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EFFECT OF PIT LATRINES ON DUG-WELL WATER QUALITY - A CASE STUDY OF THE ASANKRANGWA COMMUNITY IN THE WASSA AMENFI WEST DISTRICT OF GHANA

BY
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DECLARATION

I certify that this thesis does not contain any material previously submitted for a degree or diploma in any university, and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text.

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DEDICATION

I dedicate this work to the almighty God and to my beloved wife Augustina Abekah Aidoo. my lovely daughters Blessing Akuba Aidoo and Ursula Atteah Aidoo. May God richly bless you.

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ABSTRACT

This study examined the water quality of dug-wells cited in close proximity to pit latrines in the Asankrangwa community in the Western Region of Ghana. Water samples were collected from 16 dug-wells and analyzed for some physical, chemical and bacteriological parameters. The results show that all the dug-wells were sited closer than the 30 metres minimum separation distance between dug-wells and pit latrines. All the physico-chemical parameters analysed (except turbidity) fell within the Ghana EPA standards for drinking water. The bacteriological analyses, however, showed that the water was contaminated with total coliforms (15.50-71.62 cfu/100ml), faecal coliforms (0.00-13.00 cfu/100ml) and *E. coli* (0.00-4.25 cfu/100ml). The high numbers of these in the water samples could be attributed to the presence of the pit latrines and the sanitation around the dug-wells as well as the use of multiple receptacles and the nature of the dug-wells (uncovered, unlined and unpaved dug-wells). The presence of these biological indicators suggest that the water is potentially harmful to human health if consumed untreated.

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LIST OF ABBREVIATIONS

ANOVA……..Analysis of Variance

CESCR……...…Convenant on Economic, Social and Cultural Rights

EPA…….Environmental Protection Agency

MDG …….. Millennium Development Goal

NTU…… Nephlometric Turbidity Units

OLS……..… Ordinary Least Squares

UNICEF…….……United Nations International Children's Emergency Fund

WHO……World Health Organization

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Water is one of the basic necessities for the sustenance of life, and it impacts nearly all areas of life. Water quality and the risk to waterborne diseases are critical public health concerns in many developing countries. Today, close to a billion people mostly living in the developing world do not have access to safe and adequate water (UNICEF/WHO, 2012). The World Health Organization (WHO) estimates that around 94% of the global diarrheal burden and 10% of the total disease burden are due to unsafe drinking water, inadequate sanitation, and poor hygienic practices (Fewtrell *et al*., 2007).

Groundwater is generally considered to be of good quality, hence, in many parts of the world it is a preferred source for water supply, irrigation and industrial purposes. Due to its proximity to the surface and the low cost of utilization, groundwater obtained from springs and wells continues to be particularly attractive as a source of water supply.

With increasing population, there is an increasing demand for more water. This in turn results in increased abstraction and, hence a strain on groundwater resources. Increased consumption of water also results in the generation of waste, such as human and industrial waste. Worldwide groundwater is being consumed in increasing quantities, and is also becoming increasingly affected by waste that is continuously discharged into the ground (Drangert & Cronin, 2004). Contamination issues are also a continental concern. In Africa, groundwater is increasingly being threatened by human activities (Xu and Usher, 2006).

One of the major challenges of protecting groundwater resources in rural areas is, therefore, preventing contamination by human waste. This can be achieved through the provision and maintenance of appropriate and environmentally friendly waste disposal facilities. Providing safe drinking water is therefore related to providing appropriate sanitation and cannot be seen in isolation. These two elements are closely intertwined. Whenever providing clean water and appropriate waste disposal are not addressed simultaneously, it is very likely that a detrimental effect on human welfare may occur. Provision of these two services is also considered a measure of human welfare. The Millennium Development Goal (MDG) aims to halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation (UNICEF, 2006).

Groundwater pollution has been the focus of attention by many researchers in recent times (Howard *et al*., 2002; Priis-Ustun *et al*., 2004; Ayanlaja *et al*., 2005; Pritchard *et al*., 2007). Leachate from pit latrines is one of the major sources of water pollution. It is partly responsible for low access to potable water and sanitation problem especially in many developing countries (WHO, 2002). Therefore, there is urgent need to provide an improved water supply and a safe means of excreta disposal.

Pit latrine is a common method of excreta disposal in the developing world. It is popular and widely used in urban slums as well as rural areas probably because it is the simplest, cheapest and the most efficient excreta disposal method that is within the reach of poor people.

One of the major contributing factors of groundwater pollution is pit latrine mostly located near water sources such as shallow wells and boreholes. In fact, pit latrines

have been identified as the major source of contamination of wells with faecal matter (Haword *et al*., 2007; Ayanlaja *et al*., 2005; Pritchard *et al*., 2007).

1.2 Problem Statement/ Justification

Asankrangwa, the district capital of the Wassa Amenfi West District of the Western Region of Ghana is a fast growing town. Pipe-borne water supply is unreliable and residents in the town depend on dug-wells (shallow wells) for their main source of domestic water supply. The dug- wells are mostly constructed in the various homes and are usually accessed by the general public.

The predominant form of excreta disposal in the community is the traditional pit latrine with a few septic tanks in some homes. The proximity coupled with the geographical location of most of these pit latrines/septic tanks to dug-wells raises concerns of possible groundwater pollution, which could consequently lead to water-borne diseases and possible outbreak of epidemics. It is against this background that this study was carried out to ascertain the quality of water in the dug- wells.

1.3 Objective

The main objective of this research was to determine the effect of pit latrines on dug-well water quality in the Asankrangwa community in the Western Region of Ghana.

The specific objectives were to:

i. measure the distances between the dug-wells and the pit latrines.
ii. determine some physico-chemical parameters (pH, temperature, turbidity, nitrates, nitrites, phosphates and ammonia) of water samples from the dug-wells.
iii. determine the levels of faecal and total coliforms as well as *E. coli* in the water samples taken from the dug- wells.

CHAPTER TWO

LITERATURE REVIEW

2.1 Drinking Water

Drinking water or potable water is defined as that having acceptable quality in terms of its physical, chemical, bacteriological and acceptability parameters so that it can be safely used for drinking and cooking (WHO, 2004). World Health Organisation (WHO) defines drinking water to be safe as long as it does not expose the population to any significant health risks over a long time of consumption and effort should be made to maintain drinking water quality at the highest possible level. The Covenant on Economic, Social and Cultural Rights (CESCR) explicitly recognised water as a fundamental human right in November, 2002 and the countries which ratified the International CESCR are compelled to ensure everyone has access to adequate and safe supply of drinking water. Any group of people that do not have access to potable source of drinking water are being exposed to high levels of possible contamination and subsequently could result in disease condition of various magnitudes.

2.2 Water Quality

Water quality is a measure of the condition of water relative to the requirement of one or more biotic species and to any human need or purpose and it is most frequently used by reference to a set of standards against which compliance can be assessed (Diersing-Nancy, 2009). Water quality parameters include the physical, chemical and biological characteristics of the water. Monitoring the quality of water facilitates evaluation of nature and extent of pollution control efforts (Abid *et al.*, 2005).

The quality of drinking water is a powerful environmental determination of health. Drinking water management has been a key pillar of primary prevention for over one and a half centuries and it continues in all continents from the poorest to the wealthiest.

2.3 Water Quality and Health

Water is the main renewable constituent of the human body (70-80% of weight) and therefore it is crucial for the health and welfare of human beings. Water has a profound influence on human health. At a very basic level, a minimum amount of water is required for consumption on a daily basis for survival and therefore, access to some form of water is essential for life. There are two main uses of water related to health; ingestion (water is the main drink) and social uses (water is used during preparation of many cooked dishes). Water is an essential element for the body hygiene and environmental quality.

Many communities suffer from important diseases linked to water ingested several years ago. As the available resources of fresh water decreases due to pollution and over exploitation, more efforts have to be devoted to improving water quality. Chemical contamination of drinking water may also have effects on health. The contaminant in drinking water can cause acute (immediate) health effects such as nausea, lung irritation, skin rash, vomiting, dizziness, and even death (Nassinyama *et al*., 2002; Priis-Uston *et al*., 2004). The contaminants can also cause chronic health effects that occurred long after repeated exposure to small amounts of chemical. Some chronic effects are cancer, liver and kidney damage, disorders of the nervous system, damage to the immune system and birth defects.

