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LATRINES AND HOUSEHOLD WELL WATER QUALITY IN WA

BY

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DECLARATION

I hereby declare that this submission is my own work towards the award of an Mphil. degree and that, to the best of my knowledge this thesis has not been presented for the award of another degree elsewhere. It contains no material previously published by another person or material, except where due acknowledgement has been made in the text.

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DEDICATION

I dedicate this thesis to my parents, Late Mr. Wilfred Asumah Braimah and Mrs. Dorothy Yayuan in honour of their unflinching support for my education.

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ABSTRACT

In many developing countries of the world, the utilization of ground water is very common due to factors such as water scarcity and its relative good quality. On the other hand, basic sanitation is a challenge in many developing countries with most rural and peri-urban communities relying on on-site sanitation systems which are often poorly managed. This study, conducted in Wa the Upper West region of Ghana, aimed at assessing the influence of on-site sanitation systems on hand dug well water quality. Samples were randomly collected from thirty wells and tested using standard methods for physico-chemical and microbiological indicators of water quality. Questionnaires were administered to assess the general knowledge and perception of respondents on the quality of the water they used for domestic purposes. Also, observation was made on the general conditions of wells from which samples were collected and available sanitation structures. It was found from the study that, all the parameters assessed were within the WHO recommended limits except bacteria (of faecal origin) and turbidity. Significant variations in conductivity, total dissolved solids, temperature and turbidity were observed between the dry and the rainy seasons. All the water samples were found to be positive for bacteria. The study also revealed majority that of respondents were content with their well water quality. Educational campaigns need to be undertaken to create awareness about the quality of well waters, human activities that adversely impact on the quality of well waters. Wells should be located at a minimum distance of 50 meters from a pit latrine in order to reduce contamination. The government through the Municipal Assembly should make available disinfectants to enable residents disinfect their waters.

TABLE OF CONTENT

Content Page

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

LIST OF ACRONYMS

APHA	American Public Health Association
EPA	Environmental Protection Agency
GHS	Ghana Health Service
GLSS	Ghana Living Standard Survey
GSS	Ghana Statistical Service
IDW	Inverse Distance Weighting
JMP	Joint Monitoring Program
MDG	Millennium Development Goals
MLGRD	Ministry of Local Government and Rural Development
MOFA	Ministry of Food and Agriculture
NTU	Nephelometric Turbidity Units
STWS	Small Town Water System
TUC	Total Coliform Units
UNICEF	United Nations Children's Fund
WHO	World Health Organisation

CHAPTER ONE

GENERAL INTRODUCTION

1.1 Introduction

The importance of water to humans cannot be overemphasized hence the need for its availability in the right quantity and quality. Good drinking water and sanitation are therefore used as socio-economic development indicators of nations. Sustainable access to safe drinking water and basic sanitation has become essential in many developmental programs and consequently a cross cutting theme in the Millennium Development Goals (MDGs).

According to the United Nations Water Statistics, the total volume of water on earth is about 1.4 billion km^3 with fresh water accounting for about 2.5 percent of the total volume. Approximately 30% of the world's freshwater is stocked as groundwater with about 97% of all the freshwater being potentially available for human use (Morris et al., 2003).

In many areas of the world, groundwater serves as an important source of water for various livelihood activities ranging from domestic through to industrial use. In Ghana, the use of groundwater as a source of drinking water for the rural and urban poor is widespread. Well water remains the number one source of water for many rural and peri-urban poor households in Ghana, making up 41% of available water sources (GLSS, 2008). About 16.0% of the urban population resort to wells as their major sources of water whiles 59.4% of the rural inhabitants use well water as their main source of water (GLSS, 2008).

Sanitation coverage is a major developmental challenge for many African countries. World Health Organization (WHO) defines sanitation as group of methods to collect human excreta and urine as well as community waste waters in a hygienic way, where human and community health is not altered (WHO/UNICEF JMP, 2008). Over half the African population use improved or shared sanitation facility and one in four practice open defecation (WHO/UNICEF JMP, 2008).

Typical of developing countries, available sanitation facilities are overstretched, human waste management is poor and sewered excreta disposal systems are rare, due to high costs and scarce water resources (Cofie et al., 2005). In most cases, on-plot or on-site sanitation systems, such as pit latrines and septic tanks are the common sanitation facilities used in most peri-urban areas (Cave et al.,1999). According to Adejuwon et al. (2011), pit latrines are the common form of excreta disposal technologies used in urban slums and rural areas mainly because of their ease to construct, relatively cheapness and affordability and effectiveness in sewage management. Although locating pit latrines within households provides some advantages such as self-dignity, privacy, enhanced sanitation among others, there is also concerns with groundwater contamination, subsequent diseases outbreak and transmission and environmental degradation (Odai, 2003; Olabisi, et al., 2007).

Poor water quality poses major public health problems particularly in highly susceptible people (children and immune compromised patients) according to Verheyen et al. (2009). According to Adejuwon et al. (2011), unsafe water and poor sanitation account for 3.7% of the global disease and 80% of all disease in the developing world with diarrhea being the highest especially among children under five years. About 2.2 million people die annually from diarrheal diseases and that 10% of the population of the developing world are severely infected with intestinal worms related to improper waste and excreta management (Murray et al., 1996: WHO, 2000). About 88% of cases of diarrhea worldwide are attributable to unsafe water, inadequate sanitation or insufficient hygiene resulting in 1.5 million deaths each year, most being the deaths of children (Prüss-Üstün et al., 2009).

1.2 Problem statement and justification

The provision of water and sanitation services in poor urban areas remains a critical challenge for the realization of the Millennium Development Goals but more importantly for poverty reduction (Kanton et al., 2010). Oteng-Ababio (2012) noted that managing normal waste from households in developing countries appears to be an insurmountable task. In Ghana, most rural and some peri-urban dwellers rely on untreated groundwater sources for domestic purpose (Odai et al., 2003).

Kortatsi (1994) asserts that in the savannah regions of northern Ghana, groundwater is generally the major source of freshwater for domestic, agricultural, small-scale industrial use and livestock watering (cited in Cobbina et al., 2012). This is because the region experiences water scarcity and many households resort to hand dug wells as their main source of water. Most of these wells are however often constructed with little regards for quality (Xu et al., 2006).

Wa in the Upper West Region is one of the deprived towns in the country. It has limited basic social amenities such as potable drinking water, roads, housing, sewered sanitation system and schools. On-site sanitation facilities are the most widely patronized systems in Wa. Almost every household in the peri-urban areas in Wa has either a latrine or a well or both. These wells are however often dug with little consideration to the impact of pit latrines to the quality of the water. To the extent that water and sanitation facilities are had pressed in the Mangu and Kambali areas of Wa coupled with the higher rates of population growth, there is the possibility that these hand dug wells may be contaminated. This consequently may lead to out breaks of water borne diseases which affect living standards of the inhabitants and their general development as a whole.

In Ghana, diarrhea has been identified as the second most common health problem treated in outpatient Clinics (Osumanu, 2007). In the Upper West region, 21,437 out patients reported to health facilities with diarrhea, making 5% of total hospital attendance recorded (GHS-UWR, 2008). Nationally, the total number of diarrhea cases among children under five years for the year 2011 was 113,786 out of which the Upper West Region recorded a total of 1,789.5 cases (Ghana Health Service Annual Report, 2011). In the Kambali and Mangu CHPS (Community Based Health Planning Services) zone, a total of 578 diarrhea cases were recorded in 2010, 1388 cases in 2011 and this reduced to 400 in 2012 (Wa Municipal Health Directorate, 2013).

Recognising the complex linkages existing between groundwater supplies, urban land use and effluent disposal (Morris et al., 2003) and its effect on environmental degradation and public health, there is the need for sustainable management of groundwater resources. There is therefore the need to carefully assess the activities of inhabitants that affect the quality of groundwater in order to reduce the health and environmental impacts (Dzwairo et al., 2006).

1.3 Aim and objectives

The main aim of the research is to assess the effects of pit latrines on well water quality and establish safety of well water for peri-urban people in Wa. The study seeks to:

- assess the quality of water from these household wells.
- determine the average distance pertaining to the siting of wells and latrines in the study area.
- ascertain the seasonal variations in well water quality.
- produce a geospatial map on latrines and well locations.
- assess the perception of inhabitants about the quality of water and their openness to water treatment and management methods.
- identify and explain the roles and extent to which the various stakeholders are involved in the water and sanitation management system.

1.4 Research questions

- What is the quality of well waters in the area?
- Are there any variations in the quality of water from the wells with respect to the seasons and well distance from latrines?
- What is the relationship and lateral distance between latrines and wells?
- How are pit latrines and wells managed?
- What are inhabitants' views about the quality of water from these wells?

CHAPTER TWO

LITERATURE REVIEW

2.1 Ground water as a resource

Groundwater refers to all the water occupying the voids, pores and fissures within geological formations (Ojo et al., 2012). It forms the invisible sub-surface part of the water cycle and unlike other natural resource is present throughout the world (Struckmeier, 2005). Water is an indispensable resource for life and subsistence. According to Howard et al. (2006), groundwater serves as the single, most important and economically viable option for drinking water. This is reiterated by Gupta et al. (2007) that in many parts of the world, groundwater extracted for a variety of purposes has made a major contribution to the improvement of the social and economic circumstances of human beings.

According to National Ground Water Association of the United States of America (2005), approximately 25% of the earth's total fresh water supply is stored as ground water, while less than 1% is stored in surface water resources, such as rivers, lakes, and creeks. Struckmeier (2005) states that the earth's total resources of fresh groundwater are estimated at about 10 million cubic kilometers more than two hundred times the global annual renewable water resources provided by rain. Morris et al. (2003) indicated that, as many as two billion people depend on it directly with 40% of the world's food produced by irrigating agricultural lands with groundwater. They also suggest that groundwater constitutes about 95% of the freshwater on our planet making it fundamental to human life and economic development.

2.2 Water quality and ground water contamination

Groundwater is a widely used source of water for a lot people especially the rural and peri-urban areas. Despite the fact that groundwater serves as an important source of drinking water, its quality is currently threatened by a combination of over-abstraction, microbiological and chemical contamination (Pedley et al., 1997). Intensive use of natural resources and the large production of wastes in modern society often pose a threat to groundwater quality and have already resulted in many incidents of groundwater contaminations (Srivastava et al., 2012). Various activities of man have led to the depletion of groundwater.

Globally, major water quality concerns include organic, nitrate and heavy metals pollution, acid mine drainage and hydrological modification (Xu et al., 2006). A protocol to manage the potential of groundwater contamination from on-site sanitation (2003) identified groundwater pollution sources to include toilets, solid waste dumpsites, grey water disposal practices, cattle kraals or feedlots, cattle dip tanks, graveyards and waste disposal from industries. According to Khan et al. (2012), sewage contamination through animal and human excreta is one of the most common and widespread cause of water contamination. In Ghana, groundwater pollution has been attributed to chemical pollution from geological processes, pathogen contamination, leachate from mining waste and underground petroleum storage tanks (Duah, 2006).

2.3 Water and sanitation in Ghana

According to the World Bank (2011), in Ghana, population with sustainable assess to improved water source increased from 54% in 1990 to 71% in 2000 and 82% in 2008 indicating brighter hopes for the attainment of the MDGs. According to the same report, 90% of the urban population had sustainable access to improved water sources whiles 74% of the rural population had access to improved water sources in 2008. Improved drinking water coverage among the populations of the ten regions of Ghana varied strongly with the Upper West and Greater Accra recording 97% and 61% coverage respectively (WHO/ UNICEF, 2008).

The world has met the MDG drinking water target of halving the proportion of the population without sustainable access to safe drinking water, five years ahead of the 2015 target (WHO/UNICEF, 2012). Unlike water, no significant gains have been made with sanitation.

The sanitation canker in Ghana is worse in the peri-urban areas which are often plagued with inadequate water supply and low access to sustainable basic sanitation with the use of unimproved and shared sanitation facilities being very common (Agyei et al., 2011). Sanitation coverage in Ghana remains fairly low, particularly in the Northern, Upper Eastern and Upper Western Regions. In each region, coverage does not exceed 20% (WEDC, 2005). According to the World Bank (2011), population with sustainable assess to improved sanitation has not been encouraging in Ghana with only 13% of the population having access to sustainably improved sanitation in 2008, an increment from 7.0% in 1990 and 9.0% in 2000. With this, the urban population accounts for 18% whiles the rural population accounted for just 7% in 2008. Populations however with non-improved sanitation facility in 2008 was 87.7% making up 88.8% of households. Out of the total population without access to improved sanitation facility, 91.8% of them are rural making up 92.8% of rural households whiles 82.1% of them are urban making up 84.3% of urban households (MLGRD, 2010).

Sanitation coverage in Ghana from available researches suggest that coverage continues to increase for rural people whiles that of the urban remains the same because of the rapid growth of urban population which partly accounts for it. MLGRD (2010) reports that treatment of waste in all regions is very abysmal and the increasing urbanization has led to increased use of on plot sanitation systems which presents a challenge to effectively managing increasing volumes of sewage as many of these houses do not have adequate drain fields.

Even though Ghana has made progress in reducing the proportion of the population without access to improved sanitation, the MDG target may not be achieved by 2015 if the current trends continue. At the current trend, the proportion of the population with access to improved sanitation will reach 21.2% by 2015 instead of 52% while the proportion of urban population with access to improved sanitation will be 23.4% instead of 55% by 2015 (World Bank, 2011).

2.4 Sanitation, water and health

Dating back to the colonial era (pre-1950) of most developing countries, water and sanitation have been recognized as promoting health and development (Seppälä, 2002 in Nkansah, 2009). Sanitation and drinking-water are universally accepted as being essential for human life, dignity and human development (WHO, 2012). Safe drinking water, sanitation and good hygiene are fundamental to health, survival, growth and development and therefore essential for the prevention of diarrhea and the reduction in the burden of diseases such as ascaris, dracunculiasis, hookworm, schistosomiasis and trachoma (WHO/ UNICEF, 2006). Good quality water is one that is devoid of pathogenic organism. The discharge of fecal matter by man and other animals are capable of transporting a variety of human pathogens that cause diseases (Olabisi et al., 2007). Increasing groundwater resource development for domestic use has led to increased demand and provision of on-site sanitation facility which can cause subsurface migration of contaminants and ultimately resulting in diseases transmission and environmental degradation (Odai et al., 2003).

According to Muruka et al. (2012), good sanitation improves the quality of life by reducing communicable diseases. Health improvements come from the proper use of sanitation facilities but the greatest benefits occur when there are improvements in sanitation and water supply combined with education on hygienic practices (Anteneh et al., 2010). The call for improvement in water and sanitation is driven by the need to reduce the prevalence of diseases (ARGOSS, 2001). According to Abay (2010), providing safe water is related to providing safe sanitation suggesting that the two are intertwined and need to be provided simultaneously.

2.5 Importance of water quality indicator

2.5.1 Microbial contamination of groundwater

The presence of microorganisms in water is an indicator widely used in assessing the quality of drinking water. Examples of such microbes include *Escherichia coli, Klebsiella Enterococcus and fecal streptococci.* The universal indicator organisms used are the coliforms which are a collection of these organisms including most specifically *Escherichia coli* (Aydin, 2007). These coliforms are usually found in faeces and are excreted in large quantities. Traditionally, the microbiological quality of drinking water is assessed by monitoring bacteria of faecal origin such as *E. coli* and *Enterococcus* spp. making them hygiene indicator bacteria. WHO's recommended value for coliform in drinking water is zero (WHO, 2011). Consuming water contaminated with coliforms can pose serious health problems. The outbreaks of cholera, diarrhea and many food borne ailments have been attributed to contamination of food or water with faecal bacteria. The ease of human infection with these pathogens is as a result of the faeco-oral transmission route of these pathogens. Sanitation therefore is very significant to water quality and food safety issues.

2.5.2 Nitrates and nitrites

Nitrate and nitrite have been identified as major pollutants in groundwater worldwide (Umezawa et al., 2008). Nitrate has been the most widely investigated chemical contaminant derived from pit latrines and this is as a result of the high concentrations of nitrogen in human excreta and its adverse impacts on human health (Graham et al., 2013). Sources of Nitrates (NO_3^-) and nitrite (NO_2^-) include the application of Nitrogen fertilizer as well as the disposal of human or animal waste. Both Nitrate (NO_3^-) and nitrite (NO_2^-) are very mobile in water, and groundwater typically contains higher levels than surface water (UNICEF, 2008).

Drinking water with concentrations between 11 and 40 mg/1 causes methemoglobinemia according to Baird (2000). This is sometimes referred to as “bluebaby syndrome”, which can lead to death by asphyxiation amongst bottle-fed infants as a result of a particular enzyme deficiency or direct contamination. Both nitrate and nitrite oxidizes and converts blood haemoglobin (Hb) to methaemoglobin (metHb) when it is taken in; thus the iron atoms in hemoglobin are oxidised from ferrous (Fe^{2+}) ion to ferric (Fe^{3+}) ions thereby rendering it incapable to bind and transport oxygen, and these oxygen-poor blood causes development of a blue colour in tissues (cyanosis). Some of the symptoms of

Methaemoglobinaemia include difficulty in breathing, vomiting and experience diarrhea and is common in infants below 6-12 months of age which is due to the fact that their stomachs are less acidic than those of older children or adults, favouring the reduction of nitrate to nitrite. Their hemoglobin is also more vulnerable to oxidation and arises from short-term rather than chronic exposure to nitrate and nitrite (UNICEF, 2008).

