M.Sc. WATER RESOURCES ENGINEERING AND MANAGEMENT

SOME HEAVY METAL LEVELS IN DRINKING WATER AND SOCIAL CHARACTERISTICS IN BURULI ULCER ENDEMIC AND NON-ENDEMIC COMMUNITIES IN THE AMANSIE WEST DISTRICT

ANNA ODEH-AGBOZO

April 2009

Kwame Nkrumah University of Science and Technology
College of Engineering
Faculty of Civil and Geomatic Engineering

SOME HEAVY METAL LEVELS IN DRINKING WATER AND SOCIAL CHARACTERISTICS IN BURULI ULCER ENDEMIC AND NON-ENDEMIC COMMUNITIES IN THE AMANSIE WEST DISTRICT

BY

ANNA ODEH-AGBOZO

A thesis submitted to the Board of Graduate Studies
Kwame Nkrumah University of Science and Technology

In partial fulfillment of the requirements for the degree of
MASTER OF SCIENCE
In
WATER RESOURCES ENGINEERING AND MANAGEMENT

Department of Civil Engineering
Faculty of Civil and Geomatic Engineering
College of Engineering

2009

CERTIFICATION

I hereby declare that this submission is my own work towards the M.Sc. 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.

Anna Odeh-Agbozo Signature .... Date 29/04/09
PG 13583-07

Certified by:
Prof. Dr. Mrs. Esi Awuah Signature .... Date 29/4/09
(Supervisor)

Certified by:
Dr. G. K. Anornu Signature .... Date 7/5/09
(Supervisor)

Certified by:
Prof. Dr. S. I. K. Ampadu Signature .... Date 10/05/2009
Head of Civil Engineering Department (KNUST)

ABSTRACT

Buruli ulcer (BU) is a skin disease caused by Mycobacterium ulcerans (MU). It is often associated with slow-flowing or stagnant water and increase in incidence of the disease is also associated with ecological transformation. Several risk factors have been identified, and a number of transmission mechanisms suggested. However, the exact mechanism of transmission and development of Buruli ulcer through water-related human activities is unknown. A study was carried out to compare concentrations of cadmium, lead and aluminum in drinking water samples and some social characteristics from endemic and non-endemic communities in the Amansie West District in Ghana. Ninety-six drinking water sources were sampled from boreholes and hand-dug wells in the study area. The analysis of the samples showed that the average concentration of cadmium was significantly higher ($p \leq 0.05$) in endemic communities than in non-endemic communities even though all the values were below the WHO guideline values of 0.003mg/L. The average concentrations of Lead and Aluminum were lower in endemic communities than in non-endemic communities, but the differences between the average concentrations were not statistically significant ($p \geq 0.95$ for Lead, $p \geq 0.30$ for Aluminum). Aluminum concentrations in all the samples were however lower than the WHO recommended guideline value of 0.1mg/L, whilst the concentration of Lead was higher than the recommended guideline value in several communities. It was therefore concluded that cadmium, Lead and Aluminum may not contribute to the occurrence and transmission of BU. In relation to the social characteristics, the educational level was generally poorer in endemic areas than in the non-endemic areas. The endemic communities used poorer source of water which include streams and hand-dug wells, unlike non-endemic communities which had better sources of water - boreholes and pipe-borne water only. Field observation showed that people in the endemic communities walked barefooted, whilst those in the non-endemic communities had footwear. In this District therefore, attitudinal behaviour/social characteristics may play a role in the occurrence of the disease. Other heavy metals like arsenic should be investigated into, as well as the water usage patterns of the people in the community (to determine whether the disease is water-washed, water-borne or water-based). The organism may be present in the water and/or soil, and it is recommended that more research be carried out to isolate it in the environment.

ACKNOWLEDGEMENT

I thank the Lord God Almighty to whom belongs all knowledge, wisdom and understanding for His guidance and provision.

Special thanks go to my supervisors, Prof. Mrs. Esi Awuah and Dr. G. K. Anornu for their assistance and guidance.

(Knowledge, they say, is not in the head of one man) I am very grateful to the following people who in diverse ways helped in the realization of this work: Mr. Joseph Adomako, Mr. Daniel Boakye and staff of the Amansie West District Health Administration; Dr. Samuel Afram, Dr. Joseph Mensah-Homiah, Mr. Richard Agyarko and staff of Millennium Villages Project, Bonsaaso; Mr. Richard Boamah, Mr. Emmanuel Botwey and Mr. Ken of the Civil Engineering Department, KNUST; Prof. Maiga, Mr. Kokou Denyigba, Dr. Joseph Wethe, Dr. Dennis Zoungrana and Mr. Dieudonne Afagnon of International Institute of Water and Environmental Engineering, Ouagadougou; and Martha Ansah.

I am also very grateful to my parents and siblings for all their love, care and support.

To all my colleagues, I say thank you for the great times we had together and for all the shaping we have given each other.

To Emmanuel, I say thank you for your love, encouragement and support.

And to numerous others who were of assistance in one way or another, I am very grateful.

May the Good Lord bless and keep you all!

DEDICATION

I dedicate this to Isaac, Lucy, Joel, Kwabena Boakye and Nana Yaw.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ACRONYMS (ABBREVIATIONS)

AWDA	Amansie West District Assembly
AWDHA	Amansie West District Health Administration
BU	Buruli Ulcer
MU	Mycobacterium ulcerans
WHA	World Health Assembly
WHO	World Health Organization

1 INTRODUCTION

1.1 Background

Buruli ulcer (BU) is a skin disease which often occurs as a disfiguring skin ulceration which is difficult to treat. It is caused by Mycobacterium ulcerans (MU) (Duker et al, 2004; Phillips et al, 2005). In its advanced stage the disease does not respond to drugs and requires surgery, often limb amputation. It sometimes results in death. In the African World Health Organization region, at least 16 of 46 member countries report cases, especially in West Africa and parts of Eastern and Central Africa. A 1999 national survey in Ghana identified over 6,000 cases, making BU the second most prevalent mycobacterial disease after tuberculosis (Amofah *et al.* 2002). Studies by Amofah et al (2001) also revealed that in Ghana, Ashanti region is the most endemic region with the Amansie West District being the district with the highest number of cases in the region.

Although the causative organism is from the family of bacteria which causes tuberculosis and leprosy, Buruli ulcer has received less attention than these diseases. It affects mainly poor rural folks predominantly children under 15 years who may acquire the disease by swimming or playing in infected (surface) water (Amofah et al, 1993; Marston et al, 2005). Due to its incapacitating complications, the disease poses socio-economic problems such as isolation or segregation of patients and families, stigmatization, dependency, depression, loss of self worth and fear, loss of man-hours and economic difficulties (Asiedu and Etuaful, 1998; Stienstra et al, 2002).

The disease has an apparent association with bodies of water, water-logged and marshy areas involved in environmental changes and disturbed soils worldwide. Duker et al. (2004) found significant spatial relationships among villages in Buruli ulcer affected areas and arsenic-enriched surface waters and adjacent farmlands. The mode of transmission is however not fully understood, as well as the mechanism of development through water-related human activities. A route of transmission has been proposed by Awuah and Owusu-Nimo (2005), whereby Arsenic may act as a catalyst for MU. This may involve the organism secreting enzymes which break down proteins in the skin, as is the case with schistosomiasis, thereby letting the organism get access to subcutaneous tissues.

This research seeks to investigate the relationship between concentrations of heavy metals in drinking water from boreholes and wells, specifically cadmium, lead, and aluminum, in endemic and non-endemic communities.

1.2 Problem Statement

The reasons for the spread of BU remain unclear. Its transmission is apparently associated with water bodies. Several risk factors have been identified and mechanisms of transmission suggested. Even though the causative organism (Mycobacterium ulcerans) has been identified, the exact mode of transmission is not fully understood.

