by rubbish thrown into the well.

8. Again in an open well situation, the use of multiple buckets and ropes can lead to contamination of the water.

9. An open and unprotected well can be dangerous for the users. Small children, especially, can fall in.

10. A programme of shallow well construction needs much more supervision capacity per person served, since it is normally necessary to make several visits to a construction site over a period of weeks during the construction phase. With a drilling programme, wells in one village could be completed with a single visit of a few days' duration. (Seamus 2000)

2.6 Pollution of Ground Water

Ground water quality varies from source to source depending upon: its depth from the surface and the sources of contaminants it encounters as it passes from rain or snow into the ground (generally when considering contamination associated with microbes, the deeper the well, the better the ground water). Ground water may contain some natural impurities or contaminants, even with no human activity or pollution. Natural contaminants can come from many conditions in the watershed or in the ground. Water moving through underground rocks and soils may pick up magnesium, calcium and chlorides. Some ground water naturally contains dissolved elements such as arsenic, boron, selenium, or radon, a gas formed by the natural breakdown of radioactive uranium in soil. Whether these natural contaminants are health problems depends on the amount of the substance present. (USEPA, 2002)

2.6.1 Naturally Occurring Sources of Pollution

Microorganisms: Bacteria, viruses, parasites and other microorganisms are sometimes found in water. Shallow wells — those with water close to ground level — are generally at most risk. Runoff, or water flowing over the land surface, may pick up these pollutants from wildlife and soils. This is often the case after flooding. Some of these organisms can cause a variety of illnesses. Symptoms include nausea and diarrhea. These can occur shortly after drinking contaminated water. The effects could be short-term yet severe (similar to food poisoning) or might recur frequently or develop slowly over a long time.

Nitrates and Nitrites: Although high nitrate levels are usually due to human activities, they may be found naturally in ground water. They come from the breakdown of nitrogen compounds in the soil. Flowing ground water picks them up from the soil. Drinking large amounts of nitrates and nitrites is particularly threatening to infants (for example, when mixed in formula).

Heavy Metals: Underground rocks and soils may contain arsenic, cadmium, chromium, lead, and selenium. These contaminants are not often found in household wells at dangerous levels from natural sources, but it is prudent to sample each new well to ensure that you are aware of contamination if it exists.

Fluoride: Fluoride is helpful in dental health, so many water systems add small amounts to drinking water. However, excessive consumption of naturally occurring fluoride can damage bone tissue. High levels of fluoride occur naturally in some areas.

2.6.2 Pollution caused by human activities

Bacteria and Nitrates: These pollutants are found in human and animal wastes. Septic tanks can cause bacterial and nitrate pollution. So can large numbers of farm animals. Both septic systems and animal manures must be carefully managed to prevent pollution. Sanitary landfills and garbage dumps are also sources. Children and some adults are at extra risk when exposed to water-borne bacteria. These include the elderly and people whose immune systems are weak due to AIDS or treatments for cancer. Fertilizers can add to nitrate problems. Nitrates cause a health threat in very young infants called "blue baby" syndrome. This condition disrupts oxygen flow in the blood.

Concentrated Animal Feeding Operations (CAFOs): The number of CAFOs, is growing. On these farms thousands of animals are raised in a small space. The large amounts of animal wastes/manures from these farms can threaten water supplies. Strict and careful manure management is needed to prevent pathogen and nutrient problems. Salts from high levels of manures can also pollute groundwater.

Heavy Metals: Activities such as mining and construction can release large amounts of heavy metals into nearby ground water sources. Some older fruit orchards may contain high levels of arsenic, once used as a pesticide. At high levels, these metals pose a health risk.

Fertilizers and Pesticides: Farmers use fertilizers and pesticides to promote growth and reduce insect damage. These products are also used on golf courses and suburban lawns and gardens. The chemicals in these products may end up in ground water. Such pollution depends on the types and amounts of chemicals used and how they are applied. Local environmental conditions (soil types, seasonal snow and rainfall) also affect this pollution. Many fertilizers contain forms of nitrogen that can break down into harmful nitrates. This could add to other sources of nitrates mentioned above. Some underground agricultural drainage systems collect fertilizers and pesticides that can pose problems to ground water, and local streams and rivers. In addition, chemicals used to treat buildings and homes for termites or other pests may also pose a threat. Again, the possibility of problems depends on the amount and kind of chemicals. The types of soil and the amount of water moving through the soil also play a role.

Industrial Products and Wastes: Many harmful chemicals are used widely in local business and industry. These can become drinking water pollutants if not well managed. The most common sources of such problems are:

• *Local Businesses:* These include nearby factories, industrial plants, and even small businesses such as gas stations and dry cleaners. All handle a variety of hazardous chemicals that need careful management. Spills and improper disposal of these chemicals or of industrial wastes can threaten ground water supplies.

• *Leaking Underground Tanks & Piping:* Petroleum products, chemicals, and wastes stored in underground storage tanks and pipes may end up in the ground water. Tanks and piping leak if they are constructed or installed improperly. Steel tanks and piping corrode with age. Tanks are often found on farms. The possibility of leaking tanks is great on old, abandoned farm sites. Farm tanks are exempt from the EPA rules for petroleum and chemical tanks.

• *Landfills and Waste Dumps:* Modern landfills are designed to contain any leaking liquids. But floods can carry them over the barriers. Older dumpsites may have a wide variety of pollutants that can seep into ground water.

Household Wastes: Improper disposal of many common products can pollute ground water. These include cleaning solvents, used motor oil, paints, and paint thinners. Even soaps and septic leaching fields. (USEPA, 2002)

2.7 Water quality

Water quality standards (WQS) are risk-based (also called hazard-based) requirements which set site-specific allowable pollutant levels for individual water bodies, such as rivers, lakes, streams and wetlands. States set WQS by designating uses for the water body (e.g., recreation, water supply, aquatic life, agriculture) and applying **water quality criteria** (numeric pollutant concentrations and narrative requirements) to protect the designated uses. An **antidegradation policy** is also issued by each state to maintain and protect existing uses and high quality waters. (US EPA, 1996)

2.7.1 Drinking water quality standards

Colour: Colour in drinking water may be due to the presence of coloured organic matter, *e.g.* humic substances, metals such as iron or manganese, or highly coloured industrial wastes. The appearance of colour in water is caused by the absorption of certain wavelengths of light by coloured substances and by the scattering of light by suspended particles, together these are termed 'apparent' colour. Treatment removes much of the suspended matter and, generally speaking, drinking water should be colourless. Source waters high in true colour can be treated to remove colour by oxidation with ozone and adsorption onto activated carbon.

