KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

COLLEGE OF SCIENCE

DEPARTMENT OF THEORETICAL AND APPLIED SCIENCES

ARSENIC LEVELS IN BOREHOLE WATER, SURFACE WATER, SURFACE WATER SEDIMENT AND SOIL WITHIN 100 M RADIUS OF BOREHOLES FROM BURULI ULCER ENDEMIC AREAS IN THE SEKYERE SOUTH DISTRICT OF ASHANTI REGION, GHANA.

BY

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A Thesis submitted to Department of Theoretical and Applied Biology, Kwame Nkrumah University of Science and Technology in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Faculty of Biosciences, College of Science

By

FRANCIS YAW OSEI **(BSc. Biol . Sc.)**

May 2011

Declaration

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

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(STUDENT)	Signature	Date

Certified by:

Prof Kwasi Obiri-Danso	……..	……
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……..	……..	……
(HEAD OF DEPT)	Signature	Date

Dedication

This document is dedicated to Josephine Osei.

Acknowledgement

I am very grateful to JEHOVAH GOD for his strength, provisions and protection throughout my academic life. My appreciation goes to my supervisor, Prof. Kwasi Obiri-Danso, who consistently gave valuable advice and constructive criticisms towards shapening the correctness of this final draft.

I would like to express my profound gratitude to Napoleon Jackson Mensah of the Soil and Plant Laboratory, Faculty of Renewable Natural Resources, who helped with my laboratory analysis. I appreciate very much the efforts of John Evans Owusu-Ababio, who conducted my team and I round all the communities in the Sekyere South District throughout the period of the study.

Finally my sincere gratitude goes to all the staff of the Sekyere South District Health Directorate and the District Assembly's Planning and Development Department for their immense contribution towards this project.

Abbreviations/Acronyms

AAS	Atomic Absorption Spectrophotometry
AOAC	Association of Official Analytical Chemists
APHO	Association of Public Health Observatories
ATSDR	Agency for Toxic Substances and Disease Registry
BGC	Bacille Calmette-Guérin
BU	Buruli Ulcer
MU	*Mycobacterium ulcerans*
NRC	National Research Council
N/D	Not detectable/below detection limit
PHED	Pesticide Handlers Exposure Database
SDD	Sekyere South District
UNICEF	United Nations Children's Fund
WHO	World Health Organization

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Abstract

Buruli ulcer (BU) is a human skin disease caused by *Mycobacterium ulcerans* (MU). It is an emerging infectious disease for which there exists a great amount of uncertainty concerning its mode of infection. It is theorized that there may be a link between arsenic ingestion and incidence of MU infection. This study measured the levels of arsenic in river water, river sediment, borehole water and soil within 100 m radius of boreholes, and occurrence of BU in the Sekyere South District of the Ashanti Region, Ghana. Atomic Absorption Spectrophotometry analysis was used in the determination of the arsenic concentrations in the samples and data for BU occurrences were collected from the District Health Directorate and through surveys conducted. Of the 38 communities studied in the District 15 were BU endemic and BU occurrences were higher than what was officially recorded. Only 5.26% of the communities sampled had their borehole water samples having arsenic concentrations above 10.0 µg /l. There was also a strong positive correlation (r = 0.66) between mean arsenic concentrations in surface water samples and occurrences of BU for the 15 BU endemic communities in the District. It was also observed that the pH of some of the boreholes in some of the communities was very acidic (4.18) and could lead to high concentrations of ions of toxic metals such as iron and cupper. Results also indicated that the farmers in the Sekyere South District did not use protective clothing on their farms, even while applying agrochemicals.

CHAPTER ONE

INTRODUCTION

1.0 **Background**

Arsenic is a highly toxic and ubiquitous metalloid which is associated with a variety of adverse human health endpoints (ATSDR, 2007) and all human populations are exposed to it in one form or another. It is mobilized in the environment through a combination of natural processes such as weathering reactions, biological activity and volcanic emissions as well as through a range of anthropogenic activities. The bioaccumulation of arsenic in human tissues through ingestion of arsenic enriched food and water, could cause, for example, immune dysfunction and thereby susceptibility to bacterial infection (Stienstra *et al*., 2001).

Buruli ulcer (BU) is a human skin disease caused by *Mycobacterium ulcerans*. BU is an emerging infectious disease for which there exists a great amount of uncertainty and for which studies into several factors which might contribute to its infection and or spread is very much being pursued the world over (Amofa *et al*., 2002). The mode of transmission of the disease is not known, and this makes primary prevention strategies currently not possible (Asiedu and Etuaful, 1998). Outbreaks of BU have in many cases been attributed to environmental disturbances such as flooding, deforestation, and damming of rivers (Duker, 2005). It is also known to be associated with riverine and poorly-drained areas. Other factors associated with exposure to these environments could contribute to the risk of infection and provided these are nearby sources, riverine and poorly-drained

environments can be locations of arsenic enrichments and the resulting increased arsenic levels can affect human health. The main route of arsenic exposure is through arsenic ingestion. The high affinity of arsenic for sulfhydryl groups makes keratin-rich cells (e.g., epidermal keratinocytes) a sensitive target for arsenic-induced toxicity, leading to dermal lesions including skin cancer, which could be on any part of the body just as BU. It is therefore theorized that there may be a link between arsenic and BU (Duker, 2005).

Arsenic is a naturally occurring element, widely distributed in the earth's crust. It is present in food, soil, air, and water, and all human populations are exposed to it in one form or another (WHO, 2009). The adult human population is thought to contain approximately 20 mg- distributed in all tissues with higher concentrations in the skin, hair and nails (Katze, 2001). It is classified as a human carcinogen by the International Agency for Research on Cancer and the National Research Council (NRC, 2002).

Food contains both organic and inorganic forms of arsenic, whereas drinking water contains primarily inorganic forms of arsenic (Steiner-Asiedu *et al*., 2009). There is lack of any toxicity reports from dietary sources; however, toxicity reports from ingestion of concentrated arsenic from water as well as from industrial exposure have been extensively documented.

In assessing the quality of water for drinking, consumers rely on their senses (Adjei, 2001). Some heavy metals render water no good for drinking owing to unacceptable taste, odor and appearance (Anon, 1993), but this is not so with arsenic, which is potentially hazardous at levels that do not impart any noticeable taste, odor, or appearance to the water (PHED and UNICEF, 1999). The toxicity of arsenic is well documented (Tseng *et al*., 2004) and includes skin ailments, hypertension, cardiovascular diseases, cerebrovascular disease, diabetes, low birth weights, higher occurrence of spontaneous abortions and stillbirths, damage to blood vessels, decreased production of blood cells, congenital malformations in the offspring, and a feeling of 'pins and needles' in the hands and feet. Others are liver and kidney damage. It is found that low-level exposure to arsenic at concentrations found commonly in US drinking water compromises the initial immune response to H1N1 or swine flu infection (Courtney *et al*, 2009). The study, conducted in laboratory mice, suggests that people exposed to arsenic in their drinking water may be at increased risk for more serious illness or death in response to infection from the virus.

It has been consistently theorized that BU is acquired when MU enters the body through a skin rupture (Van der Werf., 1999). However, several people who were affected by the disease do not recall having any break or trauma in their skin prior to being infected (Mensah-Quainoo, 1998). A possible alternative is entry through non-ruptured but unusually unhealthy or thin skin.

Several dermatological diseases (e.g., hyperkeratosis, hyperpigmentation, Bowen's disease) are related to arsenic ingestion and exposure (Tseng *et al*., 2004). Due to its high lipid solubility bioaccumulation of arsenic in the fatty tissues of the skin may provide a favorable environment for MU in the skin because arsenic is known to help microorganisms grow (Ahmann *et al*., 1994). Duker *et al* (2005) recorded a positive exposure-response relationship between arsenic in surface water and BU prevalence in the Amansie West District of Ghana. The official recognition of the occurrence of BU in the Sekyere South District was made as far back as 1997 in the then Afigya District Assembly (Ghanaweb, 1997). With the creation of the Sekyere South District, some communities such as Nkwantakese, Akom, Pentena, Pampatia, Esaase, Soko, Ahenkro and Denase, with reported cases of BU were taken away, but official records of the incidence of BU dates from March 2007 at the Sekyere South District Health Directorate.

Unless specifically targeted, many trace elements and metals including arsenic had not been part of the routine analytic suites for potability of water samples in the Sekyere South district. However, the recent linkage of arsenic to BU prevalence in the Amansie West district has prompted the need to determine the arsenic concentrations in surface water, borehole water and soil samples in the Sekyere South district which also has a high prevalence of BU in Ghana.

Several antimicrobial drugs exist for the treatment of BU, but are expensive and since the disease mostly affects the rural poor, several individuals do not attend or report to the

hospital early enough and only do so when it has become very ulcerative. In such severe cases surgery remains the only option (Amofah *et al*., 1993). Understanding the ecology of these pathogens and the environmental and social factors that drive disease dynamics is difficult because of the complex nature of the factors involved in disease processes, including changes in human demography, human behavior, global climate, and anthropogenic alterations to the landscape (Lashley, 2003). The lack of a mechanistic understanding of how environmental and social conditions interact with disease processes to ultimately cause human infections can severely hinder prevention and control programs.

BU is an emerging infectious disease for which there exists a great amount of uncertainty and for which studies into several factors which might contribute to its infection and or spread is very much being pursued the world over. The mode of transmission of the disease is not known, and this makes primary prevention strategies currently not possible (Asiedu and Etuaful, 1998).

1.2 **Justification**

There has not been any study into the levels of arsenic in samples of surface water, groundwater and soil in the Sekyere South district which is among the high ranking districts in Ghana with regard to buruli ulcer prevalence.

1.3 **Objectives**:

1.3.1 General objectives

The general objective of this research was to investigate the levels of arsenic in surface water (rivers), groundwater (borehole) and soil samples in the Sekyere South District of the Ashanti Region in Ghana.

1.3.2 Specifics objectives

1. Analyze samples of rivers, boreholes and soil for the presence of arsenic
2. Quantify the levels of arsenic in these environmental samples
3. Find the correlation between arsenic levels in samples of rivers, boreholes and soil and occurrence of buruli ulcer in the Sekyere South District.

1.4 **Significance of the study**

- The result of this study would provide baseline information on the concentration of arsenic in rivers, borehole and soil in the Sekyere South District
- Results would provide information on the safety or otherwise of which of the rivers and boreholes are safe for agricultural and domestic purposes with regards to arsenic concentration
- Results would finally indicate if arsenic concentration has any role to play in occurrence of buruli ulcer in the Sekyere South District.

CHAPTER TWO

LITERATURE REVIEW

2.1 **Sources of arsenic exposure**

Exposure to arsenic can occur through the inhalation of air, through the ingestion of food and water, and through dermal absorption (Steiner-Asiedu *et al*., 2010). Other exposures include cigarette smoking, and emissions from coal-burning power plants (ATSDR, 2007). Certain agricultural practices, such as the use of arsenic based herbicides and pesticides, introduce arsenic into the environment. For example, the treatment of US poultry with arsenicals in an effort to prevent *Coccidiodes spp* infection, and enhance growth, introduces an average of 8.07 µg arsenic per day into the US diet (Lasky *et al*., 2004).

Globally, the consumption of water from contaminated supplies is the primary non-occupational source of exposure to arsenic. Arsenic is distributed widely throughout the lithosphere (Centeno *et al*., 2007) and ranks as 20th most abundant trace element in the earth's crust. It exists mainly in three valency states (i.e., -3, +3, +5). The trivalent arsenic (As^{3+}) and the pentavalent arsenic (As^{5+}) are widely present in natural waters and are soluble over a wide range of pH and Eh conditions. In oxidizing environmental conditions As^{5+} species are more stable and predominant, whereas in reducing environmental conditions As^{3+} species are predominant. The trivalent compounds are generally more toxic than the pentavalent compounds (Smedley *et al*., 1996). The most toxic of them all is arsine gas (AsH3) (Leonar, 1991). Organic arsenical compounds exist

but these are generally low but not irrelevant toxicological significance (Gebel, 2000). Under anaerobic conditions, arsenite can be reduced to arsine by microorganisms in soil (Gao and Burau, 1997).

The presence of arsenic in groundwater is largely the result of arsenic-bearing minerals shales, phosphorites, and iron and manganese ores but especially arsenopyrites, realgar, and orpiment dissolving naturally over time as certain types of rocks and soils are weathered. Arsenic can also dissolve out of certain rock formations when groundwater levels drop significantly allowing atmospheric oxygen to penetrate into the aquifer (Gautheir, 2004).

Arsenic is used in hardening of alloys and in production of semiconductors, pigments, glass manufacturing, pesticides, rodenticides and fungicides (Hathaway *et al*., 1991). It is also used as an ingredient of drugs for the treatment of some diseases (e.g., sleeping sickness, chronic myeloid leukemia). Because of its usefulness and exploitation, arsenic contamination is now widespread in the environment.

2.2.0 **Risks of arsenic exposure**

According to the WHO (2001), the daily intake of total arsenic is from the consumption of food and beverages in the general population. ATSDR (2002), documented that all other intakes of arsenic (inhalation and dermal) are usually small in comparison to the oral route. Arsenic toxicity affects a wide variety of organisms including humans. The

symptoms and signs of arsenic toxicity differ between individual population groups and geographic regions (Steiner-Asiedu *et al*., 2010).

2.2.1 **Acute exposure**

Immediate symptoms on an acute poisoning typically include vomiting, esophageal and abdominal pain, and bloody “rice-water” diarrhea (WHO, 2002).

2.2.2 **Chronic exposure**

Chronic arsenic effects in humans have been well documented and reviewed (Pershagen, 1983) and organs most affected are those involved with arsenic in absorption, accumulation and/or excretion. These organs are the gastrointestinal tract, circulatory system, liver, kidney, skin, tissues very sensitive to arsenic and those tissues secondarily affected (e.g., heart). Signs of chronic arsenic toxicity include dermal lesions (e.g., hyperpigmentation, hyperkeratosis, desquamation and loss of hair, peripheral neuropathy, skin cancer and peripheral vascular disease. These signs have been observed mostly in populations whose drinking water contains arsenic (Smith *et al*., 2000). Among these symptoms, dermal lesions were most dominant, and were also known to occur within a period of about five years. The skin is known to localize and store arsenic because of its high content of keratin, which contains several sulfhydryl groups to which As^{3+} may bind (Kitchin, 2001) and may be the reason for its sensitivity to the toxic effects of arsenic.