Major compounds as well as trace elements can be essential toxic, potentially toxic and potentially beneficial. In addition, there are increasing numbers of synthetic organic compounds released into the environment whose effects on human health appear to be carcinogenic (Jordana and Batista, 2003).

The quality of water indeed has a great influence on health; in particular the microbiological quality of water is important in preventing ill-health. Poor microbiological quality is likely to lead to outbreak of infectious water-related diseases and may cause serious epidemic to occur. Clearly, the likelihood of acquiring a waterborne infectious disease increases with the level of contamination by pathogenic microorganisms. The microbiological quality of drinking water has been known to affect public health by way of infectious and parasitic diseases such as cholera, typhoid, dysentery, hepatitis, giardiases, guinea worm and schistosomiases (Pritchard *et al*., 2007).

2.4 Contamination of Wells

Shallow pumping wells can often supply drinking water at a very low cost, but because impurities from the surface easily reach shallow sources, a greater risk of contamination occurs for these wells when they are compared to deeper wells. Contamination of the wells increases during the rainy seasons where the aquifer is "topped up" more rapidly and both vertical and horizontal migrations of water are accelerated (Morgan, 1990).

The quality of the well water can be significantly increased by lining the well, sealing the well head, fitting a self-priming hand pump, constructing an apron, ensuring the area is kept clean and free from stagnant water and animals.

Most of the bacteria, viruses, parasites, and fungi that contaminate well water come from faecal material from humans and other animals (Dillon, 1997). Common bacterial contaminants include *E. Coli, Salmonella, Shigella* and *campylobacter jejuni.* Common viral contaminants include *norovirus, sapovirus,rotavirus,* enteroviruses and hepatitis A and E. Parasites include *Giardia lamblia, Cryptosporidium, Cyclospora cayetanensis,* and microsporidia.

2.5 Physico-Chemical Assessment of Water

Physico-chemical parameters are physical and chemical parameters associated with water which have an influence on its quality and which also affect the biological constituents of the water (Oluyemi *et al.,* 2010). The physical factors such as temperature, turbidity, colour, etc. can affect the aesthetics and taste of the water and may complicate the removal of microbial pathogens during water treatment. The chemical parameters include pH and anions such as sulphates, phosphates, nitrites, nitrates and fluorides.

2.5.1 pH

The pH of a solution is a measure of its acidity or alkalinity, and normally dependent upon the activity of hydrogen ions. It indicates the intensity of the acidic or basic character of a solution and is controlled by the dissolved chemical compounds and biochemical processes in solution (Anon, 1996). In general, a pH less than 7 is considered acidic, soft and corrosive. A pH greater than 7 is considered basic.

Changes in pH can indicate a change in water quality. Heavy metals such as cadmium, lead and chromium dissolves more easily in acidic water. This is important because many heavy metals also become much more toxic when dissolved

in water. WHO (2008) guidelines suggest that the optimum pH required in drinking water should be in the range 6.5-8.5.

2.5.2 Temperature

Temperature is the measure of how much heat is present in the water. It is desirable that the temperature of drinking water should not exceed 15^{o}C because the palatability of water is enhanced by its coolness. Low water temperatures offer a number of benefits. A temperature below 15^{o}C will tend to reduce the growth of nuisance organisms and hence minimise associated taste, colour, odour and corrosion problems.

2.5.3 Turbidity

Turbidity is a measure of the amount of light scattered by suspended particles and can be considered as the "cloudiness" of water sample. The higher the total suspended solids in the water, the higher the turbidity. It is influenced by sediments from erosion, urban run-off, re-suspended sediments from the bottom and phytoplankton. Turbidity is measured in Nephlometric Turbidity Units (NTU). The maximum allowed turbidity in drinking water established by the (WHO, 2004) should not be more than 5 NTU but ideally a value below 1 NTU is desired. Turbidity limits transmission of sunlight thereby reducing photosynthesis of aquatic plants.

Although it does not adversely affect human health, turbidity is an important parameter in that it can protect microorganisms from disinfection effects, can stimulate bacteria growth and indicates problems with treatment process (WHO, 2004).

2.5.4 Nitrate and Nitrite

Nitrate and nitrite are naturally occurring ions that are part of the nitrogen cycle. Nitrate is a major concern in developed countries as a result of its potential health problems related with excessive intake. Nitrate is a conservative element in natural groundwater. Nitrates are present in water (particularly groundwater) as a result of decay of plant and animal material, the use of agricultural fertilizers, domestic sewage or treated waste water contamination or geological formation containing soluble nitrogen compounds. The formation of nitrates is an integral part of the nitrogen cycle in our environment. In moderate amount, nitrate is a harmless constituent of food and water. Plants use nitrates from the soil to satisfy nutrient requirements and may accumulate nitrate in their leaves and stems. Due to its high mobility, nitrate can leach into groundwater (Self and Waskom, 2008).

The primary health concern regarding nitrate and nitrite is the formation of methaemoglobineamia, so- called "blue-baby syndrome". Methaemoglobinaenia in infants also appears to be associated with simultaneous exposure to microbial contaminants. Nitrate is reduced to nitrite in the stomach of infants, and nitrite is able to oxidise haemoglobin (Hb) to methaeglobin (metHb), which is unable to transport oxygen around the body. The reduction of nitrate to nitrite by gastric bacteria is also higher in infants because of low gastric acidity. The acceptable concentration of nitrates in drinking water is 50 mg/l as nitrogen. The acceptable concentration of nitrite is 3 mg/l (short-term exposure) and 0.2 mg/l (long-term exposure) (WHO, 2004).

2.5.5 Ammonia

The term ammonia includes the non-ionised (NH_3) and ionised (NH_4^-) species. Ammonia in the environment originates from metabolic, agricultural and industrial processes and from disinfection with chloramines. Natural levels in groundwater and surface water are usually below 0.2 mg/l. Ammonia contamination can also arise from cement mortar pipe linings. Ammonia in water is an indicator of possible bacterial, sewage and animal waste pollution.

Ammonia is a major component of the methabolism of mammals. On dissolution in water, ammonia forms the ammonium cation; hydroxyl ions are formed at the same time. The degree of ionisation depends on the temperature, the pH, and the concentration of dissolved salts in the water. Natural levels in ground waters are usually below 0.2 mg of ammonia per litre. Higher natural contents (up to 3 mg/l) are found in strata rich in humic substances or irons or in forests.

Toxicological effects are observed only at exposure above about 200 mg/kg of body weight. However, ammonia can compromise disinfection efficiency, indicate faecal contamination, result in nitrite formation in distribution systems, cause the failure of filters for the removal of manganese and cause taste and odour problems. Ammonia could cause taste and odour problems at concentrations above 35 mg/l and 1.5 mg/l, respectively.

2.5.6 Phosphate

Phosphate exists in three forms in water; orthophosphate, metaphosphate (or polyphosphate) and organically bound phosphate. Each compound contains

phosphorus in a different chemical state. Organic phosphates are important in nature. Their occurrence may result from the breakdown of organic pesticides which contain phosphates. Phosphates enter water ways from human and animal wastes, phosphorus rich bedrock, industrial effluents and fertilizer runoff from agriculture. This stimulates the wild growth of algae and aquatic plants which choke up the waterway and use large amount of oxygen in a condition known as eutrophication or over-fertilization of receiving waters. This process causes the death of aquatic life because of the lowering of dissolved oxygen levels. In a river or stream, the turbulent nature of the flowing water might however prevent the development of algae and aquatic plants.