Changes in colour from that normally seen can provide warning of possible quality changes or maintenance issues and should be investigated. They may, for example, reflect degradation of the source water, corrosion problems in distribution systems, changes in performance of adsorptive treatment processes (such as activated carbon filtration) and so on. It is simply and cheaply measured using a spectrophotometer or simple colorimeter or using visual comparison with known standards.

PH: The pH of water affects treatment processes, especially coagulation and disinfection with chlorine-based chemicals. Changes in the pH of source water should be investigated as it is a relatively stable parameter over the short term and any unusual change may reflect a major event. pH is commonly adjusted as part of the treatment process and is continuously monitored.

Solids: Water always contains a certain amount of particulate matter ranging from colloidal organic or inorganic matter that never settles to silts, algae, plankton or debris of all kinds that can settle quite rapidly. Various methods have been devised to identify or measure these solids. Solids can be dissolved solids or suspended solids in water: together they are referred to as total solids. They can be measured directly, separately or together by physico-chemical methods using combinations of filtration and evaporation.

The amount of solids in water affects both removal and disinfection processes. The solids content of waters can vary significantly with seasons and rainfall events. Abnormal changes in the amount or type of solids in source or treated water should be investigated. Solids, whether total or dissolved, can provide information on the pollution level of the water. Solids can affect taste and appearance of drinking water. Furthermore, a significant increase in the levels of solids could be related to contamination from a range of sources such as freshly derived surface run-off, ingress or wastewater.

Turbidity: Turbidity is a measure of suspended solids. The turbidity of water affects treatment processes and especially disinfection with chlorine-based chemicals. It is important to know the turbidity characteristics of water sources and to respond to unexplained changes in turbidity. Turbidity of surface water sources may be heavily influenced by rainfall events or algal growth and treatment processes should be tailored to respond to such changes. Most groundwaters have a relatively stable turbidity and any change reflects a major event that needs to be investigated and corrected by tailoring the treatment to the incoming water quality. Even relatively small changes may be important and outbreaks of cryptosporidiosis have been associated with small changes in turbidity of relatively short duration (Waite, 1997). Turbidity is also a good measure of the extent to which treatment processes remove suspended matter. Turbidity of filtered water should be monitored at each filter and data above the expected values should be investigated. Monitoring of the combined filtrate alone from a number of filters may not detect significant loss of performance of an individual filter. This is particularly important in relation to the removal of cryptosporidial oocysts as they are not inactivated by conventional disinfection, and effective filtration is the only treatment means for their control.

Biochemical Oxygen Demand, BOD: Biochemical oxygen demand or BOD is a chemical procedure for determining the amount of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic material present in a given water sample at certain temperature over a specific time period. It is not a precise quantitative test, although it is widely used as an indication of the organic quality of water. It is most commonly expressed in milligrams of oxygen consumed per litre of sample during 5 days of incubation at 20 C and is often used as a robust surrogate of the degree of organic pollution of water.

Chemical oxygen demand: In environmental chemistry, the **chemical oxygen demand** (**COD**) test is commonly used to indirectly measure the amount of organic compounds in water. Most applications of COD determine the amount of organic pollutants found in surface water (e.g. lakes and rivers), making COD a useful measure of water quality. It is expressed in milligrams per liter (mg/L), which indicates the mass of oxygen consumed per liter of solution

Total coliform and E Coli: The presence of *E*- coli and total coliform in the well water indicate contamination by human or animal wastes. These pathogens may pose a special health risk for infants, young children and people with severely compromised immune systems (USEPA, 2002). WHO has recommended a zero value of *E* coli and total coliform count in drinking water.

2.8 Water purification

Water purification generally means freeing water from any kind of impurity it contains, such as contaminants or micro organisms. Water purification is not a very one-sided process; the purification process contains many steps. The steps that need to be progressed depend on the kind of impurities that are found in the water. This can differ very much for different types of water. Water purification, or drinking water treatment, is the process of removing contaminants from surface water or groundwater to make it safe and palatable for human consumption. A wide variety of technologies may be used, depending on the raw water source, contaminants present, standards to be met, and available finances. The most commonly used methods which are simple and inexpensive include boiling and filtration.

2.8.1 Boiling Method

Boiling is the simplest way of purifying water. It disinfects water and kills disease causing microorganisms such as *E. coli*, *Cryptosporidium* and *Giardia lamblia*, which are commonly present in groundwater. According to the Wilderness Medical Society, water temperatures above 70 °C kill all pathogens within 30 minutes, and heating above 85 °C disinfects water within a few minutes. It is also observed that water temperature at 100 °C kills almost all the microbes, including the enteropathogens (pathogens that cause diseases in the intestine). However, some fungal pathogens such as *Clostridium botulinum* and their spores get killed only at 118 °C. To be on the safer side, it is recommended to boil drinking water for a few minutes for drinking.

2.8.2 Filtration Method

Filtration is one of the popular water purification processes, in which the contaminants are physically removed using a filter. It has the benefit of giving immediate access to drinking water without adding unpleasant taste to it. Filtration involves passing the water through layers of sand, coal and other granular material to remove microorganisms – including viruses, bacteria and protozoans such as Cryptosporidium – and any remaining floc and silt. This method of purification mimics the natural filtration of water as it moves through the ground.

CHAPTER THREE

3.0 Materials and methodology

3.1 Study Area

The study area was the North-western part of Bosso Local Government Area (LGA) in Niger State. The study location has a mean annual precipitation of 1300mm from an exceptionally long record of 50 years. The highest mean monthly rainfall is September, with almost 300/mm. the raining season starts on average between April and lasts between 190 – 200 days (October). Temperature rarely falls below 22^{0}C. The peaks are 40^{0}C (February – March) and 35^{0}C (November – December). (FUTMinna, 2011). Three locations were selected for collecting the water. Three locations were selected for collecting the water samples, which are; Maikunkele, Kampani and Mararaba.

