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GHANA

Community Perception and Laboratory Analysis of the Quality of Drinking Water Sources in the Kpedze Community of the Volta Region

By

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A Thesis submitted to the Department of Food Science and Technology,

Faculty of Biosciences

College of Science

In partial fulfilment of the requirements for the degree of

Master of Science in Food Quality Management

November, 2017

DECLARATION

I hereby declare that this submission is my own work towards the award of the MSc degree and that, to the best of my knowledge, it contains no material previously published by another person nor material which had been accepted for the award of any other degree of the university, except where due acknowledgment had been made in the text.

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ABSTRACT

This study was carried out to determine the bacteriological safety of drinking water sources of the people of Kpedze in the Volta Region, Ghana. The survey conducted using structured questionnaires captured views of households on the quality of water they use and the treatment methods employed before drinking. Membrane filtration and pour plate methods were employed for the microbiological analysis of the water samples. Of the sixty (60) randomly selected households, 78.3 % (47) preferred tap water to other drinking water sources. About 73.3 % (44) said their drinking water tasted normal while 70 % (42) said that there was no foul smell associated with their water; however, 76.7 % (46) observed sediments collected at the base of their storage containers used. Most respondents [79.2 % (42)] observed that it usually takes more than a month for broken pipe lines to be fixed. In the laboratory analyses, samples from the river had total coliform (TC) counts ranging from $1.162 \times 10^3 \pm 47.00$ cfu/100mL to $1.488 \times 10^3 \pm 279.00$ cfu/100mL, faecal coliform (FC) counts ranging from $3.92 \times 10^2 \pm 20.00$ cfu/100mL to $6.04 \times 10^2 \pm 47.00$ cfu/100mL, E. coli counts ranging from $1.18 \times 10^2 \pm 40$ cfu/100mL to $1.22 \times 10^2 \pm 51.00$ cfu/100mL, and total heterotrophic bacteria (THB) ranging from $2.60 \times 10^2 \pm 118.00$ cfu/1mL to $7.67 \times 10^2 \pm 204$ cfu/1mL. The tap water had TC counts ranging from $6.98 \times 10^2 \pm 47.00$ cfu/100mL to $1.122 \times 10^3 \pm 6.00$ cfu/100mL and 4.00 ± 2.00 cfu/100mL to $1.102 \times 10^3 \pm 210.00$ cfu/100ml for FC counts. E. coli levels in tap water ranged from 2.00 ± 1.00 cfu/100mL to $1.48 \times 10^2 \pm 53.00$ cfu/100mL while THB ranged from $9.7 \times 10^1 \pm 20.00$ cfu/mL to $1.577 \times 10^3 \pm 662.00$ cfu/mL. Water from the hand dug well had TC counts ranging from $5.73 \times 10^2 \pm 26.00$ cfu/100mL, FC levels of 31.00 ± 18.00 cfu/100mL, E. coli counts of 2.00 ± 2.00 cfu/100mL and THB of $3.09 \times 10^2 \pm 94$ cfu/mL. Samples from the borehole had TC levels of $5.10 \times 10^2 \pm 78.00$ cfu/100mL, FC counts of 3.00 ± 2.00 cfu/100mL, E. coli counts of 0.00 ± 0.00 cfu/100mL and THB counts of $2.76 \times 10^2 \pm 180.00$ cfu/mL. The physico-chemical analysis of the water samples revealed pH 5.86 for the tap water, 6.19 for the hand dug water, pH of 7 for the borehole water and 5.91 for water from the river. The observational checklist revealed that the odour and taste were inoffensive. Levels of calcium, magnesium, iron and nitrate were all found to be below the Ghana Standards Authority (GS175-1) recommended limits for drinking water. From the survey, it was identified that the Kpedze community does not rely on a single source of water for domestic purposes. Using E. coli as the indicator organism, water from the borehole was found to be safe (0.00 cfu/100ml) among all the sources sampled.

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LIST OF ABBREVIATIONS

CFU Coliform Forming Unit

EPA Environmental Protection Agency

WHO	World Health Organization
GSA	Ghana Standards Authority
GSS	Ghana Statistical Service
FC	Faecal coliform
FDA	Food and Drugs Authority
USGS	United States Geological Survey
TC	Total coliform
THB	Total Heterotrophic Bacteria

CHAPTER ONE

1.0. INTRODUCTION

1.1. BACKGROUND INFORMATION

Portable water is a need and must be accessible to every individual. Globally, in 2012, 89 % of people had access to water suitable for drinking (WHO, 2016). Nearly four billion had access to tap water while another 2.3 billion had access to wells or public taps; however, about 1.8 billion people still use unsafe drinking water source which may be contaminated with faeces. This can result in infectious diseases such as diarrhoea, cholera and typhoid fever among others (WHO, 2016). Thus, to stay healthy, human beings need continuous access to potable water and as such, all stakeholders concerned must ensure that it is readily accessible.

World Health Organization (WHO) in a related document cited that, as of 2012, 56 % of the global population has gained access to pipe borne water on their premises. Contrarily, in Ghana, only 0.18% of the population has pipe borne water on their premises, 0.61 % have access to other improved water sources, while 0.20 % only accessed unimproved water source, out of which 0.02 % filter or boil the water at the household level. Few Ghanaians (0.15 %) have improved sanitation with 0.13 % practicing hand washing after potential contact with excreta (WHO, 2014). It is estimated that over 52 % of Africa's population at least occasionally drink water that is contaminated with faecal bacterial indicators (WHO, 2014).

When it comes to water, there is always the need to follow a holistic monitoring approach to finally ensure that water reaching the end consumer is of good quality. For instance, to ensure and secure a microbiologically safe drinking water supply, there is the need to use multiple barriers, from the catchment or source to the consumer to avoid the contamination of the drinking water or to effectively reduce the levels of contaminants to one that is not injurious to health (WHO, 2014).

Thus, multiple barriers, if adequately monitored and maintained, increase safety. Some management approaches to ensure safety include, protection of water source, proper selection and a series of effective operational treatment steps and adequate management of distribution systems (pipe-borne or otherwise). This approach must also ensure that emphases are placed on preventing or reducing the entry of pathogens into water sources and thereby reduce the reliance on treatment processes.

Kpedze Awlime located in the Ho West District of the Volta Region of Ghana is a community of about 5,239 people (Ghana Statistical Service, 2011). The Awlime Taale River is the community's main source of water. It is dammed and distributed to the entire community without any form of treatment, even though the community agrees that initially, the sand filtration system in place was effective until recently. This source is constantly exposed to contaminants from humans and animal faeces (bird droppings). These faeces, nonetheless, are sources of pathogenic bacteria, viruses, protozoa and helminths (WHO, 2003). Aside this water source, the community is also resourced with wells and a mechanized borehole.

1.2. PROBLEM STATEMENT

Water plays a very important role in the daily lives of all human beings. It protects the immune system, aids chemical reactions in the body; used for cooking, and for agricultural purposes among others. Thus, water must not only be readily available and affordable but must most importantly be safe. Safe and readily available water is important for public health, whether it is used for drinking, domestic use, food production or used for recreational purposes. Improved water supply and sanitation, and better management of water resources, can boost a countries' economic growth and can contribute greatly to poverty reduction (WHO, 2016).

Microbial contamination of water sources is a known fact; however, if properly treated and distributed the risk of exposure to contamination and its effects is reduced. Where water is supplied wholly without treatment as it occurs in the Kpedze community, the community becomes exposed to the risk of outbreaks of infectious diseases and intestinal disorders (WHO, 2006). Kpedze Awlime is a typical rural community that has been privileged to have a regular water supply with its source from the Awlime Taale River. Though the water used to be treated and distributed by the gravity piped system with a slow sand filtration treatment, this system has been non-functional for some time (Juven and Pertolla, 2011). Water from this system is thus distributed without any form of treatment. Field observation showed that, distribution outlets are located at places such as schools, churches and open places in several parts of the community for easy access. In addition, there are other supplementary water sources such as mechanized bore hole and hand dug wells built. Majority of the wells are without covers and open to all kinds of pollutants with some of these wells built close to poorly built septic tanks.

The Paramount chief of Kpedze traditional area, Togbuiga Atsridom, in an interview suggested that, the lack of portable water to the people in the community constantly exposes them to waterborne diseases such as bilharzia and river blindness (Ghana Broadcasting Corporation, 2015). There is, therefore, the need for collective action both from the community and other stakeholders to put measures in place to ensure that all drinking water sources are well protected and safe for the community.

This study focussed on the quality of the various drinking water sources in the Kpedze Awlime community and the water quality perception of people living in the community.

1.3. JUSTIFICATION

It is hoped that data from this study will reveal the most contaminated of the water source(s). Data generated from the study will also provide estimates of the levels of total heterotrophic bacteria, total coliforms, faecal coliforms and *E. coli* in the water samples from the different sources used by the community. Additionally, data from the physico-chemical analysis will help reveal other non-microbial contaminants that pollute water sources from the Kpedze Community.