A study by Tseng (1977) in the Province of Taiwan (China) established a clear dose-response relationship between arsenic and dermal lesions, Blackfoot disease (a peripheral vascular disorder) and skin cancer. It has been established that peripheral vascular diseases are associated with arsenic in well water in Taiwan. However, vascular disease has also been reported among German vintners (Grobe, 1976) and inhabitants of Antofagasta in Chile (Borgono *et al*., 1977). Skin cancers including in-situ cell carcinoma (or Bowen's disease), invasive cell carcinoma and multiple basal cell carcinomas are all known to be associated with chronic arsenic exposure (ATSDR, 1990). Chen *et al*. (1995) observed that hypertension was linked to long-term arsenic ingestion as well as cerebrovascular disease (i.e., cerebral infection). Other effects are hematopoietic depression, anhydremia (due to loss of fluid from blood into tissue and the gastrointestinal tract), liver damage characterized by jaundice, portal cirrhosis and ascites, sensory disturbance and peripheral neuritis, anorexia and loss of weight. Moreover, the ability of arsenic to draw iron from ferritin could enhance the adhesion of bacteria to human tissues (Ahmad *et al*., 2000).

2.3 *Mycobacterium ulcerans* infections

Buruli ulcer (BU) is a severe human skin disease caused by *Mycobacterium ulcerans* (MU). It represents now the third mycobacterial infection in the world behind tuberculosis due to *M. tuberculosis* and leprosy, caused by *M. leprae* (Brou *et al.*, 2008). Many cases have been reported in other countries of the world with most cases in the tropics, especially in rural Africa and catastrophically in West Africa (Nigeria, Benin, Togo, Ghana, Burkina Faso, Côte d'Ivoire and Liberia) (Hayman and Asiedu, 2000).

Even before MacCallum's first publication, the disease was already known in Africa (Meyers, 1995). Several cases were reported from the Congo (Portaels, 1973) but it was in Uganda where the disease was named "Buruli ulcer" by Clancey *et al*. (1961) after the Buruli County, where there was a large number of cases during the late 1960s and 1970s.

Infection by MU occurs commonly in areas related to rivers, swampy terrain or lacustrine systems, because use of (or residence near) a river or pond has consistently been identified as a risk factor (Portaels, 1995). There have, however, been reports of endemic areas not associated with relatively large water masses (Christie, 1987). Animals (e.g., koalas) in Australia have been known to be infected (Mitchell *et al*., 1987) and it is thought that this could be from an environmental source. Portaels *et al* (1999) suggested bites by or contact with insects inhabiting plant roots in swamps as a possible mechanism of *M. ulcerans* transmission. Observations also indicate that increased incidence of MU infections occur due to anthropogenic activities. New endemic areas are associated with recent disturbances such as flooding, mining, logging of rain forest and damming of rivers (Van der Werf *et al*., 1999). A case of the disease following a human bite was reported, however, person-to-person transmission is clearly not a major route of transmission (Debacker *et al*., 2003). An earlier study in Uganda reported that bacille Calmette-Guérin (BCG) might confer protection against the disease or delay the onset of symptoms (Smith *et al*., 1976). However, a more recent case-control study found that BCG vaccination did not protect against onset of the disease, though it shortened its duration (Amofah *et al*., 1993).

2.4 **Occurrence of Buruli Ulcer in Sekyere South District**

BU begins with a painless nodule or papule in the skin and, without appropriate therapy, causes massive skin ulceration, which often results in grossly deforming sequelae (Connor *et al*., 1976). The disease has been reported in many countries, and in most of these it is known to afflict impoverished inhabitants living in remote areas where amenities of modern medical science are not available or are expensive (Guédénon *et al*., 1995). Of the BU-affected inhabitants in certain countries, many are children. For example in Ghana, about 76% of BU patients from Affram valley in the Eastern Region prior to 1989 were younger than 20 years (Van der Werf *et al*., 1989) and about 70% of BU patients from Ashanti Region prior to 1998 were younger than 15 years (Asiedu and Etuaful, 1998). The epidemiology of the disease is poorly understood, but the increasing incidence of BU in certain parts of the world, particularly in West Africa, led the WHO to recognize it as an emerging disease and called for urgent action to control it (WHO, 1998a).

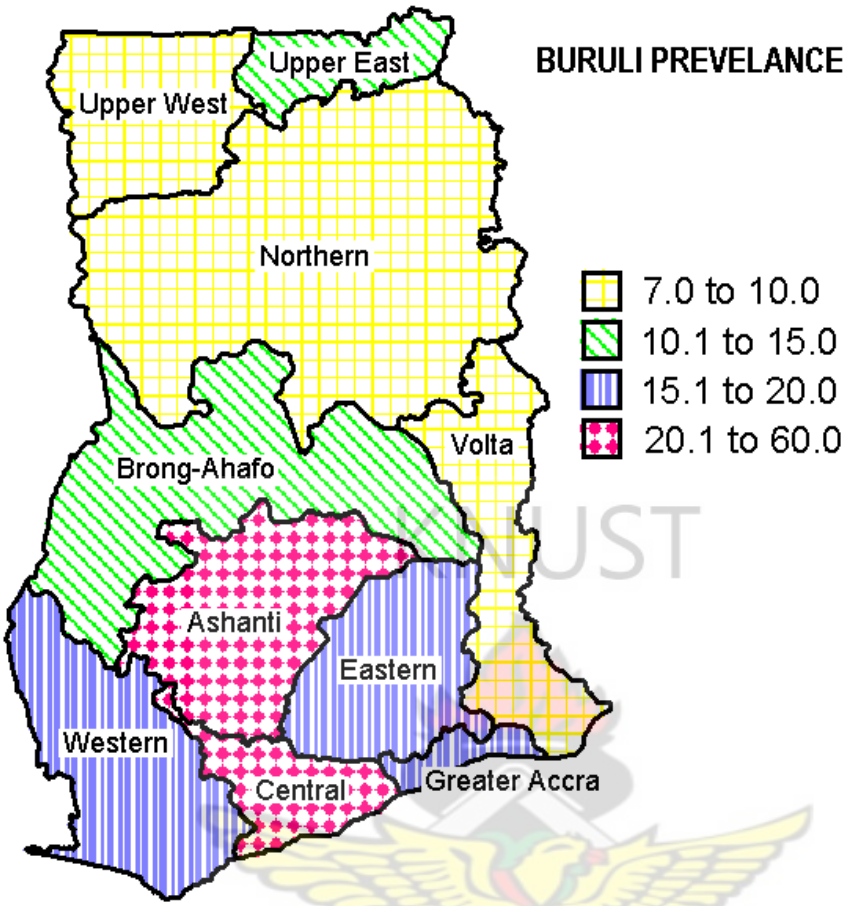

Figure 1. Prevalence of suspected active cases of Buruli ulcer, by region, Ghana, 1999 (**Source: Amofah *et al.*, 2002**)

Sekyere South District is in Ghana, where the first case of BU was reported in 1971 and, between 1991 and 1997, more than 2000 cases have been reported (Grosset *et al*., 2000). The disease has affected all of the ten regions of Ghana and at least 90 of the 110 districts in Ghana (Amofah *et al*., 2002). Sekyere South District is located in the Ashanti Region which is the worst affected region in Ghana, accounting for about 60% of all reported cases, of which the greatest percentage is in the Amansie West, followed by Asante Akim North, with Sekyere South being third with a prevalence rate of 107.1 per 100,000 people

(Amofah *et al*., 2002). Of the reported cases in the district, the ages range from 7 to 80 years, about 61% are males. Most of the infected are subsistence farmers.

2.5 **Arsenic-enriched environments and BU infections**

Arsenic is a naturally occurring element, widely distributed in the earth's crust. Human activities have exacerbated arsenic contamination in the environment (Bell, 1998). Examples of human activities that have adversely affected the environment are mining, waste disposal, indiscriminate use of fertilizers, pesticides, herbicides, manufacturing and chemical spillage. For example, the treatment of US poultry with arsenicals in an effort to prevent *Coccidiodes spp* infection, and enhance growth, introduces an average of 8.07 µg arsenic per day into the US diet (Lasky *et al*., 2004). Many incidents of arsenic contamination of the environment have been reported in several countries of the world. The situation can have significant adverse influence on health due to arsenic uptake in water and food especially by developing and rural populations who depend on local sources of food and water. Therefore any arsenic geochemical anomaly may impact negatively on health (Plant *et al*., 1996).

Some of these areas include riverine and volcanic environments, mining related environments, lakes and reservoir environments, and agricultural environments. Nriagu, 1989, has shown that volcanoes are important natural sources of arsenic and under high temperatures (e.g., volcanic eruptions); arsenic is very mobile in the fluid phase and may also be present in fumaroles as sublimates and incrustations (Signorelli, 1993). The earliest report of *Mycobacterium ulcerans* infection was in 1957 and infections were

found mainly in settlements along the inundated portions of rivers (Radford, 1974b). Jahan *et al*., 2002, report that in the state of Victoria (Australia), mining of gold had caused an estimated 30,000 tones of arsenic to be redistributed to the surface across the landscape through erosion into streams and rivers. Groundwater may be contaminated by arsenic through agricultural applications by leaching through soils and fissures of rocks, especially when applied during the dry season when net movement of water is downwards.

The cost of health care in the treatment and managing of BU patients and the inability of affected persons to engage in productive activities and potential social isolation are important reasons to ensure that all factors that might contribute to the infection and spread of MU be seriously researched into so that, if possible, preventive measures are taken.

CHAPTER THREE

MATERIALS AND METHODS

3.1 **Study Area**

Sekyere South District is one of the twenty seven administrative districts in the Ashanti Region of Ghana; with a total land area of 584 square kilometers. This represents about 2.4 % of the total landmass of Ashanti Region. The district lies between latitude 6^{o} 50'N and 7^{0} 10'N and Longitude 1^{0} 40'W and 1^{0} 25' W. It shares boundaries with Ejura-Sekyedumase to the North, Mampong Municipal to East, Sekyere East and Kwabre East to South and Afigya Kwabre to the West. The vegetation of the district can be best described as moist-semi-deciduous. Greater part of the district falls within a dissected plateau with heights between 800 m to 1200 m above sea level. The only high land can be found in the northern portion which happens to be the Mampong Escarpment stretching from Jamasi to Boanim. Major rivers in the district includes the Offin, Oyon and Abankro. The Voltaian and Dahomeyan formation are the two major geological formations. Geologically the district is underlain by rocks belonging to Birimian and granites. Other rock types include sandstones, shale, mudstone and limestone. The population is mostly rural with crop farming being the main vocation in the district.

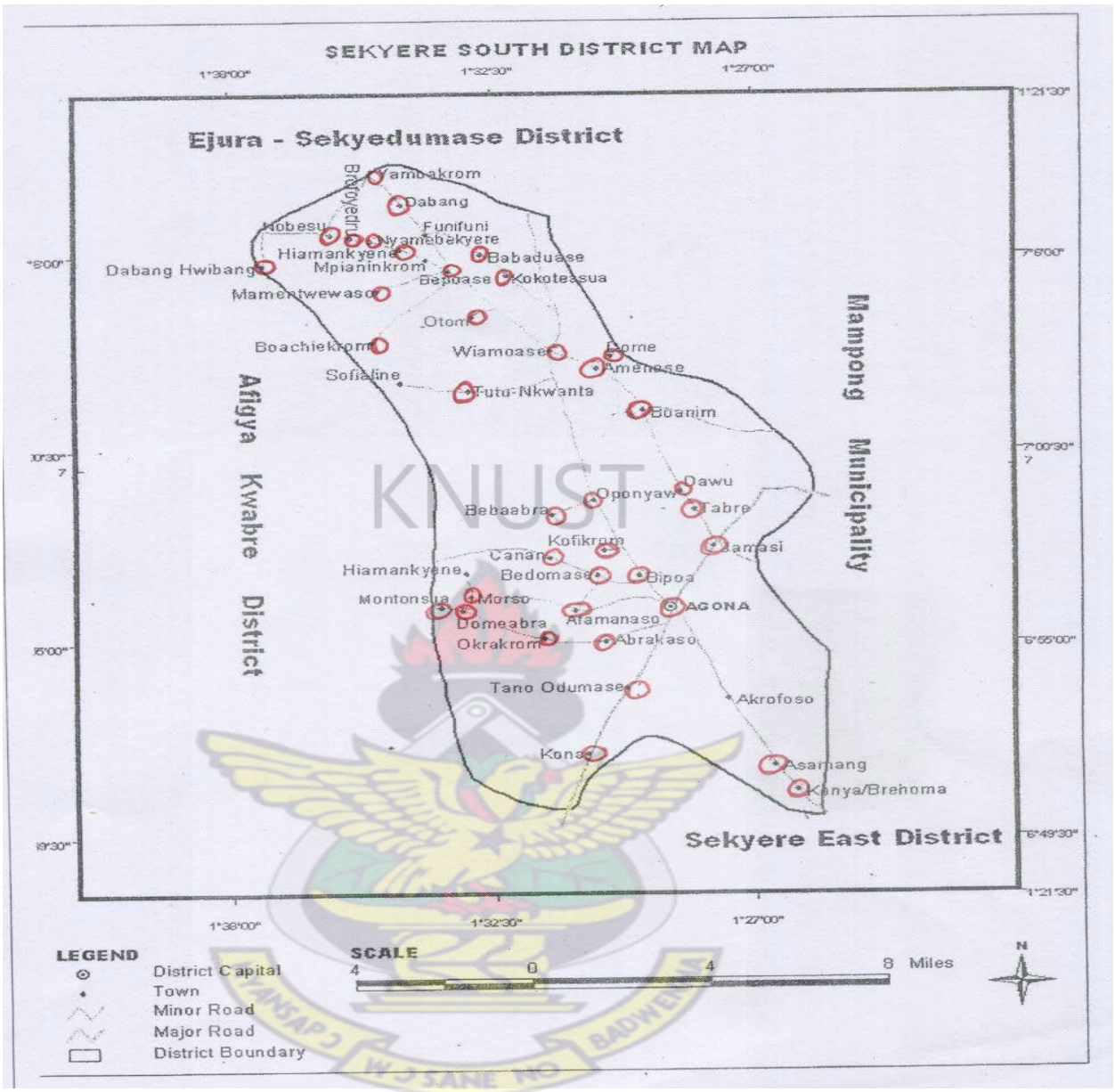

Figure 2. Map of Sekyere South District showing communities where samples were taken, marked red.

3.2 **Data collection**

3.2.1 BU data collection

Data on Buruli ulcer cases from 2004 to 2010 were obtained from the Sekyere South District Health Directorate, Agona, and through personal survey for cases. Boundary map of the District was obtained from the Sekyere South District Assembly. The study was to be comparative and the absence of BU in the control communities was vital to its success. Active disease surveillance was thus conducted in the communities to ascertain their accurate BU disease status. This was done with the help of the district health administration and volunteers in the communities.

Information, education and communication materials were used in the active case search. Households were visited, as well as people on streets interviewed, and the members screened for BU disease. This was done by showing brochures and flyers of the various symptoms and asking if anyone had seen similar symptoms. Conditions identified to resemble BU were referred to a more experienced officer for confirmation. This was done to ensure that people who had the disease but did not attend hospital, or attended hospitals outside the district and so were not recorded at the District Health Directorate could be identified.