1.3 Objectives

The main objective of this research is to investigate the link between Buruli Ulcer occurrence and heavy metal concentrations in drinking water.

The specific objectives are:

- Identify drinking water sources
- Identify and compare concentrations of heavy metals in drinking water in endemic and non-endemic communities
- Examine social behavior patterns

1.4 Justification

BU is not a localised disease, but occurs internationally. It is widespread in tropical and sub tropical areas in more than 30 countries in Africa, Asia, Latin America, Western pacific and Australia. Studies have shown that West Africa is worst affected. (Phillips et al, 2005) A lot of research is ongoing to determine the exact mode of transmission of Buruli Ulcer. The disease is apparently connected to slow moving water bodies and may be transmitted by fish and some aquatic insects (Duker et al, 2004; Eddyani et al, 2004; Portaels et al, 1999). Some research has also linked the occurrence of Buruli Ulcer to the presence of heavy metals such as arsenic in surface water. (Duker et al, 2004) Existence of the organism is said to be enhanced by disturbed soils. Boreholes inevitably disturb the soil, and drinking water from these boreholes is used, in addition to drinking, for other activities such as bathing, washing and cooking, ultimately getting the water in contact with the skin (Awuah and Owusu-Nimo, 2005).

This research will therefore help to ascertain whether a relationship exists between BU occurrence and heavy metals in drinking water by comparing metal concentrations in endemic and non-endemic areas, and contribute to the body of research on factors affecting transmission of BU.

2 LITERATURE REVIEW

2.1 Buruli Ulcer Disease

2.1.1 History

Buruli Ulcer goes by different names depending on the geographical location of its occurrence. The disease appears to have been first identified in 1897 by Sir Albert Cook, a British physician working in Kampala, Uganda. The causative organism, Mycobacterium ulcerans was first isolated by Professor Peter MacCallum and his colleagues in 1948 in Bairnsdale in Australia (Portaels et al, 1996). In southern Australia, the disease is still referred to as the Bairnsdale ulcer. The most widely used name, Buruli Ulcer, originates from Buruli County in Uganda, where many cases occurred in the 1960s (Barker, 1971; Clancey et al, 1961). Since 1980, the disease has emerged rapidly in several parts of the world, particularly in West Africa, prompting action by the World Health Organization (WHO) in 1998. The World Health Assembly (WHA) in 2004 adopted a resolution to improve the surveillance and control of BU and accelerate research to develop better tools for its control (http://www.who.int/mediacentre/factsheets/fs199/en/index.html).

2.1.2 Cause, Transmission and Epidemiology

Buruli Ulcer is a disease of the skin and subcutaneous tissues caused by Mycobacterium ulcerans, a bacterium of the same family of bacteria that cause tuberculosis and leprosy (Amofah et al. 2002; Phillips et al. 2005).

Mycobacterium ulcerans may be obtained from the environment (van der Werf et al, 1999). It has been found that Buruli ulcer frequently occurs near water bodies – slow flowing rivers, ponds, swamps and lakes. Cases have also occurred following flooding. Activities that take place near water bodies, such as farming, are risk factors. Wearing protective clothing appears to reduce the risk of the disease (Amofah et al, 1993; Marston et al, 1995). The exact mode of transmission is still under investigation. Research suggests that insects may be involved in the transmission of the disease (Portaels et al, 1999, Marsolliers et al, 2002). Swimming in a river or pond may also aid transmission (The Uganda Buruli Group 1971; Oluwasanmi et al., 1976; Aiga et al., 2004). Transmission may also be enhanced by residence near swampy and riverine areas (Asiedu and Etuaful, 1998) especially those enriched with arsenic (Duker et al, 2004). Small breaks or trauma in the skin may also increase susceptibility to the disease (Johnson et al, 1999; Portaels et al, 2001). Awuah and Owusu-Nimo (2005) proposed a route of transmission whereby arsenic may act as a catalyst, enabling the organism to secrete enzymes which break down the proteins in the skin, giving access to subcutaneous tissues.

The reasons for the growing spread of BU remain unclear. All ages and sexes are affected, but most patients are among children under 15 years who tend to swim or play in water bodies (Amofah et al, 1993). In general, there is no difference in the infection rate among males and females. The disease can affect any part of the body, but in about 90% of cases the lesions are on the limbs, with nearly 60% of all lesions on the lower limbs (WHO, 2000). Person to person transmission of the disease is rare. (Exner and Lemperle, 1987) There is little seasonal variation in the incidence of the disease (WHO, 2005).

2.1.3 Prevalence of Buruli Ulcer Disease

Prevalence and incidence are statistical measures of a disease's occurrence or frequency. Prevalence helps to determine a person's likelihood of having a disease. Therefore, the number of prevalent cases is the total number of cases of disease existing in a population, or the number of people who currently have the condition. A prevalence rate is the total number of cases of a disease existing in a population divided by the total population.

Incidence on the other hand, is the annual number of people who have a case of the condition, or the rate at which new cases occur in a population during a specified period.

Buruli ulcer has been reported from 30 countries in Africa, the Americas, Asia and the Western Pacific, mainly in tropical and subtropical regions. In La Côte d'Ivoire, approximately 24 000 cases have been recorded between 1978 and 2006. In Benin, nearly 7000 cases have been recorded between 1989 and 2006. Australia registered 25 cases in 2004, 47 in 2005 and 72 in 2006. Cases have also been reported from Cameroon, Congo, Gabon, Sudan, Togo, Uganda, Nigeria, China and Brazil. In Ghana more than 11 000 cases have been recorded since 1993. These numbers may only be an indication of the presence of the disease but do not reveal the magnitude of the problem. (WHO Factsheets, http://www.who.int/mediacentre/factsheets/fs199/en/ index.html).

According to the World Health Organization (2000), determining the exact prevalence and burden of the disease is made difficult due to:

- Insufficient knowledge of the disease among both health workers and the general public, leading to significant underreporting;
- People most affected by BU living in remote, rural areas with little contact with the health system;
- Variability in the clinical presentation of the disease leading to BU being mistaken for other tropical skin diseases and ulcers; and
- BU not being a notifiable disease in many countries.

For these and other reasons, it is difficult to establish the exact number of people affected by the disease and the size and location of all endemic areas. (WHO Factsheets, http://www.who.int/mediacentre/factsheets/fs199/en/index.html)

In 1998, the World Health Organization recognized Buruli ulcer (BU) as the third most prevalent mycobacterial disease. (WHO, Geneva 2000)

2.1.4 Signs and Symptoms

Buruli ulcer usually begins as a painless nodule or papule or oedema. If untreated, it may develop, into an ulcer leading to extensive destruction of the skin and sometimes the bones (See Plates 2.1 to 2.4).

Plate 2.1 Nodule

Plate 2.2 Papule

Plate 2.3 Oedema

Plate 2.4 Ulcer

It is treated in hospital with specific drugs and by surgery. Early diagnosis and treatment is important in preventing serious complications. If not properly treated, BU may turn into cancer. Late treatment results in deformities in the arms, legs, trunk, face and sometimes the eyes, leading to blindness. (See Plates 2.5 to 2.8) Amputation is necessary in some late and severe cases, and the disease sometimes results in death.

Plate 2.5 Deformation of Forelimb

Plate 2 6 Deformation of Hind Limb

Plate 2.7 Blindness

Plate 2.8 Amputation

2.1.5 Buruli Ulcer in Ghana

In Ghana, the first BU case was reported in 1971 from the Amansie West District, and between 1991 and 1997 more than 2000 cases were reported nationwide (Grosset et al, 2000). All ten regions and at least 90 of the 110 administrative districts have been affected (Amofah et al, 2002). The Ashanti Region is worst affected, with the Amansie West District having the highest number of cases. Buruli Ulcer is the second most prevalent mycobacterial disease after tuberculosis (Amofah et al. 2002). The disease has however not received as much attention as Tuberculosis. A national search for cases of Buruli ulcer in Ghana identified 5,619 patients, with 6,332 clinical lesions at various stages. The overall crude national prevalence rate of active lesions was 20.7 per 100,000, but the rate was 150.8 per 100,000 in the most disease-endemic district (Amofah et al, 2002). The national Buruli Ulcer Control Programme reported 1202 cases of Buruli Ulcer in 2005, from 20 districts mainly located in the Ashanti, Eastern and Greater Accra Regions. (WHO Country Office, Ghana, Annual Report, 2005). Duker et al (2004) identified significant spatial relationships between arsenic-enriched surface water and the occurrence of BU.