1.4. AIM

To access the community's perception on water quality in comparison with laboratory analysis of the drinking water sources in the Kpedze Community of the Volta Region

1.5. SPECIFIC OBJECTIVES

1. To access the perception of the community on issues related to water quality and hygienic practices and their impact on human health.
2. To estimate the levels of total heterotrophic bacteria, total coliforms, faecal coliforms and *E. coli* in the water samples from the different sources used by the community
3. To evaluate the physical and chemical states of the sources of drinking water in relation to the perception of the community on water quality.

CHAPTER TWO

2.0. LITERATURE REVIEW

2.1. DRINKING WATER AS A VEHICLE FOR DISEASES

Water as an essential part of life needs to be accessible, adequate and supplied in a safe manner to all. Significant health benefits can be obtained if access to safe drinking water is improved and hence every effort is needed to achieve a safe and quality drinking water as possible (WHO, 2008). An estimated 560,000 people suffer from severe waterborne diseases and 7.1 million suffer from mild to moderate infections resulting in about 12,000 estimated deaths each year (Medema *et al*., 2003).

In developing countries, waterborne infections are common due to the limited access to safe water coupled with poor sanitation and hygiene practices. According the WHO (2008), more than 5 million people every year die from water associated diseases with more than 50 %, of this number, being through microbial intestinal infections, with cholera standing out as first. These microbial risks are largely related to the ingestion of water contaminated with human or animal faeces, with waste water discharges being the major source of faecal microorganisms including pathogens in fresh waters (WHO, 2008).

2.2. QUALITY CONTROL AND QUALITY ASSURANCE PROCEDURES OF AN IDEAL WATER SUPPLY SYSTEM

An ideal water supply system, must among other things, has its source well protected, have its distribution systems properly laid out and regularly maintained, and must have a continuous flow rate to endpoints with no stagnation at any point of distribution (WHO, 2006). In addition, microbial analysis of water for indicator organisms must be carried out routinely on the water samples to evaluate its effects on human health. This will enable stakeholders to be able to identify specific treatment procedures which will eventually lead to their ability to minimize, eliminate or inactivate the various pathogens present (USFDA, 2002).

2.3. THE RATIONALE OF THE USE OF INDICATOR BACTERIA

Some gastrointestinal diseases of great importance that are transmitted through water are cholera, salmonellosis, and shigellosis amongst many others. These diseases caused by bacteria are mostly transmitted through water (and food) contaminated with faeces of patients. Presence of these pathogenic bacteria in water is mostly random and erratic with the occurrence of very low levels, making their isolation and culture complicated (USFDA, 2002). Hence, routine water microbiological analysis does not always include the detection of pathogenic bacteria. Safe water, however, demands that the water be free from these pathogenic bacteria. This led to the discovery and testing for indicator bacterial such as total coliforms, faecal coliforms and

Escherichia coli, which can easily be detected in environmental waters (George and Servais, 2002).

2.3.1. Total Coliforms

Total coliforms are Gram-negative, oxidase-negative, non-spore forming rods, which ferment lactose with gas production at 35-37 ^{0}C, after 48 hours in a medium with bile salts and detergents (WHO, 2008). Several species of the four Enterobacteriaceae genera, Escherichia, Klebsiella, Enterobacter and Citrobacter will yield positive to coliform testing, thereby defining these four genera as coliforms.

2.3.2. Faecal coliforms

Faecal coliforms/thermo-tolerant coliforms are bacteria that ferment lactose at 44.5 ^{0}C in a medium with bile salts (WHO, 2008). These include *E. coli*, Klebsiella oxytoca and Klebsiella pneumoniae. They are generally associated with the intestinal tracts of warm blooded animals such as humans and cattle (Synova, 2006). In water, faecal coliforms are present when other bacterial pathogens from faecal sources are present. They are usually not pathogenic but indicate the presence of pathogenic organisms. Since faecal coliform bacteria are usually present in higher concentrations than actual pathogens and the fact that these faecal coliforms can survive longer than the pathogenic bacteria, it makes them likely to be detected. Faecal coliforms are thereby chosen as primary indicator bacteria because they are harmless to humans (EPA, 2002).

2.3.3. Escherichia coli

E. coli is a subset of the faecal coliform group and is usually chosen as secondary indicator for bacterial contamination since they are specific indicators of faecal pollution (EPA, 2002). The genus Escherichia including the species coli (*E. coli*) originate in faecal matter and has thus been used as surrogates to access enteric bacterial pathogens removals by treatment barriers due to their ease of culture (AWWA, 2006). They are bacteria found naturally in the digestive tract of warmblooded animals, such as humans and are thus used in drinking water as the definitive indicator of current faecal water contamination. For water that is intended for human consumption, there should be no indicator organism (AWWA, 2006).

Most *E. coli* strains are non-pathogenic with some possessing virulence traits that enable them to cause serious infections such as diarrhoea in humans. Pathogenic *E. coli* can be transmitted through the faecal-oral route with its primary exposure routes being contaminated food or water or by person to person transmission (Percival et al., 2004). Pathogenic *E. coli* is, however, not of concern in treated drinking water when treatment and distribution systems are properly operated and maintained (Olsen *et al*., 2002).

2.4. MICROBIAL ANALYSIS OF WATER

Microbial analysis of water can be carried out for various reasons. For instance, microbial analysis of water can be carried out, to evaluate the efficacy for human risk associated with an exposure to an identified pathogen, to assess critical control points related to factors such as watershed protection, to be able to identify specific treatment procedures to minimize, eliminate or inactivate the various pathogens present, and to be able to forecast the effects of the various management options for risk reduction (USFDA, 2002).

Elements of importance under the multi-barrier approach to safe drinking water are required to function alongside bacteriological analysis in order to produce drinking water of acceptable quality. Some of these elements include; the protection of source water, improved treatment performance for factors such as turbidity reduction and particle removal, improved technologies for the application of disinfectants, a properly designed and well maintained distribution system, and proper maintenance of the residues of disinfectants (EPA, 2002).

2.4.1. Secondary transmission of pathogens and the degree of infection with pathogens

When it comes to water, an individual could get infected with pathogens when one drinks the water. Infections could also be transmitted from such a person to others and depends to a large extent on the age of the host, non-specific host factors and the state of immunity of the host (Gerba *et al*., 1999). The state of immunity of the host may result in providing short or long term protection from re-infection and this may depend largely on the enteric pathogen involved.

2.4.2. Temporal and spatial distribution of pathogens in water

Density determination for pathogens may be difficult due to their ability to clump, be embedded or attached to organic or inorganic particulate debris. They can, however, grow and be protected in these environments. Most pathogens only appear periodically in source and drinking waters and others may also be found typically only during short periods of disease outbreaks in a community (NRC, 2004). These seasonal increments may cause the water sources to become contaminated through breakdowns of control of water contamination, thus making contamination of sources different from each contamination event (WHO, 2006).

2.4.3. Impact of rainfall on surface water quality

The flow of water has been determined as the single most important parameter that affects the transport of microbial contaminants (Ferguson *et al*., 2003). The occurrence of rainfall events has been correlated with increased microbial loading in surface waters. This supports the hypothesis that, microorganisms are transported in surface run-offs (Curriero *et al*., 2001).

It has also been shown through field experiments that Cryptosporidium oocyte peaked 20 minutes after heavy rainfall and this could be extrapolated to hold for other faecal microbes. In addition, increased field elevation was also found to have an increasing impact on the rate of microbial transport. Leaching and surface run-off showed a strong influence on the immobilization of bacteria depending on the type of soil involved and the type of vegetation present (Ferguson *et al*., 2003).

2.4.4. Surveillance of drinking water supplies of a community

A range of point sources, such as dug wells, springs that are protected, and boreholes with hand pumps, according to the WHO (2006), are all included in what is usually classified as community managed supplies. Effective implementation of programmes of surveillance to ensure the control of water safety for such supplies often face paramount constraints which includes inadequate skills and a limited capacity to carry out process control and verification. These may increase the need for both surveillance and access to the state of drinking water supplies and to provide training and support to both the surveillance staff and the members of the community. Another limitation is usually with the large numbers of widely dispersed supplies which increase significantly the total costs in carrying out surveillance activities. The role of surveillance also includes health education and its promotion to improve healthy behaviour and management of drinking water supply and sanitation (WHO, 2003).

2.4.5. Impact of population increase on water quality

As human population increases worldwide, the demand for water also increases. This increasing demand for both domestic and industrial needs have resulted in the use of groundwater (Sandhu *et al*., 1979). In Ghana, the increase in population has resulted in irregular water supplies reducing consumers' access to portable pipe borne water. As a result, most people drill their boreholes or hand dug wells on their compounds especially in the rural areas. Environmentally, there is always the need to determine the quality of water of every locality to reduce the effects of water related diseases among that population (WHO, 2006). Thus, this study determined the quality of water in Kpedze, a Community in the Ho West District of Ghana.

2.5. AFRICA'S WATER RESOURCE STRESS AND SCARCITY

Water scarcity has become a major developmental issue for Africa, with the quality being impacted by both natural processes such as climate change and hydrology and underlying geology. 70% of Africa's drinking water has been estimated to come from groundwater sources and is usually used with little or no purification. Water is often degraded due to the high demand and increasing levels of untreated waste water being discharged into water sources, coupled with the lack of established water quality monitoring programmes (WHO, 2011).