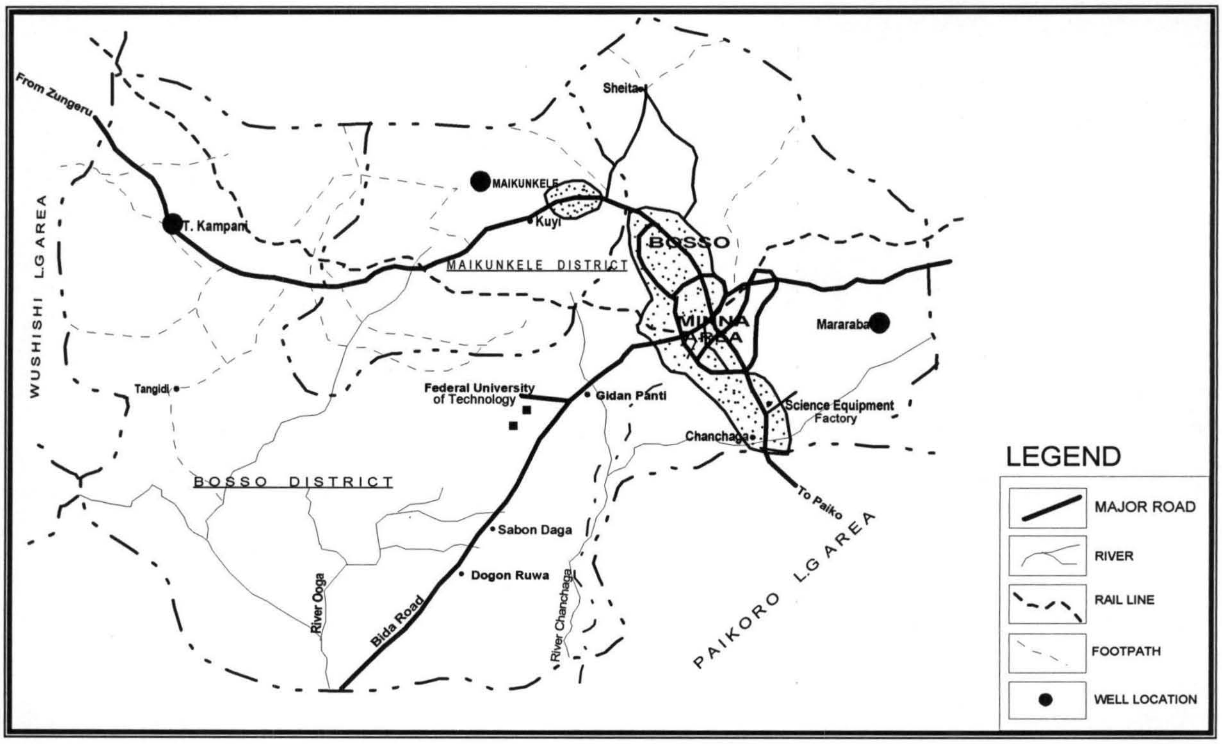


Fig 3.1 Map of Bosso Local Government Area Showing Sample Points

Table 3.0: Inventory of selected hand dug wells in study location

Description	Maikunkele	Kampani	Mararaba
Age	11yrs	6yrs	60yrs
Depth	5.5m	8.9m	12.4m
Elevation	306m	260m	254m
Latitude	N 09^{0}41, 369", E006^0 29, 060"	N 09^{0}40,140" E006^{0}26,250"	N09^{0}37,977" E006^{0}24,799"
Well cover	None	Yes	None
Soil condition	Sandy	Sandy	Sandy loam
Distance from residence	5m	16.5m	10m
Distance from dumpsite	Nill	12.2m	nill
Distance from septic tank	6.1m	17m	nill
Distance from large tree	Nill	12m	6.5m
Well purpose	Drinking and domestic purposes	Drinking and domestic purposes	Drinking and domestic purposes
Well lining	Concrete	Concrete	Concrete

26th June 2011

3.2 Materials

Brief description of the DR/2000 spectrophotometer

The DR/2000 spectrophotometer shown in figure 3.2 is a microprocessor-controlled, single-beam instrument suitable for colorimetric testing in the laboratory or the field. The instrument is pre-calibrated for over 120 different colorimetric measurements and has provisions for user entered calibrations as well as future Hach methods. Test results can be displayed in percent transmittance, absorbance or concentration in the appropriate units of measure. The instrument offers automatic ranging in the preprogrammed parameters, operated-selected languages, full prompting during testing and error messages for procedural or instrument troubleshooting. A built-in timer helps the operator observe specific reaction times called for in the test procedures by having the appropriate times programmed into the calibration data for that test. The timer can also be used manually by the operator independent of stored methods. RS232 interface capability allows an external printer or computer to interface with the spectrophotometer, and a 0 to 1-volt analog output is provided for a recorder.

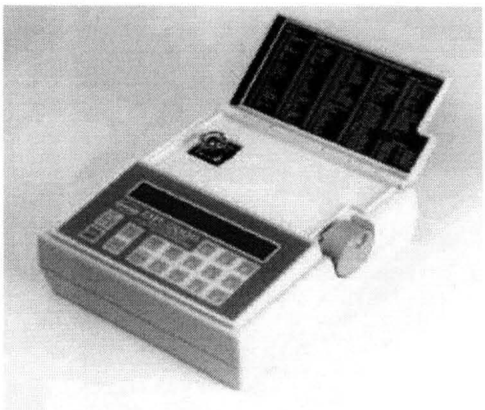


Fig 3.2: Hach DR/2000 spectrophotometer

The spectrophotometer can operate on battery power, pr AC line power using the battery eliminator/charger unit supplied with accessories. The battery holder supplied holds six D-size dry cells that will power the instrument for approximately 100 tests. An optional rechargeable battery is available, and it can be recharged with the optional battery eliminator/charger. (Hach DR/2000 Spectrophotometer instrument manual)

Other materials used for the analysis include; Hach 2000 turbidity meter, sterilized bottles, global positioning system (GPS), measuring tape, reagents

3.3 Methodology

3.3.1 Sample Collection

The well water samples were collected using 2 - liter hard plastic and screw-capped bottles that have been sterilized to avoid contamination by any physical, chemical or microbial means. The collected well water samples were transferred into plastic containers and labeled appropriately. All the water samples were collected on the 26th June 2011 at the study location (Maikunkele, Kampani and Mararaba) between 11:20 and 1:00pm Samples for bacteriological analyses were kept in screw-capped bottles that have been sterilized in an autoclave for 15 minutes at 121°C. Samples were then transferred to the Niger State Water Board laboratory in Minna, Niger state where they were stored in the refrigerator for microbial analyses.