2.2 Heavy Metals

Heavy metals are trace metals with a density at least five times that of water. As such they are stable elements which cannot be metabolized by the body. They are also passed up the food chain to humans. They are often not eliminated from the human body, hence they tend to bio-accumulate. Some of them are necessary in minute quantities for the proper functioning of the body, but above a certain threshold level they become toxic (Guidelines for Drinking-Water Quality, 3rd edition, WHO). Others have no known biological function in the human body. They get into the body by inhalation, through food, drinking water, through the skin from several chemicals invented by technology. According to Järup (2003) the main threats to human health from heavy metals are associated with exposure to arsenic, mercury, lead, aluminum and cadmium.

Heavy metals can directly influence behavior by impairing mental and neurological function leading to effects on human health such as: energy loss, respiratory problems, skin problems, increased risk of liver, lung and skin cancer, osteoporosis, learning disabilities, cardiovascular disease, amongst others (Järup, 2003).

2.2.1 Effects of Arsenic

Arsenic is implicated in several types of skin diseases including skin cancers. This may be due to its immunosuppressive affects, which enhance susceptibility to infection. Duker et al (2004) carried out proximity analysis to determine spatial relationships between BU-affected areas and arsenic-enriched farmlands and arsenic-enriched drainage channels in the Amansie West District, and found that mean BU prevalence in settlements along arsenic-enriched drainages and within arsenic-enriched farmlands was greater than elsewhere. Furthermore, mean BU prevalence was found to be greater along arsenic-enriched drainages than within arsenic-enriched farmlands (Duker et al, 2004).

The average abundance of arsenic in the earth's crust is 1.8 parts per million (ppm); in soils it is 5.5 to 13ppm; in streams it is less than 2μg/L, and in groundwater it is generally less than 100μg/L. It occurs naturally in sulphide minerals such as pyrite. As is non-essential for plants, but is an essential trace element in several animal species. The predominant form between pH 3 and pH 7 is $H_2AsO_4^-$, between pH 7 and pH 11 it is $HAsO_4^{2-}$, and under reducing conditions it is $HAsO_2$ (aq) (or H_3AsO_3). Aqueous arsenic in the form of arsenite, arsenate, and organic arsenicals may result from mineral dissolution, industrial discharges, or the application of pesticides. The chemical form of arsenic depends on its source (inorganic arsenic from minerals, industrial discharges, and pesticides; organic arsenic from industrial discharges, pesticides, and biological action on inorganic arsenic). Severe poisoning can arise from the ingestion of as little as 100mg of arsenic trioxide; chronic effects may result from the accumulation of arsenic compounds in the body at low intake levels. Carcinogenic properties also have been imputed to arsenic compounds. The toxicity of arsenic depends on its chemical form. Arsenite is many times more toxic than arsenate. For the protection of aquatic life, the average concentration of As^{3+} in water should not exceed 72µg/L and the maximum should not exceed 140µg/L. The United Nations Food and Agriculture Organisation's recommended maximum level for irrigation waters is 100µg/L. The U.S. EPA primary drinking water standard MCL is 0.05mg/L. The electro-thermal atomic absorption method is the preferred choice in absence of overwhelming interferences. When interferences are present that cannot be overcome by standard electro-thermal techniques, then the Hydride generation AA method is preferred. When interferences are absent and when sample contains no methylarsenic compounds the Silver diethyldithiocarbamate method is used for total inorganic arsenic.

2.2.2 Effects of mercury

The average abundance of mercury in the earth's crust is 0.09ppm; in soils it is 30 to 160ppb; in streams it is 0.07µg/L, and in groundwater it is 0.5 to 1µg/L. Mercury occurs free in nature, but the chief source is cinnabar (HgS). The common aqueous species are Hg_2+, $Hg(OH)_2{}^0$, Hg^0, and stable complexes. Mercury will cause severe disruption of any tissue with which it comes into contact in sufficient concentration, but the two main effects of mercury poisoning are neurological and renal disturbances.

2.2.3 Effects of Cadmium

Cadmium is relatively rare and occurs with zinc ores and is used largely in batteries. The only important ore of cadmium is greenockite, or cadmium sulfide (CdS). Most cadmium is obtained as a by-product of zinc refinement. It is usually associated with zinc at a ratio of about 1 part cadmium to 500 parts zinc in most rocks and soils. The average abundance of cadmium in the earth's crust is 0.16ppm; in soils it is 0.1 to 0.5 ppm; in streams it is 1µg/L, and in ground waters it is from 1 to 10 µg/L. Cadmium is non-essential for plants and animals, and is extremely toxic in humans, accumulating in the kidneys and liver. Prolonged intake at low levels sometimes leads to dysfunction of the kidneys. The effects of extensive cadmium exposure is not known, but are thought to include heart and kidney disease, high blood pressure, and cancer. The UN Food and Agric Organization recommended maximum level for cadmium in irrigation waters is 10µg/L. The US EPA primary drinking water standard MCL is 10µg/L. The flame atomic absorption method was used in its determination.

2.2.4 Effects of lead

The average abundance of lead in the earth's crust is 13ppm; in soils it ranges from 2.6 to 25ppm; in streams it is 3µg/L, and in groundwater it is generally less than 0.1mg/L. The common aqueous species are Pb2+ and hydroxide and carbonate complexes. Lead may be found in the air from burning fuel or solid wastes and lead smelters. Lead in a water supply may come from industrial, mine, and smelter discharges into rivers or lakes, or from the dissolution of plumbing and plumbing features in pipe-borne water. Exposure to lead may be through ingestion of food or water contaminated with lead, soil contaminated with lead, or inhalation of dust or cigarette smoke. Lead is nonessential for plants and animals. It is toxic by ingestion and is a cumulative poison, targeting the nervous system. The known acute health effects include nausea, abdominal pain, vomiting, muscle weakness, excessive bleeding memory loss, impotence, brain and kidney damage, coma, convulsions and death. Flame AAS is the preferred method for analysis.

2.2.5 Effects of Aluminum

Aluminum is an abundant element in Earth's crust: it is believed to be contained in a percentage from 7.5% to 8.1%. Aluminum is very rare in its free form. High concentrations of aluminum may be found in acidified lakes and air, but also in the groundwater of acidified soils. Excess aluminum may cause gastroenteritis, kidney damage, liver dysfunction, loss of appetite, loss of balance, muscle pain, shortness of breath and weakness. No health-based guideline values have been developed yet.

2.3 Analysis of heavy metals

Samples for the analysis of heavy metals must undergo some form of pre-treatment and sometimes digestion. The method chosen for pre-treatment and/or analysis depends on the type of metal, expected concentrations and the fraction of the metal to be analysed. The required fraction, whether dissolved, suspended, total or acid-extractable, should be decided on before sampling takes place. This will in turn determine whether the sample is acidified with or without filtration and the type of digestion required.

According to the Standard Methods for the Examination of Water and Wastewater (Eaton et al, 2005), dissolved metals are those metals in an un-acidified sample that pass through a 0.45um membrane filter. Suspended metals are those metals in an un-acidified samples that are retained by a 0.45 um membrane filter. Total metals consist of the concentration of metals determined in an unfiltered sample after vigorous digestion, or the sum of the concentrations of metals in the dissolved and suspended fractions. Total metals are defined operationally by the digestion procedure. Acid-extractable metals are the concentration of metals in solution after treatment of an unfiltered sample with hot dilute mineral acid.