2.5.1. Building a sustainable water system in Africa

Governments must have water strategies that capture the value of water as an economic benefit and provide policies to deliver it. The value of water must therefore be communicated to the local population (WHO, 2016).

In addition, since many of Africa's water sources are trans-boundary, it is important that any water strategy should take into account the requirements of other countries to foster international coordination (WHO, 2016).

CHAPTER THREE

3.0. MATERIALS AND METHODS

3.1. STUDY DESIGN

This study evaluates the perceptions of the Kpedze community on water safety and also determines the levels of microbial contamination of the various sources of drinking water. The water samples were obtained from publicly erected taps with open access to the community; a hand dug well, a river, and a borehole. Three regimes of sampling were done at a two week interval each. All sampling was done over a period of six weeks during the dry season. In addition, questionnaire was designed and administered to sixty (60) respondents.

3.2. SURVEY PROCEDURE

A total of sixty (60) respondents were randomly selected from the Kpedze community. A questionnaire with twenty five (25) questions was administered to the respondents, who were randomly selected within the community. The random sampling resulted in a selection bias with more women as compared to men.

3.3. STUDY AREA

Kpedze (red rock) is located in the Ho West district of the Volta Region with longitude 0.4958, and latitude 6.8401 with an elevation of 260m. It is a rural community with farming as their main occupation, with an estimated population of about 5,279 (GSS, 2011). It has two main rivers; which are the Taale and Lafie of which the Taale river was dammed and channelled to the community with the help of the German government, and was later handed over to the Ghana Water Company. Currently, it is managed by the community water committee (Juven and Petolla, 2011).

.3.1. Study Sites

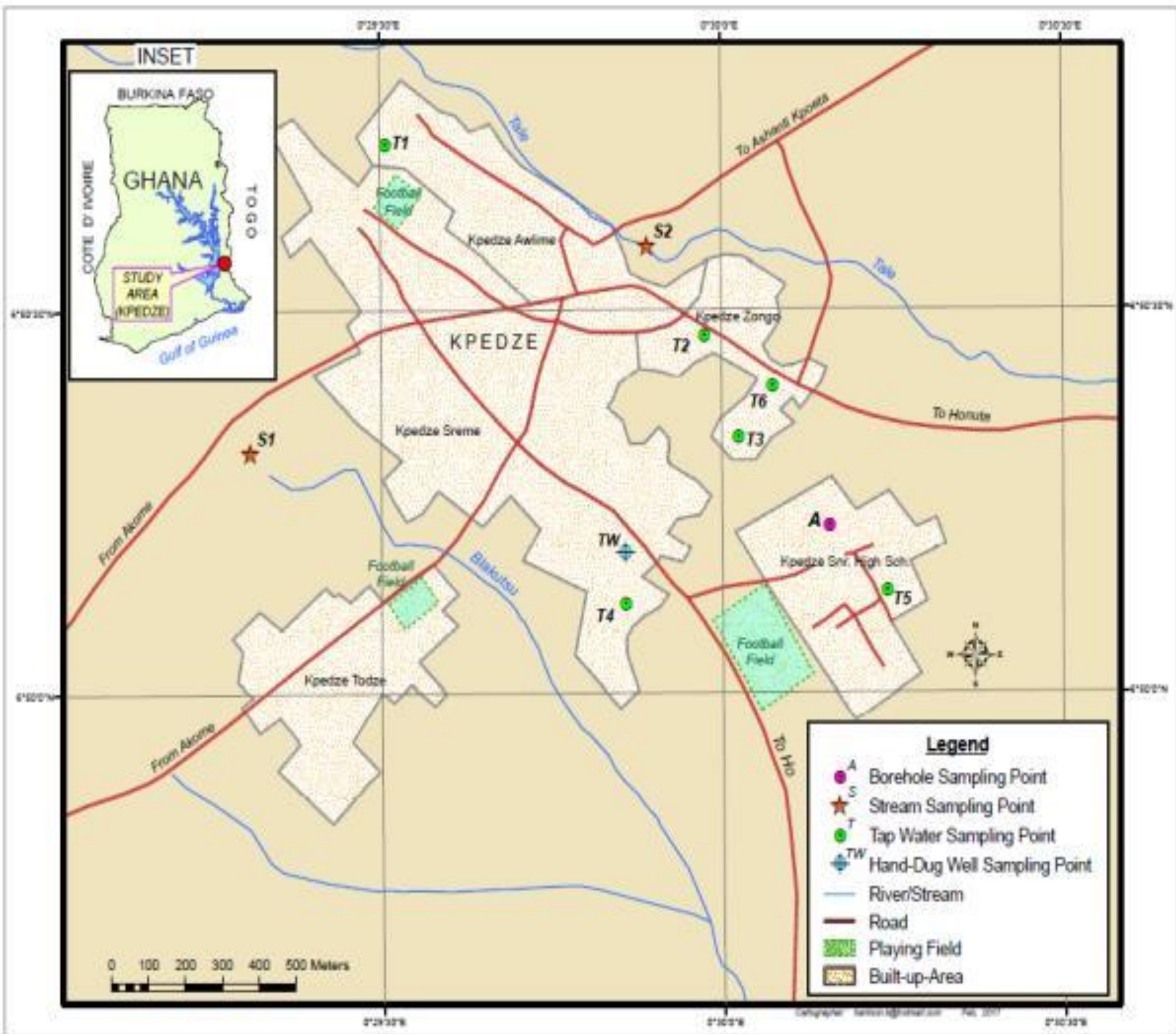

Figure 3. 1 Map showing the various sampling points

A total of ten study sites were selected based on accessibility to water source by the community. They included the upper dammed part of the Taale river and its lower reaches, six (6) public erected taps, a hand dug well, and a mechanized borehole.

3.4. SAMPLING PROCEDURE

Sterile sample bottles used were clearly labelled after each sampling procedure with the location code, water source, date and time of collection. The stand pipe to be sampled was turned on and allowed to run to waste for about 2-3 minutes. This was to ensure that the interior of the nozzles were well flushed and stagnant waters discharged. This was done to avoid overestimation of contaminants. The taps were disinfected using 70 % ethanol (because open flame could not be used on the field due to resistance from the community members) using a wash bottle to spray both the inside and outside of the nozzle with the taps closed. After disinfection, the tap water was allowed to run for another 2 minutes and adjusted to a gentle stream of flow. Samples were taken aseptically into sterile bottles and stored immediately in an ice chest with ice pack at 4 ^{0}C. pH and temperature of water samples were recorded ex-situ (Hach, 2012). Samples were then transported to the Water Research Institute of the Council for Scientific and Industrial Research, (CSIR) laboratory for analysis. All analyses were carried out within 24 hours.

3.5. LABORATORY ANALYSIS

3.5.1. Membrane Filtration

The membrane filtration method was used for the recovery of total coliforms, faecal coliforms and E. coli. Sterile filter papers of pore size 0.45µm were aseptically placed on top of the filtration manifold and on top of these were mounted sterile funnels. Hundred millilitres (100 ml) of water sample to be tested were then poured separately into the funnel and allowed to filter with the aid of a vacuum pump. After filtration, the filter papers were aseptically removed and placed on the appropriate media (Hach, 2012).

3.5.1.1. Isolation of Faecal Coliforms

Membrane Faecal Coliform (mFC) agar was used for the recovery of faecal coliforms from the water samples. mFC contains both differential and selective agents, including; Rosolic acid, which inhibits the growth of other bacteria with the exception of faecal coliforms; Bile salts, which prevents the growth of non-enteric bacteria; Aniline blue, which indicates the ability of faecal coliforms to ferment lactose to acid thereby causing a change in pH of the medium. This lactose utilization (blue colour) is the basis for identification of faecal coliforms.

Rehydration of the Membrane Faecal Coliform was done by dissolving 52.1 g in 1 liter of sterile distilled water containing 10 ml of 1 % Rosolic acid. It was then heated to boil to dissolve the medium completely. Nine millilitre (9 ml) aliquot of media were separately poured into 4cm petri dishes and allowed to solidify. Filters with filtrates were aseptically placed on the solidified agar and the plates incubated at 44 ^{0}C for 24 hours in an inverted position.

3.5.1.2. Isolation of total coliforms and *E. coli*

Chromo cult coliform agar was used for the recovery of total coliforms and *E. coli* (U.S. EPA, 2004; U.S. Geological Survey, 2007). It is a chromogenic media that is able to differentiate between total coliforms (Pink colonies) and *E .coli* (Blue colonies). Rehydration of the media was done by dissolving 26.5 g in 1 litre of sterile distilled water. It was then heated in a boiling water bath to dissolve the medium completely. Dissolved media was kept molten in water bath kept at 50 ^{0}C and poured into sterile Petri plates to solidify. Nine millilitre (9 ml) aliquot of media were separately poured into 4 cm Petri dishes and allowed to solidify. Filters with filtrates were aseptically placed on them and the plates were then incubated at 37 ^{0}C for 24 hours in an inverted position.