Banks et al. (2007) pointed out that pit latrines are important source of nitrate contamination of groundwater. They acknowledged the contribution of agriculture to nitrate contamination of ground water but suggested faecal contamination from pit latrines, domestic livestock and poor waste disposal practices as a main source of nitrates in groundwater. Fatombi et al. (2012) also associated the presence of nitrates in groundwater to domestic waste water and waste water from leaking septic tanks built near these wells. Simlarly Umezawa et al. (2008) in surveys combining nutrient monitoring in spatially broad areas based on Geographic Information Systems (GIS) and nitrate analyses suggested human wastes through latrines as a cause of groundwater contamination in urban Metro, Manila and Jakarta. They also identified the differential agricultural land uses in the suburban areas of Jakarta and Bangkok to cause different contamination levels.

2.5.3 Total dissolved solids

Total Dissolved Solids (TDS) comprise organic matter and inorganic salts, which may originate from sources such as sewage, effluent discharge, urban run-off or from natural bicarbonates, chlorides, sulphate, nitrate, sodium, potassium, calcium and magnesium (Ojo et al., 2012). TDS concentration beyond 500 mg/l, decreases palatability and may cause gastrointestinal irritation and constipation effects (Maiti, 2001). However, no health based guideline values exist for total dissolved solid. A higher level of dissolved solids increase the density of water, influences osmoregulation of fresh water organism, reduces solubility of gases like oxygen and reduces utility of water for drinking, irrigation and industrial purposes (Maiti, 2004). A study by Ramirez et al. (2010) on microbiological and physicochemical quality of well water used as a source of public supply revealed a relationship between dissolved solids and altitude; here the concentrations of dissolved solids increased in wells with lower altitudes. TDS is the summed ion concentration of minerals dissolved in water.

2.5.4 pH

pH measures the concentration of hydrogen ions. It is measured by using either an electrode, which gives a digital reading, or an acid-base indicator dye, which changes color as the pH increases or decreases. The significance of pH lies on the fact that it influences the taste and odour of a substance significantly (Ojo et al., 2012). Also, Kanyerere et al. (2012) asserts that 'low pH values can lead to health concerns associated with corrosion of the metal containers'. pH of more than 5 is found to increase the survival time of bacteria in soils than acids whiles low pH enhances the retention of bacteria (Yates et al., 1988).

According to Nguyen et al. (1991) a pH range of 5.0-8.5 is suitable for the growth of *Legionella*. Water with low pH increases the solubility of nutrients like phosphates and nitrates, thereby corroding pipes in drinking water distribution systems and releases lead, cadmium, copper, zinc and solder into drinking water. However, the pH levels of water samples are influenced by the presence of dissolved carbonates and bicarbonates (Chapman, 1996). Furthermore, the ability of pH to corrode metals possibly could influence water disinfection. Though no health guideline value has been proposed for this, it is necessary for water treatment to ensure satisfactory water clarification and disinfection.

2.5.5 Temperature

Temperature refers to the degree of coldness or hotness in the body of living organism either in water or on land (Kutty, 1978 as cited in Deekae et al., 2010). Microorganisms' growth is influenced by temperature some of which produce bad tasting metabolites and odour (Ojo et al., 2012). Sakyi et al. (2012) in a study established that water temperature is an important factor in reducing the survival of total coliform and *E. coli*. It has also been noted by Cabral (2010) that a fecal bacterium in environmental waters generally increases as temperature decreases. Low water temperatures aid in longer survival of bacteria (Yates et al., 1988). *Legionella* has been found to survive in varied water conditions, in temperatures of 0-63° C (Nguyen et al., 1991). In contrast to this however, no relationship has been established between temperature and legionella (Witherell et al., 1986).

A study revealed higher occurrence of coliform bacteria when water temperatures were above 15 °C. This shows temperature as a factor influencing bacterial growth. Thus warm climatic zones support rapid bacterial growth than cold climatic zones (WHO, 2003). The concentration of dissolved gases and their solubility in water is also influenced by temperature (Deekae et al., 2010). Increased temperatures also increases the concentration of total dissolved solids through the evaporation of water leading to decrease in water volumes.

2.5.6 Colour

Colour in drinking water is caused by the presences of coloured organic substances, usually humic, which originate from the decay of vegetation in surface water (Ojo et al., 2012). According to the same authors, Iron and Manganese in water gives it red and blue colours respectively as a result of oxidation by bacteria which gives them ferric and manganic oxides respectively.

Naturally, high colour in water does not pose any health problem except on visual grounds which the human being will not agree to consume even if it's of a very high quality as far as its bacteriological quantity is concerned. However, the presence of colour on a persistent basis in water which is disinfected by chlorination is undesirable as a result of the reaction between the colour-causing substances and the added chlorine giving rise to the presence of trihalomethanes which is a potential hazard to public health. Though Levels of colour below 15 TCU are often acceptable to consumers no health-based guideline value is proposed for colour in drinking-water.

2.5.7 Chlorine, residual

This occurs from sources such as water treatment processes, industrial effluents, chlorinated sewage and other effluents. This is not a component of untreated water but as a result of the disinfection of polluted water by using chlorine. The idea is that once disinfection has been done, chlorine residual should be available in the water to prevent any possible recontamination. This is so because chlorine is the widely mode of disinfecting water as a result of the advantages it has over other modes of disinfection. Free chlorine is very reactive and disappears easily in water hence the need for its addition during the disinfection to give combined residual rather than a free one to enable persistence in the water and continues protection. The Colorimetric (N, N-diethyl-p-phenylenediamine) method is the generally used method for testing for chlorine residual.

2.5.8 Turbidity

Turbidity is an expression of certain light scattering and light absorbing properties of water caused by the presence of clay, silt, suspended matter, colloidal particles, plankton and other microorganisms (WHO, 1984). Turbidity is said to affect water quality parameters such as colour, microbial quality as well as chemical quality of drinking water through the formation of complexes between the turbidity causing humic matter and heavy metals.

Turbidity is important, not only in determining the aesthetic acceptability of the water by the consumer, but also because high turbidity reduces the effectiveness of disinfection by chlorine, thereby increasing the health risk to the consumer and for effective disinfection of individual water supplies WHO recommends the turbidity of water to be less than 1 NTU, and less than 5 NTU to disinfect a water-supply system (Aldana, 2010). Turbidity is measured by nephelometric turbidity units (NTU) and can be initially noticed by the naked eye above approximately 4.0 NTU. To ensure effectiveness of disinfection, turbidity should be no more than 1 NTU and much lower values are recommended (WHO, 1984).

2.5.9 Conductivity

The conductivity of water is an expression of its ability to conduct an electric current hence related to the ionic content of the sample which is in turn a function of the dissolved solids concentration. It is a physical parameter of water which reflects the mineral salt content of water. The electrical conductivity of water is used as an indirect measure of the concentration of dissolved solids, which can affect the flavour and salinity of the water. Therefore, conductivity is important because it allows guidelines to be established for water that make it acceptable to users as well as an indication of contamination from sources such as human excreta (Aldana, 2010). Conductivity provides an indication that the composition of the water particularly the mineral concentration has changed (Deekae et al., 2010).

CHAPTER THREE

METHODOLOGY

3.1 Study area

The study was conducted in Wa which is the capital of the Upper West Region. Wa is located at the Southern part of the Upper West Region. The Upper West Region is located in the North-Western part of Ghana and shares borders with the La Cote D'Ivoire to the West, Burkina Faso to the North, Upper East to the East and the Northern Region to the South. Wa is located on latitude 10 03' 59.91□ □ N and longitude 2 30' 00.10□ □ W. It is the largest and most developed town in the region with an estimated landmass area of about 18,476km². The landscape is generally a gently undulating plain, at about 200-350 meters above mean sea level, and is characterized geologically as the Upper and Lower Birrimian (Blench, 2006**).** The town is found on soils formed over Birrimian rocks, post-Birrimian granites and associated basic rocks and mixed recent alluvium. It is characterized by flat plains cut by granite outcrops and out crops of red laterite. The region is cut across by the Black Volta, the only perennial system, which runs north to south across the region and is drained by a number of rivers such as the Bole, Molebele, Fuyien, Banaghasis among others, which are extensions of the Black and White Volta.

The climate is tropical equatorial or continental which prevails throughout the northern part of Ghana with one rainy season from May to October and a dry season from November to March with humidity ranging between 70-90% but falling to 20% in the dry season (Otupiri, 2012). The region receives an annual mean rainfall volume of between 840 mm and 1400 mm which is sparsely and poorly distributed over the raining months, characteristically erratic and punctuated by spells of long droughts and heavy downpours sometimes causing floods (MOFA, 2011). The area has an average minimum temperature of about 15°C and maximum of about 40°C (GHS, 2008).

The region is located within the Guinea Savanna zone (Otupiri, 2012) and is characteristically grassland and interspersed with scattered trees and shrubs with the grasses growing up to heights of about three to four meters during the raining seasons consequently informing their usage as thatch for roofing. The area is characterized by drought resistant trees which shed off their leaves during the dry season with the grasses drying up hence making them susceptible to fires a common phenomenon in the area. Some tree species found in the area are the shea, (*Vitellaria paradoxa*), the mahogany, (*Khaya senegalnesis*), the silk-cotton, (*Ceiba pentandra*) and Baobabs, (*Adansonia digitata*) as well as introduced trees, such as the neem, (*Azadirachta indica*), and the mango (*Mangifera indica*).

According to the Ghana Statistical Service (2012) census results, the Wa municipality has a population of about 107,214 of which 52,996 are males and the remaining 54,218 are women. It is a muslim dominated community and the main city of the Wala people. Wa is the seat of the Wa-Na who doubles as the Paramount Chief of the Wala traditional area.

The Upper West Region recorded 88% rate of incidence of poverty (GLSS 5, 2008) and as result average household incomes are very low. The survey also indicated that about 80% of household's expenditure is spent on food and 20% on rent, education, health, utility charges and funerals. Wa is an agricultural dominated community and according to the 2000 population and housing census organized by the Ghana Statistical Service (2000), about 69.8 % males and 63.4% of females are involved in agricultural and its related services, followed by the production and transport sector accounting for 9.4% of males and 14.6 percent of females (GSS, 2000). The main crops cultivated are corn, millet, yams, okra and groundnuts with 'tuo zaafi' (T. Z.) being the dominant food. 'Tuo zaafi' is a local dish in northern Ghana prepared from corn flour, cassava flour or both. A number of the inhabitants are involved in some petty trading in items such as grains and cattle.

In terms of basic facilities such as electricity, small town water supply system, hospitals, major financial institutions, Wa is better off in comparison to other towns in the region. Transport services for the people within the area are relatively better with motorcycles being the most dominant means of transport in the area.

Major sources of drinking water in the township include the Small Town Water System (STWS), boreholes, hand dug as well as rainwater. With respect to sanitation, the town is unsewered whiles refuse are dumped haphazardly. The drainage system is poor and many of the gutters are choked.

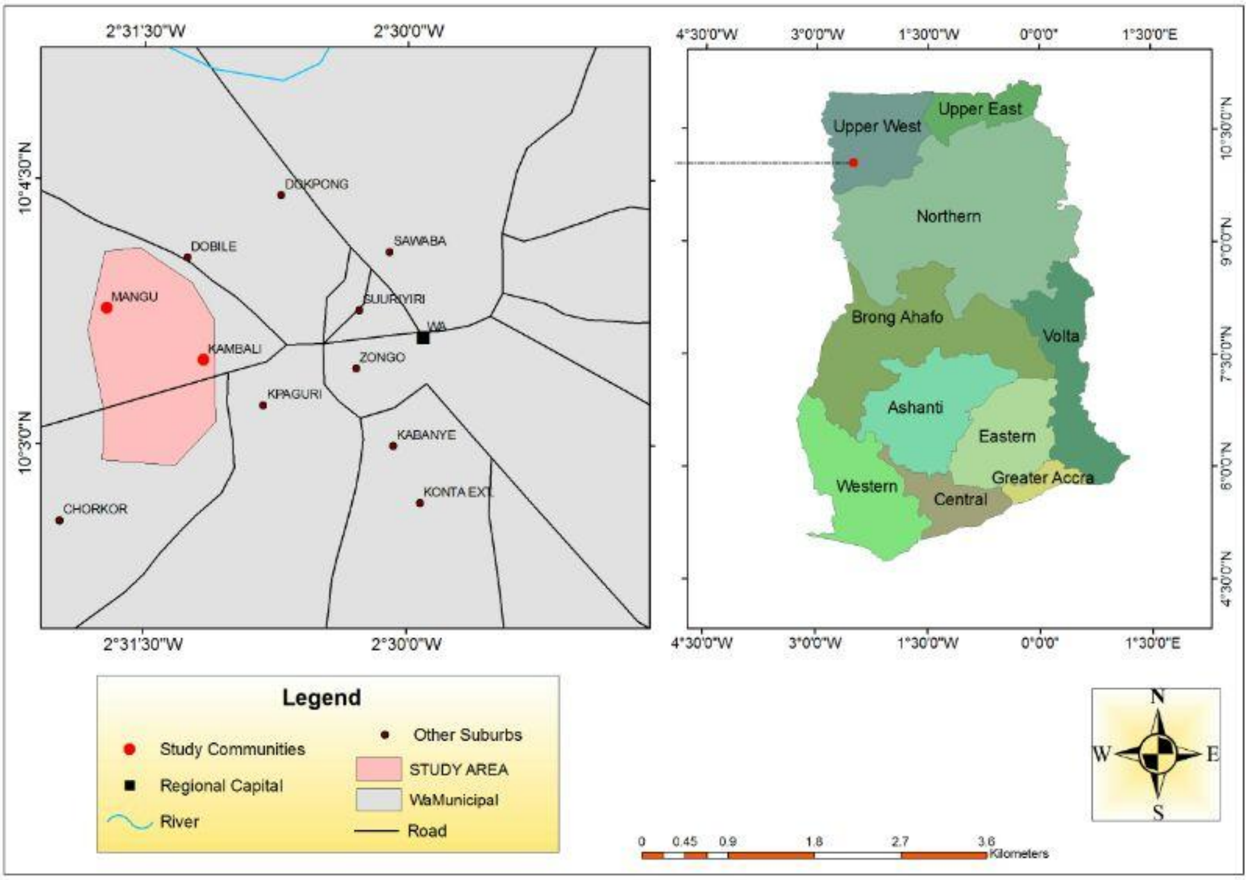

Figure 1: Map of study area

3.2 Study design

The study is a cross sectional study conducted in the Kambali and Mangu communities within the Wa Township. Non probability sampling approach was employed in selecting thirty households with wells for the sampling. The number was also selected based on an approximation that it forms about ten percent of wells in the study areas (Personal Communication). Also factors such as time and resource availability were taken into consideration. The wells were selected based on their proximity to the Kambali dam which is a valley and the water table expected to be high. Five boreholes, all at least 50 meters away from the nearest latrine, were also randomly sampled for use as controls (WHO, 1992). Lateral distances between hand dug wells and the nearest household latrine were determined using a measuring tape. The location of latrines and wells were noted using a handheld Global Position System (GARMIN 45 GPS).

3.3 Data collection

Water quality data was collected by sampling water directly from selected hand dug wells. Water sampling was done in October, 2012 and March, 2013. For each sampling session, three 500ml of water from each selected well was collected into sterilized plastic bottles and transported in ice chest at a temperature of about 4 °C to the laboratory for the analysis. A sterilized rope and a wide mouthed 4.5 liter bucket were used in drawing water from the wells. Regarding the control samples, boreholes were flushed once following which the water was directly collected into the sampling bottles. All water samplings were done early in the morning between 6 am and 8 am. Collected water samples were transported to the laboratory within three hours of collection.

3.4 Quality control

Sterilized 500ml containers were used to collect the samples because of the bacteriological assessment that was conducted. All samples were properly labeled noting time, location and date of collection. Water samples that were not analysed immediately on the field were transported to the laboratory at controlled temperature levels of 4 degrees Celsius in ice chest. During sampling, all bottles were held at the bottom and not the top or neck to prevent contamination. Standard protocols in handling scientific data according to APHA (1998) were employed.

3.5 Water analysis

3.5.1 pH

The pH of the samples was determined using the pH meter (Jenway pH meter, model no. 370). Measurement was carried out by immersing the cell in the samples. The readings were then allowed to stabilize and results recorded. The cell was rinsed in deionized water, shaken to remove internal droplets, and the outside wiped prior to immersion in the next sample to avoid possible contamination by samples from the previous well.

3.5.2 Temperature

Temperature of the samples was taken using the pH meter (Jenway pH meter, model no. 370). This was done by placing the cell below the water surface of the sample to a depth of about four inches for about a minute. The readings were then allowed to stabilize and recorded.

3.5.3 Conductivity

The general purpose hand held conductivity meter (MODEL 470) was used to measure the conductivity of the samples. Measurement was carried out by immersing the probe into the sample. The readings were then allowed to stabilize and results recorded.

3.5.4 Colour

The colour of the samples was tested using Lovibond comparator (2000+). One Nessler cylinder was filled just on the 50 ml. mark with the samples and the antimeniscus plunger fitted. The cylinder was then placed in the right hand compartment of the Nesleriser. Another Nessler cylinder was filled in the same way with deionized water and place in the left hand compartment. The disc was then inserted into the lid and Nesleriser fitted to the

Daylight 2000 unit. The disc was then rotated until the closest colour match was obtained. Displayed values were then recorded.