Preservation or pre-treatment of samples is done by acidifying to pH < 2 immediately after collection, and storing under ice. To determine either dissolved or suspended metals, the sample is filtered immediately after collection, before preserving with acid. This way, metal concentrations of several milligrams per litre are stable for up to 6 months (except mercury, for which the limit is 5 weeks). The samples must be stored in clean sample containers and away from contaminants which may alter the metal concentrations.

Analysis of metals may be done by colorimetric or instrumental methods. Colorimetric methods are applicable to specific metal determinations where interferences are known not to compromise method accuracy. Instrumental methods include: Atomic Absorption Spectroscopy (AAS) by flame, electro-thermal (furnace), hydride and cold vapour techniques; flame photometry; Inductively Coupled Plasma (ICP) Emission Spectrometry (ES) or Mass Spectrometry (MS); and Anodic Stripping Voltammetry. Below is a table showing the ranges of application of the different methods. (Adapted from Standard Methods for the Examination of Water and Wastewater)

Flame AAS methods are applicable at moderate concentrations (0.1 – 10mg/L) in clean and complex-matrix samples. Electro-thermal methods generally increase sensitivity if matrix problems do not interfere. ICP-ES techniques are applicable over a broad linear range and are especially sensitive for refractory elements. ICP-MS offers significantly increased sensitivity for some metals with concentrations as low as 0.01µg/L. Flame Photometry gives good results at higher concentrations for several Group I and II elements.

.3.1 Analysis of metals by Flame Atomic Absorption Spectrometry (AAS)

Principle

ı flame AAS the sample is aspirated into a flame and atomized. A light beam is directed ırough the flame, into a mono-chromator, and onto a detector that measures the amount f light absorbed by the atomized element in the flame. For some metals, atomic bsorption exhibits superior sensitivity over flame emission. Because each metal has its 'wn characteristic absorption wavelength, a source lamp composed of that element is sed; this makes the methods relatively free from spectral or radiation interferences. The mount of energy at the characteristic wavelength absorbed in the flame is proportional to ıe concentration of the element in the sample over a limited concentration range. The ptimum concentration ranges for the heavy metals tested for in this study are shown in 'able 2.1. Most atomic absorption instruments also are equipped for operation in an mission mode, which may provide better linearity for some elements.

'able 2.1 Atomic Absorption Concentration Ranges with Direct Aspiration Atomic Absorption

Element	Wavelength nm	Flame Gases*	Instrument Detection Level mg/L	Sensitivity mg/L	Optimum Concentration Range mg/L
Al	309.3	N – Ac	0.1	1	5 – 100
Cd	228.8	A – Ac	0.002	0.025	0.05 – 2
Pb	283.3 (217.0 recommended)	A – Ac	0.05	0.5	1 – 20

'A-Ac = air-acetylene; N-Ac = nitrous oxide-acetylene
ource: Standard Methods for the Examination of Water and Wastewater, 21st edition (2005)

3 STUDY AREA

3.1 Location

Amansie West is one of the 21 districts in the Ashanti Region located in the south-western part of the Region. It lies between latitudes 6.0°N and 6.75°N and longitudes 1°30'W and 2°15'W, covering an area of about 1,364 square kilometers. The district capital, Manso Nkwanta, is about 40 Km south of Kumasi (See Figure 3.1). It shares common boundary on its Western part with the Atwima District. It is bordered on the northern part by the Bosomtwe-Atwima Kwanwoma District, in the west by the Atwima District and in the east by the Amansie East District. A regional boundary separates it from Western Region on its southern part. The district has an area of 1,141 Km^2 and a population of 132,881 (2006, projected).

3.2 Topography and Drainage

The topography of the district is generally undulating with an elevation of 210m above sea level. The most prominent feature is the range of hills, which stretches across the north-western part of the district, especially around Manso-Nkwanta and Abore. These hills have an elevation of between 560m 630m. The district is drained in the north by the Offin and Oda rivers and their tributaries such as Jeni, Pumpin and Emuna.

3.3 Climate and Vegetation

Yearly rainfall varies from 1250 to 2000 mm and temperature from 22 to 30 °C. The district lies entirely in the forest belt with semi deciduous vegetation. It is very rich in forest resources, such as timber, herbs of medicinal value and fuel wood. It also abounds in different species of tropical hardwood, notably Odum, Mahogany and Sapale. There are

2.3.1 Analysis of metals by Flame Atomic Absorption Spectrometry (AAS)

Principle

In flame AAS the sample is aspirated into a flame and atomized. A light beam is directed through the flame, into a mono-chromator, and onto a detector that measures the amount of light absorbed by the atomized element in the flame. For some metals, atomic absorption exhibits superior sensitivity over flame emission. Because each metal has its own characteristic absorption wavelength, a source lamp composed of that element is used; this makes the methods relatively free from spectral or radiation interferences. The amount of energy at the characteristic wavelength absorbed in the flame is proportional to the concentration of the element in the sample over a limited concentration range. The optimum concentration ranges for the heavy metals tested for in this study are shown in Table 2.1. Most atomic absorption instruments also are equipped for operation in an emission mode, which may provide better linearity for some elements.

Table 2.1 Atomic Absorption Concentration Ranges with Direct Aspiration Atomic Absorption

Element	Wavelength nm	Flame Gases*	Instrument Detection Level mg/L	Sensitivity mg/L	Optimum Concentration Range mg/L
Al	309.3	N – Ac	0.1	1	5 – 100
Cd	228.8	A – Ac	0.002	0.025	0.05 – 2
Pb	283.3 (217.0 recommended)	A – Ac	0.05	0.5	1 – 20

*A-Ac = air-acetylene; N-Ac = nitrous oxide-acetylene
Source: Standard Methods for the Examination of Water and Wastewater, 21st edition (2005)

3 STUDY AREA

3.1 Location

Amansie West is one of the 21 districts in the Ashanti Region located in the south-western part of the Region. It lies between latitudes 6.0°N and 6.75°N and longitudes 1°30'W and 2°15'W, covering an area of about 1,364 square kilometers. The district capital, Manso Nkwanta, is about 40 Km south of Kumasi (See Figure 3.1). It shares common boundary on its Western part with the Atwima District. It is bordered on the northern part by the Bosomtwe-Atwima Kwanwoma District, in the west by the Atwima District and in the east by the Amansie East District. A regional boundary separates it from Western Region on its southern part. The district has an area of 1,141 Km^2 and a population of 132,881 (2006, projected).

3.2 Topography and Drainage

The topography of the district is generally undulating with an elevation of 210m above sea level. The most prominent feature is the range of hills, which stretches across the north-western part of the district, especially around Manso-Nkwanta and Abore. These hills have an elevation of between 560m 630m. The district is drained in the north by the Offin and Oda rivers and their tributaries such as Jeni, Pumpin and Emuna.

3.3 Climate and Vegetation

Yearly rainfall varies from 1250 to 2000 mm and temperature from 22 to 30 °C. The district lies entirely in the forest belt with semi deciduous vegetation. It is very rich in forest resources, such as timber, herbs of medicinal value and fuel wood. It also abounds in different species of tropical hardwood, notably Odum, Mahogany and Sapale. There are four main forest reserves in the district. These are: Oda River Forest Reserve, Apamprama Forest Reserve, Gyeni River Forest Reserve and Jimira Forest Reserve.

3.4 Geology

The area is underlain by rocks of the Lower Proterozoic Birimian and Tarkwaian series. These comprise minerals such as pyrite, arsenopyrite, chalcopyrite, sphalerite, galena, gold and secondary hematite. The major soil types in the district are ferric fluvisols.