3.5.2. Enumeration of heterotrophic bacteria

The pour plate method was used for the recovery of Total Heterotrophic Bacteria (THB). The media were prepared by dissolving 28 g in 1 litre of sterile distilled water and then heated to boil to dissolve completely. This was further sterilized by autoclaving at 121 ^{0}C for 15 minutes and kept in a water bath set at a temperature of 50 ^{0}C to keep it molten. One millilitre (1mL) each of samples under investigation was pipetted into the appropriate 4 cm Petri dishes and about 25ml of molten media added and swirled gently to mix up with the sample. Each plate was allowed to set and incubated at 37 ^{0}C for 48 hours in an inverted position.

3.5.3. Counting of colonies

All colonies formed were counted using the Stuart colony counter and the results expressed as colony forming units (cfu) per 100 mL of water sample analysed for the Total coliform, *E. coli* and the faecal coliform while Total Heterotrophic Bacteria was expressed as cfu/mL.

3.5.4 Physico-chemical water analysis

Water samples for physico-chemical analyses were collected directly into clean 1L plastic sampling bottles. The samples were preserved on ice at 4^{0}C before transporting them from the field to the CSIR – WRI Laboratories in Accra for analysis. The physico-chemical analyses were performed according to procedures outlined in the Standard Methods for the Examination of Water and Wastewater, 22nd Edition (APHA, 2012). A brief description of the methods used is outlined in the table below.

Table 3. 1 Summary of Laboratory Methods of analyses

STEPS	METHODS
pH and Conductivity	Determined using portable meters
Orthophosphate	Reaction with Ammonium Molybdate and Stannous Chloride to form blue molybdenum complex and measured at an absorbance of 690 nm

Nitrate-N	Hydrazine Reduction followed by Diazotization and colour intensity measured at an absorbance of 520 nm
Sulphate	Reaction with Barium Chloride and measurement at an absorbance of 420 nm
Fluoride	SPADNS Method
Alkalinity	Strong Acid Titration Method
Total Dissolved Solids (TDS)	Calculation from Conductivity
Total Hardness	Titration using EDTA Method
Cations and Anions	Titrimetric Method
Chloride	Argentometric Method using silver nitrate
Trace Metals	Atomic Absorption Spectrophotometer
Temperature	Temperature probe
Turbidity	HACH 2100P Turbidimeter
Conductivity	Cyberscan PC 510
Suspended solids	Gravimetric method
Sodium	JENWAY Flame Photometer
Magnessium	By calculation
Phosphate	JENWAY 6505UV Spec
Sulphate	JENWAY 6505UV Spec
Calcium	EDTA Titrimetric method
Potasium	JENWAY Flame Photometer

3.6. DATA ANALYSIS

Results from the survey analysis were entered into Statistical Package for Social Sciences (SPSS) version 16.0 using the Likert scale to code the response on a scale of one to four (1-4) in order of increasing importance to change the nominal response into an ordinal one. Results from the microbiological analysis were first, compiled into Microsoft Excel spread sheets where all the triplicate values were averaged. The averaged values were then transformed using the log normal transformation. All observations that recorded null values (cfu/100mL) were eliminated. This was, however, not expected to decrease the accuracy of the analyses. Histograms were plotted in excel to compare the bacterial concentrations at the various sampling sites.

CHAPTER FOUR

4.0. RESULTS

4.1. COMMUNITY SURVEY

4.1.1. Gender distribution of respondents in the survey

A total of sixty randomly sampled households were involved in the community survey. Details were gathered using a well-designed and a pre-tested questionnaire. From these households, the persons interviewed were mostly women. Thirty eight (63.3 %) of the respondents were females while the males comprised the remaining 36.7 % (22 males) (Table 4.1). Table 4. 1 Gender of respondents

Gender	Frequency	Percentage (%)
Males	22	36.7
Females	38	63.3
Total	60	100

4.1.2. Choice of Drinking Water Sources

4.1.2.1. Main source of water

Out of the sixty respondents, 78.3 % depended on tap water, 13.3 % depended on water from the bore hole, 6.7 % depended on well water, and the remaining 1.7 % depended on river water as their main sources of drinking water (Table 4.2).

Table 4. 2 Respondents' choice on main source of water

Water sources	Frequency	Percentage
River	1	1.7
Tap water	47	78.3
Well	4	6.7
Borehole	8	13.3
Total	60	100

4.1.2.2. Alternate source of water

All respondents had an alternate source of drinking water especially in the absence of the main source of drinking water. Of these, 23.3 % used well water, 20 % used rainfall, and 16.7 % used river water, while another 16.7 % used tap water with those that used bore-hole water scoring 16.7% as alternative drinking water source. About 6.7 % of the Respondents, however, did not state their alternate water source (Table 4.3).

Table 4. 3 Respondent's choice on alternate source of water

Alternate sources	Frequency	Percentage
River water	10	16.7
Tap water	10	16.7
Rainfall water	12	20
Well water	14	23.3
Borehole water	10	16.7
Missing water	4	6.7
Total	60	100

4.1.2.3. Source of water for school children

When asked about the source of drinking water for the school going children when at school, 60 % of the subjects were not certain about the source of drinking water available to children at school, but 30 % stated well water while 10 % stated sachet water (Table 4.[1]).

Table 4. [2] Response on the source of drinking water for school children at school

Drinking water for school children	Frequency	Percentage
Well water	12	20
Sachet water	12	20
Missing	36	60
Total	60	100

[1] **.1.3. Community's perception on water quality**

[2] **4.1.3.1. Response on taste of water**

A total of 73.3 % of the respondent stated that their drinking water was tasteless while 1.7 % claimed it tasted salty with 25 % of the respondents not giving any answer (Table 4.5). Table 4. 5 Respondents' perception on the taste of drinking water

Perception on taste of water	Frequency	Percentage
Salty	1	1.7
Tasteless	44	73.3
Total	45	75
Missing	15	25
total	60	100

4.1.3.2. Community's response to smell of water

About, 70 % of the respondents said their drinking water did not have any foul smell, while 10 % reported that their water sources were always associated with some level of foul smell (Table 4.6).

Table 4. 6 Respondent's perception on the smell of water

Smell of water	Response	Frequency	Percentage
Valid	yes	6	10
	no	42	70
	Total	48	80
Missing	99	12	20
Total		60	100

4.1.3.3. Physical appearance of water

In addition, 76.7 % of the respondents said that sediments settled at the bottom of their storage containers when water was stored for some time, 15 % stated the water always looked muddy when fetched with 8.3 % stating that their water sources were always clear (Table 4.7).

Table 4. 7 Respondents' perception on the physical appearance of water

Appearance of water	Frequency	Percentage
Muddy	9	15
Sediments	46	76.7
Clear	5	8.3
Total	60	100

4.1.4. Water Storage and Post Treatment Practices of Community Members

4.1.4.1. Duration of household water storage

From the survey, it was observed that 71.7 % of the respondents stored their water for less than one week while 28.3 % of the sample population never stored their water (Table 4.8).

Table 4. 8 Duration of water storage

Duration of storage	Frequency	Percentage
Less than a week	43	71.7
Never	17	28.3
Total	60	100

4.1.4.2. Cleaning of storage containers

On the cleaning of the storage containers, 81.7 % of the respondents said they cleaned their water storage containers daily while 11.7 % cleaned their storage containers weekly with the remaining 6.7 % cleaning their storage containers as and when necessary to do so (Table 4.9).

Table 4. 9 Duration taken to clean water storage containers

Duration	Frequency	Percentage
Weekly	7	11.7
Daily	49	81.7
Missing	4	6.7
Total	60	100

4.1.4.3. Household water treatment

When asked whether or not they treated their water in any form before usage, 87.1 % stated that they do not treat the water while 9.7% claimed they boil it. Few of the respondents (3.2 %), however, did not respond to this question (Table 4.10).

Table 4. 10 Household treatment of water before drinking

Treatment of water	Frequency	Percentage
No	27	45
Yes	3	5
not sure	1	1.7
Total	31	51.7
missing	29	48.3
total	60	100

4.1.4.4. **Duration to fix broken pipelines**

With reference to the duration it takes to fix broken pipelines, 70 % of respondents stated that broken pipe lines took more than a month to be fixed while 5 % answered that, broken pipe lines were fixed within a week with 13.3 % stating that they are usually fixed daily once they are identified. The rest of the respondents (11.7 %) did not comment (Table 4.11).

Table 4. 11 Duration taken to fix broken pipe lines

Duration to fix pipelines	Frequency	Percentage
More than a month	42	70
A week	3	5
Daily	8	13.3
Total	53	88.3
missing	7	11.7
total	60	100

4.1.5. Awareness of Waterborne Diseases

To ascertain the communities' perception on water borne diseases, the respondents were asked whether or not they were aware of water borne diseases. Majority of the respondents (73.3 %) stated that they were aware of water borne diseases while 21.7 % claimed they had never heard of water borne diseases. Few respondents (5 %) did not answer the question (Table 4.12).