3.2.2 Arsenic data collection

Data on arsenic were obtained from samples of rivers and/or streams, bore holes and soil. Samples were collected August to October 2010, representing the wet season, and December 2010 to February 2011, representing the dry season. Samples were collected from 38 endemic and non-endemic communities within the District, with the help of the topographical map of the District (Fig 2).

3.2.2.1Collection of soil samples

Soil scoops were used to scrape the top soil, before the sub-soil was taken. The sub-soil so collected was put in sealable food packs. Samples were taken within 100 m radius of boreholes and points where river samples had been collected, from three different randomly selected sites.

3.2.2.2 Collection of water samples

Water samples were taken from rivers and boreholes used for agricultural and domestic purposes with 500 ml amber graduated bottles previously washed with distilled water and dried in an oven for few minutes to avoid contamination. Boreholes were pumped for about ten minutes before samples were taken. This was done in order to avoid sampling of stagnant annulus water that would be in the region of pump and pump systems. Rivers and streams were collected from points where the communities abstract the water.

3.3.0 **Field Treatment of samples**

3.3.1 pH determination for water samples

The pH for the water samples was determined using a pH meter (pH Testr 20). The pH meter was first calibrated using three buffer solutions of pH 4, 7, and 9. A 50 ml quantity of each of the water samples was put in a clean 100 ml beaker and the pH measured.

3.3.2 Acidification of water samples

Acidification of the water samples was done just after the 50 ml had been taken for the pH determination. A 3 ml concentrated HNO_3 was added to 300 ml of the samples, which had been previously filtered with a 0.5 µm pore size membrane filter paper. This was done to preserve the water samples and as an initial step to bring the particulate metals into solution form and also to prevent the growth of algae (APHO, 1992). The samples were then covered tightly in plastic bottles and transported to the laboratory for further treatment.

3.4.0 **Laboratory treatment of samples**

3.4.1 pH determination of soil samples

The pH meter was calibrated using three buffer solutions of pH 4, 7, and 9. A 10 g soil sample was placed into 100 ml beaker, and 50 ml deionized water added. The soil was allowed to absorb the deionized water without stirring for ten minutes. The mixture was

then stirred for 10 minutes and allowed to stand for 30 minutes, and then stirred again for 2 minutes. This was done to ensure that a homogeneous mixture was formed (Motsara and Roy, 2008; Okalebo and Gathua, 1993) after which the pH was determined with the pH meter.

3.4.2 Digestion of soil samples

Two grams of finely ground soil was weighed and placed into 300 ml volumetric flask and 20 ml of di – acid mixture of HNO_3 and $HClO_4$ with ratio 9: 4 was added and the contents well mixed by swirling thoroughly (Motsara and Roy, 2008; Okalebo and Gathua, 1993). The flask with contents was then placed on a hotplate in the fume chamber and heated, starting at 85^{o}C and then temperature raised to 150^{o}C. The heating continued until the production of red NO_2 fumes ceased. The contents were further heated until volume was reduced to 3 – 4 ml and became colorless or yellowish, but not dried. This was done to reduce interference by organic matter and to convert metal associated particulate to a form (the free metal) that can be determined by the Atomic Absorption Spectrophotometer (AAS). Contents were cooled and volume made up with distilled water and filtered through No 1 filter paper. The resulting solution was preserved at 4^{o}C, ready for AAS determination.

3.4.3 Digestion of water samples

The sample was thoroughly mixed by shaking and 100 ml transferred into a conical flask. A 5 ml concentrated HNO_3 and a few boiling chips were added (APHO, 1992). The mixture was then heated until the volume was reduced to about 15 ml and complete digestion was indicated by either a light colored or clear solution. Contents were washed down with double distilled water and then filtered. The filtrate was transferred into 100 ml volumetric prior washed plastic containers and volume finally adjusted to 100 ml with double distilled water and stored at 4^0 C, ready for AAS analysis (APHO, 1992).

3.4.4 Atomic Absorption Spectrophotometry analysis

AAS 220 model was used in determining the total dissolved arsenic concentration in the previously digested samples. The acetylene gas and compressor were fixed and compressor turned on and the liquid trap blown to rid off any liquid trapped. The Extractor was turned on and the AAS 220 power turned on (AOAC, 2006). The capillary tube and nebulizer block were cleaned with cleansing wire and opening of the burner cleaned with an alignment card. The worksheet of the AAS software on the attached computer was opened and the hollow cathode lamp inserted in the lamp holder. The lamp was turned on; ray from cathode aligned to hit target area of the alignment card for optimal light throughput, then the machine was ignited. The capillary was placed in a 10 ml graduated cylinder containing deionized water and aspiration rate measured, and set to 6 ml per minute. The analytical blank was prepared, and a series of calibration solutions of known amounts of analyte element (standards) were made. The blank and standards

were atomized in turn and their responses measured. A calibration graph was plotted for each of the solutions, after which the sample solutions were atomized and measured. Arsenic concentration from the sample solution was determined from the calibration, based on the absorbance obtained for the unknown (AOAC, 2006).

3.5 **Statistical Analysis**

To determine whether any correlation existed between the incidences of BU and concentration of arsenic in soil, borehole water, and surface water samples, Spearman's coefficient of correlation was used to make the determination. The results were also subjected to one-way analysis of variance and Student-Newman-Keuls range test to determine the significant differences, if any, existing between the seasons' data.

3.6 **Quality control**

- Analysis of blanks: In order to assess contamination, a blank, which was deionized water, was analyzed along with the sample.
- Analysis of duplicate: For a batch of five samples, one was duplicated in order to assess the reproducibility of the machine.
- Method accuracy: Certified reference materials were ran to check the accuracy of the equipment.

3.7 **Precautions**

- The digestion of the soil samples was done in a fume chamber since nitrogen (iv) oxide fumes could cause choking.
- The digested samples before analysis with AAS were covered tightly to prevent contamination with pollutants or other gases in the atmosphere since these could affect the final results.

CHAPTER FOUR

RESULTS

Of the forty-three communities within the Sekyere South District of the Ashanti Region, 38 (88.4 %) were enumerated for the occurrence of Buruli ulcer (Appendix A). Of the 38 communities, 15 were BU endemic while 23 were not and occurrences ranged from 0 to 12 (Appendix A). Those infected with the disease were between 7 to 80 years of age of which forty-two percent were females. Most of the infected were subsistent farmers who farmed along water bodies (72%) and school children (14%).

Mean arsenic concentrations (mg/l) for borehole water and surface water samples during the dry season were below detection limit. However, during the wet season, arsenic was detected in all (100%) the surface water samples ranging between 0.116 to 0.671 mg/l (Table 2), but only in 18.4% of borehole water samples which were between 0.033 and 0.123 mg/l (Table 1).

Table 1: Mean total arsenic concentration (mg/l) in borehole water samples in 38 communities in Sekyere South District of Ashanti Region, Ghana.

		WET SEASON CONC		DRY SEASON CONC	
	COMMUNITY	MEAN	SDEV	MEAN	SDEV
1	Abrakaso*	N/D	N/D	N/D	N/D
2	Afamanso*	0.062	0.0031	N/D	N/D
3	Agona*	0.102	0.035	N/D	N/D
4	Asamang*	0.075	0.0103	N/D	N/D
5	Bepoase*	0.043	0.0025	N/D	N/D
6	Bipoa*	0.033	0.0019	N/D	N/D
7	Boanim*	N/D	N/D	N/D	N/D
8	Dabang*	N/D	N/D	N/D	N/D
9	Dawu*	0.123	0.0028	N/D	N/D
10	Hiamankyene 1*	N/D	N/D	N/D	N/D
11	Jamasi*	0.044	0.0123	N/D	N/D
12	Kona*	N/D	N/D	N/D	N/D
13	Nobesu*	N/D	N/D	N/D	N/D
14	Tano-Odumase*	N/D	N/D	N/D	N/D
15	Wiamoase*	N/D	N/D	N/D	N/D
16	Amenase	N/D	N/D	N/D	N/D
17	Babaduase	N/D	N/D	N/D	N/D
18	Bebaabra	N/D	N/D	N/D	N/D
19	Bedomase	N/D	N/D	N/D	N/D
20	Boachiekrom	N/D	N/D	N/D	N/D
21	Brehoma	N/D	N/D	N/D	N/D
22	Brofoyedru	N/D	N/D	N/D	N/D
23	Canan	N/D	N/D	N/D	N/D
24	Dabang-Hwibaa	N/D	N/D	N/D	N/D
25	Dome	N/D	N/D	N/D	N/D
26	Domeabra	N/D	N/D	N/D	N/D
27	Kofikrom	N/D	N/D	N/D	N/D
28	Kokoteasua	N/D	N/D	N/D	N/D
29	Mamentwewaso	N/D	N/D	N/D	N/D
30	Montonsua	N/D	N/D	N/D	N/D
31	Morso	N/D	N/D	N/D	N/D
32	Nyamebekyere	N/D	N/D	N/D	N/D
33	Okrakrom	N/D	N/D	N/D	N/D
34	Oponyaw	N/D	N/D	N/D	N/D

35	Otom	N/D	N/D	N/D	N/D
36	Tabre	N/D	N/D	N/D	N/D
37	Tutu-Nkwanta	N/D	N/D	N/D	N/D
38	Yamoakrom	N/D	N/D	N/D	N/D

* BU ENDEMIC AREAS

Table 2: Mean total arsenic concentration (mg/l) in surface water in 38 communities in Sekyere South District of Ashanti Region, Ghana.

		WET SEASON CONC		DRY SEASON CONC	
		MEAN	SDEV	MEAN	SDEV
1	Abrakaso*	0.384	0.0137	N/D	N/D
2	Afamanso*	0.557	0.0098	N/D	N/D
3	Agona*	0.671	0.0143	N/D	N/D
4	Asamang*	0.410	0.0055	N/D	N/D
5	Bepoase*	0.349	0.0230	N/D	N/D
6	Bipoa*	0.578	0.0181	N/D	N/D
7	Boanim*	0.567	0.0262	N/D	N/D
8	Dabang*	0.342	0.0187	N/D	N/D
9	Dawu*	0.320	0.0304	N/D	N/D
10	Hiamankyene 1*	0.245	0.0335	N/D	N/D
11	Jamasi*	0.663	0.0293	N/D	N/D
12	Kona*	0.496	0.0156	N/D	N/D
13	Nobesu*	0.329	0.0274	N/D	N/D
14	Tano-Odumase*	0.469	0.0667	N/D	N/D
15	Wiamoase*	0.278	0.0322	N/D	N/D
16	Amenase	0.146	0.0082	N/D	N/D
17	Babaduase	0.244	0.0402	N/D	N/D
18	Bebaabra	0.251	0.0032	N/D	N/D
19	Bedomase	0.156	0.0390	N/D	N/D
20	Boachiekrom	0.161	0.0279	N/D	N/D
21	Brehoma	0.383	0.0097	N/D	N/D
22	Brofoyedru	0.148	0.0127	N/D	N/D
23	Canan	0.219	0.0701	N/D	N/D
24	Dabang-Hwibaa	0.251	0.0208	N/D	N/D
25	Dome	0.307	0.0129	N/D	N/D
26	Domeabra	0.358	0.0228	N/D	N/D
27	Kofikrom	0.357	0.0333	N/D	N/D
28	Kokoteasua	0.219	0.0149	N/D	N/D
29	Mamentwewaso	0.317	0.0032	N/D	N/D
30	Montonsua	0.131	0.0237	N/D	N/D
31	Morso	0.116	0.0068	N/D	N/D
32	Nyamebekyere	0.289	0.0665	N/D	N/D
33	Okrakrom	0.239	0.0473	N/D	N/D
34	Oponyaw	0.142	0.0348	N/D	N/D
35	Otom	0.351	0.0333	N/D	N/D

36	Tabre	0.263	0.0380	N/D	N/D
37	Tutu-Nkwanta	0.282	0.0532	N/D	N/D
38	Yamoakrom	0.123	0.0082	N/D	N/D

*BU ENDEMIC AREAS

Mean arsenic levels in soil samples within 100 m radius of boreholes showed significantly higher levels (0.015 to 0.154 mg/l) for the wet season compared to dry season samples (0.014 to 0.122 mg/l) (Table 3). Similarly surface water sediment samples had significantly higher arsenic concentrations in the wet season compared to the dry season (Table 4).

Overall arsenic levels in surface water sediment were higher during the wet season compared to levels in soil samples around the boreholes. However the reverse was the case in the dry season where the levels in the soil around the boreholes were higher than in the surface water sediments.

Table 3: Mean total arsenic concentration (mg/g) in soil within 100 m radius of boreholes in 38 communities in Sekyere South District of Ashanti region, Ghana.

		MEAN WET CONC		MEAN DRY CONC	
		MEAN	SDEV	MEAN	SDEV
1	Abrakaso*	0.077	0.0060	0.052	0.0017
2	Afamanso*	0.116	0.0099	0.051	0.0006
3	Agona*	0.138	0.0042	0.045	0.0063
4	Asamang*	0.084	0.0022	0.021	0.0034
5	Bepoase*	0.066	0.0005	0.097	0.0101
6	Bipoa*	0.085	0.0000	0.077	0.0148
7	Boanim*	0.062	0.0000	0.089	0.0119
8	Dabang*	0.084	0.0005	0.078	0.0332
9	Dawu*	0.106	0.0036	0.066	0.0094
10	Hiamankyene 1*	0.103	0.0017	0.075	0.0231
11	Jamasi*	0.154	0.0016	0.067	0.0080
12	Kona*	0.106	0.0024	0.067	0.0708
13	Nobesu*	0.104	0.0016	0.110	0.0243
14	Tano-Odumase*	0.080	0.0035	0.114	0.0440
15	Wiamoase*	0.097	0.0053	0.058	0.0027
16	Amenase	0.073	0.0048	0.015	0.0020
17	Babaduase	0.063	0.0031	0.070	0.0087
18	Bebaabra	0.103	0.0005	0.090	0.0000
19	Bedomase	0.075	0.0022	0.014	0.0019
20	Boachiekrom	0.085	0.0015	0.034	0.0055
21	Brehoma	0.118	0.0009	0.070	0.0107
22	Brofoyedru	0.077	0.0013	0.072	0.0296
23	Canan	0.069	0.0042	0.084	0.0080
24	Dabang-Hwibaa	0.084	0.0087	0.122	0.0067
25	Dome	0.090	0.0019	0.058	0.0144
26	Domeabra	0.059	0.0019	0.072	0.0329
27	Kofikrom	0.058	0.0005	0.082	0.0090
28	Kokoteasua	0.088	0.0000	0.063	0.0072
29	Mamentwewaso	0.067	0.0000	0.109	0.0459
30	Montonsua	0.051	0.0005	0.063	0.0455
31	Morso	0.057	0.0005	0.061	0.0012
32	Nyamebekyere	0.056	0.0005	0.091	0.0221
33	Okrakrom	0.054	0.0023	0.105	0.0020
34	Oponyaw	0.179	0.0005	0.081	0.0209
35	Otom	0.104	0.0025	0.093	0.0332

36	Tabre	0.053	0.0029	0.103	0.0159
37	Tutu-Nkwanta	0.086	0.0084	0.086	0.0125
38	Yamoakrom	0.105	0.0021	0.067	0.0128

*BU ENDEMIC AREAS

Table 4: Mean total arsenic concentration (mg/g) in surface water sediment in 38 communities in Sekyere South District of Ashanti region, Ghana.