The district is made up of about 310 settlements. The projected population for 2006 was 132,881 with a male: female ratio of 48%:52% and the average household size is 6. Of the adult population, 70% are engaged in farming of cocoa, citronella and food crops, 22% in both small-scale and illegal mining, and the rest in petty trading.

Diseases of public health importance are: Malaria, Tuberculosis, Diabetics, Hypertension, HIV/AIDS, and Buruli ulcer. In a national survey in 1999 conducted by Amofah et al (2002), the Amansie West District (study area) had the highest rate with a prevalence of 150.8 per 100,000. High incidence of BU occurs in settlements in close proximity to the Offin River.

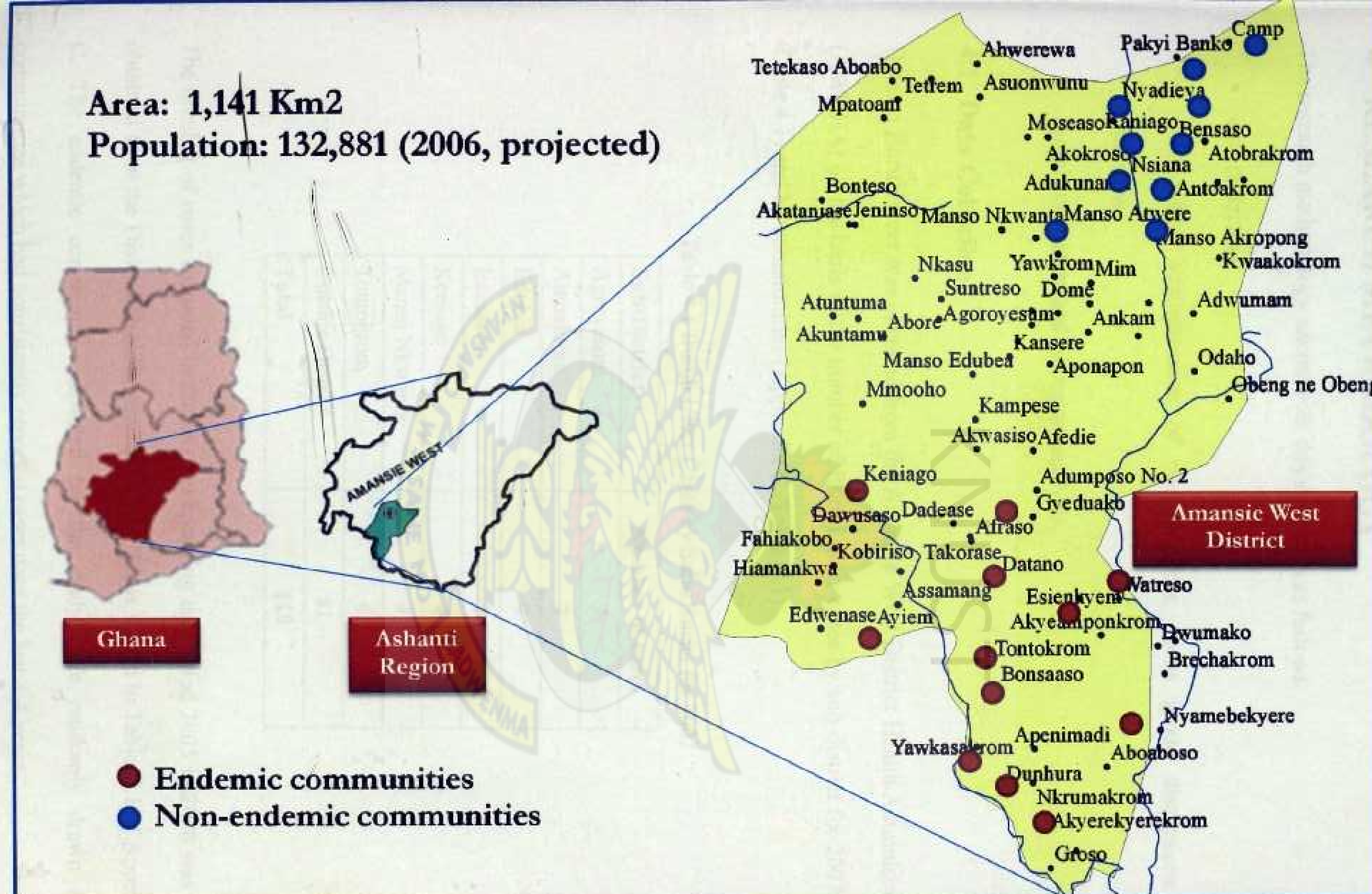

Figure 3.1 Map of Amansie West District

Source: Millennium Villages Project, Bonsaaso, 2006)

4 RESEARCH METHODOLOGY

The research methodology adopted for this study was as follows:

- data collection
- field visits, administration of questionnaires, focus group discussions and interviews
- sample collection and laboratory analysis.

4.1 Data Collection

Data on Buruli ulcer was obtained from the Amansie West District Health Administration (AWDHA) on the basis of the number of Buruli ulcer cases by sub-district for 2007 (see Table 4.1) and by communities (Appendix C, Table C.1).

Table 4.1 Buruli Ulcer Cases by Sub-District for 2007

Sub-District	Number of cases
Agroyesum	3
Antoakrom	2
Edubia	9
Essuowin	1
Keniago	4
Manso Nkwanta	4
Tontokrom	6
Outside District	81
Total	**110**

The number of cases recorded in the District spanning the period 2005 to 2008 was also obtained from the District Health Administration. This is shown in Table C.1 of Appendix C. The endemic communities selected for the study were randomly drawn from communities which had consistently reported cases over the last 3-4 years.

4.2 Field Visits, Surveys, Focus Group Discussions and Structured Interviews

A reconnaissance survey and transect walk were carried out in the communities selected for the study. The functioning water sources and activities carried out in the communities were observed during the transect walk.

In each of the communities visited ten questionnaires were administered. A total of 220 questionnaires were administered in the 12 endemic and 10 non-endemic communities. A sample of the questionnaire is found in Appendix D. Structured interviews and focus group discussions were also carried out. The aim was to assess community understanding of the disease, sources and treatment of drinking water, and activities carried out close to drinking water sources. Four focus group discussions were conducted. One involved the chief and elders of Bonsaaso, another involved some women in the community at Tontokrom. The third and fourth focus group discussions involved the community members at Manso Atwere and Asarekrom respectively. Those interviewed in the communities included the chief of Bonsaaso and some elders, the Assembly man, Unit Committee chairman or members, the health extension workers, and in some cases the agriculture extension officer.

4.3 Sample Collection and Analysis

For each of the communities selected for the research, all the functioning water points identified were sampled. A total of 66 water points in 22 communities were sampled using 0.5 litre acid-rinsed plastic containers. The temperature, potential of Hydrogen (pH) and conductivity of the samples were measured after collection. Each sample was filtered using 0.45 um cellulose filters to remove suspended solids. They were then acidified with 1.5 ml of concentrated nitric acid and stored under ice.

Heavy metal analysis was carried out by Flame Atomic Absorption Spectroscopy using a Perkin Elmer AAnalyst 200 setup at the International Institute for Water and Environmental Engineering, Ouagadougou, Burkina Faso. The metals tested for are Cadmium, Lead, and Aluminum. The concentrations present in endemic areas were compared with those in non-endemic areas.

5 RESULTS AND DISCUSSION

5.1 Results

5.1.1 Sources of drinking water

The communities selected for the study were 22 in number, 12 of which were endemic for Buruli Ulcer (Table 5.1). Observations made during the reconnaissance survey and field visits show that the sources of drinking water in the endemic communities are boreholes, streams and hand-dug wells (Table 5.1). Most of the communities had at least one borehole, whilst a few others had a hand-dug well or stream in addition. In the non-endemic communities, boreholes and pipe-borne water were the only sources of drinking water.