Table 4. 12 Perception on water borne diseases

Waterborne diseases	Frequency	Percentage
Yes	44	73.3
Not aware	13	21.7
Missing	3	5
Total	60	100

4.2. MICROBIOLOGICAL LABORATORY ANALYSIS

4.2.1. Total Coliform Count in the Water Samples

From the microbiological analysis presented in Figure 4.1, S2 (lower reaches of the river) had the highest counts of total coliforms of 1.488 x 10^3 ± 276.00 cfu/100mL followed by S1 (dammed part of the river) with 1.162 x 10^3 ± 47.00 cfu/100mL. The dammed river is distributed through taps T1, T2, T3, T4, and T5 with total coliform counts of 1.121 x 10^3 ± 6.00 cfu/100mL, 1.116.00 x 10^3 ± 372.00 cfu/100mL, 6.97 x 10^2 ± 46.00 cfu/100mL, 1.072 x 10^3 ± 180.00 cfu/100mL, and 1.102 x 10^3 ± 111.00 cfu/100mL, respectively. Site T6 is a tap that has also been linked with the mechanized borehole and had total coliform (TC) levels of 1.002 x 10^3 ± 163.00 cfu/100mL. W, which is a hand dug well had TC level of 5.73 x 10^2 ± 26.00 cfu/100mL with site BH, which is water from the borehole having an average TC count of 5.10 x 10^2 ± 78.00 cfu/100mL.

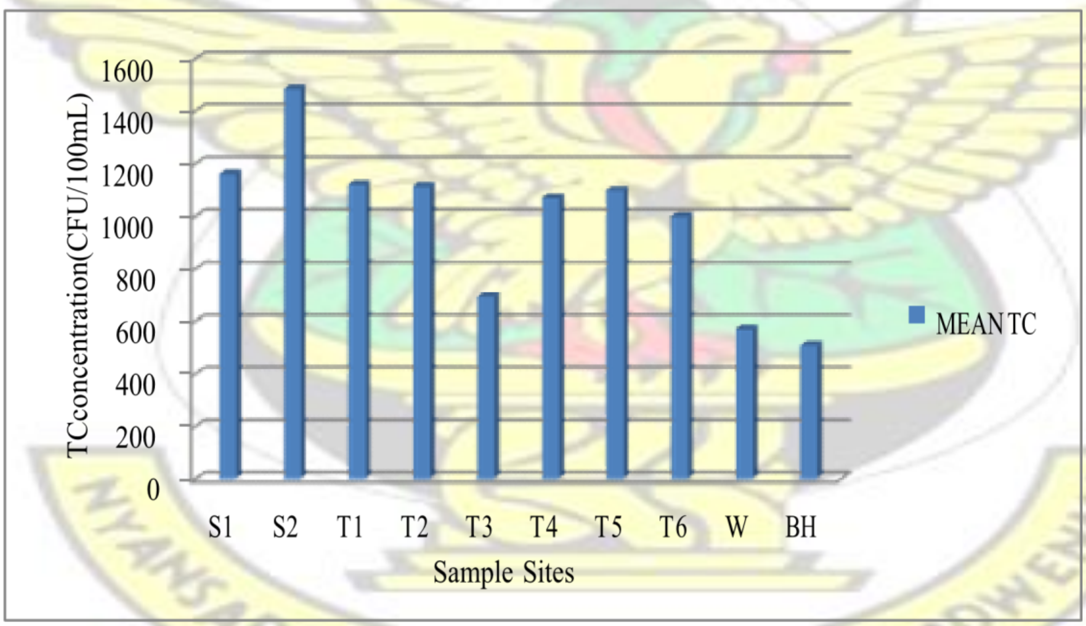

Figure 4. 1 Total Coliform Count in the Various Sources of Water

TC = Total coliform; S1 = the dammed part of the river; S2 = the lower reaches of the river; T1 to T6 = the first to sixth taps; W = the hand dug well and BH = the mechanized borehole.

4.2.2. Load of Faecal Coliforms in the Water Samples

As presented in Figure 4.2, faecal coliform (FC) counts were highest at the second tap from T2 with $1.102 \times 10^3 \pm 210.00$ cfu/100mL, followed by samples from the dammed site (S1) with counts of $6.04 \times 10^2 \pm 47.00$ cfu/100mL and the first tap (T1) with $5{,}27.00 \times 10^2 \pm 31.00$ cfu/100mL. S2, which is downstream of S1 had $3.92 \times 10^2 \pm 20.00$ cfu/100mL. T4 had $4.89 \times 10^2 \pm 161.00$ while T3 had $2.87 \times 10^2 \pm 42.00$ cfu/100mL. Sample from the well (W) had $3.1 \times 10^1 \pm$ 18.00 while the borehole had 3.00 ± 2.00 cfu/100mL.

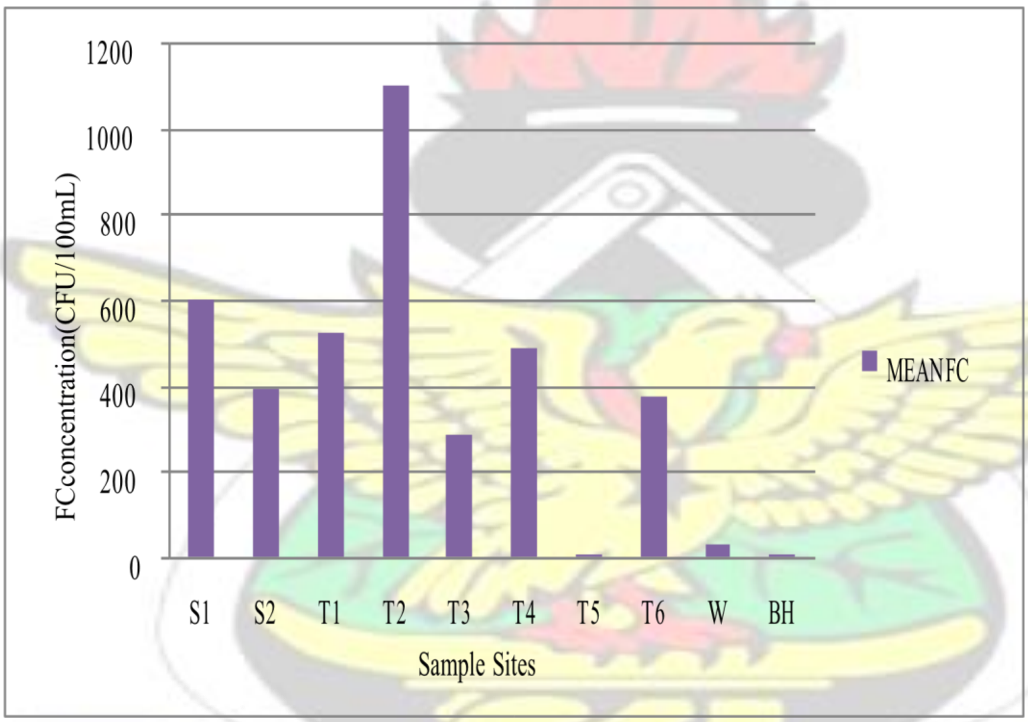

Figure 4. 2 Faecal coliform count in the various sources of water

TC = Total coliform; S1 = the dammed part of the river; S2 = the lower reaches of the river; T1 to T6 = the first to sixth taps; W = the hand dug well and BH = the mechanized borehole.

4.2.3. *E. coli* count in the water samples

E. coli levels were highest at site T4 (forth tap from the source) with counts of 1.48 x 10^2 ± 53.00 cfu/100mL, followed by S2 with counts of 1.22 x 10^2 ± 51.00 cfu/100mL and S1 with counts of 1.18 x 10^2 ± 40 cfu/100mL. Site T2 also saw decreased levels of 6.1 x 10^1 ± 17.00 cfu/100mL followed by T3, T6, and T5 with counts of 5.2 x 10^1 ± 17.00 cfu/100mL, 6.00 ± 2.00 cfu/100mL, and 2.00 ± 1.00 cfu/100 mL respectively. Samples from the hand dug well (W) had counts of 1.1 x 10^1 ± 2.00 cfu/100mL with 0.00cfu/100mL for the borehole (Fig. 4.3).