2.6 MICROBIOLOGICAL QUALITY OF WATER

2.6.1 Faecal coliform

Faecal coliform bacteria have been used as indicators of contamination by humans and other warm-blooded animals (Pritchard *et al*., 2007). These particular bacteria normally grow in the large intestines (colon) of humans and are present in high numbers in the faeces of humans. They are also present in the waste of other warm-blooded animals such as birds and mammals and may reach water bodies through faecal discharge. These are coliform organisms that are able to ferment lactose at 44.0^{o}C to 44.5^{o}C within 48 hours or 2 days.

Identification of faecal coliform bacteria in water bodies can suggest the possible presence of pathogenic organisms which cause cholera, diarrhoea and other diseases (Ntengwe, 2006). Faecal contamination of surface waters, shallow wells and boreholes is a problem which is largely due to lack of proper sewage disposal

facilities. Sewage, land and urban run-off and domestic waste waters are widely discharged into water bodies, particularly rivers. Coliforms also enter water in individual house wells via backflow of water from a contaminated source, carbon filters or leaking well caps that allow dirt and dead organisms to fall into the water (Nkansah *et al*., 2010). Shallow wells and wells that do not have watertight casings could be contaminated by bacteria infiltrating the water through the soil near the well, especially in course-textured soils (Conboy and Gross, 1999).

According to Mallin *et al.,* (2000), faecal coliform bacteria are the most commonly isolated organisms for identifying sewage input into streams. The presence of faecal coliforms in water indicates contamination by mammals and birds waste (faeces), and signify the possible presence of pathogenic bacteria and virus (Prichard *et al*., 2007).

2.6.2 Total coliform

The total coliform group of bacteria has been the most commonly used indicator of biological water quality. The coliform group consists of all aerobic and facultative anaerobic, gram-negative, non-spore forming, rod-shaped bacteria that ferment lactose in a broth medium with gas formation within 48 hours at 35^{o}C. Most coliforms also produce enzyme B-D galactosidase which can be detected with a colour forming reagent. The group generally comprises the genera klebsiella, enterobacter and citrobacter. The presence of these bacteria in drinking water is indicative of inadequate filtration or disinfection in the distribution system.

2.6.3 Escherichia coli

Escherichia coli (commonly abbreviated *E. coli*) is a gram negative rod shaped bacterium that is commonly found in the lower intestines of warm blooded organisms. *E- coli* and related bacteria constitute about 0.1% of gut flora (Eckburg *et al.*, 2005) and faecal oral transmission is the major route through which pathogenic strains of the bacterium causes diseases. Cells are able to survive outside the body for a limited amount of time which makes them ideal organisms to test environmental samples for faecal contamination. *E. coli* can be differentiated from other thermotorelant coliforms by the ability to produce indole from typtophan or by the production of the enzyme β-glucuronidase.

E. coli is present in very high numbers in human and animal faeces and is rarely found in the absence of faecal pollution. It is considered the most suitable index of faecal contamination and as such it is the first organism of choice in monitoring programmes for verification, including surveillance of drinking water quality (Asbolt *et al.*, 2001). Water temperatures and nutrient conditions present in potable water distribution systems are highly unlikely to support the growth of these organisms (Grabow, 1996).

CHAPTER THREE

MATERIALS AND METHODS

3.1 THE STUDY AREA

3.1.1 Location

The Wassa Amenfi West District is located in the middle of the Western Region of Ghana. Its capital, Asankrangwa is about 160 km from the regional capital of Sekondi-Takoradi. The district lies between latitudes 5^{o} 30'N and 6^{o} 15'N and longitudes 1^{o} 45'W and 2^{o} 11'W. The district has a total land area of 3,464.61 km^2. This forms about 14.5% of the total land area of the Western Region. The district is bounded to the west by Sefwi Wiawso and Aowin - Suaman districts, to the south by Jomoro and Nzema East, to the south-east by Wassa Amenfi West and to the north by Bibiani-Anhwiaso-Bekwai and to north-east by Wassa Amenfi East (Figure 1). The district has an estimated population of 211,000 with an average population density of about 75 per sq. km. The district is predominantly rural with a population growth rate of 3.2%. (Wassa Amenfi West District Assembly, 2006)

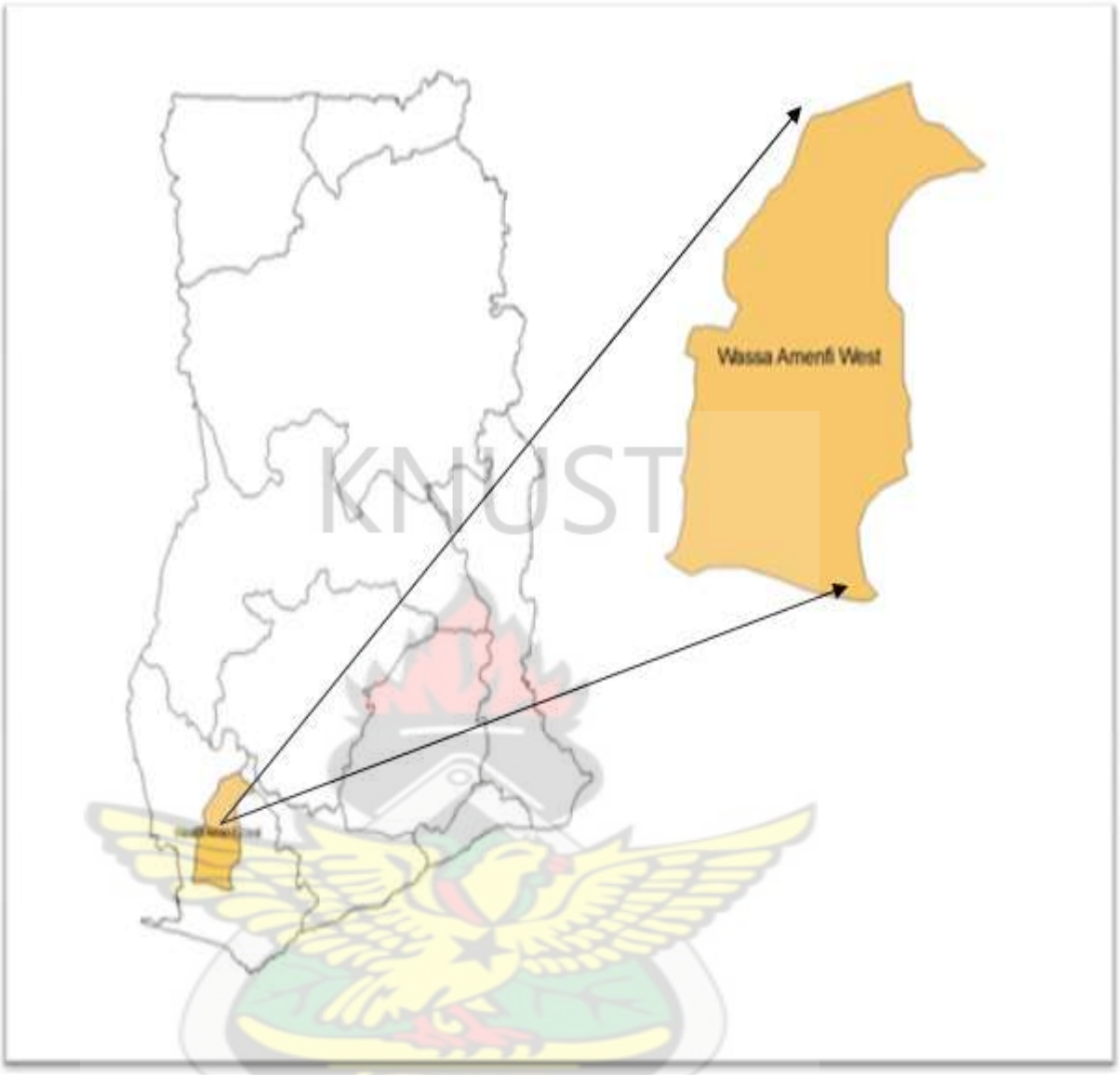

Figure 1 Map of Ghana showing the Wassa Amenfi West District

3.1.2 Topography and Drainage

The topography is generally undulating with heights averaging 153 metres. There is a good network of rivers and streams. Notable are the Tano and Ankobra rivers. The rivers could be a source of water for irrigation purposes especially for vegetable farmers during the dry season. The volume of these rivers reduces considerably during the dry season. Most of the streams dry out completely in the dry season

when they are needed most. Thus, many enclaves in the district suffer acute water shortage during the dry season.