3.3.2 Laboratory Analysis

Colour: A 25ml sample cell was rinsed and filled with the water sample to be tested; another 25ml sample cell was filled with distilled water which is to serve as the blank. The program number for the colour test (120) was entered and the wavelength was dialed (455). The surfaces of the sample cells was wiped using a clean cloth. The sample cell containing the distilled water (blank) was inserted into the sample holder and the lid was closed. The reading for the distilled water was taken and which the sample cell was removed. The sample cell containing the sample to be tested was then inserted and the reading was taken.

Turbidity (Ftu): A 25ml sample cell was rinsed and filled with the water sample to be tested. Another 25ml sample cell was filled distilled water which is to serve as the blank. The program number for turbidity test (750) was entered and the wavelength was dialed to 450.The surfaces of the sample cells were wiped using a clean cloth. The sample cell containing the distilled water was inserted into the sample holder and the lid was closed after which the reading was taken. The sample cell containing the water sample to be tested was inserted and the reading was taken.

Total Suspended Solids: A 25ml sample cell was filled with the water sample to be tested. Another 25ml sample cell was filled with distilled water which is to serve as the blank. The program number for total suspended solids test (630) was entered and the wavelength was dialed to 810. The surfaces of the sample cells were wiped using a clean cloth to avoid obstruction of light. The sample cell containing the distilled water was inserted into the sample holder and the lid was closed after which the reading was taken. The sample cell containing the water sample to be tested was inserted and the reading was taken.

Total Dissolved Solids: A measured sample of the water to be tested was poured in a cup, the conductivity/TDS meter probe was then inserted into the water sample and the reading was taken

Electrical conductivity: a measured sample of the water to be tested was poured into a cup, then the conductivity/TDS meter probe was inserted into the sample and the reading was taken.

Taste: The taste of the water samples was determined using the tongue. A measured sample of the water to be analyzed was taken and tested with the tongue

Odour: The odour of the water was determined using the nose. A measured sample of the water to be analyzed was taken and perceived by the nose

Chloride: The program number for chloride test (70) was entered and the wavelength was dialed to 455. A 25ml sample cell was rinsed and filled with the water sample to be tested. Another 25ml sample cell was filled with deionized water which is to serve as the blank. 2ml of mercuric thiocyanate solution was added to each sample cell and swirled to mix. 1.0ml of ferric ion solution was also added to each sample cell and swirled to mix, The samples were kept for a reaction time of 2 minutes, using the spectrophotometer as the timer. The blank was inserted into the sample holder immediately after the beep and the reading was taken. The prepared sample was then inserted into the holder and the reading was taken.

Copper: The program number for copper test (135) was tested and the wavelength was dialed to 560nm. A 25ml sample cell was rinsed and fill with the sample to be tested. Another 25ml sample cell was filled the sample to serve as the blank. One powder pillow of cu ver 1 copper reagent was added to the sample and swirled to mix. The sample was kept for a reaction time of 2 minutes, using the spectrophotometer as the timer. When the reaction time elapsed, the blank was inserted into the cell holder and the reading was taken. The prepared sample was then inserted into the cell holder and the reading was taken.

Chromium: The program number for chromium test (90) was entered and the wavelength was dialed to 540nm. A 25ml sample cell was rinsed and filled with the sample. One chromaver 3 reagent powder pillow was added to the sample and swirled to mix. The sample was left to react for 5 minutes. Another 25ml sample cell was filled with the water sample to serve as the blank. When the reaction time elapsed, the blank sample was inserted into the cell holder and the reading was taken. Then the prepared sample was then inserted into the cell holder and the reading was taken.

Manganese: The program number for manganese test (295) was entered and the wavelength was dialed to 525nm. A sample cell was rinsed and filled with the water sample to be tested. One powder pillow of buffer (citrate types) was added and swirled to mix), one content of sodium periodate powder pillow was also added and swirled to mix after which the sample was kept for a reaction time of 2 minutes. Another sample cell was filled with the water sample to serve as the blank. When the reaction time elapsed, the blank sample was inserted into the cell holder and the reading was taken. After which the prepared sample was inserted into the the cell holder and the reading was taken.

Nickel: The program number for nickel test (340) was entered and the wavelength was dialed to 560nm. 25ml of the water sample was measured into a mixing cylinder, 25ml of deionised water was measured into another mixing cylinder to serve as the blank. One powder pillow each of phthalate-phosphate reagent was added to each cylinder and allowed to dissolve. 1.0ml of 0.3% PAN indicator solution was also added to each cylinder, the cylinder was inverted several times to allow the reagents to mix after which the samples were kept for a reaction time of 15 minutes. When the reaction time elapsed, one powder pillow each of EDTA reagent was added to each cylinder and was allowed to dissolve. A 25ml sample cell was rinsed and filled with the blank and inserted into the sample cell holder after which the reading was taken. Another 25ml sample cell was also filled with the prepared sample and inserted into the sample cell holder after which the reading was taken.

Sulphate: The program number for sulphate test (680) was entered and the wavelength dialed to 450mn. A 25ml sample cell was rinsed and filled with the water sample to be tested. One powder pillow of sulfa ver 4 reagent was added to the sample cell and swirled to dissolve, and the sample was then kept for a reaction time of 5 minutes. another sample cell was filled with the water sample to be tested to serve as the blank. When the reaction time elapsed, The blank was inserted into the sample cell holder and the reading was taken, after which the prepared sample was inserted into the sample cell holder and the reading was taken.