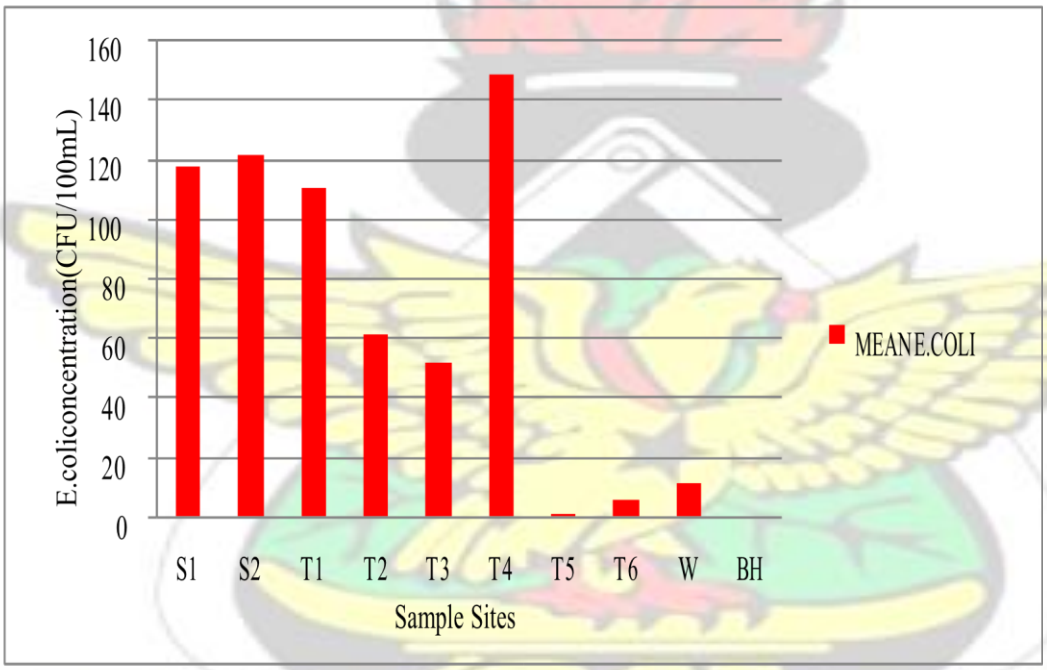

Figure 4. 3 Load of *E. coli* in the various sources of water

TC = Total coliform; S1 = the dammed part of the river; S2 = the lower reaches of the river; T1 to T6 = the first to sixth taps; W = the hand dug well and BH = the mechanized borehole.

4.2.4. Load of total heterotrophic bacteria in the water samples

As presented in Figure 4.4, the average counts of total heterotrophic bacteria at all the sites were below 5.00 x 10^2 cfu/mL except for sites T3 and T6 which had average count of 1.577 x 10^3 ± 662.00 cfu/mL and 5.20 x 10^2 244.00 cfu/100 mL, respectively.

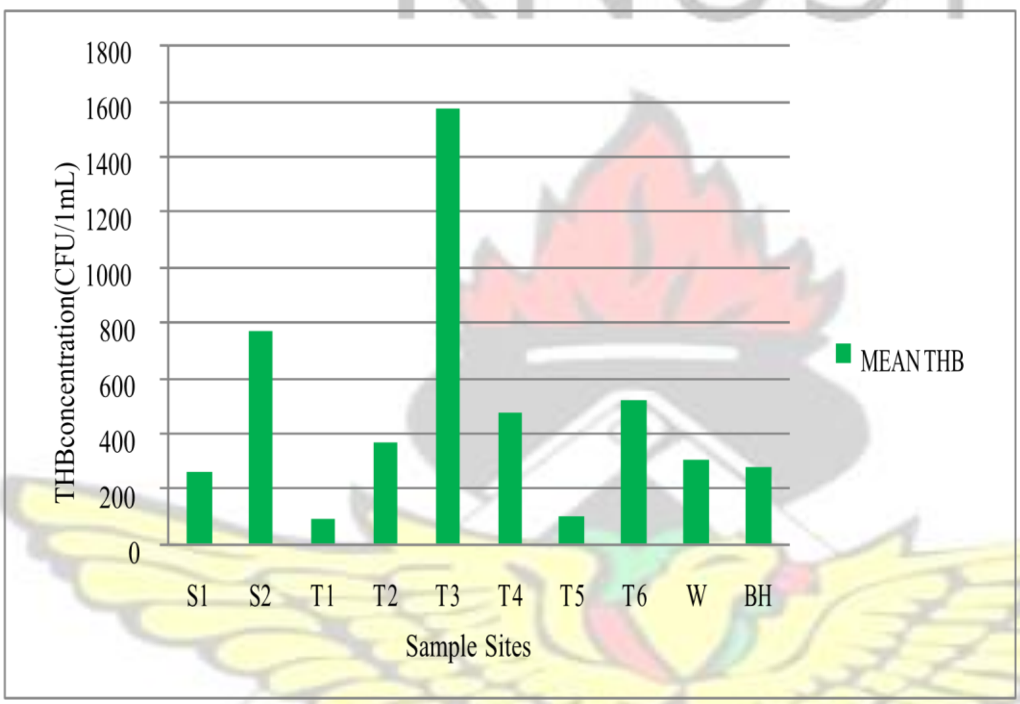

Figure 4. 4 Load of THB in the various sources of water

TC = Total coliform; S1 = the dammed part of the river; S2 = the lower reaches of the river; T1 to T6 = the first to sixth taps; W = the hand dug well and BH = the mechanized borehole.

4.3. PHYSICO-CHEMICAL PARAMETERS

Physical characteristics of the water samples (hand dug well, tap water and mechanized borehole) were analysed and parameters analysed included; colour, turbidity, total suspended particles, odour, total hardness, presence of minerals such as manganese, magnesium, iron and nitrates (Tables 4.13 - 4.15).

4.3.1. Physico-chemical parameters of samples from the tap water

The results as presented in Table 4.13, shows the turbidity and colour of the tap water were found to be acceptable with a pH of 5.86. The odour of the water was found to be inoffensive and total dissolved solids were 102, with magnesium (4.7) and iron (0.1) level, and total hardness of 59.6.

Table 4. 13 Physico-chemical parameters of samples from the tap water

Parameter	Method No.	Unit	Value	GS 175-1/WHO Guideline
Turbidity	3	NTU	2	5
Colour (apparent)	2	Hz	<2.50	15
Odour				inoffensive
pH	4	pH units	5.86	6.5-8.5
Tot.dis. Solids (TDS)	6	mg/l	102	1000
Magnesium	26	mg/l	4.7	150
Total Iron	31	mg/l	0.104	0.3
Nitrate (NO2-N)	14	mg/l	0.015	1
Nitrate (NO3-N)	15	mg/l	0.076	10
Total hardness (as CaCO3)	25	mg/l	50	500

4.3.2. Physico-chemical parameters of samples from the borehole

The turbidity and colour of the borehole water was found to be acceptable for drinking with a pH of 7, the odour of the water was found to be inoffensive. Total dissolved solids were 76.2, with magnesium and iron levels of 8.7 and 0.097, respectively and total hardness of 58.4 (Table 4.14).

Table 4. 14 Physico-chemical parameters of samples from the borehole

Parameter	Method No.	Unit	Value	GS 175-1/WHO Guideline
Turbidity	3	NTU	2	5
Colour (apparent	2	Hz	7.5	15
Odour				inoffensive
pH	4	pH units	7	6.5-8.5
Tot.dis. Solids (TDS)	6	mg/l	76.2	1000
Magnesium	26	mg/l	8.7	150
Total Iron	31	mg/l	0.097	0.3
Nitrate (NO2-N)	14	mg/l	<0.001	1
Nitrate (NO3-N)	15	mg/l	0.072	10
Total hardness (as CaCO3)	25	mg/l	58.4	500

4.3.3. Physico-chemical parameters of samples from the hand dug well

The turbidity and colour of the tap water were found to be acceptable for domestic purposes. The pH was 6.19 whiles the odour of the water was found to be inoffensive. Total dissolved solids were also 87.6, with magnesium and iron levels 3.6 and 0.12, respectively and a total hardness of 59.6 (Table 4.15).

Table 4. 15 Physico-chemical parameters of samples from the hand dug well

Parameter	Method No.	Unit	Value	GS 175-1/WHO Guideline
Turbidity	3	NTU	3	5
Colour (apparent	2	Hz	<2.5	15
Odour				Inoffensive
pH	4	pH units	6.19	6.5-8.5
Tot.dis. Solids (TDS)	6	mg/l	87.6	1000
Magnesium	26	mg/l	3.6	150
Total Iron	31	mg/l	0.12	0.3
Nitrate (NO_2-N)	14	mg/l	0.01	10
Nitrate (NO_3-N)	15	mg/l	0.333	10
Total hardness (as CaCO3)	25	mg/l	59.6	500

CHAPTER FIVE

5.0. DISCUSSION

This study aims to eventually help the Kpedze community and the various stakeholders concerned in assessing the quality and safety of their water sources used for drinking and other domestic purposes. A survey was carried out to access the community's perception on issues relating to water safety, to evaluate their hygienic practices, and to subsequently educate the community on hygienic behaviours that could promote good health.

In this study, female respondents formed a majority (63.3 %) (Table 4.1). This could be due to the fact that most of the women in the community plied their businesses from home or were unemployed compared to their male counterparts. In addition, females in most households were more willing to discuss issues relating to their water usage as compared to the males who in most instances referred the interviewing team to the women. Moreover, women generally form the majority of those who fetch water to be used for all domestic purposes and as such they are more conversant with the state of their water resources (UNESCO, 2004). The availability of different sources of water in the Kpedze community shows that the community is endowed with water for various domestic purposes.

Among these water sources, tap water was the most preferred (Table 4.2). They perceived a lower risk with the quality of the tap water as compared to the other sources. Works by Attari *et al*. (2010), also suggested that individual choices of water sources for drinking or other household chores could also be affected by pro-environmental attitudes as well as the number of persons depending on such sources. Interestingly, because most of the taps were sited at open places and not in individual homes, most people felt more comfortable drawing water from such places as compared to the hand dug well and mechanized borehole which were cited at protected places.