		MEAN WET CONC		MEAN DRY CONC	
		MEAN	SDEV	MEAN	SDEV
1	Abrakaso*	0.324	0.0693	0.056	0.0016
2	Afamanso*	0.285	0.0437	0.023	0.0006
3	Agona*	0.348	0.0053	0.057	0.0020
4	Asamang*	0.214	0.0022	0.053	0.0013
5	Bepoase*	0.212	0.0228	0.034	0.0006
6	Bipoa*	0.259	0.0048	0.042	0.0014
7	Boanim*	0.281	0.0033	0.042	0.0017
8	Dabang*	0.221	0.0177	0.048	0.0005
9	Dawu*	0.231	0.0164	0.042	0.0016
10	Hiamankyene 1*	0.266	0.0409	0.026	0.0011
11	Jamasi*	0.273	0.0171	0.053	0.0033
12	Kona*	0.220	0.0056	0.024	0.0010
13	Nobesu*	0.230	0.0179	0.028	0.0008
14	Tano-Odumase*	0.240	0.0052	0.050	0.0021
15	Wiamoase*	0.230	0.0100	0.057	0.0023
16	Amenase	0.170	0.0041	0.038	0.0005
17	Babaduase	0.173	0.0168	0.028	0.0010
18	Bebaabra	0.138	0.0041	0.044	0.0006
19	Bedomase	0.150	0.0106	0.038	0.0004
20	Boachiekrom	0.095	0.0187	0.022	0.0011
21	Brehoma	0.165	0.0184	0.033	0.0007
22	Brofoyedru	0.188	0.0120	0.041	0.0005
23	Canan	0.112	0.0129	0.018	0.0007
24	Dabang-Hwibaa	0.179	0.0213	0.028	0.0005
25	Dome	0.147	0.0034	0.038	0.0006
26	Domeabra	0.177	0.0248	0.033	0.0008
27	Kofikrom	0.173	0.0197	0.025	0.0010
28	Kokoteasua	0.171	0.0220	0.034	0.0007
29	Mamentwewaso	0.139	0.0042	0.029	0.0007
30	Montonsua	0.195	0.0402	0.024	0.0006
31	Morso	0.164	0.0447	0.028	0.0004
32	Nyamebekyere	0.211	0.0317	0.034	0.0007
33	Okrakrom	0.148	0.0227	0.028	0.0008
34	Oponyaw	0.218	0.0217	0.034	0.0007
35	Otom	0.141	0.0189	0.029	0.0006

36	Tabre	0.204	0.0196	0.043	0.0008
37	Tutu-Nkwanta	0.193	0.0250	0.039	0.0007
38	Yamoakrom	0.165	0.0098	0.038	0.0003

*__BU__ ENDEMIC AREAS

Correlation between arsenic levels and occurrence of buruli ulcer

There was a strong positive correlation (r = 0.66) between occurrence of BU and mean arsenic concentrations in surface water samples (Fig 3) and a correlation of r = 0.25 for soil samples within 100 m of the boreholes in the 15 BU endemic communities during the wet season (Fig 4). However, there was a weak negative correlation (r = -0.29) between arsenic concentrations in soil samples within 100 m radius of the boreholes and occurrence of BU during the dry season (Fig 5).

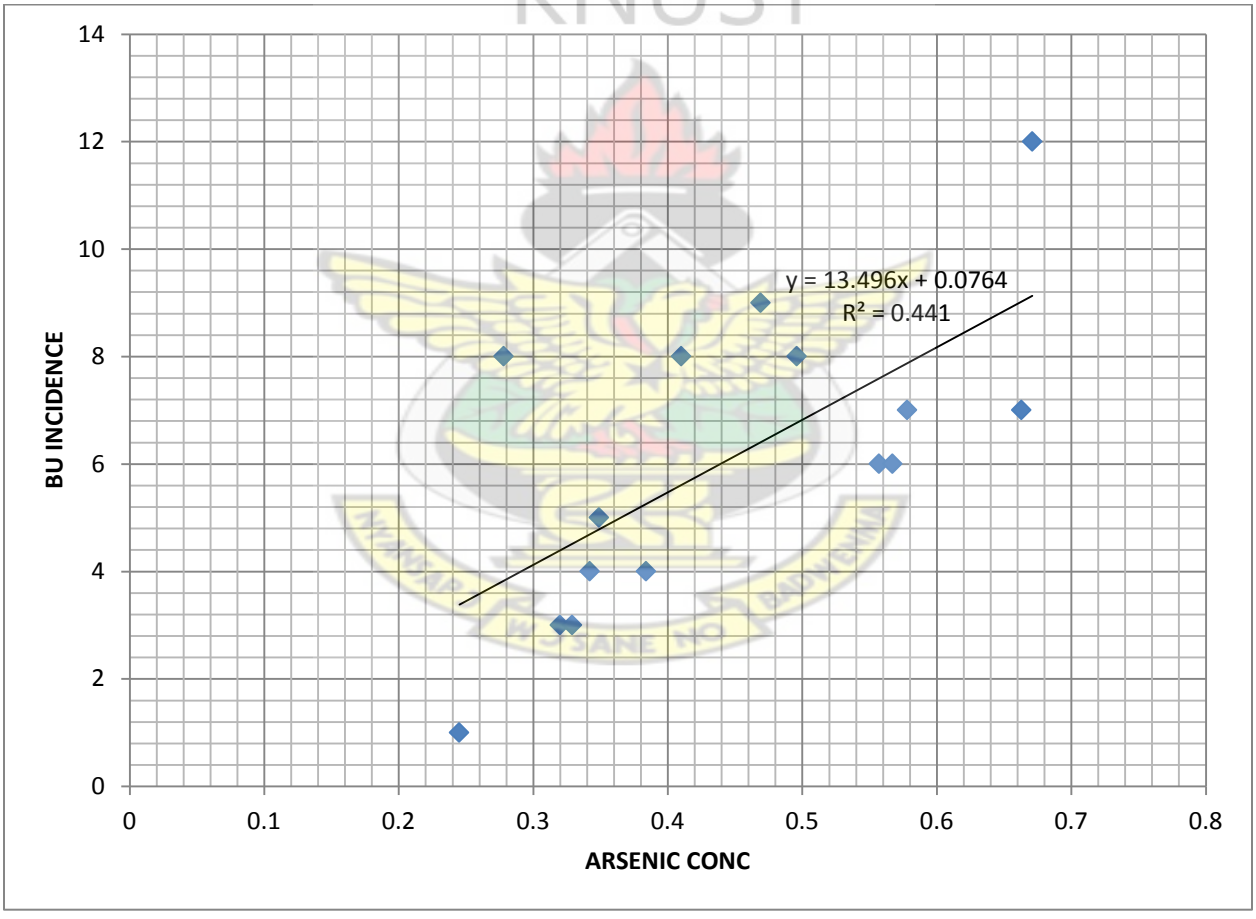

Fig 3: Correlation between arsenic levels in surface water wet season and occurrence of BU in 15 BU endemic communities.

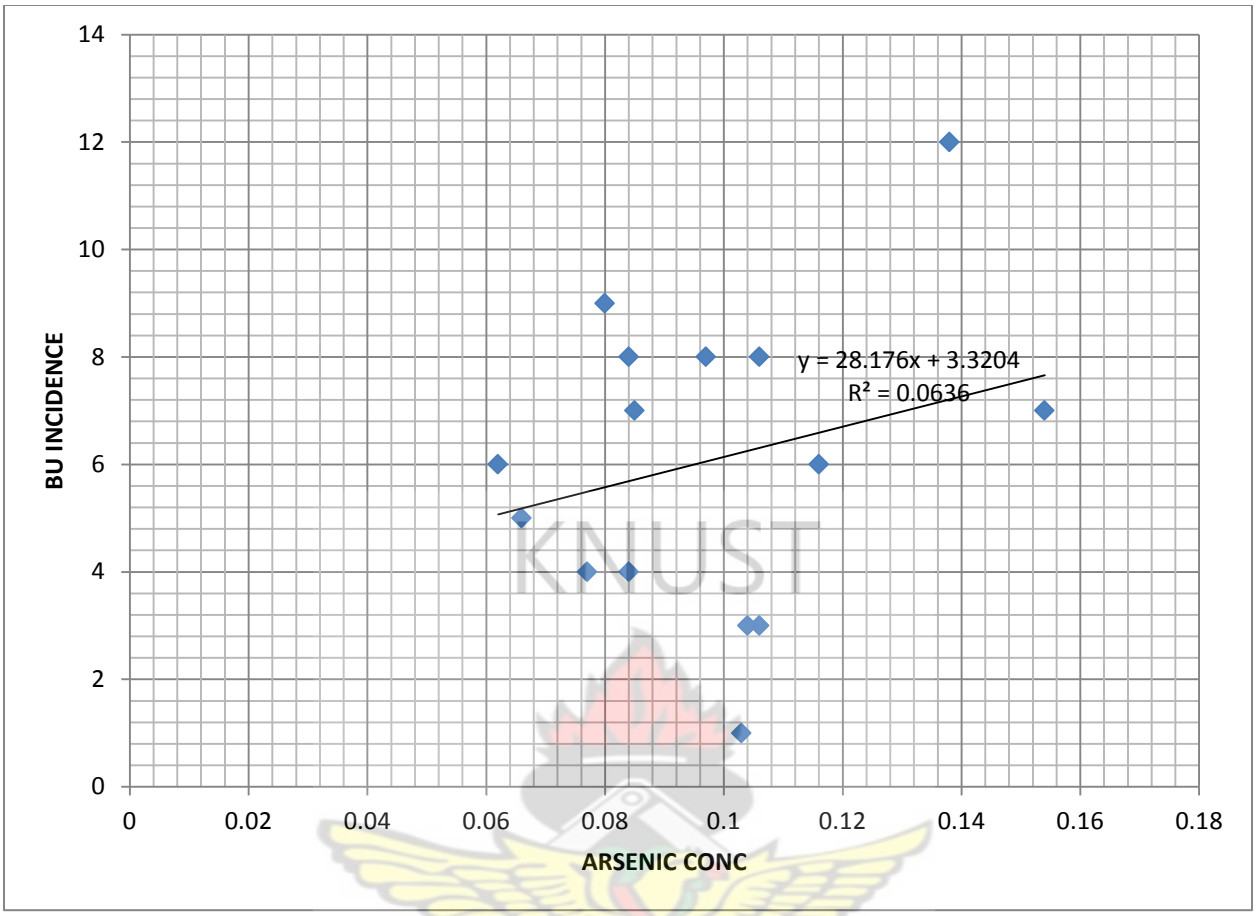

Fig 4: Correlation between arsenic levels in soil within 100m radius of boreholes wet season and occurrence of BU in 15 BU endemic communities.

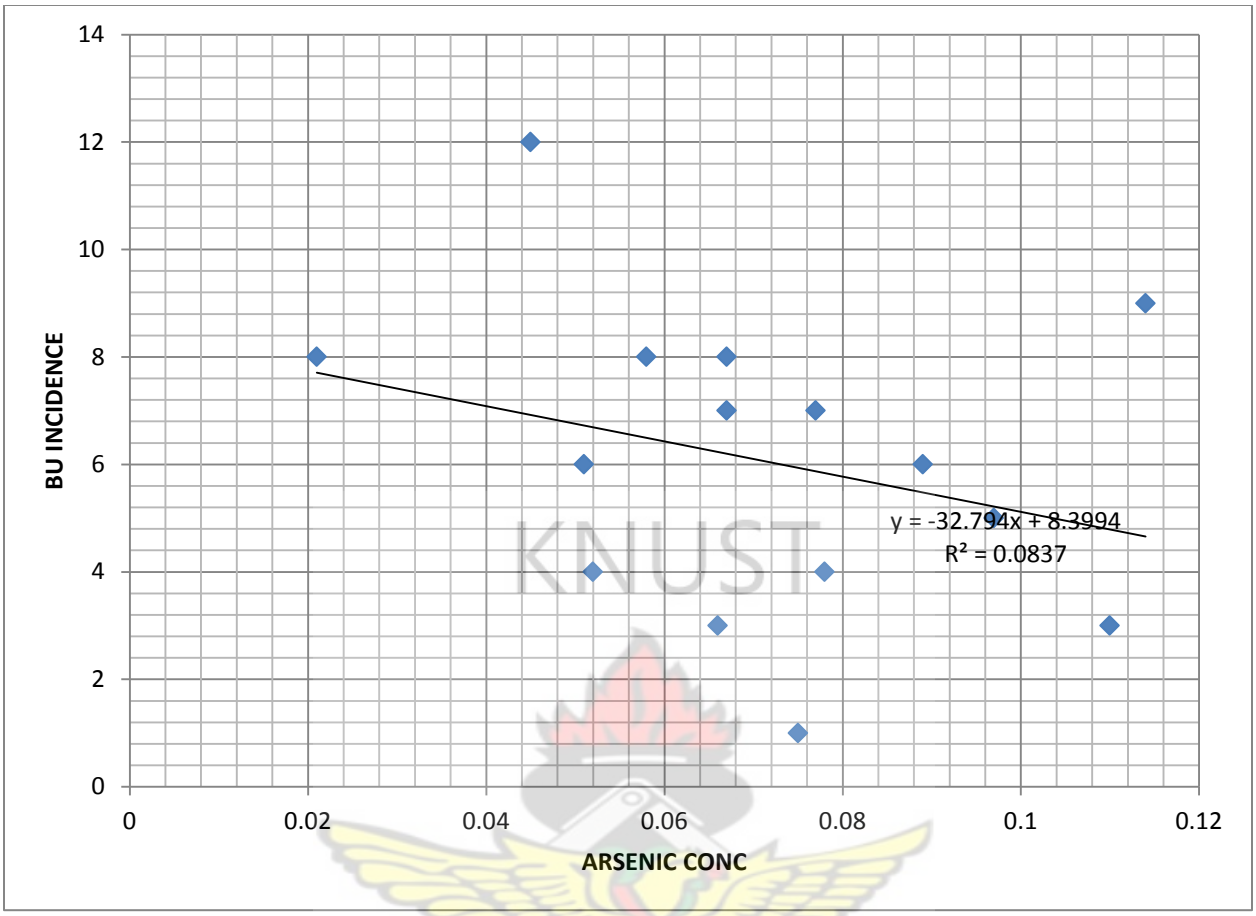

Fig 5: Correlation between arsenic levels in soil within 100m radius of boreholes dry season and occurrence of BU in 15 BU endemic communities.