Nitrate as N: The program number for the test (355) was entered and the wavelength dialed to 500nm. A 25ml sample cell was rinsed and filled with the sample to be tested. One powder pillow of Nitra ver 5 nitrate reagent was added and was shook for 1 minute, after which it was kept to react for 5 minutes. Another sample cell was filled with the water sample to be tested to serve as the blank. When the reaction time elapsed, the blank was inserted into the sample cell holder and the reading was taken. The prepared sample was also inserted into the sample cell holder and the reading was taken.

Aluminium: The program number for aluminium test (10) was entered and the wavelength dialed to 522nm. A 50ml mixing cylinder was filled with the sample to be tested and one ascorbic powder pillow was added and inverted several times to dissolve. Aluver 3 aluminium reagent pillow was also added and inverted several times to dissolve. A 25ml sample cell was then rinsed and filled with the sample to serve as the blank. Contents of one bleaching 3 reagent powder was then added to the remaining sample in the cylinder and shook vigorously for 30 seconds. This was then poured into a sample cell and kept for a reaction time of 15 minutes. When the reaction time had elapsed, the blank solution was inserted into the sample cell holder and the reading was taken, after which the prepares solution was also inserted into the sample cell holder and the reading was taken

Total Hardness: 50 ml of the water sample was measured into a 125ml flask. 2ml of buffer solution was added to the solution. The buffer solution of pH 10-+0.01 was prepared by dissolving 1.179g EDTA di-sodium salt and 0.780g $MgSO_4.7H_2O$ in distilled water which was later added to 16.9g NH_4Cl and 143 ml concentrated NH_4OH, mixed together and later diluted with distilled water. A small quantity of Erichrome Black T indicator was then added to the mixture of the water sample and the buffer solution. It was then titrated with 0.01M EDTA (ethylene – diaminetetraethanoic acid) slowly while stirring continuously until the last reddish tinge changes to blue.

$$\text{Total Hardness in mg/l as } CaCO_3 = \frac{A \times D \times 1000}{\text{ml of sample}}$$

Where, A = ml of titrant used

D = molarity of titrant x molar mass of $CaCO_3$ = 0.01 x 100

Where the molar mass of $CaCO_3$ = 40+12+ (16x3) = 100

Determination of Calcium Hardness

50ml of the water sample was measured into 125ml flask. 25ml of 1M sodium hydroxide buffer solution was added to the sample followed by the addition of 0.1 to 0.2g drops of murexide indicator. The resultant pink color were titrated with 0.01M EDTA di-sodium salt until the color changes from pink to purple

$$\text{Calcium Hardness in mg/l as } CaCO_3 = \frac{A \times D \times 1000}{\text{ml of sample}}$$

Where, A = ml of titrant used

D = molarity of titrant x molar mass of $CaCO_3$ = 0.01 x 100

The Magnesium Hardness = Total Hardness – Calcium Hardness

Alkalinity: 50ml of the water sample was measured into 125ml flask. 6 drops of phenolphthalein indicator was added. Since there was no color change, it means that the hydroxide alkalinity and the carbonate alkalinity are zero while the bicarbonate alkalinity equal to the total alkalinity. The total alkalinity was gotten by using a standard solution of 0.02M H_2SO_4 as the titrant where 6 drops of mixed indicators which are bromocresol and methyl red are added to the unchanged solution of the water sample.

$$\text{Total Alkalinity} = \frac{\text{A x N x 50,000}}{\text{ml of sample}}$$

Where, A = ml of H_2SO_4 used

N = molarity of acid used (0.02m)

Microbial Analysis of water

The membrane lauryl sulphate broth was used for this analysis. It was diluted with distilled water and autoclaved at 21°C for 15 minutes. It was allowed to cool at room temperature before pouring it on an absorbent pad placed into each of the two empty sterile petri dishes. The pads were allowed to get soaked with the membrane lauryl sulphate broth. The excess medium was cleaned off from the dishes with the cotton wool to prevent confluent growth.

The sterile filtration apparatus was set up and connected to a source of vacuum with the stop cock turned off. The funnel was carefully removed and a sterile membrane filter was placed onto the porous disc of the filter base. The funnel was later returned and 100 ml of the water sample was poured into the funnel. The stop cock was then opened and the vacuum pump was switched on to filtrate the sample. The vacuum pump was stopped and the stop cock was closed after the sample has been filtered to prevent air from being drawn into the membrane filter.

The funnel was later removed and the membrane filter was carefully transferred to one of the pads saturated with the membrane lauryl sulphate broth. The membrane filter was then covered with the lid of the petri dish. The same process of the filtration was also carried out for the second volume of sample and the membrane filter was also transferred to the other saturated pad and was also covered with the lid of the petri dish.

The two petri dishes were then placed in a sealed container to prevent drying after which they were inverted and placed in an incubator at 30^{o}C for 4 hours. One dish was later transferred to an incubator at 37^{o}C for 14 hours (for the total coliform) and the other dish to an incubator at 44^{o}C for 14 hours (For the E-coli)

After the total incubation period of 18 hours, the membrane filters were examined under the colony counter. The number of yellow colonies counted on the membrane filter incubated at 37^{o}C is the total coliform while the number of yellow colonies counted on the membrane filter incubated at 44^{o}C is the number of E-coli present in the water sample.

CHAPTER FOUR

4.0 Results and Discussion

4.1 Presentation of result

Table 4.1: The physico-chemical and bacteriological results of the well water analysed are presented in Table 4.1 and 4.2.