From the microbiological analysis, in terms of total coliform counts in the six taps sampled in

Fig 4.1, all had total coliform levels were slightly lower than the samples from the river source. According to the WHO (2011), for a water source to be regarded as safe for the purposes of drinking, it must have zero total coliform for every 100mL of sampled water. Thus, water samples from both the taps and river had total coliform levels unsafe for drinking without further treatment. In the case of the E. coli concentrations, as presented in Fig 4.3, there was presence of *E. coli* in all the taps sampled. The presence of *E. coli*, poses great health risk to consumers since every safe drinking water is expected to have 0.00 cfu/100mL of *E. coli*. In most reported cases of waterborne disease outbreaks, *E. coli* has usually been detected, making it more representative of faecal pollution compared to other coliforms (EPA, 2003).

Total heterotrophic bacteria (THB) counts were lower than the recommended load of 500 cfu/1mL [Ghana Standards Authority (GS175-1)], except for T3 and T6 in Figure 4.4. THB generally only shows a representation of the general cleanliness of drinking water even though it is not considered a potential threat to human health (US EPA, 2003). Hence, they are also not regarded as a compliance measure; however, their numbers are usually monitored to gain understanding, on the changes in a drinking water system, over a period of time to give a clear indication of their increase in numbers (USEPA, 2003). High THB levels in the tap water of the Kpedze community may suggest the presence of biofilms in these systems. From personal communication with the community water and sanitation members, it was identified that the distribution systems had not undergone maintenance activities such as flushing, cleaning or disinfection, due to lack of funds. About 13.3 % of the respondents (Table 4.2) chose water from the borehole as their main source of drinking water. Their choice could mainly be based on the proximity of the borehole to their homes as compared to other sources. In addition the level of total dissolved salts was within acceptable limits (Table 4.14). Turgeon *et al*. (2004), suggested that the distance from a water source tends to influence perception on water quality. Even though the borehole was constructed for the community Senior High School as a source of drinking water, part of the community closest to the school also access this for other domestic purposes. Levels of faecal coliforms in the borehole (Figure 4.2), was 1.03.00 x $10^2 \pm 178.00$ cfu/100mL making it more polluted than the hand dug well but less polluted when compared to faecal coliform concentrations from the river and all the taps. Boreholes are generally known to have proper sanitary protection and thereby supplies water that contains few or no faecal indicator bacteria. Thus, in instances where indicator bacteria are identified, it implies that the sources of contamination may be from on-site immediate surroundings, such as nearby latrines (WHO, 2003).

This study, however, shows that the mechanised borehole was located at an isolated area away from rubbish, latrines and farm activities, but had high microbial counts. In such a situation, the source of contamination must further be investigated since communities usually have multiple sources of environmental faecal contamination making it difficult to access the minimal impacts of contamination (Ngure *et al*., 2013). On-site observation showed that water from bathhouses of the students was channelled towards the borehole and this could account for the levels of microbial load.

Even though total coliform counts in Fig. 4.1 was low for the bore hole in relation to the other water sources, this level is far higher than the WHO (1996) recommended level of 0.00 cfu/100mL. Nevertheless, it has been estimated that there have been cases of waterborne disease outbreaks even in areas where total coliform bacterial were not detected (US EPA, 2003). Their presence, therefore, in the borehole suggests that the water must go through some form of treatment before being used as a source of drinking water. The water from the borehole did not have a detectable count of *E. coli*, making it the safest in terms of *E. coli* contamination during the period of sampling. Even though these results may suggest some level of safety, it is still highly recommended that all stakeholders take a critical look at the possibility of regular monitoring of the water sources. Deutsch (2003), suggested that boreholes are generally safer sources of drinking water when they are properly constructed and maintained and that they will consistently supply safe and wholesome water with low microbial load which may need minimal treatment.

Water from the hand dug well (Table 4.2), was chosen by 6.7 % of the respondents as their main source of water. Such a low patronage could be due to the fact that the hand dug well is located on an enclosed compound thereby limiting access. Prospective patrons also find it difficult to seek permission from those who manage the well. Hence, most of the respondents stated that they feel uncomfortable drawing water from the hand dug well. On-site observation showed a pit latrine located less than thirty meters away from the opened hand dug well. This hand dug well, however, happened to be very deep but with lots of cracks along its concrete walls that also looked mouldy. The perceptions of the respondents on the choice of drinking water could be mostly psychological and may also be influenced by a protective behaviour to prevent illness (Redding *et al*., 2000). The microbial analysis of the water sample from the hand dug well suggested that the water from the hand dug well is less contaminated, in terms of faecal coliform concentration, as compared to the water from the taps (Fig. 4.1). This source is, however, not potable for drinking since the concentrations are above the recommended limits of 0.00 cfu/100mL [Ghana Standards (GS1751)]. According to the WHO (2003), the most common risks to well-water quality is their open head nature and the use of inappropriate water-lifting devices (buckets) in most communities that easily expose the water to contamination by consumers. Other serious sources of pollution include contamination from both human and animal waste which eventually leads to increased levels of microorganisms. These factors make hand dug wells one of the worst groundwater sources in relation to faecal contamination (WHO, 2003).

From the survey, (Table 4.2), 1.7 % of the respondents chose water from the river as their main source of water. Because the dam site (S1) is not accessible to the community, it implies that water is usually fetched from downstream (S2). Visual observation showed massive human activities around the water body, including intense farming and logging activities, leading to the destruction of a greater part of the barricades around the dammed site.

Human activities capable of polluting catchment area around water resources will most definitely alter the quality of water downstream as well as aquifers which will in turn impact on treatment steps needed to ensure water safety (WHO, 2006). According to the WHO (2014), an estimated 644 million people in sub-Sahara Africa still practice open defecation without protection or treatment thus, shallow groundwater or surface water should not be used as a source of drinking water (WHO, 2006). It is, however, estimated that sub-Sahara Africa is making minimum or no efforts in providing access to treated pipe-borne water to consumers and hence a large percentage of individuals continue to depend on untreated sources of water, mainly surface water (WHO, 2014). UNICEFF and WHO (2011), suggested that even drinking water from improved sources are necessarily not free from faecal pathogens and hence cannot be considered totally safe for human health. Data from this study showed that all sources including the protected borehole had levels of faecal coliforms and hence there is a need for these waters to go through some form of household treatment before use.

Water from the hand-dug-well was chosen by 20 % of the respondents (Table 4.5), as the sources of drinking water for children at school. Children are most vulnerable to water borne diseases because once they are thirsty they drink any available water not caring about quality. This study observed that all the basic schools in the community had taps erected on their premises suggesting that, most if not all, pupils as well as those providing catering services patronise tap water which falls below the WHO (1996) guidelines for drinking water of 0.00 cfu/100mL (Fig. 4.1 – 4.3). Levy *et al*. (2012), also concluded that there seems to be a moderate correlation between faecal contamination in drinking water and diarrhoea in children.

Even though all the sampling sites had the presence of pathogens, it has been cited from literature that most pathogenic E. coli with the exception of the Enterohemorrhagic *E. coli* group requires the ingestion of relatively high numbers (1.05×10^2 -1.010×10^3 cfu/100mL) in order to produce illness (Pond, 2005; Hillborn *et al*., 2013). This may be consoling since the average total counts of *E. coli* observed in this study were slightly below 1.05×10^2 cfu/100mL at all the sampling sites as presented (Fig. 4.3). It is most appropriate to apply precautionary measures to prevent elevated levels since microbes easily multiply (Pond, 2005). Even in the presence of low microbial counts it is likely that their death may result in the production of toxins which can remain in the water body since most of the enterotoxins are heat stable and also generally resistant to degradation (NRC, 2004). These toxins can also cause illnesses such as those relating to gastrointestinal tract infections (Hillborn *et al*., 2013). Consumers with immune-compromised systems may be prone to infections when they drink from these sources. In addition, it may be most likely that most of these pathogens that were detected in this study may only appear periodically, in the water sources and drinking water, while others may occur only during short periods of disease outbreaks in the community (NRC, 2004).

On the organoleptic perception of drinking water sources, 73.3 % stated that it was tasteless, implying that the general perception on taste was acceptable even though 1.7 % suggested that their drinking water tasted salty (Table 4.5). This group (1.7%) were mostly located near the borehole and hence could be using it as their main source of water. It has been observed that when there is a change in the normal taste of water, it could imply the presence of increased biological activity or sanitary pollution (WHO, 2003).

All the water sampled in this study, were all found to have inoffensive odours after the physicchemical analysis. In water, odour is generally caused by volatile substances as a result of the presence of organic and inorganic materials such as algae and hydrogen (La Dou, 2004). Drinking water must, therefore, be free from odours and tastes objectionable to the consumer (WHO, 2003).

Though water from borehole was reported as always clear upon collection and storage as compared to the tap water (Table 4.7), results from the physico-chemical analysis in this study (Table 4.13-4.15) suggested that all the water samples were clear.