Table 5.1 Communities in AWD selected for the study and their water sources

Endemic Communities	Bore-hole	Stream	Hand-Dug Well	Non-Endemic Communities	Bore-hole	Pipe-Borne Water
Keniago	8	1	-	Bensaaso	1	
Ayiem	1	-	-	Besease	1	
Essienkyem	5	-	-	Mpranease	2	
Datano	6	2	-	Nanhin	3	
Watreso	3	1	-	Nyadieya	2	
Akyerekyerekrom	4	-	-	Asarekrom	3	
Dunhura	2	-	2	Nsiana	4	
Yawkasakrom	2	-	2	Antoakrom	3	
Bonsaso	2	2	-	Akropong	2	
Tontokrom	3	1	-	Manso Atwere	1	1
Afraso	3	-	-	**Total**	**22**	**1**
Adagya No. 1	2	-	-			
Total	**41**	**7**	**4**			

5.1.2 Physical parameters

The drinking water sources in both endemic and non endemic communities were acidic with a pH range of 4.8 to 6.4 with no significant difference in values. Conductivity measurements showed low dissolved solids with values ranging from 117 to 319 µS. Temperature values were all in the mesophillic range 27.6 to 29.8 °C. (Tables 5.2 and 5.3).

Table 5.2 Summary of Field Measurements for Endemic Communities

	Community	pH	Conductivity (µS)	Temperature (°C)	TDS (ppm)
1	Keniago	5.7	162	29.8	80.9
2	Ayiem	5.1	151	27.6	75.2
3	Esienkyem	5.0	319	29.9	159.0
4	Datano	5.2	154	28.1	77.1
5	Watreso	5.9	172	27.5	85.9
6	Akyerekyerekrom	5.8	237	27.6	118.5
7	Dunhura	4.9	276	27.7	138.5
8	Yawkasakrom	6.2	185	27.5	92.2
9	Bonsaaso	6.4	279	28.1	139.2
10	Tontokrom	5.8	145	27.8	72.3
11	Afraso	5.6	117	27.9	58.6
12	Adagya No. 1	5.9	171	27.6	85.7

Table 5.3 Summary of Field Measurements for Non-Endemic Communities

	Community	pH	Conductivity (µS)	Temperature (°C)	TDS (ppm)
1	Bensaaso	6.3	244	27.7	122.0
2	Besease	5.8	134	27.7	67.1
3	Mpranease	4.8	314	27.8	157.4
4	Nanhin	6.2	243	27.7	121.7
5	Nyadieya	6.3	326	27.7	162.0
6	Asarekrom	6.2	276	27.8	137.7
7	Nsiana	5.6	161	27.8	80.5
8	Antoakrom	5.7	232	27.7	116.1
9	Akropong	6.2	264	27.9	131.5
10	M. Atwere	6.4	334	27.7	153.0

The field measurements are summarized in table 5.4.

Table 5.4 Summary of Field Measurements

Value	pH		Conductivity (µS)		Temperature (^oC)		TDS (ppm)	
	E	N-E	E	N-E	E	N-E	E	N-E
Minimum	4.89	4.82	117.30	134.3	27.53	27.7	58.63	67.1
Maximum	6.41	6.43	318.76	334.0	29.94	27.9	158.98	162.0
Average	5.63	5.94	197.28	252.8	28.09	27.7	98.60	124.9

TDS= Total Dissolved Solids

E=Endemic communities

N-E=Non-endemic communities

5.1.3 Heavy metal concentrations

In the endemic communities, the concentrations ranged from 0.7 to 2.3 µg/L for cadmium, 0 to 33.7 µg/L for lead and 0 to 1.3 µg/L for aluminum. The concentrations in the non-endemic communities ranged from 0 to 2.5 µg/L for cadmium, 0 to 35.5 µg/L for lead and 0 to 1. 5 µg/L for aluminum (Tables 5.5 and 5.6).

Table 5.5 Summary of Heavy Metal Concentrations for Endemic Communities

Community	Water Point code	Concentration (µg/L)					
		Cd	SD	Pb	SD	Al	SD
Keniago	Kg	1.8	1.1	0.0	11.4	0.3	1.0
Ayiem	Ay1	1.0	1.6	0.0	9.0	0.0	0.1
Essienkyem	Es	2.0	1.3	1.2	7.7	0.4	0.7
Datano	Dt	1.0	1.2	19.3	15.2	0.3	1.4
Watreso	Wt	2.3	2.0	14.0	11.5	0.0	0.1
Akyerekyerekrom	Ak	1.2	1.2	24.0	9.1	0.8	1.1
Dunhura	Dh	1.5	0.6	0.0	10.6	0.5	0.2
Yawkasakrom	Y	1.7	1.1	33.7	5.7	0.3	1.0
Bonsaaso	Bn	1.7	1.9	0.0	9.0	1.3	0.1
Tontokrom	Tk	2.3	1.2	10.7	7.6	0.3	0.4
Afraso	Af	0.7	1.9	9.3	11.3	0.0	0.5
Adagya No. 1	Ad	1.5	1.5	25.0	0.5	0.0	1.5

SD = Standard Deviation

Table 5.6 Summary of Heavy Metal Concentrations for Non-Endemic Communities

Community	Water Point code	Concentration (μg/L)					
		Cd	SD	Pb	SD	Al	SD
Bensaaso	Bn1	0.0	1.4	19.0	14.2	0.0	0.2
Besease	Bs1	1.0	0.9	0.0	13.1	1.0	0.1
Mpranease	Mp	0.0	1.2	16.5	9.2	1.5	0.2
Nanhin	Nh	1.7	1.4	4.3	13.4	0.0	0.3
Nyadieya	Nd	0.5	1.0	35.5	3.8	0.5	3.1
Asarekrom	Ar	0.3	1.0	14.0	9.2	0.7	1.4
Nsiana	Ns	2.5	1.3	8.8	10.7	0.5	0.1
Antoakrom	An	2.0	1.5	0.7	26.9	0.0	0.1
Akropong	Ag	1.0	0.9	16.5	17.3	0.5	0.2
M. Atwere	MA	0	0.8	2	1.1	0.9	0.1

SD = Standard Deviation

When comparisons of concentrations of heavy metals were made in the Endemic and non-endemic Buruli ulcer communities, it was realized that the concentrations of cadmium were significantly higher ($p \leq 0.05$) in buruli ulcer communities than non buruli ulcer communities although the levels were below the WHO recommended values of 3 μg/L (Figures 5.1 and 5.4).

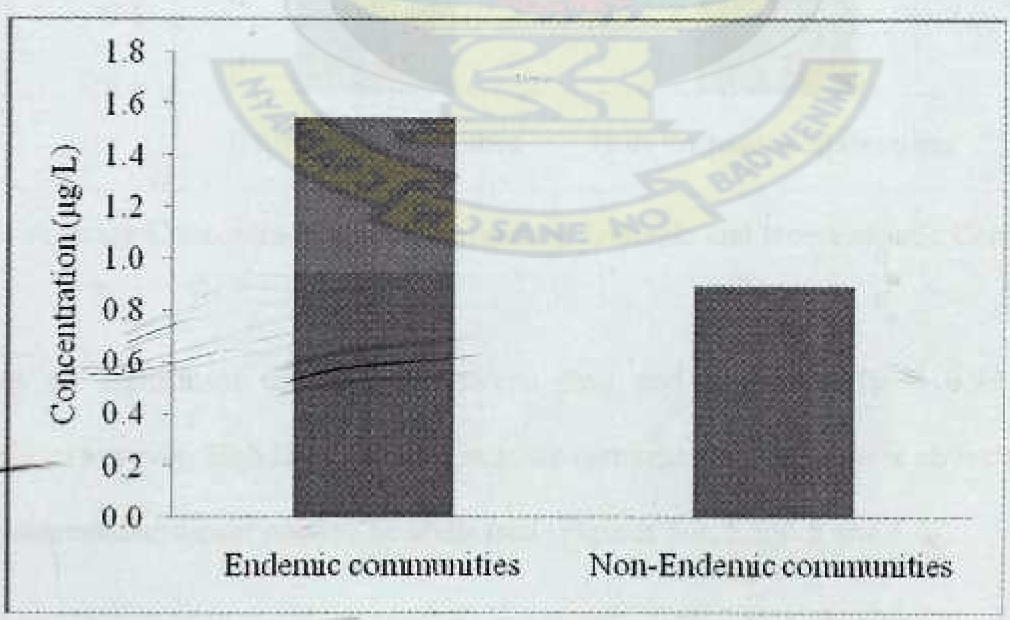

Figure 5.1 Average Concentrations of Cadmium in Endemic and Non-endemic Communities