S/N	PARAMETERS	MAI	KAM	MAR	NSDWQ
1	Turbidity (FTU)	7.00	6.00	6.00	5.00
2	Colour (PtCo)	35.00	30.00	31.00	15.00
3	Temperature (C)	26.1	26.9	26.6	Ambient
4	Suspended Solids (mg/l)	1.00	5.00	2.00	NS
5	Electrical conductivity (us/cm)	580	250	200	1000
6	Total dissolved solids (mg/l)	290	120	100	500
7	Total solids (mg/l)	291	125	102	NS
8	Total Hardness (mg/l)	155.00	126.50	55.00	150.00
9	Calcium hardness (mg/l)	120.00	63.00	27.00	NS
10	Magnesium hardness (mg/l)	35.00	63.00	28.00	NS
11	Total Alkalinity (mg/l)	199.00	128.00	98.00	NS
12	ammonia(mg/l)	11.59	1.34	3.05	NS
13	Nitrate (mg/l)	41.99	4.86	11.05	50.00
14	Nitrite (mg/l)	0.20	0.01	0.05	0.02
15	Sulphate (mg/l)	27.00	1.00	0.00	100.00
16	Manganese (mg/l)	0.30	0.30	0.30	0.02
17	Copper (mg/l)	0.01	0.01	0.00	1.00
18	Nickel (mg/l)	0.02	0.00	0.01	0.02
19	PH	7.47	7.28	7.11	6.5-8.5
20	Chloride (mg/l)	59.50	15.50	19.90	250.00
21	Calcium (mg/l)	48.10	25.25	10.82	NS
22	Magnesium (mg/l)	8.54	15.37	6.83	NS
23	Boron (mg/l)	0.00	0.00	1.00	NS
24	COD (mg/l)	80	2	15	NS
25	BOD (mg/l)	44	1.1	8.25	NS
26	E. coli	185	240	160	0
27	Total coliform	460	320	280	10

Table 4.2: Summary of physico-chemical and bacteriological parameters of Maikunkele, Kampani and Mararaba well water samples

PARAMETERS	RANGE (MIN-MAX)	MEAN	STANDARD DEV	WHO
Turbidity (FTU)	6.00-7.00	6.33	0.58	5.00
Colour (PtCo)	30.00-35.00	32.00	2.65	15.00
Temperature (C)	26.1-26.9	26.53	0.40	-
Suspended Solids (mg)	1.00-5.00	2.67	2.08	-
Electrical conductivity(us/cm)	200-580	343.33	206.48	150.75
Total dissolved solids (mg/l)	100-290	170.00	104.40	1000
Total solids (mg/l)	102-291	172.67	103.12	1000
Total Hardness (mg/l	55.00-155.00	112.17	51.52	200
Calcium hardness (mg/l	27.00-120.00	70.00	46.89	-
Magnesium hardness (mg/l)	28.00-35.00	42.00	18.52	-
Total Alkalinity (mg/l)	98.00-199.00	141.67	51.87	200
Ammonia (mg/l)	1.34-11.59	5.33	5.49	-
Nitrate (mg)	4.86-41.99	19.30	19.89	10
Nitrite (mg/l)	0.01-0.20	0.087	0.10	-
Sulphate (mg/l)	0.00-27.00	9.33	15.31	400
Manganese (mg/l)	0.30-0.30	0.30	0.00	-
Copper (mg/l)	0.00-0.01	0.01	0.07	1.00
Nickel (mg/l)	0.00-0.02	0.01	0.01	-
PH	7.11-7.47	7.29	0.18	6.5-8.5
Chloride (mg/l)	15.50-59.50	31.63	24.23	250
Calcium (mg/l)	10.82-48.10	28.06	18.79	-
Magnesium (mg/l)	6.83-15.37	10.25	4.52	-
Boron (mg/l)	0.00-1.00	0.33	0.58	-
COD (mg/l)	2.00-80.00	32.33	41.79	-
BOD (mg/l)	1.10-44.00	17.79	22.98	-
E. coli	160-240	195.00	40.93	0
Total coliform	280-460	353.33	94.52	0

4.2 Discussion of Result

The values of colour in all samples are above the 15.0 CTU WHO values permitted in drinking water (WHO, 1993). The value of turbidity for all the three samples was slightly higher than WHO standard of 5.0 NTU. High turbidity values in these wells are indications of suspended materials, algae and aquatic microscopic organisms (Clesceri, 1989). The high turbidity may have also resulted into high color values respectively. The water temperature of the three sample, which is s less than 29°C, may affect the chemistry of the groundwater as well as metals toxicity (Awofolu *et al.*, 2007). PH values of the well samples are in the normal range of WHO standard in drinking water. However, lower pH may result from deposition of CO during precipitation. Total Dissolved Solid and Total Solid values fall below the international permissible standard in drinking water (WHO, 1993). The value of Total Suspended Solid in these wells is low. Normally, Total Solid value in water should be in the range of 25-80 mg L (Robert, 1978). A positive significant correlation between Total Suspended Solid and turbidity has been established (Bertram and Balance, 1998). Invariably, high Total Suspended Solid indicates high load of both organic and inorganic materials in the water, while low suspended solid indicates low load of both organic and inorganic materials in the water. Electrical conductivity is a measure of the ions or salinity. It is a reflection of high dissolved solids. The electrical conductivity of the water samples was high with maikunkele having the highest value of 580us/cm. Based on groundwater classification (Freeze and Cherry, 1979), the samples fall within brackish water. Total hardness are above 70 mg L in all the samples except sample from Mararaba, therefore the water from maikunkele and Kampani can be described as hard (Environment Canada, 1977).

Calcium concentration is within the 10-100 mg L permissible in potable groundwater (Adediji and Ajibade, 2005; Walker, 1973). Calcium has no health effects on human. Magnesium concentrations in the sampled well water also fall within 1.0-40 mg L normal range values in potable groundwater (Adediji and Ajibade, 2005). Manganese, copper and Nickel concentrations are within the WHO limits permitted in potable water. Chloride and sulphate mean concentrations are within the WHO minimum permissible limits of 250 and 400 mg L respectively. High chloride concentration in groundwater may indicate pollutions by sewage, industrial wastes or saline water intrusions (Bertram and Balance, 1998). Both chloride and sulphate have no health implication on human but at high concentrations chloride could impart taste in water while sulphate could cause gastrointestinal irritation (WHO, 1971). The nitrate values were higher than WHO standard of 10.0 mg L in drinking water. This has a lot of health implication especially on the growing infants and pregnant women (Adekunle *et al.*, 2007). However, the high nitrate values in all the aquifers sampled are of health-concern especially to growing infants as it causes methaemoglobinaemia. The symptoms of methaemoglobinaemia are paleness, bluish mucous membranes, digestive and respiratory problems (McCasland *et al.*, 2007).