Mean pH values ranged from acidic (4.18) to slightly alkaline (8 .33) (Tables 5, 8). pH values in the endemic communities did not significantly differ from non-endemic areas.

Table 5: Mean pH values for borehole water in 38 communities in Sekyere South District of the Ashanti Region, Ghana

		Mean wet season		Mean dry season	
	Community	Mean	SDEV	Mean	SDEV
1	Abrakaso*	6.03	0.38	5.5	0.25
2	Afamanso*	6.58	0.36	6.41	0.16
3	Agona*	6.50	0.02	5.70	0.23
4	Asaman*g	6.15	0.28	5.63	0.25
5	Bepoase*	6.01	0.13	6.17	0.13
6	Bipoa*	6.02	0.28	6.17	0.61
7	Boanim*	4.86	0.74	5.09	0.50
8	Dabang*	4.18	0.27	4.53	0.64
9	Dawu*	5.88	0.10	5.75	0.30
10	Hiamankyene 1*	6.47	0.25	5.58	0.17
11	Jamasi*	6.43	0.41	5.68	0.38
12	Kona*	5.61	0.07	5.19	0.05
13	Nobesu*	6.06	0.25	5.85	0.41
14	Tano-Odumase*	5.26	0.13	6.01	0.26
15	Wiamoase*	5.80	0.07	5.74	0.16
16	Amenase	6.13	0.30	5.85	0.13
17	Babaduase	6.46	0.38	6.29	0.50
18	Bebaabra	6.05	0.41	6.35	0.55
19	Bedomase	5.70	0.08	5.78	0.48
20	Boachiekrom	4.95	0.57	5.38	0.62
21	Brehoma	5.48	0.26	5.42	0.28
22	Brofoyedru	5.88	0.17	5.28	0.11
23	Canan	5.57	0.23	5.33	0.05
24	Dabang-Hwi	5.92	0.16	5.84	0.34
25	Dome	6.67	0.21	5.73	0.23
26	Domeab	6.47	0.35	6.05	0.24
27	Kofikrom	5.83	0.19	6.11	0.13
28	Kokoteasua	6.35	0.42	5.97	0.11
29	Mamentwewa	6.43	0.41	5.84	0.20
30	Montonsua	6.17	0.20	6.06	0.28
31	Morso	5.96	0.24	5.81	0.41
32	Nyamebekye	6.37	0.63	5.80	0.48
33	Okrakrom	6.10	0.18	6.31	0.14
34	Oponyaw	6.52	0.21	5.62	0.18

35	Otom	5.55	0.37	6.11	0.22
36	Tabre	6.47	0.06	5.83	0.12
37	Tutu-Nkwanta	6.41	0.14	5.91	0.07
38	Yamoakrom	6.43	0.40	5.65	0.28

- BU ENDEMIC AREAS

Table 6: Mean pH values for soils within 100 m radius of borehole in 38 communities in the Sekyere South District of the Ashanti Region, Ghana.

		Mean wet season values		Mean dry season values	
	Community	Mean	SDEV	Mean	SDEV
1	Abrakaso*	5.86	0.19	7.24	0.40
2	Afamanso*	6.65	0.27	8.01	0.12
3	Agona*	7.69	0.27	6.92	0.27
4	Asamang*	6.06	0.38	6.19	0.63
5	Bepoase*	7.15	0.40	7.18	0.59
6	Bipoa*	6.80	0.21	6.14	0.24
7	Boanim*	5.94	0.06	5.89	0.41
8	Dabang*	4.90	0.30	4.25	0.28
9	Dawu*	7.71	0.16	6.38	0.35
10	Hiamankyene 1*	6.21	0.52	5.97	0.56
11	Jamasi*	7.27	0.37	6.89	0.34
12	Kona*	6.73	0.25	5.75	0.32
13	Nobesu*	6.31	0.14	5.82	0.31
14	Tano-Odumase*	6.55	0.19	5.83	0.08
15	Wiamoase*	8.08	0.24	6.85	0.08
16	Amenase	6.27	0.21	5.82	0.35
17	Babaduase	6.25	0.51	6.51	0.31
18	Bebaabra	6.63	0.29	5.96	0.48
19	Bedomase	6.09	0.17	5.99	0.22
20	Boachiekrom	6.02	0.39	6.89	0.02
21	Brehoma	6.85	0.04	6.27	0.54
22	Brofoyedru	7.10	0.28	6.32	0.10
23	Canan	6.71	0.17	5.51	0.46
24	Dabang-Hwi	6.09	0.24	6.40	0.50
25	Dome	7.21	0.22	5.61	0.83
26	Domeabra	6.56	0.27	5.97	0.10
27	Kofikrom	6.38	0.28	5.75	0.39
28	Kokoteasua	6.18	0.50	5.83	0.68
29	Mamentwewa	6.75	0.56	5.96	0.11
30	Montonsua	6.21	0.53	6.35	0.06
31	Morso	6.29	0.58	6.30	0.37
32	Nyamebekye	6.11	0.16	5.88	0.51
33	Okrakrom	5.89	0.58	6.18	0.35
34	Oponyaw	6.18	0.58	6.09	0.22

35	Otom	6.05	0.15	5.69	0.27
36	Tabre	6.20	0.51	5.73	0.38
37	Tutu-Nkwanta	5.97	0.18	5.42	0.23
38	Yamoakrom	5.95	0.21	6.12	0.38

* BU ENDEMIC AREAS

Table 7: Mean pH values for surface water in 38 communities in the Sekyere South District of the Ashanti Region, Ghana.

		Mean wet season values		Mean dry season values	
	Community	Mean	SDEV	Mean	SDEV
1	Abrakaso*	6.55	0.29	6.35	0.05
2	Afamanso*	6.56	0.28	6.65	0.17
3	Agona*	6.38	0.16	6.21	0.11
4	Asaman*g	6.11	0.42	6.22	0.31
5	Bepoase*	6.71	0.21	6.13	0.42
6	Bipoa*	6.67	0.20	6.47	0.35
7	Boanim*	6.80	0.04	5.81	0.06
8	Dabang*	6.03	0.25	6.25	0.22
9	Dawu*	6.42	0.33	6.40	0.04
10	Hiamankyene 1*	7.34	0.48	6.99	0.36
11	Jamasi*	6.20	0.38	6.04	0.29
12	Kona*	6.08	0.20	6.27	0.27
13	Nobesu*	6.43	0.51	6.38	0.41
14	Tano-Odumase*	6.36	0.09	5.85	0.07
15	Wiamoase*	5.36	0.47	5.14	0.47
16	Amenase	6.56	0.19	6.25	0.29
17	Babaduase	6.02	0.36	6.24	0.62
18	Bebaabra	5.92	0.15	6.35	0.17
19	Bedomase	6.50	0.53	6.48	0.34
20	Boachiekrom	5.83	0.17	6.09	0.17
21	Brehoma	6.96	0.27	6.16	0.19
22	Brofoyedru	6.52	0.33	5.83	0.15
23	Canan	6.25	0.80	6.48	0.24
24	Dabang-Hwibaa	7.12	0.54	6.05	0.35
25	Dome	6.78	0.36	5.98	0.25
26	Domeabra	6.27	0.53	5.84	0.16
27	Kofikrom	6.72	0.85	6.33	0.57
28	Kokoteasua	6.62	0.22	6.06	0.42
29	Mamentwewaso	5.89	0.16	5.88	0.41
30	Montonsua	6.25	0.34	5.59	0.24
31	Morso	5.89	0.21	5.84	0.03
32	Nyamebekyere	5.85	0.52	6.68	0.51
33	Okrakrom	6.02	0.33	5.85	0.49
34	Oponyaw	6.13	0.55	6.15	0.30

35	Otom	6.43	0.09	5.83	0.07
36	Tabre	5.96	0.34	6.23	0.11
37	Tutu-Nkwanta	6.22	0.47	5.76	0.08
38	Yamoakrom	6.03	0.45	6.18	0.44

* BU ENDEMIC AREAS

Table 8: Mean pH values for surface water sediment in 38 communities in the Sekyere South District of the Ashanti Region, Ghana.

		Mean Wet season values		Mean dry season values	
	Community	Mean	SDEV	Mean	SDEV
1	Abrakaso*	6.67	0.11	6.69	0.17
2	Afamanso*	6.35	0.26	6.57	0.11
3	Agona*	7.62	0.17	8.02	0.12
4	Asamang*	7.28	0.61	6.46	0.09
5	Bepoase*	8.30	0.35	6.97	0.45
6	Bipoa*	6.53	0.10	6.79	0.23
7	Boanim*	5.83	0.16	6.13	0.07
8	Dabang*	6.42	0.10	4.19	0.24
9	Dawu*	5.98	0.13	6.18	0.18
10	Hiamankyene 1*	6.92	0.37	8.33	0.46
11	Jamasi*	6.86	0.11	6.68	0.02
12	Kona*	6.68	0.14	6.70	0.15
13	Nobesu*	6.55	0.16	6.54	0.13
14	Tano-Odumase*	5.57	0.11	6.04	0.05
15	Wiamoase*	6.60	0.15	8.01	0.12
16	Amenase	6.60	0.28	6.30	0.15
17	Babaduase	6.64	0.26	6.53	0.08
18	Bebaabra	7.61	0.46	6.82	0.16
19	Bedomase	6.22	0.46	6.65	0.19
20	Boachiekrom	6.73	0.15	6.71	0.14
21	Brehoma	6.11	0.41	6.79	0.12
22	Brofoyedru	6.20	0.56	5.85	0.61
23	Canan	6.59	0.17	6.52	0.85
24	Dabang-Hwibaa	6.88	0.30	7.32	0.07
25	Dome	6.50	0.46	6.11	0.13
26	Domeabra	5.77	0.33	6.00	0.41
27	Kofikrom	5.73	0.18	6.31	0.16
28	Kokoteasua	6.31	0.15	6.72	0.20
29	Mamentwewaso	6.07	0.56	6.34	0.11
30	Montonsua	6.06	0.51	5.96	0.12
31	Morso	6.06	0.39	6.03	0.37
32	Nyamebekyere	5.95	0.64	5.85	0.11
33	Okrakrom	5.95	0.39	6.31	0.10
34	Oponyaw	5.90	0.58	6.59	0.76

35	Otom	5.75	0.05	6.29	0.07
36	Tabre	6.33	0.12	6.85	1.00
37	Tutu-Nkwanta	6.22	0.41	5.76	0.59
38	Yamoakrom	5.46	0.33	6.96	0.23

* BU ENDEMIC AREAS

CHAPTER FIVE

DISCUSSION

5.1 **Occurrence of BU in the Sekyere South District**

The results of this study indicated that most of the people infected with the BU (72%) in the Sekyere South District, worked along water bodies, and are poor peasant farmers. This observation agrees with results obtained by Asiedu and Etuaful (1998) and Portaels (1995), who reported that BU is prevalent among poor rural populations where medical amenities is lacking; and although humans are dead-end hosts for the causative agent of BU, *Mycobacterium ulcerans*, there is a consensus within the public health and scientific community that the risk of infection is greatly increased by marked exposure to aquatic and forests environments. Secondly, the prevalence of the disease as reported in this study was higher than what was officially on records in the District. The reason for this discrepancy could be due to the fact that only those who reported at the hospitals in the District were recorded as being infected with the disease although a number of infected persons are known to travel to relatives outside the District to be treated in other hospitals. Also the difference in the BU data could be as a result of the time interval. Whereas this study considered cases from 2004 to 2010, data as recorded in the District Health Directorate dated from 2007 to 2010.

5.2 **Occurrence of arsenic in some environmental samples in the Sekyere South District**

Results on the occurrence of arsenic in borehole water indicated that arsenic levels were generally very low in the dry season compared to the wet season.

The presence of arsenic in groundwater is largely the result of arsenic-bearing minerals; shales, phosphorites, and iron and manganese ores which dissolve naturally over time as certain types of rocks and soils are weathered (Nickson *et al*., 2000). Arsenic can also dissolve out of certain rock formations when groundwater levels significantly drop allowing atmospheric oxygen to penetrate into the aquifer (Gautheir, 2004), and to oxidize arsenopyrite, leading to desorption of the adsorbed arsenic (Smedley and Kinniburgh, 2002). These results compare favorably with those of Smedley *et al.* (1996), working on arsenic concentrations in groundwater in Ghana. Smedley *et al.* (1996) found a range of arsenic concentration of between 2 – 64 µg/l in groundwater in Ghana. They observed a median value of 2 µg/l in the Obuasi vicinity and that of 64 µg/l, not generally in the vicinity of the mine areas or related directly to mining activity. Rather, the higher concentrations were found to be present in relatively reducing groundwater. With the exception of Agona and Dawu, which recorded an average borehole water of 10.2 and 12.3 µg/l, respectively, for the wet season, all the borehole water in the Sekyere South District had arsenic concentration lower than 10.0 µg/l (WHO, 2004 maximum permissible limit for As in drinking water). This translates to 5.26 % of the borehole water sampled and compares with the results found by Smedley *et al.* (1996) in Bolgatanga area of the Upper East Region of Ghana. Even though groundwater may be contaminated by arsenic through agricultural applications by leaching through soils and fissures of rocks, especially when applied during the dry season when net movement of water is downwards, the results obtained confirms farming practices information gathered that not much is done during the dry season, in terms of pesticides application, and farming in general, in the District, thereby leading to a significant decrease of arsenic concentration in the environmental samples analyzed. That these results were observed is

an indication that the underlying bedrocks for most of the boreholes have very low quantities of arsenical compounds.

Results obtained from the studies on arsenic levels in surface water showed measurable arsenic levels in all the 38 communities for the wet season.

Concentrations of arsenic in surface water vary according to the composition of the surface recharge, the contribution from base flow and the bedrock lithology (Smedley and Kinniburgh, 2002). That the dry season samples had arsenic levels below detectable limit of 0.01 mg/l, and the wet season samples were higher than those of the borehole water, clearly demonstrate that the arsenic burden of the surface water was due to anthropogenetic sources. These sources such as pesticides used on farmlands get washed into the river bodies during the rainy season, hence increasing the arsenic concentrations in these water bodies. Mean values obtained ranged within that obtained by Smedley *et al.* (1996), which were <2 – 7900 µg /l. People dependent on or in contact with these rivers, mostly farmers, would therefore be much exposed to any adverse effects associated with increased arsenic levels in water. These farmers use the water for irrigation and drinking purposes, washing and dilution of agrochemicals on the farms. They are therefore much exposed to the water with its contents such as arsenic than would those who are not farmers. Such a result is consistent with those obtained by Martson *et al*. (1995). The strong correlation figure obtained, r = 0.66, between mean arsenic levels in surface water and incidence in BU, for BU endemic communities, gives further credence to the suspected case that arsenic might play a role in BU occurrence in the District. Similar results were obtained by Duker (2005) working on the spatial relationship between arsenic and prevalence of BU in the Amansie West

District, Ghana. Children of school going age, who also visit these surface water bodies regularly for swimming, get exposed to the effects of their contents. It was also observed from the BU results that none of the affected was below the age of seven. This is because children below this age group would not be allowed to go swimming, especially those five years and below. These groups would therefore not be exposed to the contents of the water bodies such as arsenic. Furthermore, the results indicated that of the farmers, large proportions of those infected were farming along river bodies.