3.1.3 Geology

The Wassa Amenfi West District is located on the middle Precambrian rocks of Birimian formation. The district lies within the Kumasi Basin and partly within the Sefwi Gold belt. However, major part of the district is positioned in the transitional zone of Sefwi and the Axim-Konongo gold belts. The Asankrangwa-Manso-Nkwanta belt features as a prominent vault which has gold potential. The rock type also provides mineralization for Bauxite, Manganese, and Iron-ore deposits.

The Opon Mansi iron ore deposit features as an economic asset for the district. Alluvial gold deposits occur in the Tano River basin within the district. However, the policy on Small Scale Mining in Ghana does not encourage gold dredging, due to the serious environmental concerns. The presence of high mineral deposit usually affects the underground water quality. There are a number of drilled boreholes which have high iron content. This makes the use of such water for domestic activities like drinking and washing very difficult.

The principal soils which cover the area are ochrosols, oxysols and forest ochrosol-oxysol intergrades (Wassa Amenfi West District Assembly, 2006). The soil is usually red, reddish brown, brown, yellow-brown or orange-brown. These soils contain greater quantities of soil nutrients, well-drained, generally alkaline in nature and rich in humus.

3.1.4 Climate and Vegetation

The District falls within the wettest parts of the country with average annual rainfall of 1400 mm to 1730 mm. There are two main rainfall regimes: March to July and September to early December, with two dry spells separating them; December to February and in August in terms of range and intensity. Temperatures are generally high, ranging from 24^{o}C to 29^{o}C. Maximum temperatures are in March and coolest month in August (Anon, 2006).

The interplay of heavy rainfall and good soil promote thick vegetation cover. The semi- deciduous forest is found in the northern part whilst the tropical rainforest is to the south where rainfall is heaviest. In between the two is the transitional zone. The district has forest reserves covering a total land of 413.94 sq. km. The forests also protect the water bodies such as Ankobra and Tano (Anon, 2006).

3.2 Sampling Sites

The Asankrangwa community where sampling was carried out was categorised into four main suburbs namely, Plotoso, Blockso, Newtown and Asikafoamantem. Four dug- wells with reference to pit latrines were purposively selected from each suburb for sampling. One dug-well in Asikafoamantem which has no reference to pit latrine was used as the control dug-well. The sampling locations are shown in Figure 2.

Figure 2. Map showing the location of some selected dug-wells and pit latrines in the Asankrangwa community.

3.3 Field Measurements

The distances between the dug-wells and the nearest pit latrines were measured using a steel tape. A GPS device was used to determine the geographic positions of the dug wells and the pit latrines. Visual inspection of the hand dug-wells, sanitation systems and their immediate environs was conducted around each of the selected dug-wells.

3.4 Sample Collection

Monthly water samples were collected from November 2012 to February 2013. The samples were collected in pre-washed and sterilised 500 ml screw-capped bottles. The collected samples were then transported in ice-cold containers to the Ashanti Regional Water Company laboratory for analysis.

3.5 DETERMINATION OF PHYSICO-CHEMICAL PARAMETERS

3.5.1 Temperature

The temperature of the water samples was taken *in-situ* with the use of digital thermometer. The thermometer was inserted in all the samples to know their various temperatures. Temperature was measured immediately the water was collected and recorded.

3.5.2 The pH

The pH of the water samples was determined using the pH meter which consists of the electrode. 100 ml of each sample was measured into 500 ml beaker. The electrode of the pH meter was immersed in the water samples. The reading on the pH meter was recorded after 2 minutes when the reading was stabilised.

3.5.3 Turbidity

Turbidity of the water samples was determined using the 200P Turbidimeter. Twenty-five (25) ml of each water sample was measured into the cell in the Turbidimeter. The cell was then fixed into the Turbidimeter and covered. The button was then pressed and after stabilization, the value was recorded in Nephlometric Turbidity Units (NTU).

3.5.4 Nitrite

ILosvay's reagents number one and number two were used in the determination of the nitrite levels. Fifty (50) ml of each water sample was measured into a beaker. Two (2) ml each of the reagents (number one and two) were measured and added to the water samples. It was then allowed to stand for 15 minutes. The appearance of a pinkish colour development in the samples showed that there is the presence of nitrite. After the colour development, the Lovibond comparacter with a nitrite disc in it is then read to match colour. The value recorded with the colour match was then converted to ml/l by multiplying the value by 0.02.

3.5.5 Nitrate

The Palintest Nitratest method was used in the determination of the nitrate levels of the water samples. The nitrate tube was filled with 20 ml each of the water samples. One level spoonful of Nitratest Powder and one Nitratest tablet was added to the water samples. The screw cap was replaced and the tube shook for about one minute and later gently inverted three times to aid flocculation. The tube was allowed to stand for two minutes to ensure complete settlement. The screw cap was then removed and the top of the tube wiped with a clean tissue. The clear solution was carefully decanted into a round test tube, filling to the 10 ml mark. One Nitricol tablet was then added crushed and mixed to dissolve. It was then allowed to stand for about 10 minutes to allow full colour development. A wavelength of 570 nm on the Palintest Photometer was selected and the reading recorded. The Nitratest calibration chart was then consulted for the values.

3.5.6 Ammonia

The Palintest Ammonia test is based on the Indophenol method. The test tube was filled with each of the sample to the 10 ml mark. One Ammonia number one tablet and Ammonia number two tablet was added, crushed and mixed to dissolve. It was allowed to stand for 10 minutes to allow colour development. A wavelength of 640 nm was then selected on the photometer. The photometer reading was recorded and then the ammonia calibration chart consulted for the values.

3.5.7 Phosphate

A test tube was filled with 10ml of the water samples. One phosphate High Range tablet was crushed and mixed to dissolve. This was allowed to stand for about 10 minutes to allow for full colour development. A wavelength of 490 nm was selected on the photometer and readings taken.

3.6 BACTERIOLOGICAL ANALYSES

The Pour Plate Count method was used for the total coliforms, faecal coliforms and *E. Coli.* 100 ml of each water sample was measured into a sterilised petri dish. For total coliform and faecal coliform, 10 ml of sterilised nutrient agar was added.

For the *E.Coli* determination, 10 ml of EC broth was added to 100 ml of each water sample. It was then swirled to mix up and allowed to settle for about 10 minutes. It was then incubated at 37^{o}C for total coliforms and 44^{o}C for faecal coliforms and *E. Coli.* for 24 hours. After the 24 hours, growth was counted with colony counter.

3.7 Statistical Analyses

Statistical analysis of the results was done using Microsoft Excel and one-way randomised analysis of variance (ANOVA). All statistical tests were estimated at 95% level of confidence.

The Ordinary Least Squares (OLS) regression model was used to test the effect of distance of pit latrines from dug-wells on the levels of the bacteriological parameters measured. In each case, the measured parameter was used as the dependent variable and the distance between the dug-wells and the nearest pit latrines as the independent variable in the model

CHAPTER FOUR

RESULTS

4.1 RESULTS OF THE SANITATION SURVEY AND DISTANCE MEASUREMENT

Distances of the dug-wells from nearest pit latrines are presented in Table 1. The dug-wells were sited between 10.3 and 27.2 metres from nearby pit latrines.

The sanitation survey conducted revealed that less than half of the dug-wells (43.8%) were covered with either a metallic or a wooden lid (Table 1). More than 60% (10 dug-wells) had their inside walls lined with concrete with just over 30% having their immediate surroundings paved with concrete (Table 1). In all the dug-wells, various receptacles (rubber tubes and aluminium buckets) were used to draw water.