3.5.5 Turbidity

Turbidity was measured using HACH 2100Q and 2100Qis. The turbidity meter was powered on after which the 20 NTU (Nephelometric Turbidity Unit) cell was filled with the sample. The cell was then cleaned with a cloth. The sample cell holder was then inserted and covered with the lid and the readings read.

3.5.6 Nitrate and nitrite

Nitrite and nitrate tests were done employing Hach Aquachek. A strip was dipped into the sample for a second and removed. The strip was held level, with the pad side up for about 30 seconds. The nitrite test pad (bottom pad) was then compared to the color chart and the recordings taken. Afterwards, the nitrate test pad was also dipped in to the sample and the pad side held up for 60 seconds after which the test pad (top pad) was also compared to the color chart. The results were then also estimated and recorded.

3.5.7 Chlorine, residual

Chlorine residual in the samples was determined using HANNA Instrument. A pipette was used to fill each glass vial with 5 ml of sample. One of the vials was then inserted into the left hand opening of the checker disc. This is known as or referred to as the blank. Deionized water was then added to the other vial up to the 10 ml. mark. The cap was then placed back and shaken to mix after which 1 packet of HI 93701-0 reagent was added. This was also shaken vigorously to mix to form the reacted sample. The reacted sample was then inserted into the right hand of the checker disc. The checker disc was then held to light to illuminate the samples from the back of the window. The checker disc was kept at a distance of 30-40 cm (12-16'') from the eyes to match the color. The disc was then rotated whiles looking at the color test windows and stopped when the color match was found. Readings and recordings were then noted.

3.5.8 Bacteriological analysis

Presence of bacteria was determined using the Pour Plate method. MacConkey Broth (70g) powder was weighed (double strength) and dispersed in distilled water. This was mixed well by shaking and dispensed into bottles with inverted Durham tubes. Sterilization was done by autoclaving for 15 minutes at 121^0Celcius. The water sample (10ml) was added to 10ml media solution (MacConkey) and incubated for 24hrs at 35^0C. Gas and acids changed from pink to yellow colour indicating the presence of bacteria.

3.6 Well and latrine assessment

An assessment of the wells and latrines was undertaken based on field observation as well as unstructured interviews. Questions were based on factors such as latrine type, location, hygiene practices and type of structure used.

3.7 Questionnaire administration

Sociological data and other relevant information on the perception of inhabitants about the quality of water they consume, their sources of water, knowledge of groundwater pollution by pit latrines, factors influencing their choice of well and latrine location were elicited using questionnaire. A total of two hundred questionnaire were purposively administered based on the availability of well in the house. They were however randomly administered to one respondent from each household above the age of eighteen. This was carried out in March (dry season) alongside the dry season sampling.

3.8 ArcMaps

GPS coordinates for Nitrates, pH, Turbidity, Conductivity and Total Dissolved Solids were plotted in ArcMap based on the data of wells and latrines available and their corresponding attributes. Ranks were then generated for the parameters based on the spatial location of wells using symbology in ArcMap. Latrine concentration map was then generated by creating a grid of 5 seconds interval over the study area and values were assigned to grids containing latrine facility depending on the number within each grid. An Inverse Distance Weighted (IDW) spatial analyst interpolation technique was then employed to show the distribution of the latrines. The parameters were then overlaid on the latrine concentration raster and the corresponding maps produced. Analysis and interpretations were then made pictorially.

3.9 Statistical analysis

The Statistical Package for Social Scientist was used in undertaking the statistical analysis. The t-test was used to establish the differences between well water quality for both the dry and the raining season. Means and standard deviations were also run using the same package for comparison with the WHO standards. These values were then illustrated on a table. Microsoft excel was used to generate bar graphs and pie charts to clearly illustrate the results obtained from both the laboratory analysis and the social survey.

CHAPTER FOUR

RESULTS

4.1 Mapping of wells and latrines

The figure (2) below shows the hand dug wells and latrines that were sampled. A total of thirty hand dug wells together with five control boreholes have been mapped. Latrines that are within a recommended distance of 50 meters from household wells were also mapped to be used for the generation of latrine distribution map.

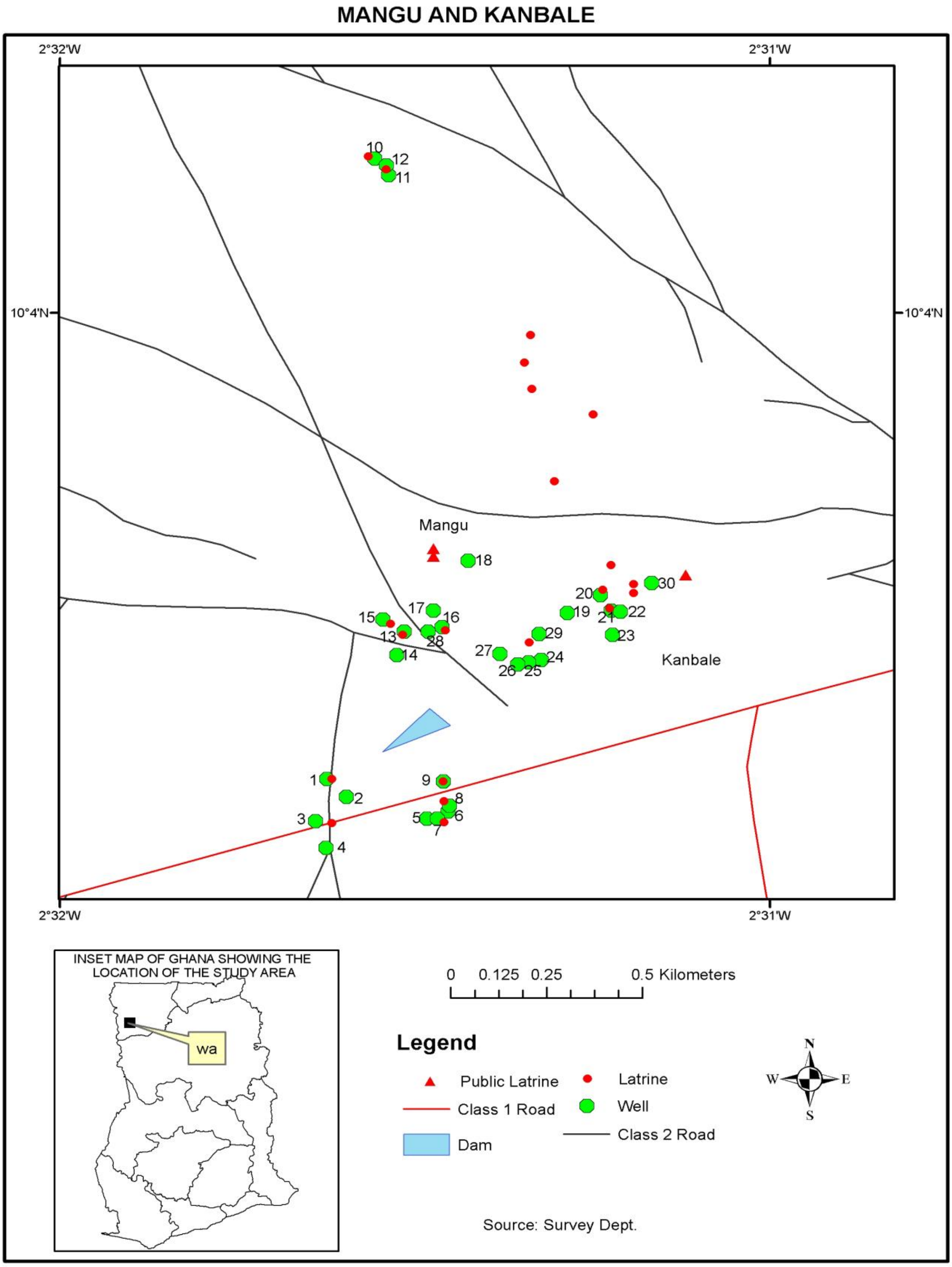

Figure 2: GPS locations of wells and latrine

4.2 Well assessment

Fifteen wells were visually inspected. Out of these, 11(73%) of them were in the middle of the households that served as compound houses and the remaining 4 (27%) wells were outside the houses. Five (33%) out of the fifteen wells lacked headwalls allowing surface water to get into the wells. The headwalls were of varying heights ranging from about half to one meter from the ground. The inner perimeters of all 15 wells were however lined with either concrete (plate 2) alone or concrete and stones (plate 8) except that the linings were not of good quality (plate 8). Thirteen (87%) wells had covers made from wood and metal and 9 (69%) out of the 13 were locked (Plate: 1 and 2). Surroundings of the wells were kept clean since most of them are situated in the middle of the house. All households use ropes tied to gallons (plate 1) or buckets (plate 2) to draw the water. It was realized that none of the wells had a fence around it to prevent animals and fowls from coming closer and in certain situations animals were seen lying beside the headwalls (plate 7).

4.3 Latrine assessment

Latrines were constructed by digging pits to contain the sludge and they were usually housed in either a concrete structure or sheds. All of the latrines had cover slabs. Foot rests which were made of concrete were raised above the slabs to make squatting very convenient. However, 7 (47%) out of the 15 pit latrines assessed had lids to prevent flies and odour from emanating from the pits. Out of the 7 latrines that had lids, 5 households however used boards that were large enough to cover the whole openings to the pit. All latrines had a single opening for both urine and the faeces dumping. All the latrines had superstructures which served as protection from rain and sun. Majority of the households, 12 out of the 15 (80%) had one pit latrine and 3(20%) of the households had two pit latrines. All the pit latrines have vents whiles none of the latrines had hand washing facility for users to wash after use. Averagely, five people use a latrine all of which the inhabitants claim have linings in the pit walls to prevent collapsing. All the latrines are shared with 10 (67%) of them properly cleaned.

4.4 Household latrine and well distance

The distances between household latrines and wells ranged from 5 meters (for household 9) to 30 meters (household 6) and this is shown on table 1. The average distance recorded between household latrines and wells was 13.7 meters. In general, wells were at a lower elevation than household latrines. Thus 8 (57%) wells were located on a lower elevation than the household latrine, 5(36%) of the household had their latrines on a lower elevation to the wells and 1(7%) had its latrine and well occupying the same elevation (table 4.1).

Table 4.1: Household wells and latrine distances and elevations

House	Distance (m)	Well Elevation (m)	Toilet Elevation (m)	Remarks
1	14	299.6	301.5	well is low
3	13	301.1	299	well is high
6	30	302.1	298.7	well is high
7	14	296.6	310	well is low
8	19	306.3	298.7	well is high
9	5	302.1	302.1	the same
10	16	292	285	well is high
11	17	288.7	290.8	well is low
13	10	296.9	298.7	well is low
15	10	302.1	304.2	well is low
16	11	292.9	300.8	well is low
20	16	298.7	296.9	well is high
21	8	296.3	298.7	well is low
28	9	291.7	292	well is low

Plate 1: A protected hand dug well

Plate 2: An unprotected hand dug well

Plate 3: A protected hand dug well

Plate 4: The pit of a latrine

Plate 5: A well in a backyard garden

Plate 6: A well closer to a pit latrine

Plate 7: Animals leaving by a hand dug well

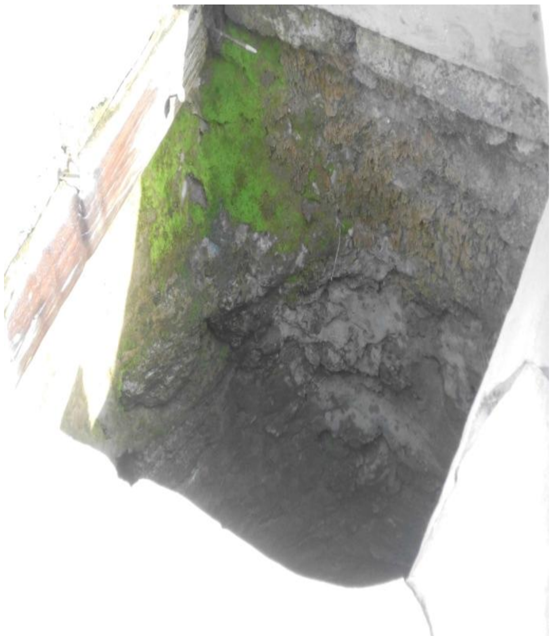

Plate 8: The interior of a hand dug well

4.5 Water quality

The water quality parameters assessed have been presented in Table 4.2. WHO standard acceptable limits were not available for colour, conductivity and temperature. The mean level of all the parameters determined were all below WHO limits apart from nitrates which was significantly high.

Table 4.2: Physico-chemical characteristics of ground water in the study area.

Parameter	Range	Mean	SD	Mean*	WHO limit (2011)
pH	6.56-7.67	7.206	0.33	6.96	6.5-8.5
Chlorine (mg/l)	00.0-00.0	0.00	0.00	0.00	5mg/l
Turbidity (NTU)	0.18-85.3	9.25	16.4	2.60	15 NTU
Colour (Hz)	5.00-85.0	10.3	14.2	5.00	5Hz
Conductivity (µs/cm)	85.0-921	368	192	376.8	-
Temperature (°C)	24.9-32.1	28.7	1.96	30.3	-
TDS (mg/l)	47.1-553	226	119	218	1000 mg/l
Nitrites (mg/l)	00.0-00.0	0.00	0.00	0.07	0.9 mg/l
Nitrates (mg/l)	0.00-10.0	2.08	2.84	0.90	11 g/l

* is value for borehole

4.5.1 Seasonal variation in physico- chemical parameters

Seasonal variation was noted for some of the parameters assessed. Significant variations were observed with turbidity ($p=0.012$), conductivity ($p=0.00$), temperature ($p=0.00$) and total dissolved solids (p=0.00) at 95% confidence interval. No significant variations were recorded for pH, water colour and nitrates between the dry and raining season (as shown in table 4.3). There was significant difference in pH (p=02) and temperature (.015) between the values recorded for boreholes and the hand dug wells.

Table 4.3: Variations between the seasons and the wells and boreholes at 95% confidence level

Parameter	Mean (wet)	Mean (dry)	t	Sig.	t*	Sig. *
pH	7.17	7.24	-.767	.446	2.26	.027
Turbidity	14.5	4.01	2.60	.012	1.27	.207
Colour	11.8	8.83	.814	.419	1.18	.243
Conductivity	254	483	-5.76	.000	-.135	.893
Temperature	27.2	30.3	-10.2	.000	-2.48	.015
TDS	153	299	-5.92	.000	.205	.838
Nitrates	1.48	2.67	-1.64	.107	1.29	.202

* shows difference between wells and control boreholes

4.5.2 pH

The pH values of water from the wells ranged from 6.56 to 7.67 for dry season and 6.59 to 7.6 for the wet season. The highest value for the dry season was recorded for well 26 whiles that of the wet season was recorded for well 9 (figure 3). The mean pH for the wet and dry seasons are 7.17±0.32 and 7.24±0.34 respectively whiles mean pH values recorded for boreholes for the wet and dry season are 7.19 ±0.06 and 6.72±0.13 (table 4.2). There was no significant difference between the values recorded for the dry and wet seasons (table 4.3).

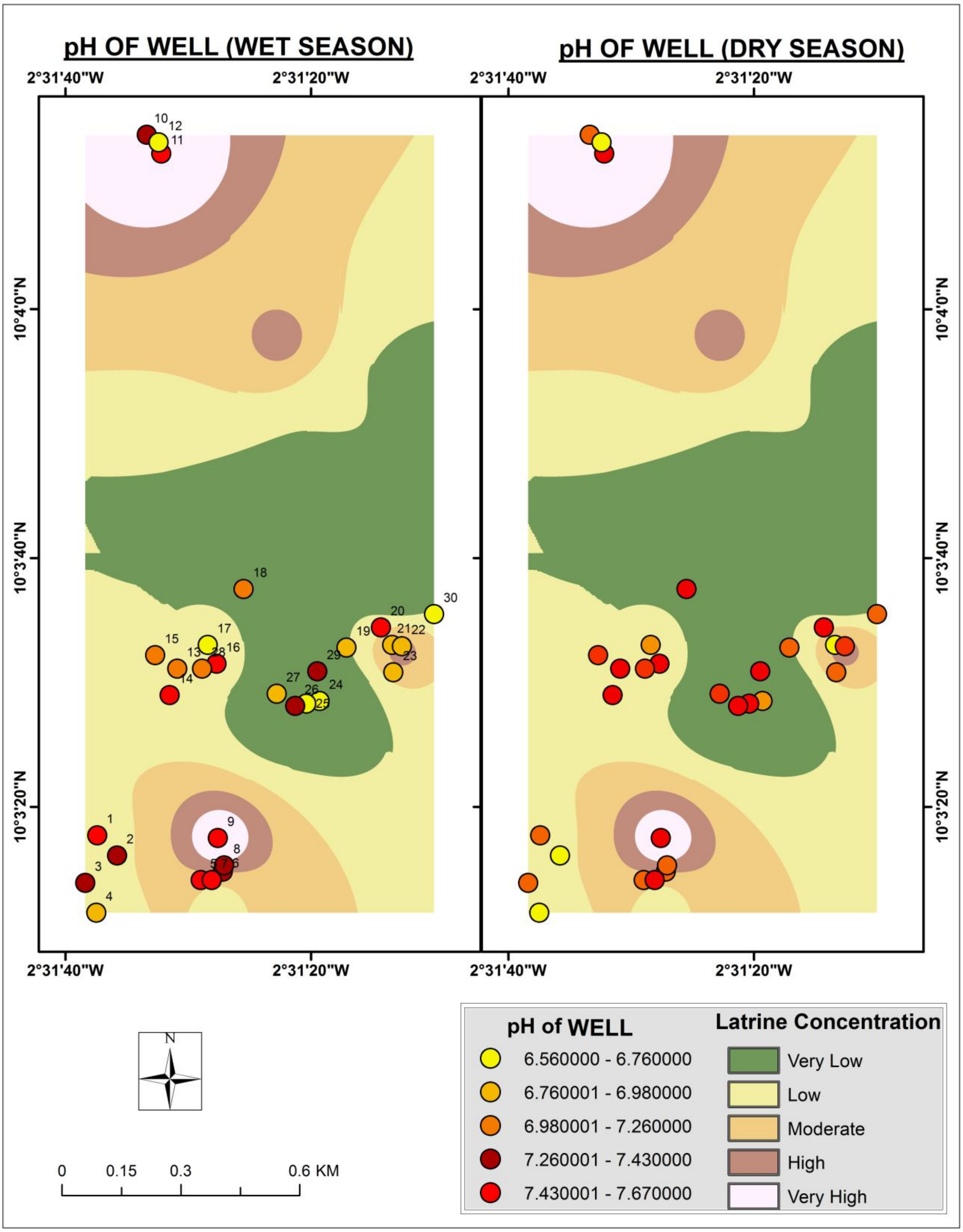

Figure 3: pH of wells for wet season (October, 2012) and dry season (March, 2013)

4.5.3 Turbidity

The figure (4) below illustrates the turbidity of well waters from the study area. Turbidity values were lowest (0.35 NTU) in well 5 and highest (15.6 NTU) in well 3 for the dry season and lowest (0.66 NTU) in well 9 and highest (85.3 NTU) in well 3 for the wet season. Mean turbidity values recorded for wet season wells were 14.50±21.51 NTU and that of the dry season recorded 4.01±4.96 NTU (table 4.2). Meanwhile the mean values recorded for the controls were 3.31±0.95 NTU and 1.94±1.59 NTU for the wet season and dry season respectively. There is significant differences in the values recorded for the dry and wet season in the study area ($p<0.05$) from table 4.3.