Results obtained showed detectable levels of arsenic in surface water sediment and soils within 100 m radius of boreholes for both dry and wet seasons. Although the dominant source of As in soils is geological, and hence dependent to some extent on the concentration in the parent rock material, additional inputs may be derived locally from industrial sources such as smelting and fossil-fuel combustion products and agricultural sources such as pesticides and phosphate fertilizers (Nickson *et al*., 2000). That for both samples dry season results were lower than wet season results affirms the fact earlier made that agricultural sources might be the main source of arsenic in soils in the Sekyere South District of the Ashanti Region.

More so, whereas dry season sample results for soils within 100 m radius of boreholes were higher than those of the surface water sediment, results for the wet season showed the contrary. This might be due to the fact that in the dry season because there are no run-offs into the rivers whatever is deposited by way of agricultural inputs, largely remains in the soil and does not get washed into the rivers. In the rainy season, however, surface run-offs carry agricultural residues, especially those of pesticides and fertilizers into rivers thereby contributing to the increases in

contaminant burden of which arsenic is part. Farmers would obviously be exposed to the contents of the soils on which they are working, such as arsenic. That most grown-ups infected by the BU in the District are farmers might suggest that arsenic probably plays a role in BU infection. Most farmers eat with unwashed hands, having worked in soils, on the farms. Such a practice would lead to the direct ingestion of the soil contents. Therefore if there is arsenic in a soil sample and someone eats with an unwashed hand, having worked the hands in the soil, this would constitute direct ingestion of arsenic. Such practice, often the norm with rural farmers, would lead to increasing the arsenic burden of the individual. It was also evident that these farmers consumed mostly the food crops they produced. Alam *et al*. (2003) found that food crops grown in arsenic enriched soils tend to take up arsenic. Therefore it could be deduced that poor farmers depending solely on food grown on arsenic enriched soils and arsenic contaminated rivers would most likely be in danger of arsenic influenced diseases of which BU could likely be one.

5.2 **pH of some environmental samples in the Sekyere South District**

The results obtained for pH values for these environmental samples showed no significant difference between the BU endemic and non-endemic communities. However, some communities such as Dabang which recorded a pH value of 4.18 for its borehole drinking water is a matter of concern since strong acidic pH water could contain ions of toxic metals such as iron and copper (Addy *et al.*, 2004) and also cause the premature damage to pipe water systems.

The distribution of the species of arsenic in an environment is a function of pH of the given environment. Arsenic is perhaps unique among the heavy metalloids and oxyanion-forming

elements (e.g. arsenic, selenium) in its sensitivity to mobilization at the pH values typically found in groundwater (pH 6.5–8.5) and under both oxidizing and reducing conditions. Arsenic can occur in the environment in several oxidation states (-3, 0, +3 and +5) but in natural waters and soils is mostly found in inorganic form as oxyanions of trivalent arsenite (As(III)) or pentavalent arsenate (As(V)) (Smedley and Kinniburg, 2002).

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

From the results of the study:

- Borehole water in the Sekyere South District of the Ashanti Region, Ghana, is safe for human consumption, with regard to arsenic concentration levels.
- Arsenic found in the environmental samples in the Sekyere South District is mainly due to anthropogenetic activities such as pesticides and fertilizers application.
- Occurrence of BU in the Sekyere South District is higher than what is officially recorded
- Occurrence of BU in the Sekyere South District is higher in poor farming communities who mostly rely on surface water and soils enriched with arsenic.
- Farmers in the Sekyere South District do not use protective clothing on the farms while applying agrochemicals.
- There is a strong correlation between arsenic in surface water and occurrence of BU in the Sekyere South District.
- The pH of some boreholes in some of the communities is very acidic and could lead to high concentrations of ions of toxic metals such as iron and cupper.

Recommendations

- ✓ Follow up studies should be undertaken from time to time since significant changes in arsenic transport in groundwater may occur locally due to the influence of mining, groundwater pumping and irrigation. The water table is also often lowered by drainage or pumping and this can induce air entry and enhanced oxidation.
- ✓ Detailed studies should be undertaken to provide a sound basis for determining which pesticides and fertilizers have arsenic constituents so as to regulate their usage in the district.
- ✓ Farmers in the District should be encouraged not use surface water as sources of drinking water.
- ✓ The farmers should be encouraged to use protective clothing while applying pesticides and herbicides, and to protect themselves from the bites of insects while on the farms.
- ✓ Levels of some toxic metals such as iron, manganese, lead and zinc should be determined in the communities whose borehole water is below a pH of 6.

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Appendix A

Incidence of BU in the Sekyere South District of Ashanti Region, Ghana (2004-2010)

TOWN	BU incidence*
Abrakaso	4
Afamanso	6
Agona	12
Asamang	8
Bepoase	5
Bipoa	7
Boanim	6
Dabang	4
Dawu	3
Hiamankyene 1	1
Jamasi	7
Kona	8
Nobesu	3
Tano-Odumase	9
Wiamoase	8
Amenase	0
Babaduase	0
Bebaabra	0
Bedomase	0
Boachiekrom	0
Brehoma	0
Brofoyedru	0
Canan	0

Dabang-hwibaa	0
Dome	0
Domeabra	0
Kofikrom	0
Kokoteasua	0
Mamemtwewaso	0
Montonsua	0
Morso	0
Nyamebekyere	0
Okrakrom	0
Oponyaw	0
Otom	0
Tabre	0
Tutu-nkwanta	0
Yamoakrom	0

*Data include those obtained from the District Health Directorate and through personal interview.

Appendix B

Test results for arsenic concentration in some environmental samples in the Sekyere South District of the Ashanti Region, Ghana.

Appendix B1

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF RENEWABLE NATURAL RESOURCES

SOIL AND PLANT LAB ANALYSIS SHEET

TEST RESULTS FOR TOTAL ARSENIC CONCENTRATION (mg/L) IN BOREHOLE WATER IN 38 BURULI ULCER ENDEMIC AND NON-ENDEMIC COMMUNITIES IN SEKYERE SOUTH DISTRICT OF ASHANTI REGION, GHANA.

		MEAN WET SEASON CONCENTRATIONS									MEAN DRY SEASON CONCENTRATIONS								
	COMMUNITY	AUG-2010			SEPT-2010			OCT-2010			DEC-2010			JAN-2011			FEB-2011		
1	Abrakaso*	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
2	Afamanso*	0.062	0.067	0.063	0.06	0.059	0.057	0.064	0.065	0.063	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
3	Agona*	0.112	0.111	0.118	0.101	0.01	0.115	0.117	0.115	0.119	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
4	Asamang*	0.089	0.085	0.087	0.076	0.075	0.07	0.065	0.067	0.06	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
5	Bepoase*	0.045	0.043	0.04	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
6	Bipoa*	0.034	0.03	0.035	0.031	0.032	0.033	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

7	Boanim*	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
8	Dabang*	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
9	Dawu*	0.126	0.122	0.125	0.12	0.123	0.119	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
10	Hiamankyene 1*	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
11	Jamasi*	0.057	0.061	0.059	0.045	0.039	0.041	0.033	0.03	0.031	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
12	Kona*	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
13	Nobesu*	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
14	Tano-Odumase*	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
15	Wiamoase*	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
16	Amenase	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
17	Babaduase	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
18	Bebaabra	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
19	Bedomase	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
20	Boachiekrom	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
21	Brehoma	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
22	Brofoyedru	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
23	Canan	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
24	Dabang-Hwibaa	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
25	Dome	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
26	Domeabra	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

27	Kofikrom	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
28	Kokoteasua	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
29	Mamentwewaso	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
30	Montonsua	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
31	Morso	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
32	Nyamebekyere	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
33	Okrakrom	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
34	Oponyaw	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
35	Otom	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
36	Tabre	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
37	Tutu-Nkwanta	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
38	Yamoakrom	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Distilled Water	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	BLANK	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Detection limit of AAS 220 is 0.01																		

*BU ENDEMIC AREAS

CLIENT: FRANCIS YAW OSEI

CHECKED BY: MENSAH NAPOLEON J

Appendix B2

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF RENEWABLE NATURAL RESOURCES

SOIL AND PLANT ANALYSIS SHEET

TEST RESULTS FOR TOTAL ARSENIC CONCENTRATION (mg/L) IN SURFACE WATER IN 38 BURULI ULCER ENDEMIC AND NON-ENDEMIC COMMUNITIES IN SEKYERE SOUTH DISTRICT OF ASHANTI REGION, GHANA.

		MEAN WET SEASON CONCENTRATIONS									MEAN DRY SEASON CONCENTRATIONS								
	COMMUNITY	AUG-2010			SEPT-2010			OCT-2010			DEC-2010			JAN-2011			FEB-2011		
1	Abrakaso*	0.388	0.387	0.39	0.397	0.395	0.397	0.367	0.366	0.365	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
2	Afamanso*	0.568	0.569	0.567	0.544	0.548	0.545	0.554	0.558	0.559	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
3	Agona*	0.675	0.67	0.671	0.654	0.657	0.652	0.687	0.685	0.689	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
4	Asamang*	0.403	0.4	0.409	0.416	0.414	0.416	0.409	0.41	0.412	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
5	Bepoase*	0.363	0.365	0.369	0.316	0.321	0.319	0.367	0.362	0.36	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
6	Bipoa*	0.593	0.59	0.587	0.594	0.588	0.587	0.555	0.554	0.553	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
7	Boanim*	0.567	0.569	0.564	0.537	0.539	0.537	0.598	0.599	0.597	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
8	Dabang*	0.366	0.361	0.363	0.321	0.321	0.319	0.341	0.346	0.344	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
9	Dawu*	0.302	0.3	0.305	0.319	0.302	0.398	0.318	0.317	0.319	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
10	Hiamankyene 1*	0.201	0.211	0.206	0.287	0.276	0.285	0.245	0.249	0.242	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

11	Jamasi*	0.688	0.69	0.685	0.687	0.665	0.678	0.621	0.634	0.623	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
12	Kona*	0.51	0.512	0.5	0.473	0.478	0.476	0.506	0.503	0.505	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
13	Nobesu*	0.366	0.364	0.356	0.311	0.312	0.343	0.304	0.309	0.3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
14	Tano-Odumase*	0.532	0.533	0.531	0.498	0.487	0.49	0.386	0.385	0.379	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
15	Wiamoase*	0.236	0.233	0.238	0.295	0.289	0.297	0.308	0.301	0.305	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
16	Amenase	0.138	0.137	0.137	0.155	0.158	0.154	0.148	0.142	0.147	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
17	Babaduase	0.298	0.297	0.29	0.232	0.234	0.233	0.206	0.204	0.203	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
18	Bebaabra	0.251	0.249	0.25	0.249	0.247	0.249	0.25	0.257	0.255	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
19	Bedomase	0.197	0.199	0.19	0.166	0.165	0.166	0.108	0.106	0.107	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
20	Boachiekrom	0.194	0.197	0.195	0.154	0.156	0.157	0.133	0.132	0.13	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
21	Brehoma	0.375	0.373	0.367	0.398	0.387	0.388	0.387	0.388	0.388	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
22	Brofoyedru	0.145	0.144	0.147	0.133	0.135	0.137	0.162	0.164	0.165	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
23	Canan	0.286	0.288	0.289	0.239	0.238	0.239	0.132	0.129	0.128	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
24	Dabang-Hwibaa	0.277	0.276	0.276	0.246	0.248	0.249	0.229	0.23	0.227	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
25	Dome	0.322	0.319	0.326	0.298	0.288	0.299	0.301	0.3	0.311	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
26	Domeabra	0.389	0.388	0.387	0.349	0.347	0.345	0.345	0.332	0.343	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
27	Kofikrom	0.312	0.317	0.315	0.39	0.387	0.389	0.376	0.357	0.367	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
28	Kokoteasua	0.231	0.229	0.235	0.198	0.2	0.201	0.226	0.227	0.225	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
29	Mamentwewaso	0.322	0.312	0.319	0.315	0.317	0.319	0.315	0.313	0.317	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
30	Montonsua	0.129	0.125	0.127	0.168	0.159	0.154	0.102	0.109	0.11	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

31	Morso	0.12	0.119	0.117	0.109	0.105	0.108	0.121	0.123	0.122	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
32	Nyamebekyere	0.376	0.356	0.369	0.293	0.289	0.278	0.219	0.211	0.213	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
33	Okrakrom	0.239	0.238	0.235	0.297	0.296	0.288	0.188	0.186	0.18	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
34	Oponyaw	0.194	0.189	0.178	0.111	0.109	0.112	0.132	0.124	0.131	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
35	Otom	0.398	0.379	0.388	0.357	0.343	0.355	0.319	0.309	0.311	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
36	Tabre	0.289	0.29	0.287	0.217	0.209	0.212	0.287	0.29	0.288	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
37	Tutu-Nkwanta	0.342	0.335	0.339	0.297	0.289	0.287	0.219	0.217	0.215	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
38	Yamoakrom	0.117	0.121	0.12	0.119	0.116	0.114	0.132	0.135	0.134	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Distilled Water	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	BLANK	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Detection limit of AAS 220 is 0.01																		

*BU ENDEMIC AREAS

CLIENT: FRANCIS YAW OSEI **CHECKED BY: MENSAH NAPOLEON J**

Appendix B3

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF RENEWABLE NATURAL RESOURCES

SOIL AND PLANT LAB ANALYSIS SHEET

TEST RESULTS FOR TOTAL ARSENIC CONCENTRATION (mg/g) IN SOIL WITHIN 100m FROM BOREHOLES IN 38 BURULI ULCER ENDEMIC AND NON-ENDEMIC COMMUNITIES IN SEKYERE SOUTH DISTRICT OF ASHANTI REGION, GHANA.