The presence of *E*- coli and total coliform in the well water indicate contamination by human or animal wastes. These pathogens may pose a special health risk for infants, young children and people with severely compromised immune systems (USEPA, 2002). WHO has recommended a zero value of *E* coli and total coliform count in drinking water. The values of E coli count are very high with Kampani having the highest value of 240, indicating the pollution of the wells by faecal matters. This is dangerous in groundwater to be used for drinking purposes. Result of total coliform per mL was also extremely high, with maikunkele having the highest value of 460. This could be as a result of the proximity of the well to latrine and also exposure. The water from the well at maikunkele is only used for domestic purposes like washing of clothings and bathing.

The water from the well at Mararaba and Kampani is used both for consumption and domestic purposes. The inhabitants of these communities complained of people suffering from diarrhoea mainly children especially during the rainy season. This could be traced to the consumption of contaminated water without treatment. Table 4.2 shows the standard deviation of the parameters. The standard deviation is a measure of how widely values are dispersed from the average value (the mean).

Considering the mean values of some of the physical parameter like colour (6.33), turbidity (32.00) and bacteriological parameters like total coliform (353.33) and E-coli (195.00) which are high when compared with the WHO standards, makes the water unsafe for drinking without treatment.

CHAPTER FIVE

5.0 Conclusion and recommendation

5.1 Conclusion

The well water is one of the major sources of drinking water to the inhabitants in this area; most especially when there is power failure and lack of electricity supply. After the study the following conclusion were made;

1. The high values of some physico-chemical (color, turbidity, nitrate, manganese,) and microbiological parameters (bacteria and total coliform) in the study well higher than the recommended limits is an indication of pollution hazards. This however, in return has implications on human health as these wells are the main source of drinking water supply to the residents.
2. The high level of contaminant could result from factors like the distance of the well from pollution sources e.g waste dumpsite and latrine also the exposure of the well.
3. Based on the results, the groundwater resource in this area, without treatment is unfit for drinking and domestic uses.

5.2 Recommendation

1. It was recommended to the people in these communities that they should boil their water before consumption as this help to destroy the pathogens in the water thereby reducing health risk.
2. It is recommended that increased and continued combined environmental interventions, through public health education by community based health workers, awareness and

sensitization campaigns be carried out for improved household and community sanitation in rural areas.

3. Adequate solid waste disposal method should be adopted, phasing out open dumpsites to safeguard public health from water borne diseases.
4. It is also recommended that wells should not be dug near contamination sources, the wells should always be properly lined and covered. Moreover, water from the well should be treated before consumed.
5. Further research works should be conducted on the sampled wells for proper monitoring to have a complete picture of the seasonal variations.

REFERENCES

Adediji, A. and L.T. Ajibade, (2005). Quality of well water in Ede Area Southwestern Nigeria. J. Hum. Ecol., 17: 223-228.

Adekunle, I.M., M.T. Adetunji, A.M. Gbadebo and O.B. Banjoko, (2007). Assessment of groundwater quality in a typical rural settlement in southwest, Nigeria. Int. J. Environ. Public Health, 4: 307-318.

Awofolu, O.R., R. Duplessis and I. Rampedi, (2007). Influence of discharge effluent on water quality of surface water utilized for agricultural purposes. Afr. J. Biotechnol., 6: 2251-2258.

Bertram, J. and R. Balance, (1998). Water Quality Monitoring: A Practical Guide to the Design and Implementation of Freshwater Quality Studies and Monitoring Programmes. 1st Edition. Taylor and Francis, USA, pp: 400.

Chartres, C. and Varma, S. (2010) Out of water. From Abundance to Scarcity and How to Solve the World's Water Problems FT Press (USA).

Clesceri, L.S., (1989). Standard Methods for the Examination of Water and Wastewater. 17th Edition. American Public Health Association, Washington, DC., USA, pp: 1624.

Drinking-water quality guidelines for parameters of concern in agricultural drainage water. Retrieved from http://www.fao.org 10-25-2011

Eaton A.D., Clesceri L.S., and Greenberg A.E. (1995): Standard methods for the Examination of Water and Wastewater. 19th Edition

Environment Canada, (1977). Surface Water Quality in Canada: An Overview. Inland Waters Directorate, Water Quality Branch, Canada. http://catalogue.nla.gov.au/Record/2503379

FAO Water Unit/Water News: water scarcity. Fao.org. http://www/fao.org. Retrieved 05-07-2011

Freeze, R.A. And J.A. Cherry, (1979). Groundwater. 1st Edition. Prentice Hall Inc. Englewood Cliffs, New York, USA, pp: 604.

Ground water. Retrieved from http://www.wikipedia.org 04-03-2011

Hach Company (1991), Hach DR/2000 Spectrophotometer Instrument manual.USA, pp 3

Molden, D. (Ed). (2007) Water for food, Water for life: A Comprehensive Assessment of Water Management in Agriculture. Earthscan/IWMI.

Musa, S. M. (1996), Ground Water Hydrology and Wells. Unpublished seminar paper presented at the Department of Agricultural Engineering, University of Maiduguri. Nigeria. pp. 2-10.

Ogedengbe, K. (2004), Introduction to Agricultural Engineering.1st Edition. Stirling, Horden Publishers. Ibadan. Nigeria. pp. 24-25.

Robert, R.J., (1978). Fish Pathology. 2nd Edition. BailliereTindall, London, pp: 360.

Seamus C. (2000), Hand Dug Shallow Wells. Ist Edition. SKAT, Swiss centre for development cooperation in technology and management. Pp 15-40

Schewab, G.O., D.D. Fangmeier, W.J. Elliot and R.K. Fresvert (1992), Soil and Water Conservation Engineering. 4th Edition. New York. pp. 256-65.

Template:Http://silkroadintelligencer.com.Aral-sea-trickles-back-to-life/ retrieved 05-07-2011

United Nations Press Release. (2007), POP/952. World population will increase by 2.5 billion by 2050

USEPA, (1996). National standards for drinking water. United States Environmental Protection Agency 816-F-02-013.

USEPA, (2002). National standards for drinking water. United States Environmental Protection Agency 816-F-02-013.