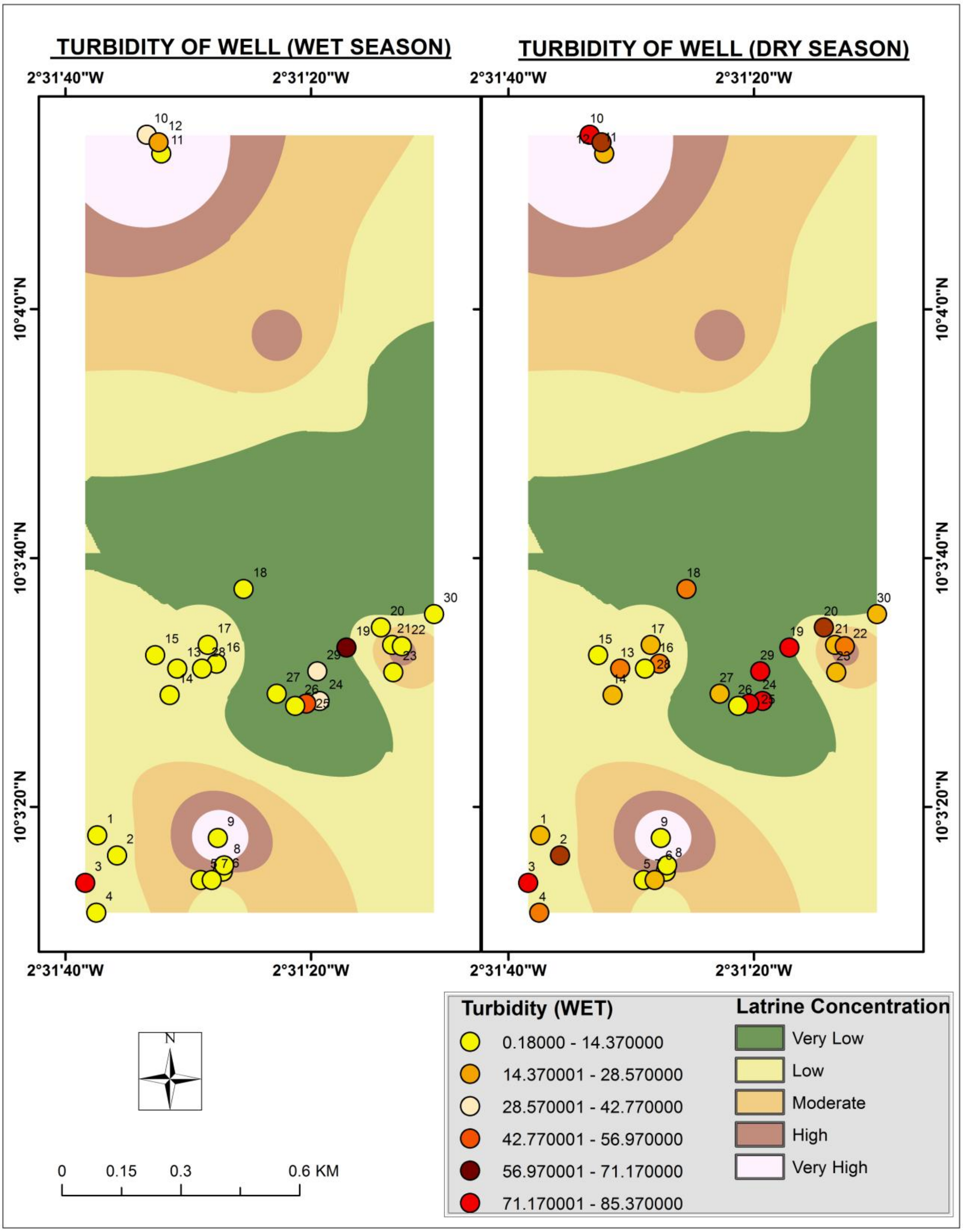

Figure 4: Turbidity of wells for wet season (October, 2012) and dry season (March, 2013)

4.5.4 Colour

Colour of well water for the study area ranged from a minimum of 5 Hz to 85 Hz. Wet season water colour ranged from 5 Hz to 60 Hz at well 19 with a mean of 11.83±13.86 Hz. Values recorded for the dry season ranged from 5Hz to 85Hz with mean value of 8.83±14.66 Hz (table 2). Boreholes colour was 5 Hz for both seasons with a mean value of 5Hz (table 2). No significant difference was established in colour with reference to the dry and wet seasons in the study area (table 3).

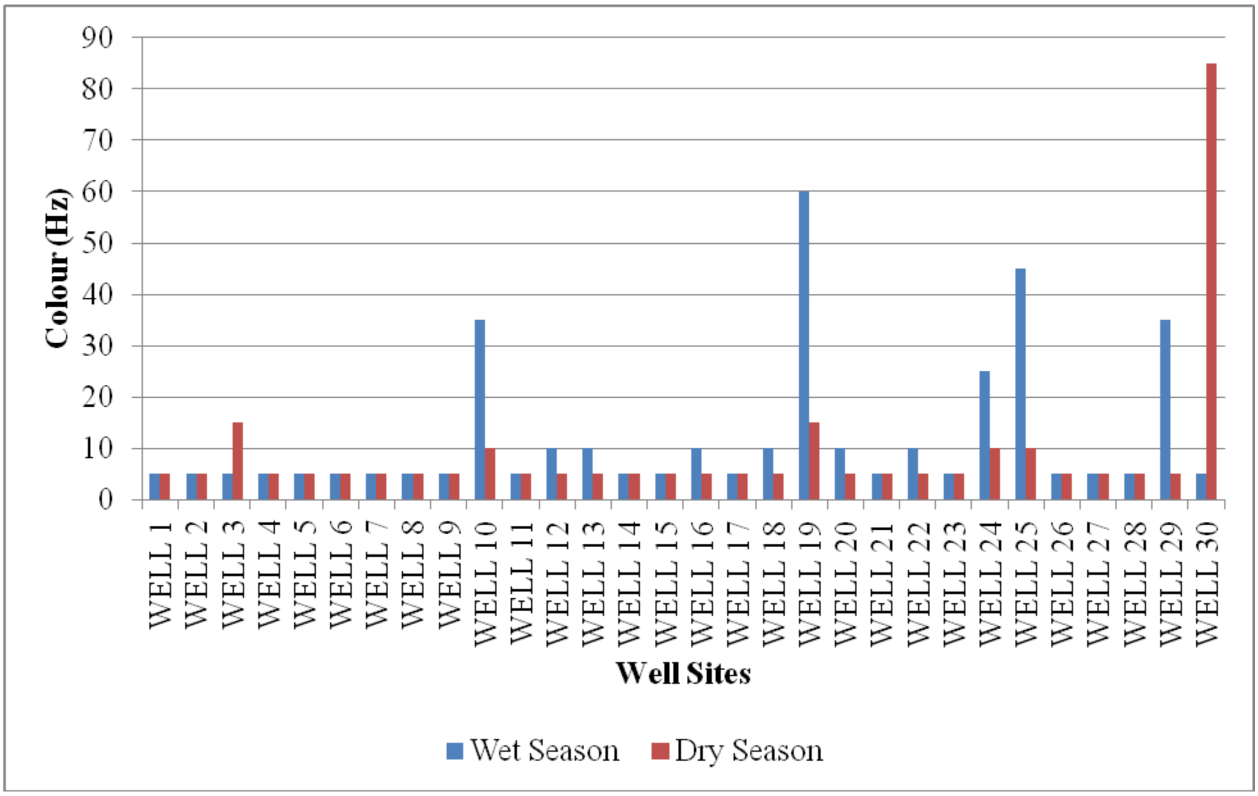

Figure 5: Colour of well water for wet season (October, 2012) and dry season (March, 2013)

4.5.5 Conductivity

Values recorded for conductivity of well water as illustrated in the figure (6) below ranged from 85µS/cm at well 3 to 481µS/cm at well 22 for the raining season with mean value of 253.63±101.96 µS/cm whiles that of the dry season ranged from 101.1µS/cm at well 3 to 921µS/cm at well 5 with a mean value of 483.17±192.88 µS/cm (table 2). Control boreholes recording ranged from 344µS/cm to 530 µS/cm with a mean of 418.80 ±75.90 µS/cm for the wet season and a range of 202 µS/cm to 420 µS/cm for the dry season also recording a mean value of 334.80±86.77 µS/cm (table 2). There was significant difference in the levels recorded at $p<0.05$ significant level for both seasons in the study area (table 3).

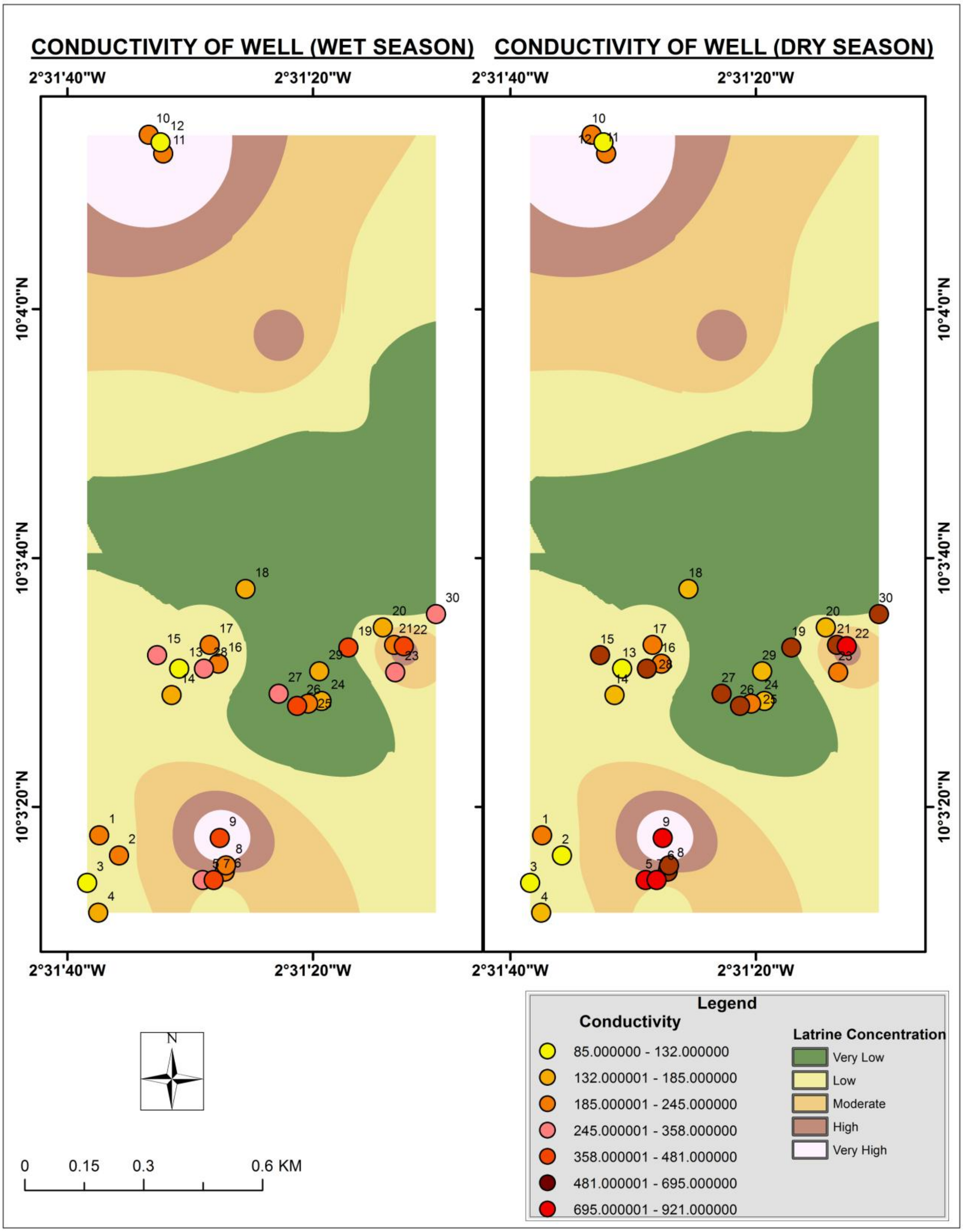

Figure 6: Conductivity of well water for wet season (October, 2012) and dry season (March, 2013)

4.5.6 Temperature

The temperatures recorded for the well sites ranged from 24.9 °C at well 13 to 30 °C at well 29 (mean of 27.2±1.47 °C) for the raining season. Recorded temperatures for the dry season ranged between 28.8 °C for well 5 and 32.1 °C for well 9 (mean of 30.3±0.90 °C). Temperatures of boreholes for the wet season also ranged from 28.4 °C to 31.1 °C (with a mean value of 29.3±1.22 °C) whiles that of the dry season ranged from 31.20°C to 31.6 °C (with a mean value of 31.38±0.20 °C). Figure 7 below shows the recorded well water temperatures for both seasons. Temperature recorded for the study areas showed significant difference between the dry and the wet seasons at $p<0.05$ significant level.

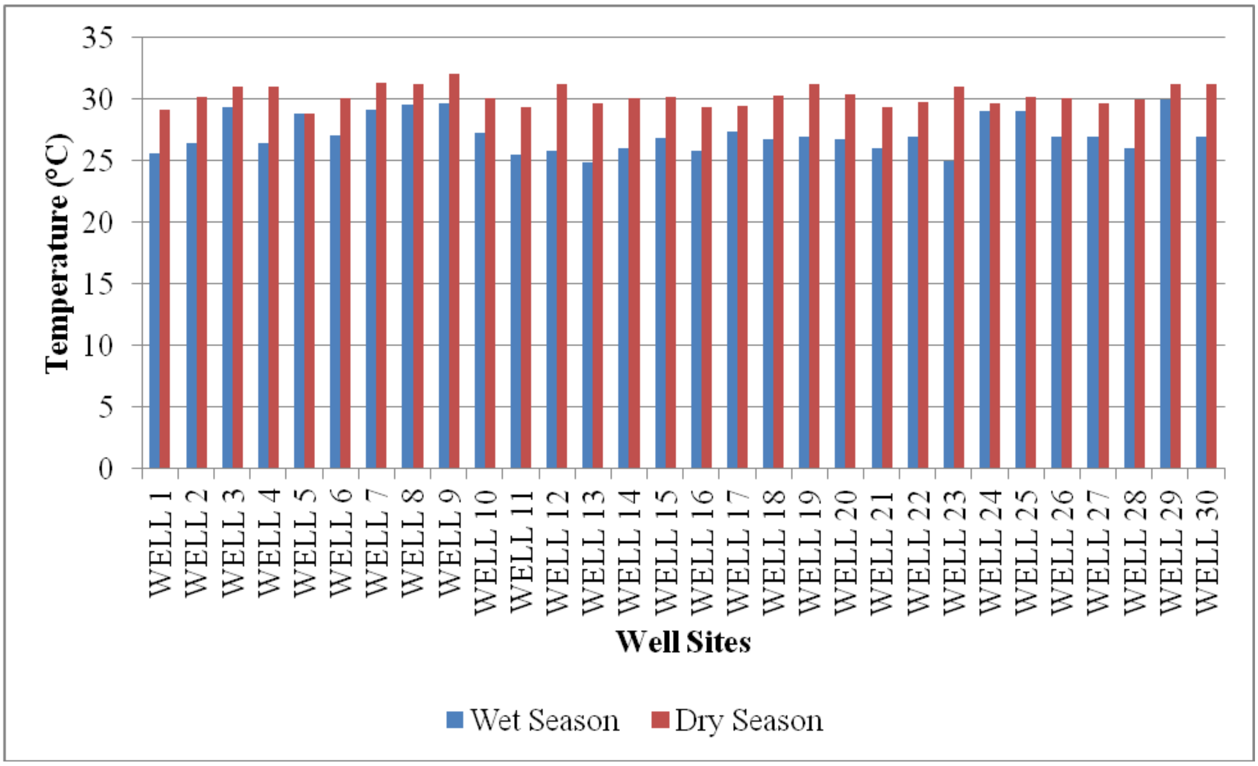

Figure 7: Temperature of wells for wet season (October, 2012) and dry season (March, 2013)

4.5.7 Total dissolved solids

The values recorded for total dissolves solids from well waters varied from a minimum of 47 mg/l at well 3 to 469 mg/l at well 22 with a mean of 153.39±62.20 mg/l for the wet season whiles dry season values ranged from 61 mg/l at well 3 to 553 mg/l at well 5 with a mean value of 298.56±50.30 mg/l from figure 8 and table 2 respectively. The recording made for the control boreholes ranged from 200 mg/l to 318 mg/l with a mean value of 237±50.30 mg/l and 124 mg/l to 254 mg/l with a mean value of 199.16±51.87 mg/l for the wet and dry seasons respectively. Values recorded for total dissolved solids showed significant difference between the dry and the wet season at $p<0.05$ significant level.