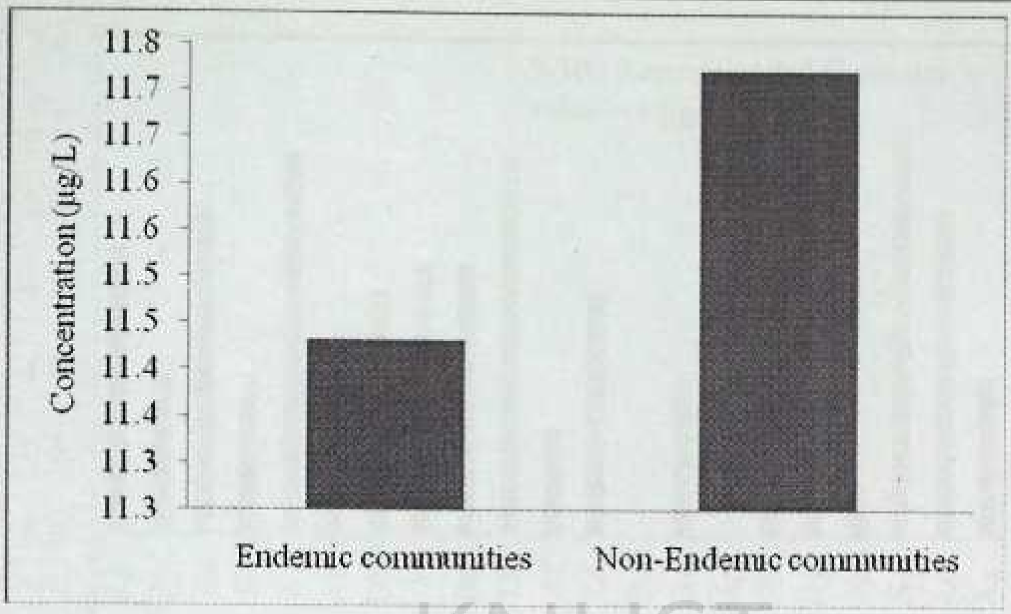

Figure 5.2 Average Concentrations of Lead in Endemic and Non-endemic Communities

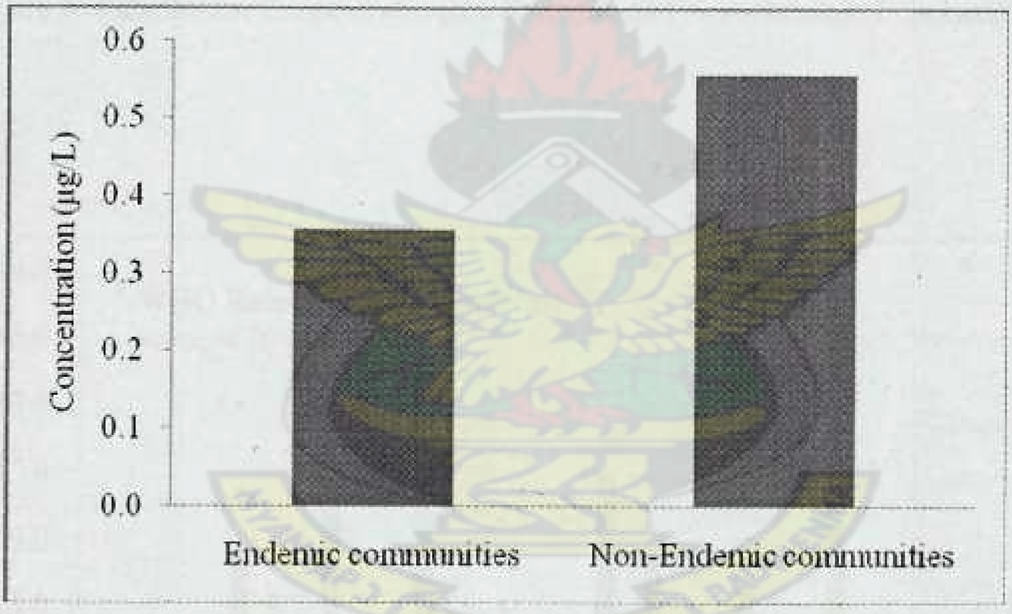

Figure 5.3 Average Concentrations of Aluminum in Endemic and Non-endemic Communities

There was no significant differences between lead and aluminum ($p = 0.95$ and 0.3 respectively). However, high levels of lead in some communities which were above the WHO (2006) recommended values need to be addressed (Figures 5.2, 5.3, 5.5 and 5.6).