		MEAN WET SEASON CONCENTRATIONS									MEAN DRY SEASON CONCENTRATIONS								
	COMMUNITY	AUG-2010			SEPT-2010			OCTO-2010			DEC-2010			JAN-2011			FEB-2011		
1	Abrakaso*	0.075	0.078	0.073	0.078	0.088	0.082	0.068	0.071	0.079	0.054	0.055	0.053	0.051	0.051	0.051	0.051	0.05	0.051
2	Afamanso*	0.112	0.101	0.113	0.121	0.111	0.131	0.110	0.114	0.131	0.05	0.051	0.051	0.051	0.051	0.051	0.052	0.052	0.051
3	Agona*	0.135	0.137	0.138	0.129	0.141	0.144	0.139	0.136	0.139	0.041	0.04	0.041	0.042	0.042	0.04	0.053	0.052	0.055
4	Asamang*	0.083	0.088	0.085	0.083	0.082	0.082	0.083	0.085	0.087	0.016	0.017	0.017	0.022	0.022	0.021	0.025	0.024	0.024
5	Bepoase*	0.066	0.065	0.066	0.066	0.065	0.066	0.066	0.065	0.066	0.094	0.094	0.095	0.088	0.088	0.086	0.109	0.111	0.11
6	Bipoa*	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.061	0.062	0.061	0.094	0.094	0.097	0.074	0.075	0.073
7	Boanim*	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.073	0.073	0.073	0.099	0.099	0.097	0.094	0.095	0.096
8	Dabang*	0.084	0.084	0.083	0.084	0.084	0.083	0.084	0.084	0.083	0.079	0.078	0.078	0.163	0.063	0.063	0.056	0.059	0.06
9	Dawu*	0.107	0.105	0.109	0.11	0.105	0.113	0.102	0.104	0.103	0.056	0.056	0.057	0.065	0.065	0.065	0.078	0.078	0.078
10	Hiamankyene 1*	0.102	0.103	0.101	0.101	0.106	0.103	0.105	0.103	0.104	0.059	0.059	0.059	0.106	0.106	0.106	0.06	0.061	0.061
11	Jamasi*	0.152	0.152	0.153	0.155	0.154	0.157	0.155	0.154	0.153	0.057	0.058	0.058	0.066	0.066	0.066	0.076	0.076	0.076
12	Kona*	0.107	0.105	0.106	0.104	0.102	0.103	0.109	0.108	0.108	0.161	0.161	0.161	0.012	0.012	0.012	0.028	0.028	0.029
13	Nobesu*	0.102	0.104	0.105	0.107	0.104	0.105	0.102	0.104	0.105	0.095	0.095	0.096	0.107	0.107	0.107	0.173	0.104	0.104
14	Tano-Odumase*	0.079	0.08	0.076	0.078	0.081	0.075	0.083	0.085	0.084	0.134	0.134	0.134	0.151	0.151	0.152	0.056	0.056	0.056
15	Wiamoase*	0.096	0.098	0.095	0.092	0.095	0.093	0.110	0.098	0.098	0.061	0.061	0.061	0.055	0.055	0.056	0.056	0.057	0.056
16	Amenase	0.065	0.068	0.069	0.079	0.077	0.078	0.073	0.075	0.074	0.011	0.013	0.013	0.016	0.016	0.016	0.016	0.017	0.015
17	Babaduase	0.063	0.062	0.061	0.066	0.067	0.068	0.06	0.06	0.061	0.07	0.07	0.07	0.06	0.06	0.06	0.08	0.08	0.08
18	Bebaabra	0.103	0.102	0.103	0.103	0.102	0.103	0.103	0.102	0.103	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
19	Bedomase	0.076	0.077	0.079	0.072	0.073	0.073	0.075	0.074	0.075	0.012	0.012	0.012	0.016	0.016	0.017	0.014	0.014	0.014

20	Boachiekrom	0.084	0.083	0.085	0.087	0.086	0.087	0.087	0.084	0.085	0.041	0.041	0.04	0.028	0.028	0.028	0.034	0.033	0.033
21	Brehoma	0.117	0.118	0.119	0.117	0.118	0.119	0.117	0.118	0.119	0.059	0.061	0.057	0.067	0.067	0.066	0.081	0.084	0.084
22	Brofoyedru	0.077	0.078	0.078	0.075	0.076	0.075	0.077	0.078	0.078	0.109	0.112	0.111	0.061	0.061	0.062	0.045	0.045	0.045
23	Canan	0.064	0.065	0.066	0.074	0.074	0.075	0.068	0.069	0.067	0.094	0.095	0.094	0.078	0.078	0.078	0.079	0.078	0.079
24	Dabang-Hwibaa	0.084	0.086	0.083	0.094	0.093	0.095	0.073	0.075	0.074	0.129	0.129	0.129	0.123	0.125	0.124	0.115	0.114	0.113
25	Dome	0.088	0.089	0.087	0.092	0.093	0.091	0.09	0.09	0.09	0.039	0.04	0.039	0.068	0.068	0.068	0.071	0.07	0.061
26	Domeabra	0.058	0.056	0.057	0.06	0.061	0.062	0.058	0.058	0.058	0.11	0.11	0.11	0.073	0.073	0.073	0.034	0.034	0.034
27	Kofikrom	0.057	0.058	0.058	0.057	0.058	0.058	0.057	0.058	0.058	0.093	0.093	0.093	0.073	0.073	0.072	0.079	0.079	0.079
28	Kokoteasua	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.055	0.056	0.056	0.061	0.061	0.061	0.072	0.072	0.072
29	Mamentwewaso	0.067	0.067	0.067	0.067	0.067	0.067	0.067	0.067	0.067	0.055	0.055	0.056	0.11	0.11	0.11	0.161	0.162	0.161
30	Montonsua	0.05	0.051	0.051	0.05	0.051	0.051	0.05	0.051	0.051	0.011	0.011	0.011	0.061	0.061	0.061	0.116	0.116	0.116
31	Morso	0.057	0.058	0.057	0.057	0.058	0.057	0.057	0.058	0.057	0.06	0.06	0.061	0.061	0.061	0.061	0.063	0.063	0.063
32	Nyamebekyere	0.056	0.056	0.057	0.056	0.056	0.057	0.056	0.056	0.057	0.091	0.091	0.091	0.117	0.117	0.117	0.066	0.066	0.066
33	Okrakrom	0.055	0.056	0.051	0.055	0.056	0.051	0.055	0.056	0.051	0.106	0.106	0.106	0.107	0.107	0.107	0.103	0.102	0.103
34	Oponyaw	0.179	0.178	0.179	0.179	0.178	0.179	0.179	0.178	0.179	0.062	0.062	0.065	0.072	0.072	0.071	0.109	0.109	0.107
35	Otom	0.101	0.106	0.106	0.101	0.106	0.106	0.101	0.106	0.106	0.049	0.05	0.049	0.107	0.107	0.107	0.122	0.122	0.122
36	Tabre	0.051	0.052	0.053	0.057	0.056	0.058	0.051	0.051	0.051	0.123	0.123	0.123	0.099	0.099	0.099	0.087	0.087	0.087
37	Tutu-Nkwanta	0.086	0.088	0.087	0.078	0.075	0.074	0.098	0.093	0.092	0.084	0.084	0.084	0.072	0.072	0.072	0.1	0.101	0.101
38	Yamoakrom	0.103	0.105	0.106	0.108	0.107	0.108	0.102	0.104	0.106	0.061	0.061	0.061	0.056	0.056	0.056	0.084	0.084	0.083
	Distilled Water	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	BLANK	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Detection limit of AAS 220 is 0.01																		

*BU ENDEMIC AREAS

CLIENT: FRANCIS YAW OSEI

CHECKED BY: MENSAH NAPOLEON J

Appendix B4

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF RENEWABLE NATURAL RESOURCES

SOIL AND PLANT LAB ANALYSIS SHEET

TEST RESULTS FOR TOTAL ARSENIC CONCENTRATION (mg/g) IN SURFACE WATER SEDIMENT IN 38 BURULI ULCER ENDEMIC AND NON-ENDEMIC COMMUNITIES IN SEKYERE SOUTH DISTRICT OF ASHANTI REGION, GHANA.

		MEAN WET SEASON CONCENTRATIONS									MEAN DRY SEASON CONCENTRATIONS								
	COMMUNITY	AUGUST			SEPTEMBER			OCTOBER			DEC			JAN			FEB		
1	Abrakaso*	0.185	0.384	0.383	0.357	0.356	0.356	0.364	0.262	0.265	0.057	0.056	0.057	0.054	0.054	0.055	0.058	0.058	0.057
2	Afamanso*	0.338	0.334	0.336	0.285	0.286	0.279	0.234	0.234	0.238	0.024	0.023	0.024	0.022	0.023	0.023	0.023	0.023	0.023
3	Agona*	0.347	0.345	0.347	0.343	0.342	0.345	0.357	0.349	0.356	0.055	0.059	0.056	0.054	0.058	0.054	0.058	0.058	0.059
4	Asamang*	0.216	0.217	0.217	0.216	0.215	0.213	0.212	0.212	0.212	0.051	0.051	0.051	0.054	0.054	0.054	0.053	0.053	0.053
5	Bepoase*	0.216	0.217	0.215	0.184	0.185	0.184	0.237	0.237	0.236	0.033	0.034	0.034	0.034	0.034	0.035	0.033	0.034	0.034
6	Bipoa*	0.255	0.256	0.257	0.254	0.256	0.255	0.266	0.262	0.266	0.041	0.043	0.042	0.042	0.04	0.039	0.043	0.042	0.043
7	Boanim*	0.282	0.285	0.283	0.278	0.277	0.276	0.282	0.282	0.285	0.044	0.041	0.043	0.042	0.043	0.04	0.04	0.044	0.044
8	Dabang*	0.242	0.243	0.242	0.2	0.2	0.205	0.219	0.22	0.22	0.049	0.049	0.048	0.048	0.049	0.048	0.048	0.048	0.049
9	Dawu*	0.24	0.239	0.238	0.243	0.245	0.244	0.211	0.207	0.209	0.042	0.043	0.042	0.039	0.043	0.043	0.044	0.043	0.04
10	Hiamankyene 1*	0.232	0.229	0.23	0.249	0.247	0.249	0.318	0.32	0.321	0.027	0.027	0.026	0.025	0.024	0.025	0.026	0.027	0.027

11	Jamasi*	0.299	0.295	0.294	0.26	0.261	0.261	0.263	0.263	0.264	0.051	0.051	0.051	0.052	0.055	0.053	0.053	0.051	0.061
12	Kona*	0.214	0.214	0.216	0.227	0.227	0.228	0.218	0.22	0.219	0.025	0.024	0.024	0.026	0.025	0.025	0.023	0.024	0.023
13	Nobesu*	0.235	0.236	0.236	0.206	0.209	0.206	0.245	0.248	0.248	0.027	0.028	0.027	0.028	0.029	0.028	0.029	0.028	0.029
14	Tano-Odumase*	0.243	0.243	0.243	0.233	0.234	0.234	0.245	0.245	0.244	0.05	0.049	0.049	0.05	0.051	0.055	0.049	0.048	0.049
15	Wiamoase*	0.233	0.233	0.233	0.239	0.239	0.239	0.217	0.216	0.217	0.052	0.055	0.057	0.059	0.059	0.057	0.059	0.058	0.058
16	Amenase	0.171	0.172	0.173	0.173	0.174	0.173	0.166	0.167	0.162	0.037	0.037	0.038	0.038	0.038	0.038	0.037	0.037	0.038
17	Babaduase	0.196	0.196	0.195	0.157	0.161	0.162	0.165	0.164	0.165	0.027	0.028	0.026	0.027	0.028	0.027	0.028	0.029	0.029
18	Bebaabra	0.14	0.143	0.143	0.134	0.133	0.132	0.14	0.139	0.138	0.044	0.044	0.044	0.043	0.043	0.044	0.044	0.044	0.045
19	Bedomase	0.141	0.142	0.142	0.165	0.164	0.164	0.146	0.144	0.145	0.039	0.038	0.038	0.038	0.038	0.038	0.038	0.039	0.038
20	Boachiekrom	0.116	0.116	0.117	0.095	0.098	0.095	0.073	0.075	0.072	0.021	0.021	0.021	0.022	0.022	0.022	0.023	0.024	0.023
21	Brehoma	0.184	0.188	0.187	0.143	0.145	0.144	0.166	0.165	0.166	0.033	0.032	0.033	0.032	0.032	0.033	0.034	0.033	0.033
22	Brofoyedru	0.196	0.195	0.194	0.173	0.172	0.172	0.199	0.195	0.198	0.041	0.04	0.041	0.04	0.041	0.041	0.04	0.04	0.041
23	Canan	0.101	0.111	0.107	0.128	0.127	0.129	0.1	0.1	0.101	0.017	0.018	0.017	0.019	0.018	0.018	0.018	0.017	0.017
24	Dabang-Hwibaa	0.188	0.187	0.187	0.151	0.151	0.151	0.199	0.197	0.198	0.027	0.028	0.027	0.028	0.027	0.028	0.027	0.028	0.028
25	Dome	0.146	0.143	0.145	0.145	0.143	0.145	0.151	0.15	0.152	0.038	0.038	0.038	0.037	0.038	0.038	0.038	0.039	0.037
26	Domeabra	0.188	0.19	0.19	0.145	0.146	0.143	0.198	0.197	0.199	0.032	0.033	0.033	0.032	0.033	0.034	0.034	0.033	0.032
27	Kofikrom	0.165	0.166	0.166	0.153	0.155	0.156	0.198	0.199	0.198	0.024	0.024	0.023	0.025	0.026	0.026	0.024	0.025	0.024
28	Kokoteasua	0.195	0.194	0.194	0.143	0.145	0.144	0.172	0.177	0.172	0.034	0.033	0.033	0.035	0.034	0.034	0.034	0.035	0.034
29	Mamentwewaso	0.142	0.142	0.143	0.134	0.135	0.132	0.14	0.142	0.142	0.028	0.028	0.029	0.03	0.029	0.03	0.029	0.029	0.029
30	Montonsua	0.155	0.156	0.156	0.247	0.245	0.246	0.182	0.183	0.183	0.024	0.025	0.024	0.023	0.024	0.024	0.024	0.024	0.025

31	Morso	0.101	0.106	0.106	0.2	0.195	0.2	0.189	0.188	0.187	0.029	0.028	0.029	0.028	0.028	0.028	0.028	0.028	0.028
32	Nyamebekyere	0.172	0.172	0.173	0.217	0.216	0.217	0.245	0.245	0.245	0.033	0.034	0.033	0.034	0.033	0.033	0.034	0.035	0.034
33	Okrakrom	0.128	0.128	0.128	0.177	0.178	0.178	0.138	0.139	0.138	0.027	0.028	0.028	0.027	0.028	0.029	0.029	0.028	0.027
34	Oponyaw	0.216	0.216	0.216	0.245	0.244	0.243	0.195	0.193	0.194	0.033	0.034	0.033	0.034	0.034	0.034	0.035	0.034	0.035
35	Otom	0.118	0.118	0.117	0.161	0.161	0.161	0.143	0.143	0.143	0.029	0.029	0.029	0.028	0.028	0.029	0.03	0.029	0.029
36	Tabre	0.216	0.216	0.216	0.178	0.178	0.178	0.217	0.218	0.22	0.042	0.043	0.043	0.042	0.043	0.044	0.044	0.043	0.042
37	Tutu-Nkwanta	0.161	0.161	0.161	0.218	0.217	0.218	0.199	0.199	0.199	0.039	0.038	0.038	0.04	0.039	0.039	0.038	0.038	0.039
38	Yamoakrom	0.161	0.161	0.161	0.156	0.156	0.156	0.178	0.177	0.178	0.038	0.039	0.038	0.038	0.038	0.038	0.038	0.038	0.038
	Distilled Water	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	BLANK	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Detection limit of AAS 220 is 0.01																		

***BU** ENDEMIC AREAS

CLIENT: FRANCIS YAW OSEI

CHECKED BY: MENSAH NAPOLEON J

Appendix C

Test results for pH for some environmental samples in the Sekyere South District of the Ashanti Region, Ghana.