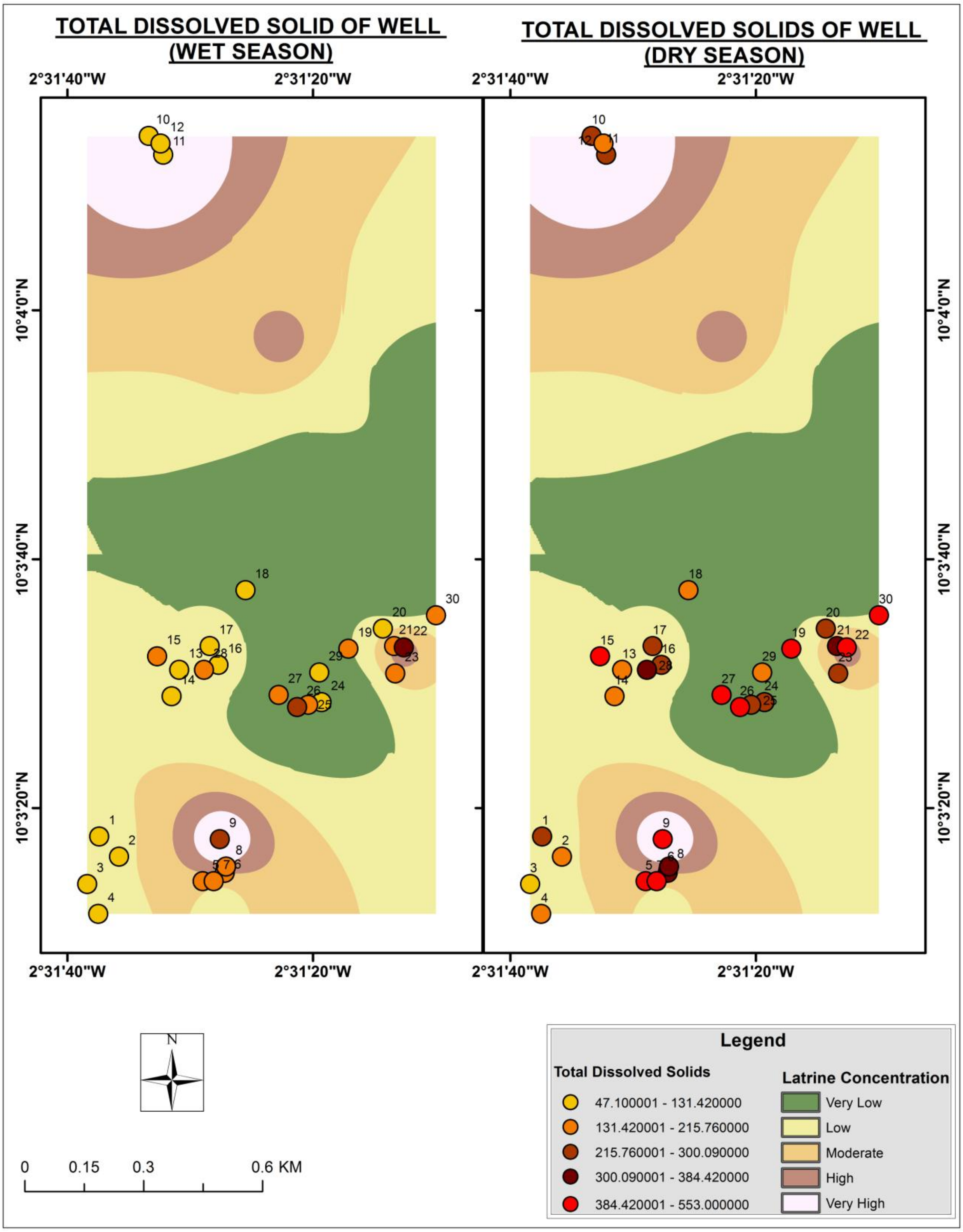

Figure 8: Total dissolved solids from well for wet season (October, 2012) and dry season (March, 2013)

4.5.8 Nitrates

Figure (9) below illustrates the values that were recorded for nitrate levels in wells in the study area. The highest value for the wet season was recorded for well 16 (4.5 mg/l) whiles that of the dry season was 7.5 mg/l for the same well. Mean values recorded for nitrate for the wet and dry season are 1.48±1.80 mg/l and 2.67±3.52 mg/l respectively. Borehole means recorded for the wet season stood at 1.20±1.30 mg/l whiles that of the dry season stood at 0.60±0.89 mg/l. Nitrate levels recorded in the wells did not show significant difference at $p<0.05$ significant level with reference to the various seasons (table 3).

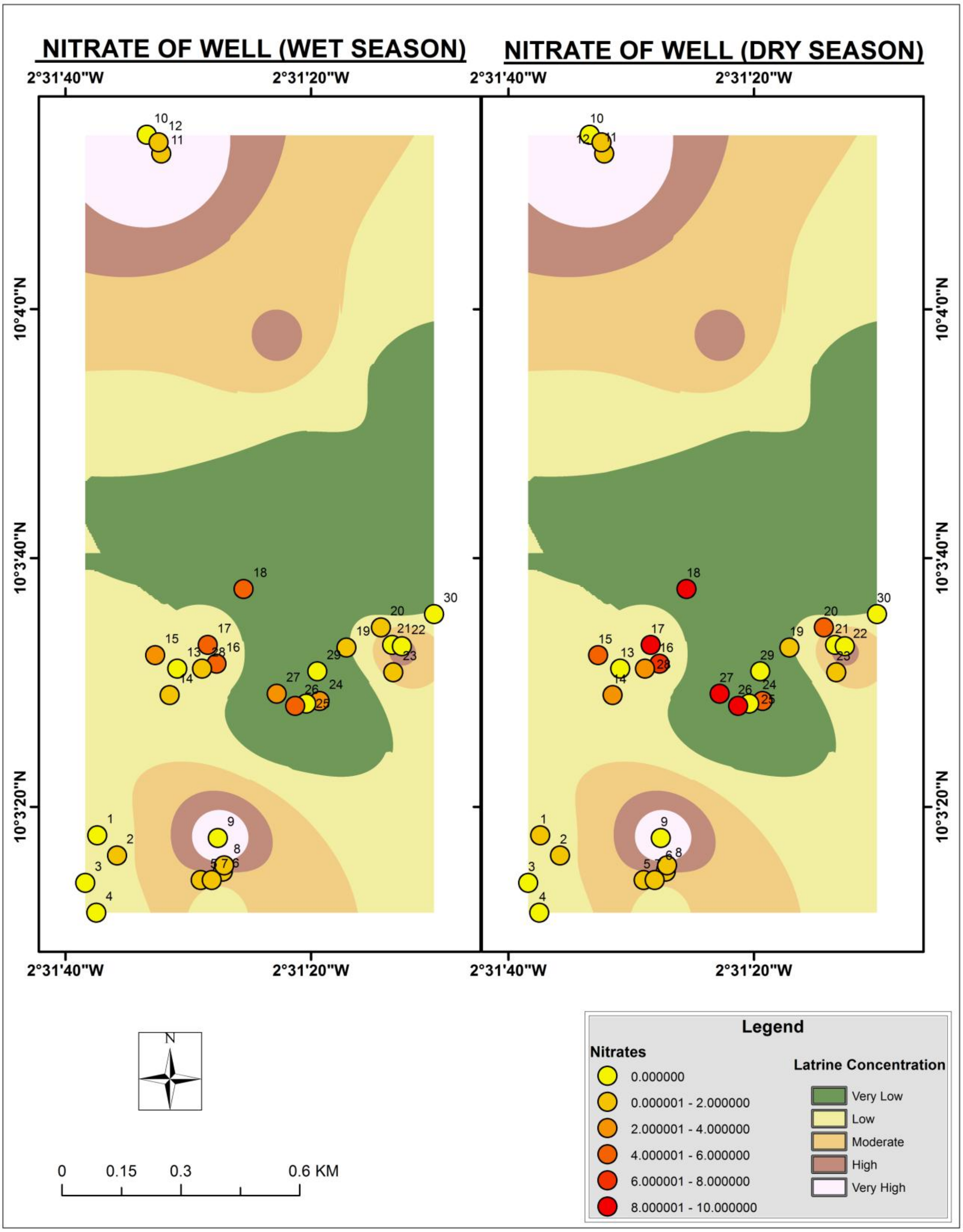

Figure 9: Nitrate levels in wells for wet season (October, 2012) and dry season (March, 2013)

4.5.9 Chlorine, residual and nitrites

Results recorded indicated that no nitrites were found in the wells. Also Chlorine, residual was also found to be absent in well waters in the study area for both seasons. Smaller amounts of nitrites were however present in boreholes 4(0.5) and 5 (0.15) during the wet season but absent for the dry season.

4.5.10 Bacteriological levels

Bacteriological analysis showed the presence of bacteria in samples for both seasons. Buds of 8 and above were recorded for all samples in both seasons. However, boreholes in the study area all tested negative for the bacteria.

4.6 Social Survey

4.6.1 Socio-demographic characteristics of respondents

The demographic information on respondents was focused on sex, age, marital status, educational level, period of stay in the area and household size as shown in Table 4. Majority of the respondents were females representing 51% of the total respondents. Out of the two hundred respondents, 3.5% of them were less than 20 years, 14% of them were in the age range of 20-29, 29% of them were in the age range of 30-39, 30% of them were in the age ranges of 40-49, 15% of them were in the age ranges of 50-59 whiles 8.5% of them were 60 years and above (Table 4). With respect to education, 57 (28.5%) respondents had no formal education, 63 (31.5%) respondents attained tertiary education, 62 (31%) respondents had secondary education whiles 18 (9%) respondents acquired primary education (Table 1). Most (55%) respondents were married with a few (6.5%) being divorced (Table 4). Responses were also sought on how long the respondents had lived in the area together with their household sizes. Majority of the respondents also had households size of less than five making up 41% (82 respondents) of the total respondents. Below is a table illustrating the gender and marital status of respondents in the study area.

Table 4.4: Socio-demographic characteristics of respondents

Characteristics	Frequency	Percent
Gender (n=200)		
Male	98	49
Female	102	51
Age category (n=200)		
< 20	7	3.5
20-29	28	14
30-39	58	29
30-39	60	30
50-59	30	15
60+	17	8.5
Marital status (n=200)		
Married	110	55
Single	43	21.5
Widow/ Widower	34	17
Divorce	13	6.5
Educational level(n=200)		
Primary	18	9
JHS/ SHS	62	31
Post SHS/ Tertiary	63	31.5
None	57	28.5
Household size (n=200)		
<5	82	41
5-9	72	36
10-14	31	15.5
15-19	13	6.5
20+	2	1

4.6.2 Sources of water

Out of the 200 hundred respondents, 95 of them constituting 47.5% of the respondents use wells as source of domestic water, 70 (35.0%) of them patronize borehole, 29 (14.5%) of the respondents use pipe borne with just 6 (3.0%) employing the services of water vendors as their major source of water (Figure 10). The reasons for the patronage of a particular source of water include poverty (16%), distance (33%), availability (49%) and quality (2%) from Figure (11).

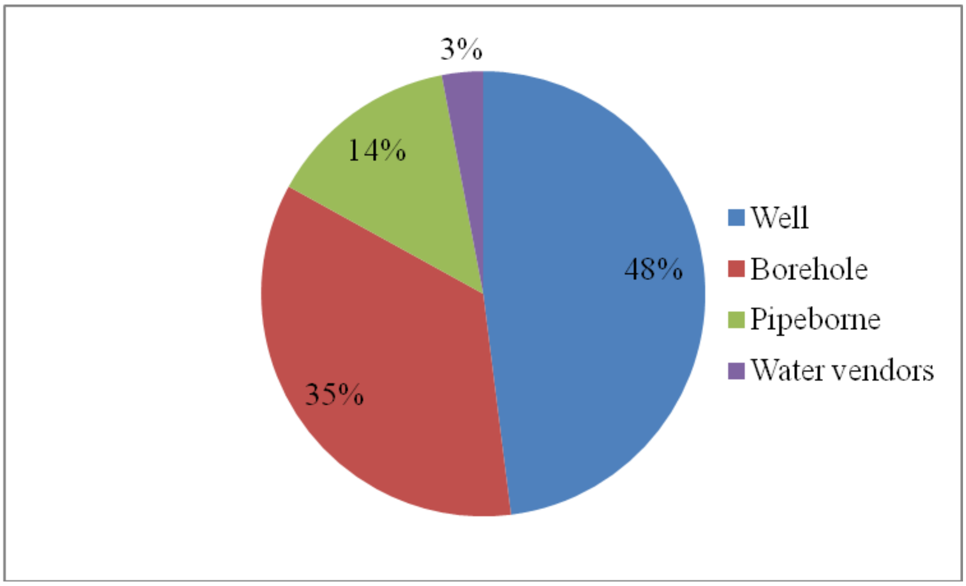

Figure 10: Sources of water

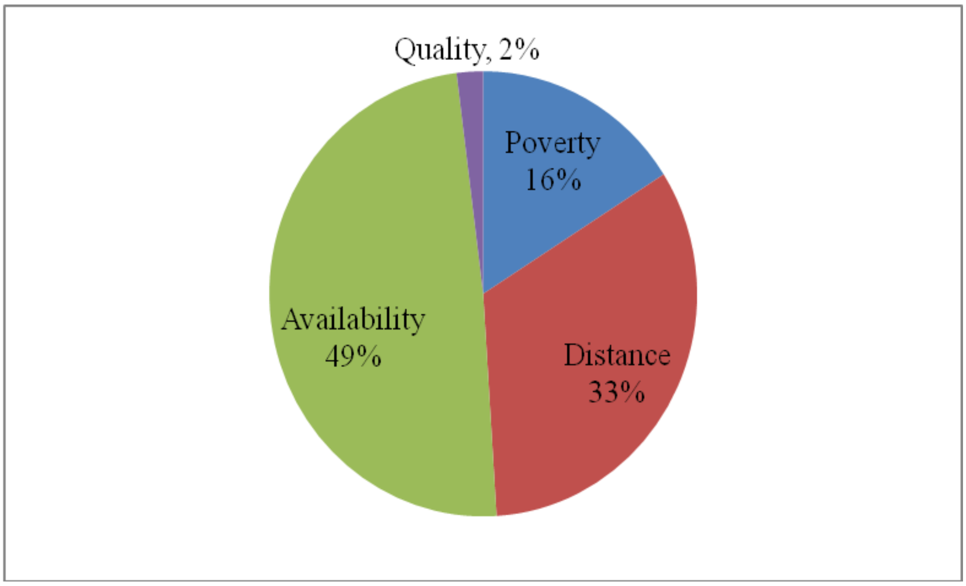

Figure 11: Reasons for patronage of water sources

4.6.3 Water availability and usage

Since the survey was purposive, all respondents interview had wells in their houses. The questionnaire sought to find out what therefore prompted the respondents to dig wells since varied sources of water according to them were available. Accordingly 109 (54.5%) respondents said it was because of water scarcity that they dug wells, 44 (22%) respondents dug wells because of distance from other sources, and 24 (12%) respondents said the dug wells as a result of the nearness of the water table to the surface and 23 (11.5%) of them said it was because of cost involved in accessing other water sources. The respondents were also asked the major uses that the well water is put and out of the total, 32.5% (65) directly consumed it, 48.0% (96) used it for washing and bathing, 29 of them constituting 14.5% of the population use well water to cook whiles 5% equaling 10 respondents use it for agricultural purpose and this is shown in the figure below (Figure 12). Out of the total, 80 (40%) respondents considered their usage of well water to be very high, 44 (22.0%) recorded their usage as moderately high, (30%) respondents recorded moderately low usage and 16 (8%) respondents considered their usage of well water to be very low (Figure 13). When asked whether their wells produced enough water throughout the year, 120 respondents said yes whiles 80 of them said no. All the 80 who said no however said it was during the dry season that they faced this problem of water shortage.