Aside poor handling habits at home, breakages in pipe lines can significantly compromise the quality of water and sometimes such broken pipe lines in the Kpedze community could stay for a long time unrepaired. Leaks and breaks in distribution systems coupled with slow flow or low water pressures are more likely to cause increased cases of illness such as gastrointestinal diseases (Ercumen *et al*., 2014). In this study, 79.2 % of respondents explained that it usually takes more than a month for broken pipe lines to be fixed. Personal conversation with respondents also showed that, it is usually those affected that have to pay before the pipelines are repaired. Corral-Verdugo *et al*. (2002), concluded that in most parts of the world, individuals are not making efforts to improve their own water quality with majority of consumers relying on government agencies to protect water quality.

It was observed also in this study that, 71.7 % of the respondents store their water for duration above a week. According to WHO (2011), the main health risk associated with water is the ease with which recontamination can easily occur during transport and storage especially where community members do not follow good hygienic practices such as regular cleaning of household water storage facilities. In addition, these storage vessels must have tight fitting lids. It is essential for every household to store their drinking water in close or narrow-necked containers to minimise contact with hands that are contaminated, as this will play an important part of household water management and sanitation (WHO, 2011).

It was realised that almost all households interviewed had metal water storage barrels with no lids on them. These storage containers were placed outside within the compound and their physical appearance as of the time of the interview looked dusty and rusty. This could be due to the fact that most respondents were either uncomfortable or shy to state the truth. This was seen when there was no link between the 71.1% that stored water for more than a week and the 81.7% that cleaned their storage containers daily (Table 4.10). These and other poor water handling habits in this community could explain the poor quality of the water samples analysed (Fig. 4.1 – 4.4).

Household water treatment can play a significant role in protecting against waterborne pathogens, especially, where water sources are either untreated, not properly treated or usually become contaminated during distribution or storage (WHO, 2011). When asked whether or not they treat their water in any form before usage, 87.1 % (Table 4.10) stated that they did not treat the water before use since they did not see the need for any post treatment because their water looked good. This explains why only 9.7 % treat their drinking water by boiling. Boiling is considered as one of the most commonly used household water treatments that have been found to efficiently reduce pathogens (Clasen *et al*., 2008). Even though it cannot be proven to substantially reduce diarrhoeal levels in homes where it has been practiced, factors such as poor storage and handling can eventually lead to its recontamination after boiling (WHO, 2014). Household water treatments must therefore be done consistently and correctly to achieve the acceptable results of eliminating waterborne pathogens and ensuring the eventual safety of drinking water at the household level (Brown and Clasen, 2012)

About 73.3 % of respondents though aware of water borne diseases, did not know how to control it. Cairncross *et al*. (2005), identified factors such as information on water quality and hygienic behaviours employed to improve water quality as the major driving force on hygienic behaviours in developing countries. Even though most of the respondents interviewed had some level of formal education, it was realised that those with higher educational backgrounds were aware of water quality and scarcity issues. Jalan and Ravallion (2003), also suggested that, educational status combined with household income could explain households' hygienic behaviour. It is, however, estimated that lack of hygienic practices are amongst the major causes of diseases in many developing countries. As such, hygienic interventions such as education could reduce diarrhoeal incidence by about 45 % while improvements in the quality of drinking water through household water treatment, can drastically lead to a reduction in diarrhoeal cases by up to 39 % (WHO, 2004). As such, respondents were educated on water related issues during the course of the interview.

From the physico-chemical analysis, (Tables 4.14-4.16), pH values ranged from 5.86 to 7.Which imply a slightly acidic to near neutral nature of the water samples. Both the hand dug well and boreholes were well within the limits acceptable (pH 6.5-8.5) for all the uses of water not excluding drinking water supplies (WHO, 2009). The tap water, however, fell below the WHO acceptable limits with low pH that can also corrode metal pipes and other substances (USGS, 2016). In terms of total hardness (Tables 4.12-4.14), using calcium, magnesium alongside their carbonates, the water samples were all soft as their measurements were less than 75mg/l (US EPA, 2006). Essential for the human nervous system and bone formation is calcium which was commonly present in all the water sources and may have been leached from underneath rocks (Agunwamba, 2000). Magnesium concentrations were found to be lower than those of calcium in all the samples except for samples from the borehole. Large amounts of magnesium in drinking water tend to give it an unpleasant taste (WHO, 2009).

In small amounts, iron is considered important since it affects both the domestic and industrial uses of water as it can stain distribution systems, clog pipes and cloth in laundry (Deutsch, 2003). The World Health Organizations (2009), recommendation for drinking water, states that iron levels must not be greater than 0.3mg/L. Results from this study showed iron levels below the recommended limits (Tables 4.13-4.15).

Even though Nitrate levels in all the water samples were below the recommended limits according to GS175-1, nitrates cannot be removed from water by boiling but must rather be treated by distillation (Adeyemo et al., 2002). As such, human activities that contribute to increasing nitrate levels must be discouraged in communities where water does not go through treatment before distribution as is the case of the Kpedze water distribution system.

Turbidity in drinking water possess a great threat to human health as it is known to provide pathogens with the needed food and shelter and thus can promote regrowth of pathogens in distribution systems leading to outbreak of waterborne diseases such as gastroenteritis (USGS, 2016). Turbidity levels (Tables 4.13-4.15) for all sources of water sampled were below the GS1751 recommended levels. However, these sources require regular monitoring to ensure that the levels do not increase.

The taste of drinking water is largely affected by the levels of total dissolved solids present in it. Total dissolved solids in all drinking water sources were below 300mg/L and as such the taste is considered acceptable according to the WHO (2011).

CHAPTER SIX

6.0. CONCLUSIONS AND RECOMMENDATIONS

6.1. CONCLUSIONS

Survey from the community showed that majority (78.3%) of the respondents preferred water from the community distributed taps as compared to well water, mechanized bore hole or the river. Aside the fact that these taps are more accessible as compared to the other sources of water, it was realised that the general perception of the consumers was that the tap water was the least polluted. Physico-chemical analysis showed that the smell of all the water sources sampled were inoffensive with total suspended solids less than 1 mg/L. Even though 76.7 % of the respondents stated there were always sediments that settled when water is collected, only 9.7 % of the total respondents treated their water sources before usage either by boiling or filtering.

Laboratory analysis further proved that water samples from the hand dug well was least polluted in terms of total faecal coliform concentrations. Samples from the mechanized bore-hole were the only source that met the WHO recommended level for drinking water in terms of E. coli counts.

6.2. RECOMMENDATIONS

Further work should include sampling throughout the major seasons in order to observe seasonal variation in bacteria counts.

Since farming activities were observed around the dam site during this study, further works should include test for pesticides in the water.

Future surveys should be designed to be able to compare perceived risk and the actual contamination levels both at the source of water and in the homes.

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APPENDICES

APPENDIX A: Tables

Table A-1

Site code	Av (TC)	Stdev. (TC)	Log. (TC)	Av (FC)	Stdev. FC)	Log(FC)
S1	1162	47	7.06	604	47	6.40
S2	1488	279	7.31	392	20	5.97
T1	1122	6	7.02	527	31	6.27
T2	1116	372	7.02	1102	210	7.01
T3	698	47	6.55	287	42	5.66
T4	1072	180	6.98	489	161	6.19
T5	1102	111	7.00	2	4	0.85

T6	1002	163	6.91	377	101	5.93
W	573	26	6.35	31	18	3.43
BH	510	78	6.24	2	3	0.69

Table A- 2

Site code	Av. (E.coli)	Stdev.(E.coli)	Log(E.coli)	Av. (THB)	Stdev. (THB)	Log(THB)
S1	118	40	4.77	260	118	5.56
S2	122	51	4.80	767	204	6.64
T1	111	34	4.71	97	20	4.57
T2	61	17	4.12	372	96	5.92
T3	52	17	3.94	1577	662	7.36
T4	148	53	5.00	473	129	6.16
T5	1	2	0.29	103	46	4.64
T6	6	2	1.79	520	244	6.25
W	11	2	2.43	309	94	5.73
BH	0	0	-	276	180	5.62

APPENDIX B

FIGURES

Figure B. 1 The dammed section on River Taale with its distribution pipes

Questionnaires for water analysis

Name of community ____

Name of suburb ____

Sex ☐ Male ☐ Female

Occupation ____

Number of people in your household ________________________________

Age of youngest member

☐ 0-2 years ☐ 3-5 years ☐ 6-10 years ☐ 10-15 years ☐ 16-20 years ☐ others

Age of oldest member

☐ 25-35 years ☐ 36-45 years ☐ 46-55 years ☐ 56-65 years ☐ 66- 75 years ☐ others

1. What is your main source of water?

A. river B. Well C. Tab water D. Rainfall E. others

2. What are the alternate sources of water used?

A. River B. Well C. Tab water D. Tanker services E. others

3. What do you use the water from your main source for?

A. Drinking B. Bathing C. Cooking D. washing E. other F. all of the above

4. If you drink this water, is it

A. Salty B. Tasty C. Tasteless

5. If you wash with it does it lather with soap

A. yes B. No

6. Do you treat this water before drinking?

A. Yes B. No C. Sometimes

7. If yes, how do you treat it.

A. Boiling B. Add a chemical C. Filtering D. Others (specify)

8. Where do your children get their drinking water from when at school?

A. River B. tap C. Sachet water

Figure B. 2 Questionnaire for the community survey