Water Development and Management Unit - Topics - Irrigation". FAO. http://www.fao.org/nr/water/topics_irrigation.html. Retrieved 12-06-2011.

Walker, W.H., 1973. Where have all the toxic chemical gone? Groundwater, 11: 11-20. DOI: 10.1111/j.1745-6584

Water resources. Retrieved from http://wikipedia.org/water resources, 07-05-2011

Water sources. Retrieved from http://Library.thinkquest.org 27-06-2011

Water well. Retrieved from http://wikipedia.org/waterwell, 27-06-2011

WBCSD Water Facts & Trends". http://www.wbcsd.org/includes/getTarget.asp?type=d&id=MTYyNTA. Retrieved 12-06-2011.

World Health Organization, 1971. Drinking Water Quality. 3rd Edition., Geneva. pp: 15-157.

World Health Organization, 1993. Guidelines for Drinking-Water Quality (Vol. 1). 2nd Edition, World Health Organization (WHO), Geneva, pp: 36.

APPENDICES

A Facts and Figures on Water Quality and Health

- No safe drinking-water: almost 1 billion people lack access to an improved supply
- Diarrhoeal disease: 2 million annual deaths attributable to unsafe water, sanitation and hygiene
- Cholera: more than 50 countries still report cholera to WHO
- Cancer and tooth/skeletal damage: millions exposed to unsafe levels of naturally-occurring arsenic and fluoride
- Schistosomiasis: an estimated 260 million infected
- Emerging challenges: increasing use of wastewater in agriculture is important for livelihood opportunities, but also associated with serious public health risks

The Health Opportunities: Implementing good practice

- 4% of the global disease burden could be prevented by improving water supply, sanitation, and hygiene
- A growing evidence base on how to target water quality improvements to maximize health benefits
- Better tools and procedures to improve and protect drinking-water quality at the community and urban level, for example through Water Safety Plans
- Availability of simple and inexpensive approaches to treat and safely store water at the household-level

B FAO Drinking water quality standard

Table B1. Bacteriological quality of all water intended for drinking

Organisms	Guideline value
E. coli or thermotolerant coliform bacteria	Must not be detectable in any 100-ml sample

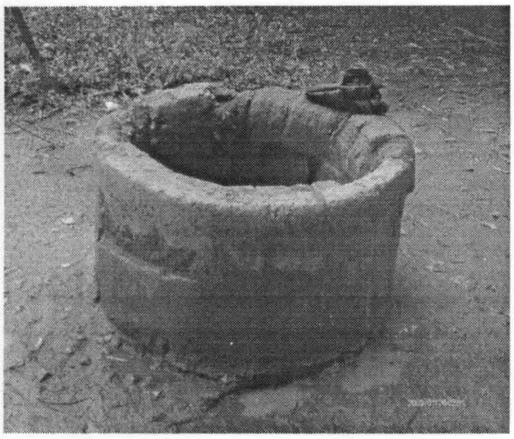
Table B2. Inorganic constituents of health significance in drinking-water

	Guideline value (mg/litre)	Remarks
Arsenic	0.01 (P)	For excess skin cancer risk of 6×10^{-4}
Boron	0.5 (P)	
Cadmium	0.003	
Chromium	0.05 (P)	
Copper	2 (P)	Based on acute gastrointestinal effects
Lead	0.01	It is recognized that not all water will meet the guideline value immediately; meanwhile, all other recommended measures to reduce the total exposure to lead should be implemented
Manganese	0.5 (P)	Substance at or below the health-based guideline value may affect the appearance, taste and odour of the water.
Mercury (total)	0.001	
Molybdenum	0.07	
Nickel	0.02 (P)	
Nitrate (as NO_3^-)	50 (acute)	
Nitrite (as NO_2^-)	3 (acute) 0.2 (P) (chronic)	
Selenium	0.01	
Uranium	0.002 (P)	

Table B3: Substances and parameters in drinking-water that may give rise to complaints from consumers

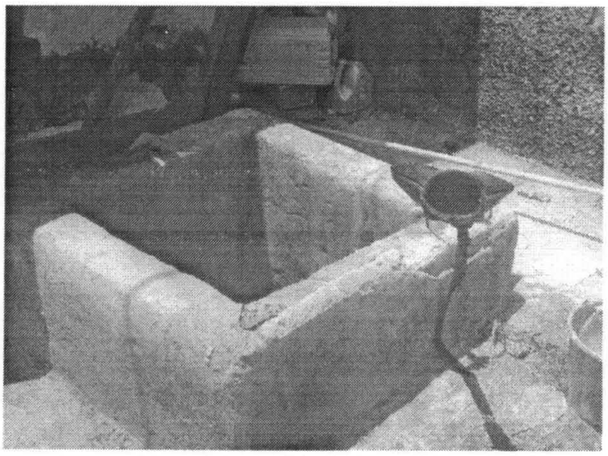
Physical parameters	Levels likely to give rise to consumer complaints	Reasons for consumer complaints
Colour	15 TCU	Appearance
Taste and odour	-	should be acceptable
Temperature	-	should be acceptable
Turbidity	5 NTU	appearance; for effective terminal disinfection, median turbidity = 1 NTU, single sample = 5 NTU

Inorganic constituents	Guideline value mg/litre	Remarks
Aluminium	0.2	depositions, discoloration
Ammonia	1.5	odour and taste
Chloride	250	taste, corrosion
Copper	1	staining of laundry and sanitary ware (health-based provisional guideline value 2 mg/litre)
Hardness	-	high hardness: scale deposition, scum formation low hardness: possible corrosion
Hydrogen sulphide	0.05	odour and taste
Iron	0.3	staining of laundry and sanitary ware
Manganese	0.1	staining of laundry and sanitary ware (health-based guideline value 0.5 mg/litre)
Dissolved oxygen	-	indirect effects
pH	-	low pH: corrosion high pH: taste, soapy feel preferably <8.0 for effective disinfection with chlorine
Sodium	200	Taste
Sulphate	250	taste, corrosion
TDS	1 000	Taste
Zinc	3	appearance, taste



C1: Well at Mararba

C2: Well at Kampani



C3: Well at Maikunkele