Appendix C1

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF RENEWABLE NATURAL RESOURCES

SOIL AND PLANT LAB

ANALYSIS SHEET

		WET SEASON			DRY SEASON		
	COMMUNITY	AUG-2010	SEPT-2010	OCTO-2010	DEC-2010	JAN-2011	FEB-2011
1	Abrakaso	6.57	6.65	6.78	6.54	6.87	6.67
2	Afamanso	6.06	6.43	6.56	6.49	6.52	6.69
3	Agona	7.77	7.67	7.43	8.06	7.88	8.11
4	Amenase	6.33	6.58	6.89	6.43	6.13	6.34
5	Asamang	7.59	7.68	6.58	6.43	6.39	6.56
6	Babaduase	6.35	6.72	6.85	6.57	6.44	6.57
7	Bebaabra	7.46	7.24	8.12	6.99	6.67	6.79
8	Bedomase	5.69	6.54	6.43	6.87	6.54	6.55
9	Bepoase	8.62	7.93	8.35	6.93	7.43	6.54

10	Bipoa	6.50	6.45	6.65	6.98	6.86	6.54
11	Boachiekrom	6.86	6.56	6.76	6.8	6.78	6.54
12	Boanim	5.87	5.66	5.97	6.08	6.21	6.11
13	Brehoma	6.56	5.98	5.78	6.65	6.87	6.85
14	Brofoyedru	5.98	5.78	6.84	5.54	5.46	6.56
15	Canan	6.77	6.56	6.44	7.34	6.56	5.65
16	Dabang	4.22	4.21	4.23	3.95	4.43	4.20
17	Dabang-Hwibaa	6.98	7.12	6.54	7.38	7.25	7.34
18	Dawu	5.94	6.12	5.87	6.26	6.31	5.98
19	Dome	6.65	6.87	5.98	6.11	5.98	6.23
20	Domeabra	6.11	5.76	5.45	6.45	5.65	5.89
21	Hiamankyene 1	6.78	7.34	6.65	8.68	8.50	7.80
22	Jamasi	6.97	6.76	6.85	6.67	6.70	6.68
23	Kofikrom	5.76	5.89	5.54	6.45	6.34	6.13
24	Kokoteasua	6.34	6.14	6.44	6.50	6.78	6.88
25	Kona	6.81	6.69	6.54	6.58	6.65	6.86
26	Mamentwewaso	6.71	5.67	5.83	6.45	6.34	6.24
27	Montonsua	5.67	5.87	6.63	5.89	5.90	6.10
28	Morso	5.61	6.33	6.23	5.77	5.87	6.45
29	Nobesu	6.38	6.57	6.69	6.57	6.39	6.65
30	Nyamebekyere	6.43	5.23	6.20	5.78	5.98	5.80
31	Okrakrom	5.76	5.70	6.40	6.34	6.20	6.40
32	Oponyaw	5.87	5.34	6.50	7.28	5.78	6.70
33	Otom	5.80	5.75	5.70	6.21	6.32	6.35
34	Tabre	6.23	6.30	6.47	7.89	6.75	5.90

35	Tano-Odumase	5.47	5.68	5.55	6.06	5.98	6.08
36	Tutu-Nkwanta	6.56	6.33	5.76	5.08	6.09	6.11
37	Wiamoase	6.43	6.65	6.72	8.10	7.87	8.05
38	Yamoakrom	5.65	5.08	5.65	7.21	6.77	6.90

CLIENT: FRANCIS YAW OSEI. **CHECKED BY: MENSAH NAPOLEON J**

Appendix C2

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF RENEWABLE NATURAL RESOURCES

SOIL AND PLANT LAB

ANALYSIS SHEET

TEST RESULTS FOR pH VALUES FOR SURFACE WATER

		WET SEASON			DRY SEASON		
	COMMUNITY	AUG-2010	SEPT-2010	OCTO-2010	DEC-2010	JAN-2011	FEB-2011
1	Abrakaso	6.23	6.65	6.78	6.32	6.41	6.33
2	Afamanso	6.46	6.87	6.34	6.85	6.54	6.56
3	Agona	6.23	6.37	6.54	6.31	6.09	6.23
4	Amenase	6.78	6.45	6.44	6.21	6.56	5.98
5	Asamang	6.58	5.95	5.79	6.25	5.89	6.51
6	Babaduase	6.44	5.78	5.85	6.95	5.87	5.90
7	Bebaabra	6.08	5.79	5.88	6.52	6.34	6.18
8	Bedomase	6.75	6.87	5.89	6.75	6.59	6.09
9	Bepoase	6.89	6.75	6.48	6.62	5.85	5.93
10	Bipoa	6.71	6.45	6.85	6.07	6.75	6.58
11	Boachiekrom	5.84	5.65	5.99	6.17	6.21	5.89
12	Boanim	6.78	6.77	6.84	5.80	5.76	5.88

13	Brehoma	7.27	6.78	6.82	5.95	6.33	6.19
14	Brofoyedru	6.22	6.87	6.47	5.80	5.99	5.70
15	Canan	7.17	5.86	5.71	6.51	6.71	6.23
16	Dabang	5.87	5.90	6.31	6.00	6.40	6.34
17	Dabang-Hwibaa	6.78	7.74	6.85	6.45	5.87	5.83
18	Dawu	6.80	6.18	6.29	6.37	6.45	6.38
19	Dome	7.16	6.45	6.73	5.98	6.23	5.74
20	Domeabra	6.87	5.88	6.06	5.99	5.67	5.87
21	Hiamankyene 1	7.70	7.52	6.80	7.39	6.70	6.88
22	Jamasi	6.38	6.45	5.76	5.70	6.22	6.19
23	Kofikrom	7.54	6.76	5.85	5.67	6.65	6.66
24	Kokoteasua	6.45	6.87	6.55	6.54	5.88	5.76
25	Kona	6.09	6.27	5.87	6.31	6.52	5.99
26	Mamentwewaso	5.78	6.07	5.81	5.76	5.55	6.34
27	Montonsua	5.87	6.54	6.34	5.87	5.47	5.43
28	Morso	6.05	5.98	5.65	5.84	5.81	5.87
29	Nobesu	6.85	6.57	5.86	6.45	6.75	5.93
30	Nyamebekyere	5.44	5.67	6.43	6.32	6.45	7.26
31	Okrakrom	6.08	5.67	6.32	5.83	6.34	5.37
32	Oponyaw	6.75	5.68	5.97	5.80	6.32	6.32
33	Otom	6.43	6.34	6.52	5.90	5.83	5.76
34	Tabre	5.67	5.88	6.33	6.22	6.34	6.13
35	Tano-Odumase	6.44	6.37	6.27	5.89	5.77	5.89
36	Tutu-Nkwanta	5.68	6.54	6.45	5.67	5.83	5.79
37	Wiamoase	4.86	5.44	5.78	4.98	5.67	4.78

38	Yamoakrom	5.67	6.54	5.88	6.45	6.43	5.67

CLIENT: FRANCIS YAW OSEI. **CHECKED BY: MENSAH NAPOLEON J**

Appendix C3

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF RENEWABLE NATURAL RESOURCES

SOIL AND PLANT LAB

ANALYSIS SHEET

TEST RESULTS FOR pH VALUES FOR SOIL WITHIN 100 M RADIUS OF BOREHOLE WATER

		WET SEASON			DRY SEASON		
	COMMUNITY	AUG-2010	SEPT-2010	OCTO-2010	DEC-2010	JAN-2011	FEB-2011
1	Abrakaso	5.67	5.87	6.05	7.45	6.78	7.48
2	Afamanso	6.74	6.35	6.86	7.89	8.03	8.12
3	Agona	7.38	7.87	7.83	6.76	7.23	6.78
4	Amenase	6.04	6.45	6.33	5.43	5.90	6.12
5	Asamang	5.67	6.42	6.09	5.68	6.89	5.99
6	Babaduase	6.65	6.42	5.67	6.87	6.34	6.33
7	Bebaabra	6.96	6.55	6.39	6.43	5.98	5.47
8	Bedomase	5.90	6.23	6.15	6.21	5.78	5.98
9	Bepoase	7.08	7.58	6.78	7.89	6.79	7.85
10	Bipoa	6.94	6.89	6.56	5.87	6.22	6.32
11	Boachiekrom	5.66	5.98	6.43	6.89	6.87	6.91
12	Boanim	5.87	5.97	5.99	5.43	6.03	6.21

13	Brehoma	6.87	6.87	6.80	5.65	6.58	6.59
14	Brofoyedru	7.21	6.78	7.30	6.22	7.34	6.41
15	Canan	6.70	6.54	6.88	5.79	4.98	5.76
16	Dabang	4.56	5.04	5.11	6.53	4.23	7.98
17	Dabang-Hwibaa	5.87	6.34	6.06	6.42	5.89	6.89
18	Dawu	7.72	7.54	7.86	6.22	6.15	6.78
19	Dome	7.21	7.43	6.99	6.44	7.60	4.78
20	Domeabra	6.44	6.38	6.87	5.87	5.98	6.07
21	Hiamankyene 1	6.78	5.76	6.08	6.13	6.43	5.34
22	Jamasi	7.38	7.57	6.85	7.23	6.87	6.56
23	Kofikrom	6.07	6.61	6.45	5.91	7.31	6.03
24	Kokoteasua	5.73	6.09	6.71	5.04	6.21	6.23
25	Kona	6.98	6.48	6.74	5.44	5.72	6.08
26	Mamentwewaso	7.38	6.58	6.29	5.97	6.07	5.85
27	Montonsua	6.82	5.88	5.93	6.39	6.28	6.37
28	Morso	5.65	6.45	6.77	5.87	6.48	6.54
29	Nobesu	6.19	6.47	6.27	5.47	6.07	5.93
30	Nyamebekyere	6.23	6.18	5.93	5.37	6.38	5.89
31	Okrakrom	5.86	6.48	5.32	6.57	5.89	6.07
32	Oponyaw	6.84	5.78	5.92	5.83	6.21	6.22
33	Otom	5.89	6.08	6.18	5.87	5.38	5.83
34	Tabre	6.78	5.84	5.98	6.03	5.87	5.30
35	Tano-Odumase	6.48	6.76	6.41	5.76	5.81	5.92
36	Tutu-Nkwanta	5.86	6.17	5.87	5.64	5.19	6.44
37	Wiamoase	8.26	8.18	7.81	6.77	6.86	6.92

38	Yamoakrom	5.76	6.17	5.91	6.45	5.71	6.19

CLIENT: FRANCIS YAW OSEI. **CHECKED BY: MENSAH NAPOLEON J.**

Appendix C4

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF RENEWABLE NATURAL RESOURCES

SOIL AND PLANT LAB

ANALYSIS SHEET

TEST RESULTS FOR pH VALUES FOR BOREHOLE WATER

		WET SEASON			DRY SEASON		
	COMMUNITY	AUG-2010	SEPT-2010	OCTO-2010	DEC-2010	JAN-2011	FEB-2011
1	Abrakaso	6.78	6.83	6.47	6.29	6.78	6.43
2	Afamanso	6.27	6.98	6.49	6.27	6.38	6.59
3	Agona	6.53	6.49	6.49	5.43	5.79	5.87
4	Amenase	5.87	6.06	6.45	5.98	5.84	5.72
5	Asamang	6.05	6.47	5.93	5.76	5.34	5.78
6	Babaduase	6.85	6.45	6.09	5.76	6.74	6.38
7	Bebaabra	5.83	5.79	6.52	5.76	6.45	6.84
8	Bedomase	5.68	5.63	5.78	5.46	5.55	6.33
9	Bepoase	5.89	5.99	6.14	6.11	6.07	6.32
10	Bipoa	5.87	5.84	6.34	6.87	5.89	5.76
11	Boachiekrom	6.56	6.68	7.61	6.66	6.81	6.67
12	Boanim	5.17	6.78	6.64	7.75	7.86	6.67

13	Brehoma	5.78	5.39	5.28	5.73	5.19	5.33
14	Brofoyedru	6.05	5.71	5.87	5.39	5.28	5.17
15	Canan	5.74	5.66	5.31	5.32	5.28	5.38
16	Dabang	4.37	3.87	4.29	3.95	4.43	5.22
17	Dabang-Hwibaa	5.76	5.92	6.08	6.12	5.94	5.47
18	Dawu	5.79	5.87	5.99	6.04	5.77	5.45
19	Dome	6.84	6.43	6.74	5.94	5.76	5.49
20	Domeabra	6.87	6.21	6.34	5.97	5.87	6.32
21	Hiamankyene 1	6.76	6.33	6.32	6.78	5.47	5.49
22	Jamasi	6.56	6.76	5.98	6.03	5.73	6.28
23	Kofikrom	6.05	5.76	5.68	6.11	6.23	5.98
24	Kokoteasua	6.71	5.89	6.45	5.97	5.87	6.08
25	Kona	5.54	5.67	5.63	5.21	5.13	5.23
26	Mamentwewaso	6.78	6.54	5.98	6.07	5.77	5.69
27	Montonsua	5.98	6.37	6.17	5.79	6.34	6.05
28	Morso	5.76	5.88	6.23	5.74	5.45	6.25
29	Nobesu	5.87	5.98	6.34	6.04	5.38	6.14
30	Nyamebekyere	5.65	6.71	6.76	5.69	5.38	6.32
31	Okrakrom	6.22	6.19	5.89	6.45	6.32	6.17
32	Oponyaw	6.75	6.47	6.34	5.43	5.78	5.66
33	Otom	5.13	5.67	5.85	6.31	6.16	5.87
34	Tabre	6.43	6.54	6.44	5.77	5.76	5.97
35	Tano-Odumase	5.11	5.29	5.37	6.21	5.72	6.11
36	Tutu-Nkwanta	6.43	6.54	6.27	5.87	5.99	5.88
37	Wiamoase	5.81	5.87	5.73	5.89	5.57	5.76

38	Yamoakrom	6.54	6.76	5.98	6.85	5.33	5.77

CLIENT: FRANCIS YAW OSEI. **CHECKED BY: MENSAH NAPOLEON J**