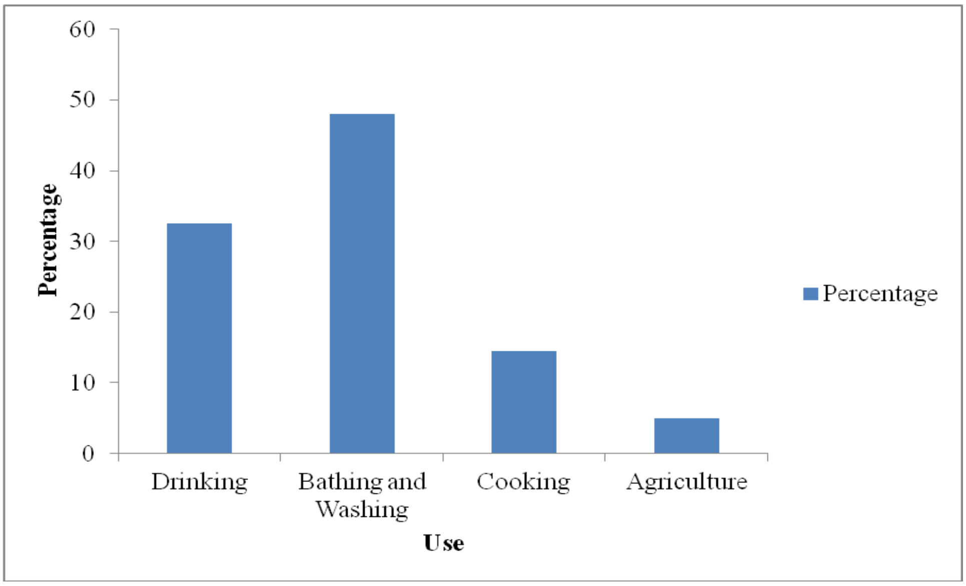

Figure 12: Major uses of well water

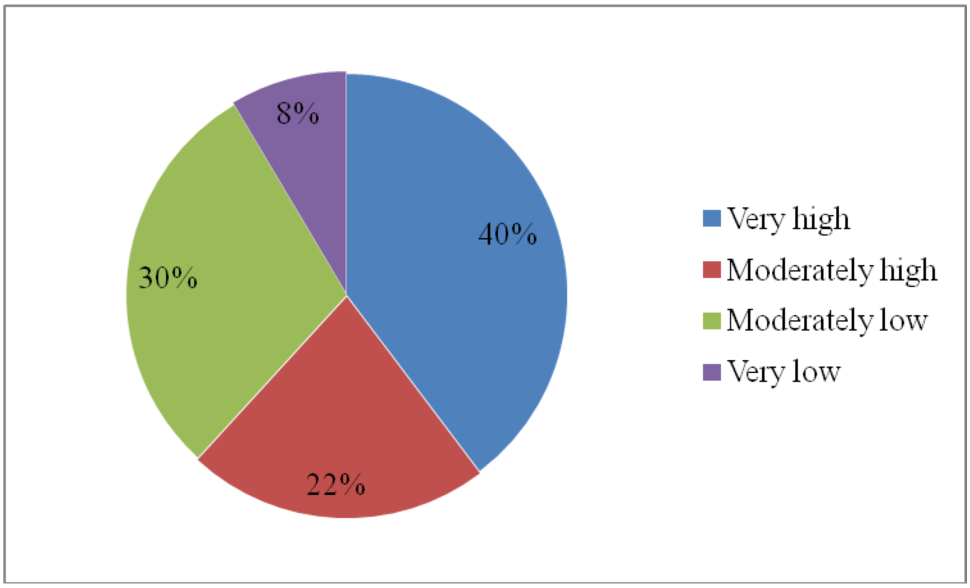

Figure 13: Levels of well water usage

4.6.4 Well status

Questions were asked regarding the ages of the wells used by these respondents. It was revealed 16% (32) of wells were less than five years old. A little over half of the wells

(102 wells representing 51% of the wells) were between the ages of five and ten. Also 20 % (40) of the wells were between the ages of 11-25, 23 wells constituting 11.5% of the wells were between the ages of 16-20 whiles 3 (1.5%) wells were older than twenty years. The table (Table 5) below illustrates the above information. The respondents when asked what informed their decision in locating their wells, majority of them representing 50.5% (101 respondents) considered distance from the house as a number one factor in locating their wells, 31% (63) considered nearness of the water table to be of utmost importance in locating their wells, 10% (19 respondents) considered sanitation and hygiene whiles 9% (18 respondents) were influenced by the availability of space as shown in figure 14 below. With reference to the quality of well water they used, majority (97 representing 48.5% of the respondents) of the respondents said their wells were clean for consumption whiles 85 (42.5%) of them said no and the remaining 18 said they did not know (9%). With respect to testing well water to know its quality status, 3.5% of the respondents have had their water tested to know whether it was clean for drinking, 95.5% (191) of them said no, whiles 1% (2) did not answer. Among the challenges faced with reference to testing their well waters however, 80 of the respondents constituting 40% had not thought of testing their water. With respect to cost, 60 (30%) of them think it is costly and their resource cannot cater for that. The results also showed that 46 (23%) respondents said they do not know where to go and test their water whiles 14 (7%) of them said it was wasteful since they could not read or analyse the results themselves as illustrated (figure 15) below.

Table 4.5. Age of household wells.

Period(Years)	Frequency	Percent
<5	32	16.0
5-10	102	51.0
11-15	40	20.0
16-20	23	11.5
>20	3	1.5
Total	200	100.0

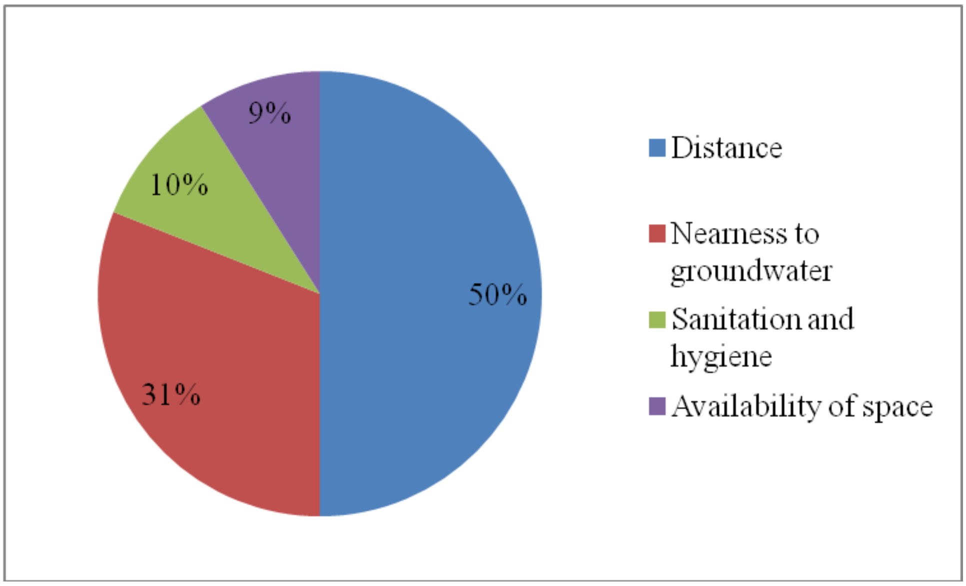

Figure 14: Factors considered in locating wells

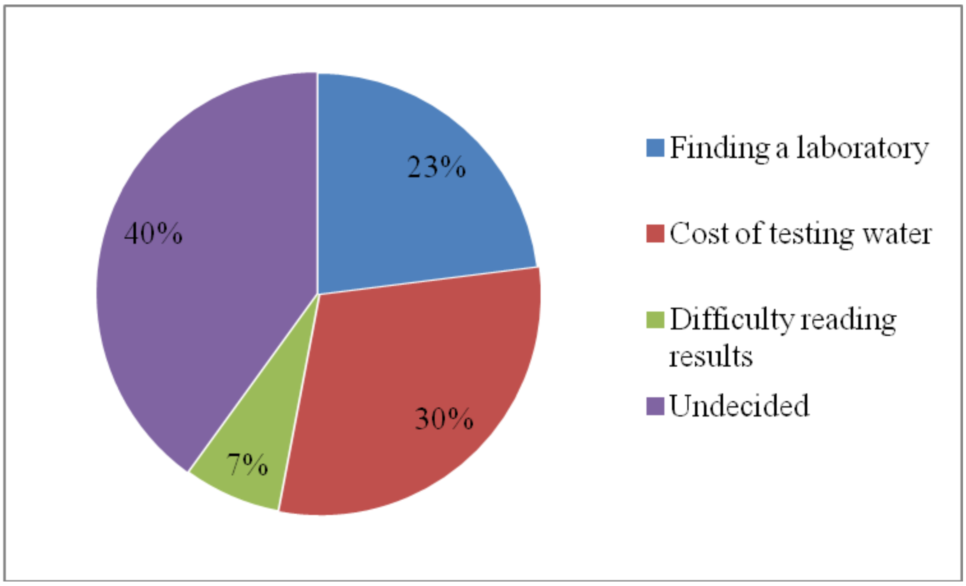

Figure 15: Challenges in testing well water

4.6.5 Toilet characteristics and management

Out of the total respondents interviewed (Table 6), 115 of them had latrines at home representing 57.5% of the respondents whiles 85(42.5%) respondents said they did not have latrines at home. Respondents with latrines were therefore asked what factor was of utmost importance to them in deciding where to locate their latrines. Majority of them (57 representing 49.6%) considered distance to be very paramount in locating their toilets. Also 10 of the respondents making up 8.7% of the total population however considered the availability of space in the house as the factor considered in locating their toilets as shown in figure 16 below. The challenges the respondents faced with regards to the location of their latrines include odour (48 making up 42% of total respondents with latrines), flies and insects (20 accounting for 17%) whiles 47 (41%) of them said they did not face any problem (Figure 17). The respondents were also asked if they think pit latrines had adverse effects on the environment. Out of the total respodents interviewed, 80% of them said yes, 10% said no whiles 7.5% of them said they did not know. The number of respondents who did not answer this were 5 hence termed as missing values. However, when asked whether underground movement of faecal sludge from latreines could lead to well water pollution, 119 respondents said yes, 27 of them said no whiles the remaining 14 of them said they did not know.

Table 4.6: Latrine availability

Response	Frequency	Percentage
Yes	115	57.5
No	85	42.5
Total	200	100.0

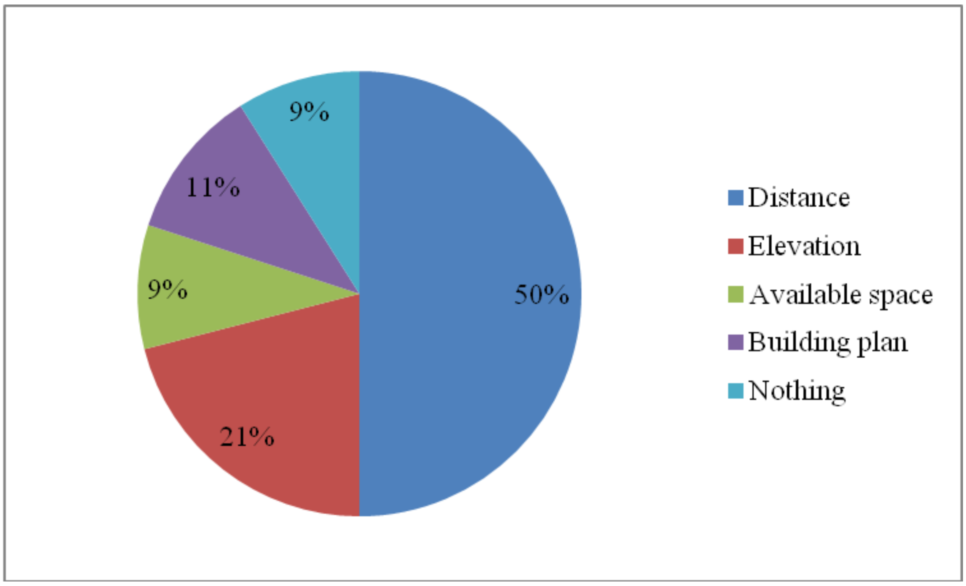

Figure 16: Factors of consideration in locating wells.

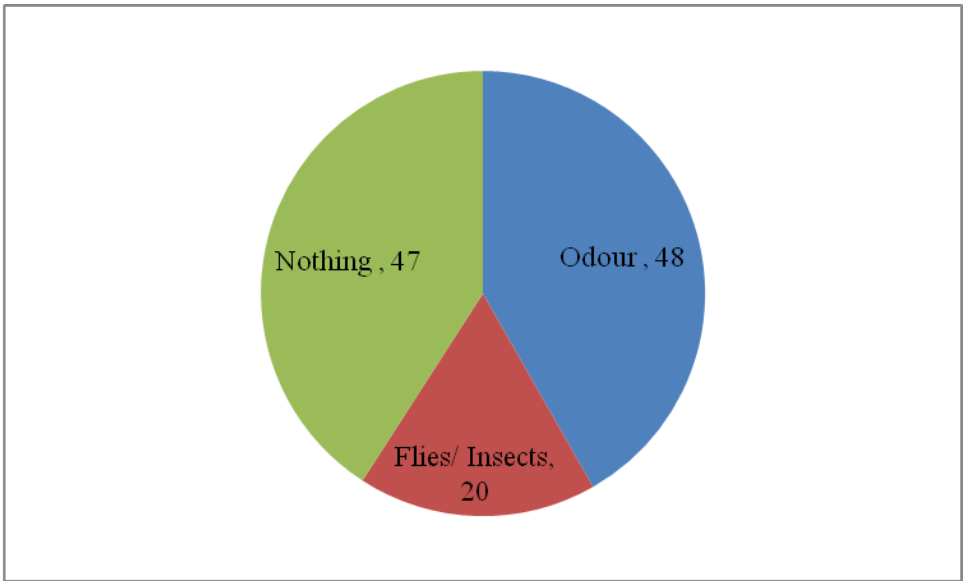

Figure 17: Challenges faced with regards to pit latrines

4.6.6 Health and sanitation

The questionnaire also elicited information as to whether inhabitants had suffered from any sickness or illness they suspect to be caused by their source of water. According to 186 of them representing 93% of them, they had not suffered from any sickness they suspect to be caused by their source of water whiles the remaining 7% making up 14 respondents suffered from diseases they suspect to be caused by the well water. All of them however mentioned diarrhea as the sickness they suffered from. Respondents were also asked which ways in their views could well water be contaminated apart from the pit latrine.

It was revealed that 45% (90) of the respondents identified not covering well as a major source of well pollution aside pit latrine. Also, 36% (72) recognize the water drawing equipment to cause well water pollution, 2% (4) identifies bathrooms whiles 17% (34) identified surface runoff to be a source of well water pollution apart from the pit latrine

(Figure 18). Respondents were asked if they were aware of modern methods of treating well water and 72 (36%) respondents said yes and 128 (64%) of them said no. When asked what this modern method was, all respondents said it was by adding chemicals to the water but the name of which a number (20%) of them did not know. All respondents are however ready to welcome new methods of improving their well water quality.

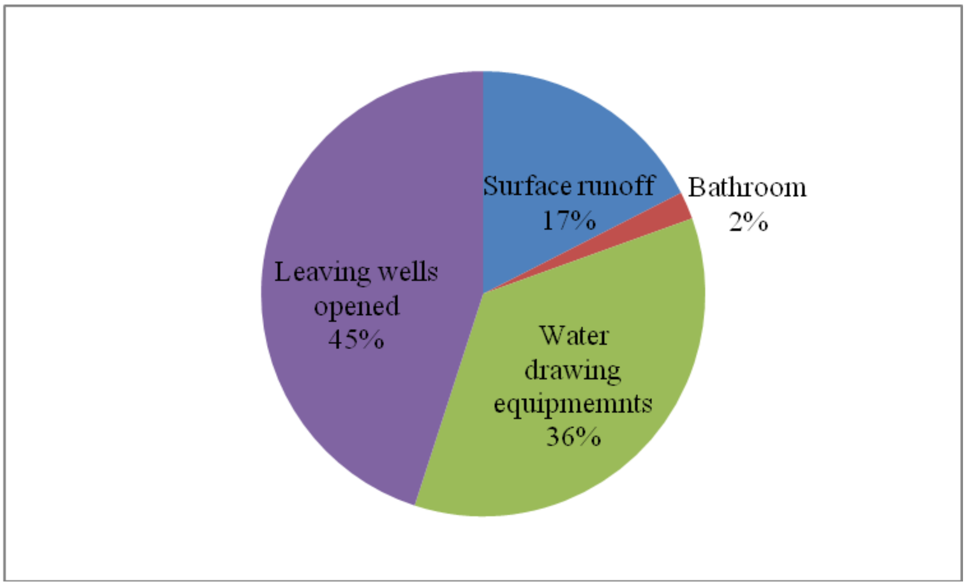

Figure 18: Sources of well pollution aside latrines well water treatment

4.6.7 Stakeholders

Questions were asked on the various stakeholders in the water sector. Several of them were mentioned such as the Government through the Municipal Assembly, Ghana Urban Water Company, Community Water and Sanitation Agency just to mention a few and the various roles ranged from provision of water to financial and technical advice. However when asked who was responsible for the provision of water, 166 (83%) mentioned the Municipal Assembly, 15(7%) said the community, 12(6%) said Non-Governmental

Organisations, and 5(3%) said the individuals whiles 2(1%) said they did not know (Figure 19). When asked whether the water was satisfactorily provided, none of the respondents strongly agreed, only one agreed, 93(46.5) of them disagree, 103(51.5) of them strongly disagree whiles 4 (2%) had not decided as illustrated in figure 20 below.