Table 1: Distance of dug-wells from pit latrines and environmental conditions

Suburb	Well ID	Distance to latrine (m)	Well characteristics	Location of well (in relation to latrine)
Plotoso	**W1**	26.5	Well covered with metallic lid, inside lined with concrete, surroundings paved and multiple receptacles used	Flatland
	W2	17.8	Well not covered, inside lined with concrete, surroundings unpaved, multiple receptacles used with multiple latrines	Flatland
	W3	15.2	Well not covered, inside not lined, surroundings unpaved with multiple receptacles used	Downslope
	W4	21.1	Well covered with metallic lid, inside lined with concrete, surroundings paved and multiple receptacles used	Downslope
Blockso	**W5**	16.1	Well not covered, inside lined with concrete, surroundings not well paved and multiple receptacles used. Also close to refuse dump and sheep pen	Flatland
	W6	10.3	Well not covered, inside not lined, surroundings not paved and multiple receptacles used	Downslope
	W7	14.2	Well not covered, inside not lined, surroundings not well paved and multiple receptacles used. Also close to a refuse dump	Flatland
	W8	22.0	Well not covered, inside not lined, surroundings not paved and multiple receptacles used. Multiple toilet facilities	Flatland

Table 1: Distance of dug-wells from pit latrines and environmental conditions cont.

Suburb	Well ID	Distance to latrine (m)	Well characteristics	Location of well (in relation to latrine)
Newtown	**W9**	13.6	Well covered with a wooden lid, inside lined with concrete, multiple receptacle used and well located 5 m from sheep pen	Flat land
	W10	27.2	Well not covered, inside lined with concrete, surroundings not paved and multiple receptacles used	Downslope
	W11	16.4	Well covered with wooden lid, inside lined with concrete, surroundings paved, multiple receptacle used and close to sheep pen	Flatland
	W12	20.0	Well not covered, inside not lined, surroundings not paved and multiple receptacles used	Downslope
Asikafo-amantem	**W13**	16.7	Well covered with wooden lid, inside lined with concrete, surroundings paved and multiple receptacles used	Downslope
	W14	24.0	Well not covered, inside not lined, surroundings not paved and multiple receptacles	Flatland
	W15	16.0	Well covered with wooden lid, inside lined, surroundings paved and multiple receptacles used	Downslope
	W16	Control	Well covered with wooden lid, inside lined with concrete, surroundings paved and multiple receptacles used	N/A

4.2 PHYSICO-CHEMICAL PARAMETERS

Mean pH of all the dug-wells from the four suburbs ranged from 6.71 to 7.33, and were within the Ghana EPA recommended range of 6.5-8.5 (Table 2). The mean pH from the four suburbs was not statistically significant at 5% level of significance (Appendix I).

Mean temperatures of the water samples ranged from 26.0^{o}C in W12 at the Newtown sampling site to 27.7^{o}C in W14 at the Asikafoamantem sampling site. All the temperature values were within the 22-29^{o}C range recommended by the Ghana EPA.

The average range for turbidity was 3.50 - 36.77 NTU. With the exception of dug-well W4 (3.50 NTU), all the dug-wells recorded values that exceeded the Ghana EPA limit of 5.0 NTU (Table 2).

Concentrations of nitrate, phosphate, ammonia and nitrite in the dug- wells varied between sites. Range of values for nitrate, phosphate, ammonia and nitrite were 0.21-10.89 mg/l, 0.21-0.82 mg/l, 0.04-0.81 mg/l and 0.01-0.34 mg/l, respectively (Table 2). Highest concentrations of nitrate (10.89 mg/l) was recorded in dug-well W6, phosphate (0.82 mg/l) in dug-well W7, ammonia (0.81 mg/l) in dug-well W6 and nitrite (0.34 mg/l) in dug-well W6. Values for the above nutrients were within the respective guideline values recommended by the Ghana EPA.

The mean concentrations of nitrate, nitrite, ammonia and phosphate did not vary from the suburbs ($p>0.05$) (Appendices III, IV, V and VI).

Table 2**: Physico-chemical and nutrient concentrations of the water samples**

Suburb	Well ID	Temp (^{o}C)	pH	Turbidity (NTU)	Nitrate (mg/l)	Phosphate (mg/l)	Ammonia (mg/l)	Nitrite (mg/l)
Plotoso	**W1**	26.6±0.3	6.86±0.54	7.34±3.90	6.31±4.28	0.21±0.10	0.04±0.02	ND
	W2	26.5±0.2	6.99±0.65	21.35±11.34	4.91±7.61	0.35±0.10	0.16±0.04	0.01±0.01
	W3	27.6±0.7	7.18±0.50	9.72±2.53	9.98±11.21	0.37±0.12	0.79±1.51	0.02±0.02
	W4	26.6±0.1	6.86±0.54	3.50±1.14	2.77±2.53	0.36±0.05	0.08±0.10	ND
Blockso	**W5**	26.6±0.3	7.04±0.74	36.77±32.30	7.84±9.03	0.42±0.18	0.33±0.21	0.02±0.01
	W6	27.3±0.4	7.23±0.60	11.53±8.69	10.89±9.39	0.60±0.15	0.81±0.45	0.34±0.57
	W7	26.8±0.1	6.84±0.88	28.83±27.42	5.42±5.57	0.82±0.39	0.08±0.04	0.01±0.00
	W8	26.6±0.3	7.33±0.65	8.89±7.33	4.50±3.26	0.66±0.02	0.12±0.11	ND
Newtown	**W9**	27.1±0.5	6.78±0.83	9.40±5.59	4.20±4.56	0.37±0.10	0.13±0.03	0.01±0.01
	W10	27.2±3	6.94±0.81	8.82±6.83	3.59±3.22	0.36±0.22	0.06±0.04	ND
	W11	27.4±0.3	7.11±0.66	17.62±8.52	2.64±2.50	0.36±0.05	0.21±0.11	0.01±0.01
	W12	26.0±0.2	6.71±0.94	30.52±34.01	0.44±0.44	0.40±0.12	0.10±0.01	ND
Asikafoa-mantem	**W13**	26.7±0.2	6.74±0.86	13.01±11.61	0.21±0.19	0.60±0.19	0.22±0.16	0.01±0.01
	W14	27.7±0.6	6.89±0.82	11.30±9.81	3.00±3.37	0.48±0.32	0.22±0.12	0.01±0.01
	W15	26.6±0.2	6.76±1.00	23.00±9.44	1.59±1.30	0.39±0.11	0.16±0.05	0.01±0.00
Control dug-well	**W16**	26.9±0.1	6.75±0.91	5.69±4.14	2.64±2.80	0.48±0.18	0.08±0.01	0.03±0.04
Ghana EPA		**22-29**	**6.5-8.5**	**5.0**	**50.0**	**3.0**	**1.50**	**3.0**
p-value			**0.8690**	**0.4062**	**0.0342**	**0.3458**	**0.5298**	**0.6497**

ND - Not Detected

4.3 BACTERIOLOGICAL PARAMETERS

Table 3 shows the mean and standard deviation of total and faecal coliform counts as well as *E. coli* in the water samples from the dug-wells. Mean counts of Total coliforms ranged from 15.50 to71.62 cfu/100ml while faecal coliforms were from 0.00 to 13.00 cfu/100ml. Dug-well W5 recorded the highest total coliform counts (71.62 cfu/100ml) while the highest faecal coliforms (13.00 cfu/100ml) was recorded in dug-well W7. The results indicate that all the wells (with the exception of W16) did not meet the Ghana EPA recommended value of zero for drinking water. However, differences in the total coliform and faecal coliform loads at the various sites were not significant ($p>0.05$).

Table 3 indicates that *E. coli* in the water samples ranged from 0.00 to 4.25 cfu/100ml. These were recorded in dug-well W4 and W10, respectively. Thus, with the exception of dug-well W4 and W16 (Control), all the dug-wells exceeded the Ghana EPA value of 0.00 for drinking water.