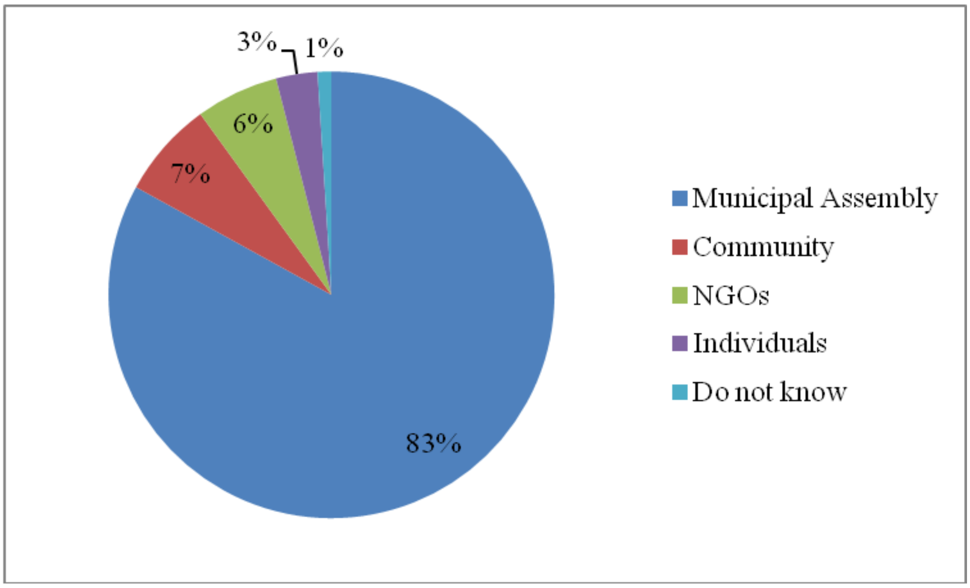

Figure 19: Stakeholders in the water sector

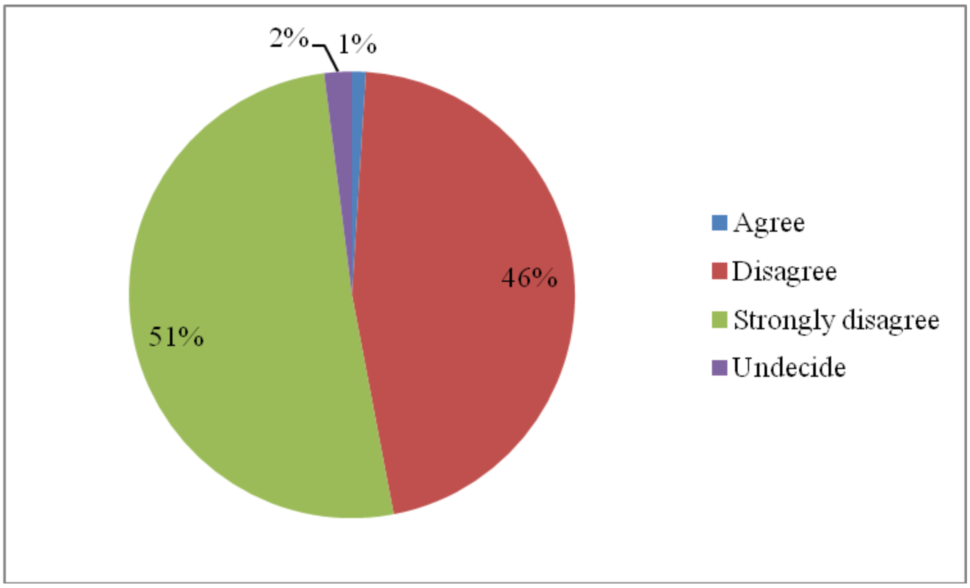

Figure 20: Level of water delivery by stakeholders

CHAPTER FIVE

DISCUSSION

5.1 Physico-chemical assessment

The study revealed that levels of pH, total dissolved solids, nitrites and nitrates were within the WHO recommended limits. Generally, it has been shown that low pH of water below recommended levels is capable of causing corrosion and scaling (WHO, 2004). This study found pH to be within the WHO recommended limits of 6.5-8.5 for well water (WHO, 2004) hence not capable of causing significant health problems. The mean values obtained by Fasunwon et al. (2008), Adetunde et al. (2011) and Nkansah et al. (2010) in similar studies are comparable to this value. No much difference was observed in the pH values among the various wells. The observed pH values however contradict results obtained by Akinbile et al. (2011) in an analysis of water samples from some boreholes near a landfill in Akure, Nigeria. Wells were found to be acidic and this he linked to the possibility of metals such as zincs, damaged battery cells and improper disposed used cans finding their way into the water.

No significant difference existed between pH values recorded for the dry and wet season. However, individual well pH recorded were generally higher during the raining season and this is a confirmation to the results by Atobatele et al. (2008) that pH decreases with increasing rains. According to Byamukama et al. (1999) lower pH levels may be as a consequence of carbon dioxide saturation in the groundwater.

Generally, turbidity of the water was high with the values for the raining season being the highest above the WHO limits hence not wholesome for human consumption. Similar high turbidity values were also reported by Akinbile et al. (2011) to be as a result of the presence of suspended particles and other materials as well as the unlined or unstable sidewalls of the wells which allow soil particles to fall into the water. There was significant difference in turbidity levels in the study area and this is in consonance with a study by Meena et al. (2012) where mean values recorded for turbidity differed with seasons with the monsoon period recording the highest. The difference observed may be attributed to the raining season and the washing of solutes into wells. In a related study Hassan (2003), associated lower values of turbidity obtained in some dug wells during April-May period (dry season) to the lack of side erosion within the wells possibly as a result of greater cohesion and vice versa especially in August during the raining season.

Water colour is attributed to materials in solution which are primarily organic compounds leached from decaying vegetation and inorganic coloured compounds found in waste (Adejuwon et al., 2011). Values for water colour at levels not more than 15TCU are normally acceptable to consumers (WHO, 2011). Generally, the colours of water samples were low within the guideline value of 5 Hz, except in wells 10, 19, 24, 25, 29 and 30. The higher values recorded during the wet season may be attributed to the higher turbidity rates obtained in those wells or leachate from latrines. Akinbile et al. (2011) considered the guideline value of 5 Hz to contradict the definition of potable water since water characteristically is colourless, odourless, tasteless and free from objectionable and pathogenic organisms. There was significant variation in the figures obtained for the various seasons an indication that rainwater also had an influence on the colour obtained from the various wells since it directly influences turbidity rates as well as infiltration rates.

Temperature of any water body depends upon several factors amongst which are the time, season and water depth. Variations in temperatures in the study area followed the ambient temperature pattern (Agbaire et al., 2009) and were highest during the dry season and lowest during the raining season throughout the study and this is in accordance with results obtained by Parmar (2012). Wirmvem et al. (2013) in a study obtained mean temperatures lower than this study and associated it with recharge and climatic influence.

The significant difference recorded between the control boreholes and the hand dug wells may be associated with the depth of the wells, exposure to the sun, as well as the climate. Similar range of variation has been shown by Ansari et al. (2008) and Saxena et al. (2012). The high temperature recorded during the dry season may be due to the higher atmospheric temperatures recorded during this time of the season (Harmattan) which can be speculated to have a bearing on the recent global warming consequently causing climate change. Light rays from the sun can penetrate through the water and as such the water would be easily heated to high temperatures (Anhwange et al., 2012). Various chemical and biological processes depend on temperature and this is likely to affect water quality (Parmar, 2012). Temperature however does not have immediate health effect to humans.

The concentration and composition of TDS in natural water is determined by geology, drainage, atmospheric precipitation and the water balance (Phyllis et al., 2007). Values recorded for total dissolved solids were significantly different between the various seasons ($P<0.05$). This was however not observed between the hand dug wells and the controls. The raining season values were higher than the dry season which may be due to some form of leachate from the ground (Agbaire et al., 2009). The higher values recorded for total dissolved solids was as a result of the higher turbidity with the exception of well 3 and this is confirmed by the results of Anhwange et al. (2012). WHO guideline values for TDS is 1000 mg/l and all values were below this permissible level hence clean for human consumption contrary to results obtained by Meena et al. (2012). The differences in the levels of contamination were because of different features of the wells in the study area. These features include type of cover, quantity of water that is drawn from the well, distance to the nearest latrine and lastly rainfall amount (Kiptum et al., 2012).

Nitrate in natural waters may be traced to percolating nitrate from sources such as decaying plant and animal materials, agricultural fertilizers as well as domestic sewage (Adeyeye et al., 2004, and Divya, 2011). Generally, the origin of nitrates in natural waters comes from organic and inorganic sources, the former including waste discharges and the latter comprising chiefly artificial fertilizers (EPA, 2001). Fertilizers therefore may be a cause since some residents apply fertilizers to their backyard gardens. This is essentially in agreement with reports by Vinger et al. (2012) that effluents from pit latrines and chemical fertilizers applied to maize field were responsible for nitrate pollution. Nitrate ions dissolve and travel within and with the groundwater towards downstream (Dziwairo et al., 2006) and this as reported by Cave et al. (1999) can be used as a crude indicator of faecal pollution where microbiological data are unavailable. Despite the fact that values recorded were within the WHO guideline value, in contrast with reports by Taiwo (2012) there is still contamination in the area and this may be linked to several factors.

Surface water nitrate concentrations can change rapidly owing to surface runoff of fertilizer, uptake by phytoplankton and denitrification by bacteria, but groundwater concentrations generally show relatively slow changes (WHO, 2011) reflecting the non-significant differences in the values obtained for both seasons. There were however some higher individual well values (wells16, 17 and 18) in the dry season than the wet season and this may be linked to evaporation effects from these wells. The higher values for the wells may be as a result of fecal contamination. Also the increased levels according to Adenike et al. (2012) may be caused by leachate from human liquid and solid waste deposit from nearby pit latrines. A study by Odai et al. (2003) revealed that the levels of nitrates decrease with increased distances. Kiptum et al. (2012) established that during the rainy season, the concentrations of nitrates and phosphates were diluted by about 25% due to the higher recharge rate from rainfall hence causing lower values of nitrates. However the opposite was the case for the controls which recorded lower values for both seasons relatively.

In the same vein, epidemiological studies have predicted association between exposures to nitrate and gastric cancer because of the reaction of nitrate with amine in diet forming carcinogenic nitrosomoamines (Umeobika et al., 2013). Recordings for the well and boreholes are however not above 50 mg/l as nitrate ion (or 11 mg/l as nitrate-nitrogen) hence do not pose danger to consumers. The occurrence of methaemoglobinaemia in bottle-fed infants therefore is being curtailed.

The results from the various wells indicated absence of chlorine residual. According to Chlorine Residual Testing Fact Sheet, the presence of chlorine residual in water indicates that sufficient amount of chlorine was added initially to the water to inactivate the bacteria and some viruses that cause diarrheal disease and against recontamination during storage. It goes on further to assert that the presence of free chlorine residual in drinking water is correlated with the absence of disease-causing organisms, and thus is a measure of the portability of water. In a related study, Muruka et al. (2012) established that the presence of coliforms in 98% of sampled wells implied that there was practically no chlorination being done. Sampled boreholes equally showed no levels of residual chlorine in them. The results obtained from the social survey however indicated that few residents chlorinated their waters a contradiction to the presence of disease causing organisms in the study area. Nitrites were also found to be absent in the samples. Nitrite exists normally in very low concentrations and even in waste treatment plant effluents levels are relatively low, principally because the nitrogen will tend to exist in the more reduced (ammonia; NH3) or more oxidized (nitrate; NO3) forms (EPA, 2001). Nitrite is the actual etiological agent of methemoglobinemia.

5.2 Bacteriological assessment

All samples tested positive to bacteria and as such does not meet the WHO guideline value of 0 CFU/ 100 ml in drinking water hence not conducive for human consumption. Several factors in the study area may be responsible for this observation, such as human faeces from pit latrines, animal dropping and the growth of microbes within the wells. This confirms the report by Obiri Danso, et al., (2009), in the Kumasi Metropolis (Ghana), which indicated that animals reared by free-range system were responsible for the introduction of faecal matter into uncovered or unprotected wells.

Amadi et al. (2013) linked the presence of coliforms detected in all samples in the study to fecal contamination to animals and humans. This study observed domestic animal pens sited close to household wells and also found animal hovering or resting close to wells. Also it was observed that buckets and gallons used in drawing water from the wells were often placed on the ground. Consequently pathogens from faeces of domestic animals could easily contaminate containers used in drawing water from the wells.

Literature shows that increased lateral separation between pollution source and groundwater supply source reduces the risk of faecal pollution (ARGOSS, 2001). For instance, Rahman et al. (2009) established an inverse relationship between total coliform and the distance between well and pit latrine. The nearness (averagely 13.7 metres) of pit latrines to hand dug wells which is below the recommended value of 50 meters (Duah, 2006) could influence the contamination levels of the wells.

None of the boreholes sampled as controls was contaminated with coliforms. This confirm works done on the assessment and comparison of microbial quality of drinking water in Chikwawa, Malawi which showed that borehole abstracted water did not reveal the presence of either total coliform or Escherichia coli (Nkansah et al., 2010). Leaching of human excreta from latrines may be said to be responsible for the presence of fecal matter from this wells in this study. Olabisi, et al. (2007) in the assessment of bacteria pollution of shallow well water in Abeokuta, Nigeria also showed that all shallow wells that were sampled tested positive to bacteria counts and this they attributed to possible anthropogenic factors such as location of latrines close to wells as well as free ranging domestic animals and other domestic solid wastes which are dumped around the house. Wirmvem et al. (2013) reported that the main sources of high total coliform in water in the Ndop plain, Cameroon was cattle grazing (non-point sources) which given the topography facilitated surface runoff of bacteria from this animals into water bodies.

5.3 Social survey

5.3.1 Sources of water

The results obtained from the social survey indicated that majority of the respondents depend on the well water for their domestic activities. Distance was a major factor in deciding where to locate a well. Poverty played a major role in determining the need to test well waters to know their quality status by respondents. The major stakeholder responsible for the provision of water in the study area is the government. However, the inability of the government to provide water has compelled the residents in the study area to resort to hand dug well as their main water source in addition to other available sources. In Ghana, majority of households use several sources of water for one activity, and water from one source is typically used for several activities (Engel et al., 2005).

A research conducted on improved water supply on the Volta basin considered quality perceptions, opportunity costs as well as supply characteristics such as location and pricing to be of utmost significance in households choice of water source. Sources for domestic water supply in the Volta basin just like in the study area included public pipes, boreholes, shallow wells, river, stream, ponds water, and rainwater. Households tend to use multiple water sources across seasons and for different purposes thus they tend to depend on one major source, which is supplemented by additional sources (Engel et al., 2005). In this study all respondents use the well water. Majority (48%) of the respondents however used the well as their major source of water and this can be as a result of the relative advantages wells have over other sources such as cost, perceived good quality, distance, nearness of the groundwater table just to mention a few . A few (3%) of the respondents however employ the services of water vendors and this may be because of the unavailable of other good quality sources compelling them to buy from these vendors.

It is significant to mention that rainwater which is seasonal serves as a supplement to the various households' major sources. It was also revealed that households used a particular source as their major and all other sources following it in the order below pipe borne, borehole, water vendors, wells and rainwater. Characteristic of most developing countries is the inability of authorities to provide social amenities to their populace, the availability of a particular source of water to the inhabitants therefore was an important indicator (49%) in deciding which source to use. The fewer sources available were at a farther distance away from many of the respondents hence discouraging them from patronizing them but rather resorting to closer sources of water. According to the GLSS (2008), about 8 out of every 10 people in the area are poor and this explains the fact that a number of the inhabitants blame poverty as a number one indicator of their choice of water source. Interestingly however, 2% of the respondents were health conscious and therefore considered the quality status of a particular source in their decision making. This may be because some of them might have suffered from certain diseases they suspect to be from their source of water or as a result of their educational orientation or levels.

5.3.2 Well water usage

The findings of the study revealed that several reasons account for the digging of wells. In a study by McGourty, (2006) users of private wells found the main reasons for using private wells as convenience, cost, tradition and taste. Distance was considered by majority of the respondents to have pushed them to dig wells. The few available water sources are far away from homes and this may be due to the inability of the government and other relevant stakeholders to provide enough boreholes as well as taps closer to where it is needed.

Generally, the nearness of groundwater table to the surface is of paramount importance when digging a well. The study area is generally low lying with a valley which has a dam in it indicating that the groundwater table is high here. This therefore motivated a number of the respondents to dig wells and as one moves upslope, it is common to see wells often referred to as 'rain wells' and these are often deep and only have water during the raining season. Further upslope, wells become nonexistent since the water table is far below thus making it almost impossible to access water here. Poverty levels in the area have also prompted a number of inhabitants to dig wells because of the low cost involved in digging them. With the exception of well water and rainwater, all other sources of water come with cost and as a consequence force people to dig wells which are relatively cheaper.

The extent of usage of well water households is influenced by a lot of factors among which are educational levels, income levels, availability of other sources just to mention a few. The higher usage of well water is as a result of the cost involved in accessing it. The availability or accessibility of other sources especially in the dry season where water is rationed could also be blamed for this. The few whose usage of well water is very low may be because they are the people who can afford the pipe borne system and water vendors hence do not actually use much of the well water for their domestic chores. The status of a household from observation is also believed to influence the usage with which water from household's well is put to. From the findings well water is used for such purposes as drinking, cooking, washing/bathing and agriculture. The study also revealed that majority of the respondents bath and wash with well water.

5.3.3 Well location and quality status

The location of wells is very important in curbing the contamination of water by latrines. Several studies have established a relationship between location of wells and latrines and the levels of contamination (Banerjee, 2011, Dziwairo et al. 2006, Zingoni et al. 2005).

In this study, nearness to the house was considered by majority of the respondents an important factor in locating their wells within their households. This is confirmed by the response above that a lot of inhabitants dug wells because other sources of water were far from them. Others located wells at places they could easily reach the groundwater table and this is because the geology of the area did not allow the digging of wells at certain place, although the middle of the house is often preferred location. The particular usage to which water is put to is an indicator of the level of quality ascribed to it. Different quality levels are required for the different uses to which water is put to. For instance, the quality of water needed for drinking is different from what is needed for cooking, washing/ bathing or for agricultural purposes.

The findings also revealed that a number of the respondents (42.5% of them) considered water from these wells not to be clean for human consumption contradicting the study by Rogenhofer, (2005) where all respondents were satisfied with the quality of water from their wells. Water quality to majority of people however is often based on the clarity of the water and the results obtained from the colour of water go to confirm the opinion of the 48.5% respondents that their water is of a good quality for consumption. According to McGourty (2006), attributes of good quality water are associated with the aesthetic qualities.

5.3.4 Latrine location and challenges

The availability of latrines in most developing countries is bounded by income levels, educational levels and the perceptions of people on the importance of latrines. Majority (57.5% of the respondents in table 6) of the households interviewed had latrines however the siting of latrines just like that of wells is influenced by a number of factors. Latrine location is very important since its improper location could have adverse impacts on the environment and human health as well. The location of latrines in the study area was influenced by a number of factors. Distance travelled to access latrines was important to respondents. Half of study respondents considered distance in locating their latrines and this is to enable easy access to the facility. Also, some of the respondents located their latrines down slope to prevent well contamination and this may be as a result of their awareness of groundwater movement and this has a bearing on their level of education. It is also significant to mention that as part of efforts by the Town and Country Planning Department to ensure orderly buildings, a number of respondents had to resort to the locations given them on their building plans.

Bad odour (accounting for 42% of all responses) from latrines was a challenge to a lot of inhabitants in the area and this is affirmed in a study by Anteneh (2010) where the residents of Kola faced the challenges of odour and flies. This may be blamed on the improper location and maintenance of the latrines consequently producing bad odour. Nevertheless, the presence of flies and insects was not a problem to majority of them since most of these latrines were covered. Also, the presence of flies and insects cannot only be associated with the latrines only and therefore, it was not surprising that it recorded the lowest response from the inhabitants.

5.3.5 Well contamination and health

Health improvement comes from the proper use of sanitation facilities which consequently interrupt the transmission of faecal related diseases. The findings however showed that majority (186 of them representing 93%) of the respondents have not suffered from any disease suspected to be caused by their source of drinking water. Diarrhea however was the disease made mention of by those who had suffered some ailments suspected to be from their source of water. A similar study by Dziwairo (2006) revealed diarrhea as a widespread disease. Diarrhea was also found to be the fifth highest in a study on fecal sludge management in Madina in September 2008 (Agyei et al., 2011). Some respondents (45%) of the respondents considered their wells may be contaminated when not covered properly and from observation majority of them were covered most especially those that were consumed directly. Bath rooms were not considered to be an important source of well pollution in the area.

5.3.6 Stakeholders and water delivery

The provision of potable water in developing countries is the role of the government through the various Metropolitan, Municipal and District Assemblies. Others include Non-Governmental Organisations, United Nation, UNICEF, Community Initiatives and Individuals. There is high awareness about the role of the assembly in the provision of portable water in the study area.

Accordingly, 83% of the population identified the government through the Municipal Assembly to be responsible for the provision of potable water in the study area. This, they strongly disagree is provided satisfactorily and may be the cause of the springing up of wells as alternative source of water. A study by Fasunwon et al. (2008) in Ago-Iwoye, Nigeria, revealed that there are still ill-defined and uncoordinated roles of Federal, State and Local Government agencies responsible for water resources development in Nigeria, especially the rural communities. Agyei et al. (2011) revealed weak political will and political interference as the main setback for effective sanitation management.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

This study examined the relationship between latrines and well water quality for peri-urban people in Wa. Well water quality was therefore examined alongside boreholes as controls to establish their levels of contamination, relationship between their distances and the quality levels as well as variations within the various seasons in the area. Generally most of the water quality parameters were within WHO limits with the exception of colour turbidity and bacteriological levels.

Because all well water sampled in the study area were contaminated with bacteria, the water is said not to be wholesome for human consumption. Some amounts of nitrates were observed but were within permissible limits.

The study also revealed that most of the inhabitants perceived their water to be of high quality and never tested them to know their quality status. Factors such as distance, accessibility and availability of space play significant roles in the relative location of wells and latrines in the study area. The various stakeholders identified in the study to be involved in the water sector include the Municipal Assembly, the Ghana Water Company Limited, NGOs such as PRONET, PLAN, ACTION AID, the Communities and Individuals. Their respective roles according to majority of the residents were however implemented satisfactorily.

6.2 Recommendation

Based on the findings of the study and from personal observation, the following recommendations are made to help improve the quality of well water in the study area.

There is the need for awareness campaigns in the area to get residents abreast with the dangers of human activities on water quality as well as effects of poor water quality on their health. They should also be encouraged to do regular water testing to be up to date with the quality of their wells.

The Municipal Assemblies in conjunction with GWCL should aid residents in testing their well waters and make available disinfectants free or cheaper to improve the quality status of wells found to be contaminated.

Aquifer vulnerability assessment should be conducted such as the DRASTIC (Depth, Recharge, Aquifer, Soil, Topographic slope, Impact of vadose zone, Conductivity of aquifer) approach by Aller et al., (1987) to ascertain the impacts of depth, recharge, aquifer, soil, topography, impact of vadose zone and conductivity on the levels of contamination in the area which this study has not been able to cover.

Residents should be encouraged to construct wells with concrete linings, sited at least 50 meters away from latrines according to WHO standards and sited at higher elevation to prevent well contamination.

Stakeholder participation aside the Municipal Assembly should be encouraged to invest more in the water sector through the provision of safe water, disinfectants, investment in researches and in the education of inhabitants on sanitation and water management practices.

Further investigation into other sources of water for the residents such as boreholes, rainwater, water vendors, the pipe borne system and others to know their quality status should be encouraged.

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APPENDICES

APPENDIX 1: Results from statistical analysis for boreholes and wells

pH

	N	Range	Mean	Std. Deviation
pH (wet)	30	1.01	7.1737	.32055
pH (dry)	30	1.11	7.2390	.33917

Residual Chlorine

	N	Range	Mean	Std. Deviation
Residual Chlorine (wet)	30	.00	.00	.00000
Residual Chlorine (dry)	30	.00	.00	.00000

Turbidity

	N	Range	Mean	Std. Deviation
Turbidity (wet)	30	84.64	14.4977	21.51400
Turbidity (dry)	30	15.42	4.0073	4.95618

Colour

	N	Range	Mean	Std. Deviation
Colour (wet)	30	55.00	11.8333	13.86408
Colour (dry)	30	80.00	8.8333	14.66190

Conductivity

	N	Range	Mean	Std. Deviation
Conductivity (wet)	30	396.00	253.6333	101.96026
Conductivity (dry)	30	819.90	483.1700	192.88193

Temperature

	N	Range	Mean	Std. Deviation
Temperature (wet)	30	5.10	27.1633	1.47262
Temperature (dry)	30	3.30	30.2800	.79888

Total Dissolved Solids

	N	Range	Mean	Std. Deviation
Total Dissolved Solids (wet)	30	262.90	153.3933	62.20257
Total Dissolved Solids (dry)	30	492.40	298.5567	118.94687

Nitrites

	N	Range	Mean	Std. Deviation
Nitrites (wet)	30	.00	.0000	.00000
Nitrites (dry)	30	.00	.0000	.00000

Nitrates

	N	Range	Mean	Std. Deviation
Nitrates (wet)	30	6.00	1.4833	1.79791
Nitrates (dry)	30	10.00	2.6667	3.52414

pH (Boreholes)

	N	Range	Mean	Std. Deviation
pH (wet)	5	.16	7.1940	.63
pH (dry)	5	.31	6.722	.126

Residual Chlorine (Borehole)

	N	Range	Mean	Std. Deviation
Residual Chlorine(wet)	5	.00	.0000	.00000
Residual Chlorine (dry)	5	.00	.0000	.00000

Turbidity (Boreholes)

	N	Range	Mean	Std. Deviation
Turbidity (wet)	5	2.00	3.306	.946
Turbidity (dry)	5	3.61	1.942	1.591

Colour (Boreholes)

	N	Range	Mean	Std. Deviation
Colour (wet)	5	.00	.0000	.00000
Colour (dry)	5	.00	.0000	.00000

Conductivity (Boreholes)

	N	Range	Mean	Std. Deviation
Conductivity (wet)	5	186.00	418.80	75.903
Conductivity (dry)	5	218.00	334.80	86.771

Temperature (Boreholes)

	N	Range	Mean	Std. Deviation
Temperature (wet)	5	2.70	29.28	1.224
Temperature (dry)	5	.40	31.38	.205

Total Dissolved Solids (Boreholes)

	N	Range	Mean	Std. Deviation
Total Dissolved Solids (wet)	5	118.00	237.00	50.299
Total Dissolved Solids (dry)	5	130.00	199.16	51.870

Nitrites (Boreholes)

	N	Range	Mean	Std. Deviation
Nitrites (wet)	5	.50	.1300	.2168
Nitrites (dry)	5	.00	.0000	.00000

Nitrates (Boreholes)

	N	Range	Mean	Std. Deviation
Nitrates (wet)	5	3.00	1.200	1.30
Nitrates (dry)	5	2.00	.6000	.894

APPENDIX 2: BOREHOLE RESULTS FOR THE WET SEASON AND DRY SEASON

Borehole results for the wet season

	pH	Residual Chlorine	Turbidity	Colour	Conductivity	Temperature	Total Dissolved Solids	Nitrites	Nitrates	Bacteria
BOREHOLE 1	7.25	0	4.2	5	384	30	200	0	0	0
BOREHOLE 2	7.09	0	4.1	5	462	28.4	254	0	3	0
BOREHOLE 3	7.2	0	3.63	5	374	28.5	202	0	0	0
BOREHOLE 4	7.24	0	2.4	5	530	28.4	318	0.5	1	0
BOREHOLE 5	7.19	0	2.2	5	344	31.1	211	0.2	2	0

Borehole water results for the dry season

	pH	Residual Chlorine	Turbidity	Colour	Conductivity	Temperture	Total Dissolved Solids	Nitrites	Nitrates	Bacteria
BOREHOLE 1	6.65	0	3.92	5	314	31.2	191	0	0	0
BOREHOLE 2	6.8	0	2.91	5	404	31.3	242	0	2	0
BOREHOLE 3	6.9	0	2.23	5	334	31.6	185	0	0	0
BOREHOLE 4	6.59	0	0.34	5	420	31.2	254	0	0	0
BOREHOLE 5	6.67	0	0.31	5	202	31.6	124	0	1	0

APPENDIX 3: QUESTIONNAIRE

University of Ghana

Faculty of Science

Environmental Science Programme

QUESTIONNAIRE ON THE INFLUENCE OF PIT LATRINES ON WELL WATER QUALITY IN WA

Questionnaire Administration

This questionnaire is being administered to residents of Wa in the Upper West Region to assess the impact of pit latrines on well water quality.

This questionnaire is a partial requirement for the award of Master of Philosophy Degree in Environmental Science. All information is therefore for academic purpose and will be treated confidentially. Your genuine response is required. Please indicate your answers by ticking and specify by writing where necessary.

Interview Date…………………………………………

Questionnaire No. ……………………………..

Interviewer ………………………………………………. Locality ……………………………………………….

Section A: Demographic information of respondent

1. Gender of respondent. A. Male ( ) B. Female ( )

2. Age category of respondent. A. < 20 ( ) B. 20-29 ( ) C. 30-39 ( ) D. 40-49 ( ) E. 50-59 ( ) F. 60+ ( )

3. Marital status of respondent. A. Married ( ) B. Single ( ) C. Widow/ Widower ( ) D. Divorce ( )

4. Level of education attained by respondent. A. Primary ( ) B. JHS ( ) C. SHS ( ) D. Post SHS/Tertiary ( ) E. None ( ) F. Others, specify…………………………………………………………………..

5. Household size of respondent. A. <5 ( ) B. 5-9 ( ) C. 10-14 ( ) D. 15-19 ( ) E. 20+ ( )

6. Number of dependents of respondent. A. <3 ( ) B. 3-5 ( ) C. 6-8 ( ) D. 9+ ( )

7. For how long have you been staying in this area? A. <5 yrs ( ) B. 5-10 yrs ( ) C. 11-15 yrs ( ) D. 16-20 yrs ( ) E. >20 yrs.

8. Which of the following do you spend most of your income on? A. Food ( ) B. Clothes ( ) C. School fees ( ) D. Health ( ) E. Funerals ( ) F. Others, specify ………………………………………………………………………

Section B: Water sources and availability.

9. What is your major source of water? A. well ( ) B. borehole ( ) C. pipe born ( ) D. water vendors ( ) E. others, specify………………………………………………………………………………

10. What informs your choice of the source? A. poverty ( ) B. distance ( ) C. availability ( ) D. others specify……………………………………………………………………………… ……………………………………………………….,

11. What is your level of usage of well water? A. very high ( ) B. moderately high ( ) C. moderately low ( ) D. very low ( )

12. What major use do you put your well water to? A. drinking ( ) B. bathing/ washing ( ) C. cooking ( ) D. Others, specify ………………………………………………………………………………..

13. What prompted you to dig a well? A. water scarcity ( ) B. cost ( ) C. nearness of groundwater ( ) D. distance ( ) E. others, specify……………………………………………………………………………… …………………….

14. Does your well produce enough water for your usage? A. yes ( ) B. no ( )

15. If no, which part of the year do you face this problem? A. dry season ( ) B. raining season ( ) C. others, specify……………………………………………………………………………… ……………………………………………….

Section C: Water quality status

16. How old is your well? A. <5 yrs ( ) B. 5-10 yrs ( ) C. 11-15yrs ( ) D. 16-20 yrs ( ) E. >21 yrs

17. What informed your decision in siting/ locating your well? A. nearness to the house ( ) B. nearness to groundwater ( ) C. sanitation and hygiene ( ) D. others,

specify

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18. Is your water clean for consumption? A. yes ( ) B. no ( ) C. do not know

19. Have you ever tested your well water to know its quality status? A. yes ( ) B. no ( )

20. Which of the following has presented or currently presents as a difficulty in testing your water quality? A. finding a laboratory or agency to do your test ( ) B. collecting water samples ( ) C. cost ( ) D. difficulty reading results ( ) E. undecided ( ) F. Others, specify……………………………………………

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Section D: Toilet characteristics and management

21. Do you have a pit latrine? If no move to 29 A. yes ( ) B. no ( )

22. What did you consider in locating your latrine? A. distance ( ) B. elevation ( ) C. availability of space ( ) D. nothing ( ) E. others, specify……………………………………………………………………………

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23. What challenges do you face with regards to the location of your toilet? A. odour ( ) B. flies/ insects ( ) C. nothing ( ) D. Others, specify………………………………...

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24. Do you think pit latrine has adverse effects on the environment? A. Yes ( ) B. No ( )

25. Are you aware of groundwater movement? A. yes ( ) B. no ( )
26. Do you think this movement can lead to well water being polluted? A. Yes ( ) B. No ( )

Section D: Health and sanitation and readiness for new technologies

27. Have you ever suffered from any disease you suspect to be caused by your source of water? A. yes ( ) B. no ( )
28. If yes what disease/ sickness is it?
29. ………………………………………………………………………………………………...
30. What in your view are the ways of well water contamination apart from the pit latrine? A. surface run off ( ) B. bath rooms ( ) C. the water drawing equipments ( ) D. leaving wells opened ( ) E. others specify……………………………………………………………
31. Are you aware of any modern methods of treating well water and preventing contamination? A. yes ( ) B. no ( )
32. If yes what is this method?

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Are you ready to welcome any new methods of improving the quality of your well water? A. yes ( ) B. no ( )

Section E: Stakeholders.

33. Who are the various stakeholders in the water sector? A. the Municipal Assembly ( ) B. the community ( ) C. NGOs ( ) D. individuals ( ) E. others, specify……………………………………………….
34. What role do the stakeholders play as far as the water and sanitation sectors are involved? A. technical ( ) B. financial ( ) C. provision of water ( ) D. Others, specify…………………………………………………………………………………
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35. The services are provided satisfactorily? A. strongly agree ( ) B. agree( ) C. disagree ( ) D. strongly disagree ( ) E. undecided ( )