No significant difference existed in the mean loads of *E.coli* in well water from the four sampling zones ($p=0.675$). The control dug-well recorded no count for *E. Coli.* (Table 3)

Table 3: Means and standard deviations of Total coliforms, Faecal Coliforms and *E. coli* in the Dug wells

Suburb	**Well ID**	**Distance to latrine (m)**	**Total coliform (cfu/100ml)**	**Faecal coliform (NTU)**	***E. coli* (cfu/100ml)**
Plotoso	**W1**	26.5	24.22±15.16	2.22±1.96	0.84±1.67
	W2	17.8	58.75±45.96	2.88±5.28	0.87±1.81
	W3	15.2	61.75±38.32	3.25±4.72	1.75±2.36
	W4	21.1	15.50±20.36	1.00±2.00	0.00±0.00
Blockso	**W5**	16.1	71.62±62.91	7.00±13.61	1.38±2.50
	W6	10.3	61.50±72.23	3.00±3.4	1.25±1.26
	W7	14.2	55.75±57.98	13.00±18.67	1.00±2.00
	W8	22.0	23.99±15.96	6.00±1.06	1.26±0.10
Newtown	**W9**	13.6	47.50±40.93	9.00±12.27	3.75±5.68
	W10	27.2	48.25±40.08	2.50±4.36	4.25±5.68
	W11	16.4	25.50±9.04	1.75±2.36	0.25±0.50
	W12	20.0	46.25±32.67	3.50±7.00	1.50±3.00
Asikafoa-mantem	**W13**	16.7	19.00±6.96	5.00±1.11	1.55±3.01
	W14	24.0	23.38±23.84	11.75±24.96	1.38±2.77
	W15	16.0	36.25±32.15	2.25±3.20	0.75±1.50
	W16	Control	21.00±21.68	0.00±0.00	0.00±0.00
Ghana EPA Standard		**30.0**	0.00	0.00	0.00
p-value			0.311	0.566	0.675

4.4 The OLS Regression Model

The effect of distance of pit latrines from dug-wells on the level of bacteriological parameters (faecal coliform, total coliform and *E. coli*) was tested using the Ordinary Least Squares (OLS) regression model. Measured distances and bacteriological parameters recorded from the four suburbs were combined and used as the dependent

variable while the distance was used as the independent variable. The results are presented in Table 4-6.

Table 4: OLS regression of the effect of distance on the amount of total coliform in dug-wells

Parameter	Coefficient	Standard Error	t statistic	P-value
Constant	145.110	32.869	4.41	<0.0001
Distance	-3.874	1.724	-2.25	0.0285

Table 5: OLS regression of the effect of distance on the amount of faecal coliform in dug- wells

Parameter	Estimate	Standard Error	t statistic	P-value
Constant	33.587	9.880	3.40	0.0012
Distance	-1.224	0.518	-2.36	0.0215

Table 6: OLS regression of the effect of distance on the amount of *E.coli* in dug-wells

Parameter	Estimate	Standard Error	t statistics	P-value
Constant	28.759	5.677	5.07	<0.0001
Distance	-1.143	0.298	-3.84	0.0003

CHAPTER FIVE

DISCUSSION

5.1 Sanitation Survey

The study revealed that the dug-wells were sited between 10.3 and 27.2 metres from nearby pit latrines. This indicates that all the dug-wells were sited closer than the 30 metre minimum separation distance recommended by the Ghana Water and Sanitation Board for drinking water supply dug-wells. This exposes the dug-wells to high risk of bacteriological contamination through inflow and seepage of faecal matter from the pit latrines. Also, many of the dug-wells did not have cover slaps and, in some cases, the inner perimeters of the wells were not lined with impermeable materials such as concrete. These, coupled with the poor sanitation around the majority of the dug-wells put them at high risk of various forms of contamination. The use of multiple receptacles (rubber tubes and aluminium buckets) with various degrees of hygiene further exposes the dug-wells to contamination.

5.2 PHYSICO-CHEMICAL PARAMETERS

5.2.1The pH

The results of the physico-chemical analysis of the water samples from the 16 dug-wells show that the pH of the water samples ranged from 6.71 to 7.33. The measured pH values indicate that all the 16 dug-wells had values that were within the Ghana EPA recommended range of 6.5-8.5 for drinking water, and did not appear to pose any problem to the water.

5.2.2 Temperature

The measured temperature values of the dug-well water samples varied in a narrow range of 26.0 to 27.7^{o}C. This shows some uniformity of the groundwater samples in the study area. Although there is no guideline value set for drinking water by the Ghana EPA, the WHO recommends a range of 22 to 29^{o}C. Higher water temperatures are not recommended mainly because they make drinking difficult.

5.2.3 Turbidity

Water becomes turbid when substances like silt, clay, colloids and organic matter are present. Mean Turbidity ranged from 3.5 to 36.8 NTU in the water samples. The EPA guideline limit for turbidity for drinking water supplies is 5 NTU. The values recorded for the samples exceeded this limit except in dug-well W4 where the mean value was within this limit.W4 in the Plotoso sampling site is a dug-well that was covered with a metallic lid and the inside walls were lined with concrete material. Also, the immediate surroundings were paved with concrete. These conditions might have combined to reduce the inflow of runoff or infiltrated water into the dug-well, hence the low value of turbidity. The generally high turbidity values could be caused by surface run-off and the fact that most of the dug wells were not lined, paved or covered. The soil becomes loose and disturbed during water withdrawal when dug-wells are unlined, unpaved or uncovered (Mishra *et al.*, 2009).

It was also observed that the rope of the receptacle for water withdrawal was usually left in the dirty water around the dug-wells after water withdrawal and reintroduced into the dug-wells during the next withdrawal. Duncan (1996) explains that high turbidity may be caused when light is blocked by large amounts of silt and

microorganisms in water. Moreover, bacteria, viruses and parasites such as giardia and cryptosporidium can attach themselves to the suspended particles in turbid waters (Metcalf and Eddy, 2003). Turbidity is also considered as surrogate microbiological parameter because it is closely linked to the microbiological safety of drinking water (FPTSDW, 2001). Turbidity can indicate that water may be contaminated with pathogens presenting human health concerns (Olson, 2004).

5.2.4 Nitrate and Nitrite

The 16 dug-wells sampled from the four suburbs recorded mean nitrate and nitrite concentrations of 0.21-10.3 mg/l and 0.01-0.34 mg/l. All the examined dug-wells had nitrate and nitrite concentrations that were within the Ghana EPA acceptable limit 50 mg/l and 3 mg/l, respectively. Although the concentrations were generally low (Table 2), the relatively high levels in some of the dug-wells suggest other anthropogenic influence such as transport of organic matter from the pit latrines. The low levels of nitrate and nitrite in the dug-wells might be due to the fact that agricultural activities were not carried out at the sampling sites. Suthar *et al*., (2009) had strongly suggested intensive agriculture and heavy use of N-fertilizer to be a major enrichment of nitrate in groundwater. This is also in agreement with an observation in a (WHO, 2003) drinking water quality report which concluded that the nitrate concentration in groundwater and surface water is normally low but can reach higher levels as a result of leaching or run-off from agricultural land or contamination from human or animal waste as a consequence of the oxidation of ammonia and similar sources. The sources of nitrate and nitrite to groundwater also include natural geologic deposit, mineralization of soil organic nitrogen, intense use of fertilizer, and human and animal sewage (Hallerg and Keeney, 1993)

5.2.5 Phosphate

The mean concentrations of phosphate recorded in the study were very low (0.21 to 0.82 mg/l), and were within the maximum allowable limit of 400 mg/l recommended by the Ghana EPA for drinking water. The low concentration of the phosphate in the dug-well water samples might be due to the geology of the area and confirms similar work done by (Adeyomo *et al.*, 2008). The results also show that addition of nutrient from anthropogenic sources to the well water is minimal. Phosphate constitutes a very important pollution problem whenever it is found in significant amount. It promotes algae growth and / or microphytes, leading to the cyclic problem of eutrophication (Thriodore, 2004). It is established that high phosphorus concentration has no health implication except for its role in causing eutrophication of water bodies (WHO, 2004).

5.2.6 Ammonia

The mean concentration of ammonia recorded in all the 16 dug-wells ranged from 0.04 to 0.81 mg/l. These were within the Ghana EPA standard of 1.5 mg/l for drinking water. The highest mean concentration of 0.81mg/l was recorded in dug-well W6 sited 10.3 metres from the nearest pit latrine at the Blockso sampling site whilst dug-well W1 sited 26.5 metres from the nearest pit latrine recorded the lowest mean concentration of 0.04 mg/l. Ammonia occurs naturally in groundwater because of leakage from agricultural land, animal keeping, sewage and metabolic processes in the ground (WHO, 2004). Ammonia is also released upon decomposition of proteinaceous matter and can be released into the atmosphere, used directly by microorganisms or converted into nitrite and nitrate (Liu, 1999). The presence of

ammonia in the wells indicates possible bacterial, sewage and animal waste pollution (WHO, 2004).

5.3 BACTERIOLOGICAL PARAMETERS

5.3. 1 Total Coliform Counts

Significant numbers of total coliforms were recorded in the dug-wells sampled. Mean total coliform numbers ranged from 15.50 to 71.62 cfu/100ml which far exceeded the Ghana EPA standard of zero count of total coliform in drinking water. This could be due to water withdrawal practices at the dug-wells which could have caused the introduction of total coliforms by the users and contamination of the wells with plants and organic materials from the environment since most of the wells were not covered. Ifabiyi (2008), and Akinbile and Yusoff (2011), have reported high values for total coliform counts in various groundwater wells. The p-value of total coliform mean loads of 0.311 implies that there were no significant differences in total coliform counts at the various suburbs at 5% level of statistical significance.

Results of the OLS regression model for the amount of total coliform in the dug-wells yielded a constant value of 145.110 with a p-value <0.0001, which gives an indication of statistical significance at 5% level. Moreover, the coefficient for the variable distance of -3.874 with p-value of 0.0285 indicates that the effect of distance on the amount of total coliform is significant. Additionally, the results suggest that for every unit increase in the distance between the dug-wells and the nearest pit latrine the amount of total coliform decreases by an approximate amount of 4 cfu/100ml.

5.3.2 Faecal Coliforms

Faecal coliform counts in the water samples ranged from 0 (in the control well) to 13.0 cfu/100ml. Thus, the majority of the wells did not meet the Ghana EPA standard limit of zero in drinking water. The high numbers recorded could be attributed to the fact that all the dug-wells sampled from the four suburbs were located within the range of 10.3-27.2 metres from the nearest pit latrines which do not conform to the pit latrines radii of influence of 30 metres as generally accepted by the Ghana Water and Sanitation Board. Studies done by Haword *et al.*, (2007), Ayanlaja *et al.*, (2005) and Pritchard *et al.*, (2007) revealed that one of the major contributing factors of groundwater pollution is pit latrine mostly located near water sources such as shallow wells and boreholes and have been identified as the major source of contamination of wells with faecal matter. The (WHO, 2002), lists leachate from pit latrines as one of the major sources of water pollution. Differences in faecal coliform counts among the suburbs were not statistically significant (p=0.566) at 5% level of significance.

From the OLS regression model, the constant figure of 33.587 indicates that approximately 34 cfu/100ml of faecal coliform loads are caused by other factors other than the presence of the nearest pit latrine in the neighbourhood of the dug-wells. The p-value of 0.0012 shows that this figure has a significant effect on the amount of faecal coliform in the dug-wells. Also, the coefficient of the variable distance of -1.224 suggests that every unit increase in the distance between the dug-wells and the nearest pit latrine decreases the amount of faecal coliform by an approximate amount of 1 cfu/100ml. The test of significance gave a p-value of

0.0215, therefore suggesting that the distance between the dug-wells and the nearest pit latrine has significant effect on the amount of faecal coliform.

5.3.3. E. coli

Generally, *E. coli* was detected in all the dug-wells sampled. Though the numbers were low, they exceeded the Ghana EPA limit of 0.00 in drinking water. The only dug-wells that did not register the presence of *E. coli* were dug-wells W4 and W6. The highest mean load of 4.25 cfu/100ml was recorded at the Newtown sampling site in dug-well 10 sited 27.2 metres from the nearest pit latrine. This high value could be attributed to the fact that dug-well W10 is close to a school and used as a defecating area by the students. The microbial indicator levels observed at these sampling sites gives an indication of contamination of the dug-well water by faecal matter of human origin (Asbolt *et al*., 2001), and makes the water unsuitable for drinking (WHO, 2004), predisposing significant health risks to humans. Even though *E. Coli* counts were relatively low, their presence in the water sample also gives an indication of the presence of other potentially harmful bacteria in the water and this confirms work done by (Kara *et al.*, 2004) that the presence of *E. Coli* indicates possible presence of pathogenic bacteria, virus and protozoans. The presence of *E. coli* in drinking water denotes that the water has been contaminated by faecal matter and therefore presents a potential health risk to households that use them untreated (Nkansah *et al*., 2010). According to (WHO 2004), *E. coli* is present in very high numbers in human and animal faeces and its presence provides conclusive evidence of recent faecal pollution and should not be found in drinking water. Thus, its presence in the wells poses health risk to consumers.

Application of the OLS regression model to the *E. coli* numbers resulted in constant and coefficient of 28.759 and -1.143 with respective p-values of <0.0001 and 0.0003, respectively. Clearly, these suggest that the constant and the variable distance are both significant at 5% level.

Moreover, the coefficient of the variable distance of -1.143 suggests that every unit increase in the distance between the dug-wells and the nearest pit latrine decreases the amount of *E. coli* by an approximate amount of 1 cfu/100ml.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

The study revealed that all the physico-chemical parameters of water analysed (except turbidity) from the various dug-wells fell within the Ghana EPA standards for drinking water. The high turbidity levels of the tested water make the water aesthetically unpleasant for human consumption.

All the dug-wells from the four suburbs tested positive to faecal coliform and *E. Coli* with the exception of the control dug-well which fell within the Ghana EPA standard of zero count in drinking water. The presence of faecal coliform and *E. coli* suggest that there is faecal contamination of the dug-wells from the pit latrines due to close proximity thus making the dug- wells unacceptable and not recommended as potable water for drinking.

It was also observed that a significant association existed between distances from dug-wells to the nearest pit latrine and the bacteriological loads in the water samples.

6.2 RECOMMENDATIONS

Based on the results of this study, the following are recommended

- The Water and Sanitation Board in the district should ensure that the distance of pit latrines to dug-wells meet the recommended distance of 30 metres by Ghana Water and Sanitation Board.
- Government should ensure adequate and efficient public water supply through the provision of pipe-borne water.

- There should be the creation of awareness and education of residents on dug-well construction, citing and maintenance.
- Water from the dug-wells should be boiled before use.
- There should be proper general sanitation management practices by residents.

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APPENDICES

APPENDIX I: Analysis of variance of mean level of pH in the dug-wells

SAS output for one way ANOVA

pH

The SAS System

The ANOVA Procedure

Class Level Information

Class	Levels	Values
Sampling sites	4	Asikafoa Blockso Newtown Plotoso

Number of Observations Read	60
Number of Observations Used	60

The SAS System

The ANOVA Procedure

Dependent Variable: PH

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	0.36406292	0.12135431	0.24	0.8690
Error	56	28.46871042	0.50836983		
Corrected Total	59	28.83277333			

R-Square	Coeff Var	Root MSE	PH Mean
0.012627	10.25802	0.713001	6.950667

Source	DF	Anova SS	Mean Square	F Value	Pr > F
Samplingsites	3	0.36406292	0.12135431	0.24	0.8690

APPENDIX II: Analysis of variance of mean level of turbidity in the dug-wells **Turbidity**

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The ANOVA Procedure

Class Level Information

Class	Levels	Values
Samplingsites	4	Asikafoa Blockso Newtown Plotoso

Number of Observations Read	60
Number of Observations Used	60

The SAS System

The ANOVA Procedure

Dependent Variable: Turbidity

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	1140.76512	380.25504	0.99	0.4062
Error	56	21602.32211	385.75575		
Corrected Total	59	22743.08723			

R-Square	Coeff Var	Root MSE	Turbidity Mean
0.050159	109.7755	19.64067	17.89167

Source	DF	Anova SS	Mean Square	F Value	Pr > F
Samplingsites	3	1140.765123	380.255041	0.99	0.4062

APPENDIX III: Analysis of variance of mean level of nitrate in the dug-wells

Nitrate

The SAS System

The ANOVA Procedure

Class Level Information

Class	Levels	Values
Samplingsites	4	Asikafoa Blockso Newtown Plotoso

Number of Observations Read 60

Number of Observations Used

The SAS System

The ANOVA Procedure

Dependent Variable: Nitrate

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	1143.937410	381.312470	3.09	0.0342
Error	56	6903.556048	123.277787		
Corrected Total	59	8047.493458			

R-Square	Coeff Var	Root MSE	Nitrate Mean
0.142148	148.2219	11.10305	7.490833

Source	DF	Anova SS	Mean Square	F Value	Pr > F
Samplingsites	3	1143.937410	381.312470	3.09	0.0342

APPENDIX IV: Analysis of variance of mean level of phosphate in the dug-wells

Phosphate

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The ANOVA Procedure

Class Level Information

Class	Levels	Values
Samplingsites	4	Asikafoa Blockso Newtown Plotoso

Number of Observations Read 60

Number of Observations Used

The SAS System

The ANOVA Procedure

Dependent Variable: Phosphate

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	25916.2398	8638.7466	1.13	0.3458
Error	56	429092.0829	7662.3586		
Corrected Total	59	455008.3227			

R-Square	Coeff Var	Root MSE	Phosphate Mean
0.056958	428.7914	87.53490	20.41433

Source	DF	Anova SS	Mean Square	F Value	Pr > F
Samplingsites	3	25916.23979	8638.74660	1.13	0.3458

APPENDIX V: Analysis of variance of mean level of ammonia in the dug-wells
Ammonia

The SAS System

The ANOVA Procedure

Class Level Information

Class	Levels	Values
Samplingsites	4	Asikafoa Blockso Newtown Plotoso

Number of Observations Read	60
Number of Observations Used	60

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The ANOVA Procedure

Dependent Variable: Ammonia

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	0.62769750	0.20923250	0.74	0.5298
Error	56	15.72918750	0.28087835		
Corrected Total	59	16.35688500			

R-Square	Coeff Var	Root MSE	Ammonia Mean
0.038375	155.6475	0.529980	0.340500

Source	DF	Anova SS	Mean Square	F Value	Pr > F
Samplingsites	3	0.62769750	0.20923250	0.74	0.5298

APPENDIX VI : Analysis of variance of mean level of nitrite in the dug-wells
Nitrite

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The ANOVA Procedure

Class Level Information

Class	Levels	Values
Samplingsites	4	Asikafoa Blockso Newtown Plotoso

Number of Observations Read 60
Number of Observations Used

The SAS System

The ANOVA Procedure

Dependent Variable: Nitrite

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	0.44148792	0.14716264	0.55	0.6497
Error	56	14.96388542	0.26721224		
Corrected Total	59	15.40537333			

R-Square	Coeff Var	Root MSE	Nitrite Mean
0.028658	161.8765	0.516926	0.319333

Source	DF	Anova SS	Mean Square	F Value	Pr > F
Samplingsites	3	0.44148792	0.14716264	0.55	0.6497

APPENDIX VII: Analysis of variance of mean temperature in the dug-wells **Temperature**

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The ANOVA Procedure

Class Level Information

Class	Levels	Values
Samplingsites	4	Asikafoa Blockso Newtown Plotoso

Number of Observations Read	60
Number of Observations Used	60

The SAS System

The ANOVA Procedure

Dependent Variable: Temperature

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	0.97229167	0.32409722	1.10	0.3572
Error	56	16.51354167	0.29488467		
Corrected Total	59	17.48583333			

R-Square	Coeff Var	Root MSE	Temperature Mean
0.055605	2.018084	0.543033	26.90833

Source	DF	Anova SS	Mean Square	F Value	Pr > F
Samplingsites	3	0.97229167	0.32409722	1.10	0.3572

APPENDIX VIII: Analysis of variance of the amount of total coliform in the dug-wells

Total coliform

The SAS System
The REG Procedure
Model: MODEL1
Dependent Variable: Totalcoliform

Number of Observations Read	60
Number of Observations Used	60

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	19926	19926	5.05	0.0285
Error	58	228975	3947.84743		
Corrected Total	59	248901			

Root MSE	62.83190	R-Square	0.0801
Dependent Mean	73.55000	Adj R-Sq	0.0642
Coeff Var	85.42746		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	145.11045	32.86933	4.41	<.0001
Distance	1	-3.87372	1.72425	-2.25	0.0285

APPENDIX IX: Analysis of variance of the amount of faecal coliform in the dug-wells

Faecal coliform

The SAS System 10:08 Thursday, August 4, 2013

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The REG Procedure

Model: MODEL1

Dependent Variable: Faecalcoliform

Number of Observations Read	60
Number of Observations Used	60

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	1990.94011	1990.94011	5.58	0.0215
Error	58	20689	356.70678		
Corrected Total	59	22680			

Root MSE	18.88668	R-Square	0.0878
Dependent Mean	10.96667	Adj R-Sq	0.0721
Coeff Var	172.21899		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	33.58681	9.88021	3.40	0.0012
Distance	1	-1.22448	0.51829	-2.36	0.0215

APPENDIX X: Analysis of variance of the amount of E. coli in the dug-wells

E.coli

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The REG Procedure

Model: MODEL1

Dependent Variable: Ecoli

Number of Observations Read	60
Number of Observations Used	60

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	1733.88107	1733.88107	14.72	0.0003
Error	58	6829.76893	117.75464		
Corrected Total	59	8563.65000			

Root MSE	10.85148	R-Square	0.2025
Dependent Mean	7.65000	Adj R-Sq	0.1887
Coeff Var	141.84942		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	28.75940	5.67675	5.07	<.0001
Distance	1	-1.14270	0.29779	-3.84	0.0003

APPENDIX XI: OLS regression of the effect of distance on the amount of total coliform in dug-wells

SAS output for OLS Regression

Total coliform

The SAS System

The REG Procedure

Model: MODEL1

Dependent Variable: Totalcoliform

Number of Observations Read	60
Number of Observations Used	60

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	19926	19926	5.05	0.0285
Error	58	228975	3947.84743		
Corrected Total	59	248901			

Root MSE	62.83190	R-Square	0.0801
Dependent Mean	73.55000	Adj R-Sq	0.0642
Coeff Var	85.42746		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	145.11045	32.86933	4.41	<.0001
Distance	1	-3.87372	1.72425	-2.25	0.0285

APPENDIX XII: OLS regression of the effect of distance on the amount of faecal coliform in dug-wells

Faecal coliform

The SAS System 10:08 Thursday, August 4, 2013

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The REG Procedure

Model: MODEL1

Dependent Variable: Faecalcoliform

Number of Observations Read	60
Number of Observations Used	60

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	1990.94011	1990.94011	5.58	0.0215
Error	58	20689	356.70678		
Corrected Total	59	22680			

Root MSE	18.88668	R-Square	0.0878
Dependent Mean	10.96667	Adj R-Sq	0.0721
Coeff Var	172.21899		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	33.58681	9.88021	3.40	0.0012
Distance	1	-1.22448	0.51829	-2.36	0.0215

APPENDIX XIII: OLS regression of the effect of distance on the amount of E. coli in dug-wells

E.coli

The SAS System

The REG Procedure

Model: MODEL1

Dependent Variable: Ecoli

Number of Observations Read	60
Number of Observations Used	60

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	1733.88107	1733.88107	14.72	0.0003
Error	58	6829.76893	117.75464		
Corrected Total	59	8563.65000			

Root MSE	10.85148	R-Square	0.2025
Dependent Mean	7.65000	Adj R-Sq	0.1887
Coeff Var	141.84942		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	28.75940	5.67675	5.07	<.0001
Distance	1	-1.14270	0.29779	-3.84	0.0003