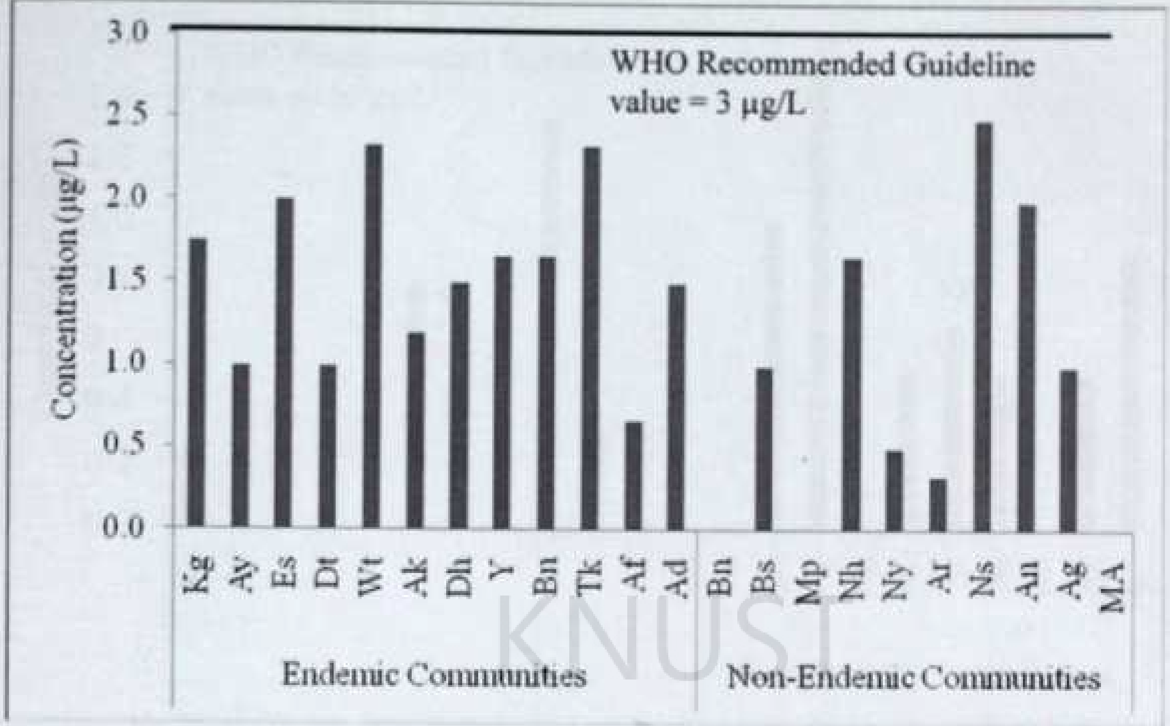

Figure 5. 4 Cadmium Concentrations in Endemic and Non-endemic Communities

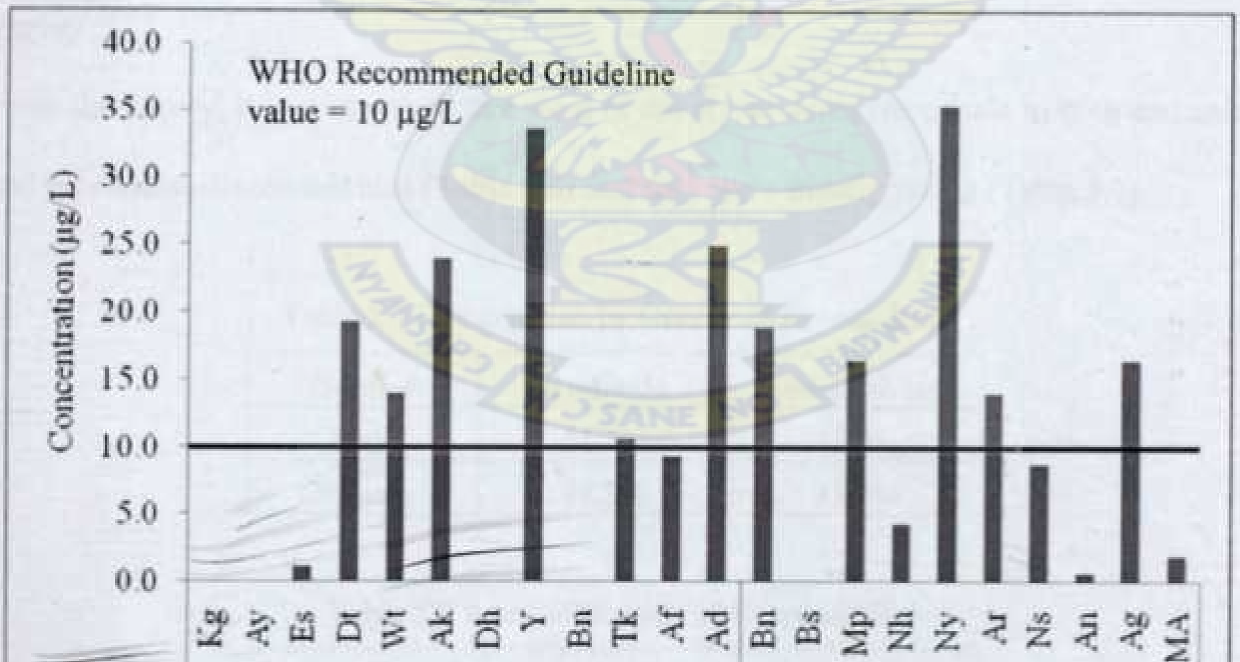

Figure 5.5 Lead Concentrations in Endemic and Non-endemic Communities

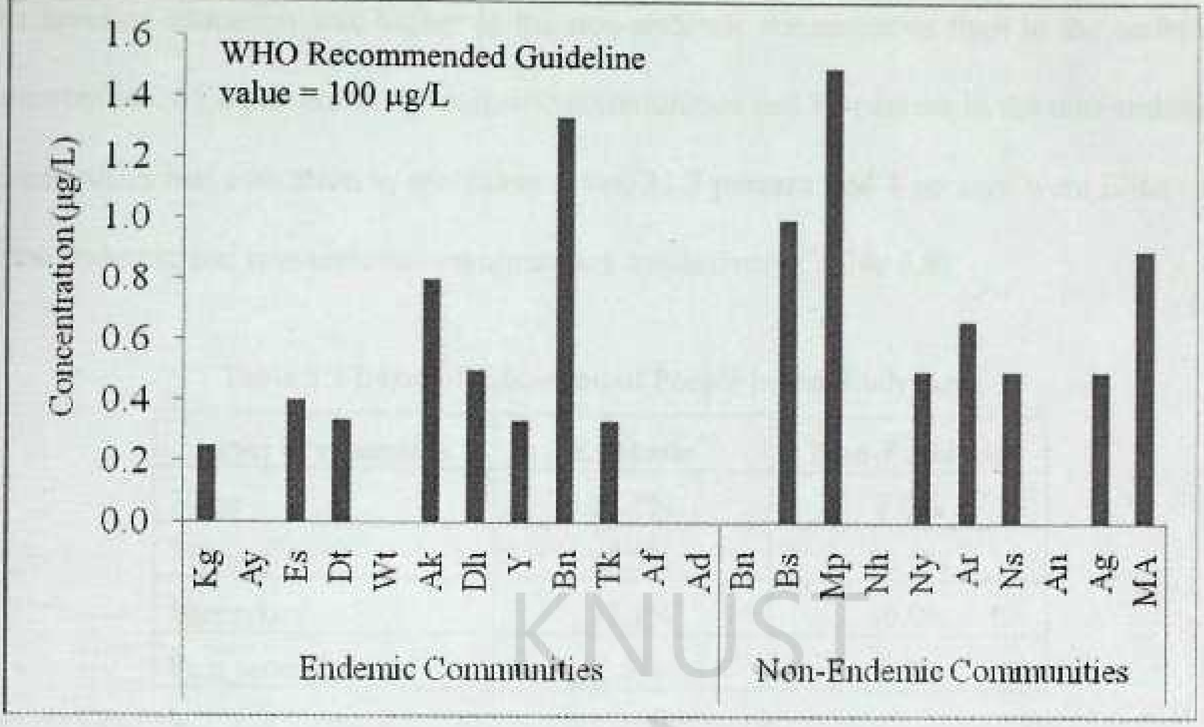

Figure 5.6 Aluminum Concentrations in Endemic and Non-endemic Communities

5.1.4 Social characteristics and focus group discussion

Survey

From the survey, it was observed that most of the respondents were male in both endemic and non endemic communities (Table 5.6) and they were mostly young (Table 5.7).

Table 5.7 Composition by Gender of Respondents

Gender	Endemic	Non-Endemic
Male	51.7%	55.0%
Female	48.3%	45.0%

Table 5.8 Age Distribution of Respondents

Age	Endemic	Non-Endemic
Below 10	0.0%	0.0%
10 to 20	14.2%	12.0%
20 to 40	55.8%	55.0%
Above 40	30.0%	33.0%

The level of education was higher in the non-endemic communities than in the endemic communities. 65.8 percent in the endemic communities and 88 percent in the non-endemic communities had education to secondary level. 31.7 percent and 4 percent were illiterates in the endemic and non-endemic communities respectively (Table 5.8).

Table 5.9 Level of Education of People in the Study Area

Level of education	Endemic	Non-Endemic
None	31.7%	4.0%
Primary	52.5%	58.0%
Secondary	13.3%	30.0%
Post secondary	2.5%	8.0%

Both communities were mostly Akan and Christians (Tables 5.9 and 5.10 respectively). It was also observed that a large proportion of the respondents in both endemic and non-endemic communities were farmers (Table 5.11). Some people in the endemic areas engage in illegal mining ('Galamsey').

Table 5.10 Ethnicity of People in the Study Area

Ethnicity	Endemic	Non-Endemic
Akan	88.3%	88.0%
Ga	2.5%	3.0%
Ewe	6.7%	4.0%
Dagbani	2.5%	5.0%

Table 5.11 Religion of People in the Study Area

Religion	Endemic	Non-Endemic
Christian	85.8%	81.0%
Muslim	10.0%	17.0%
Traditionalist	4.2%	2.0%

Table 5.12 Occupation of People in the Study Area

Occupation	Endemic	Non-Endemic
Farming	90.0%	95.4%
Petty trading	6.4%	4.6%
Illegal Mining	3.6%	0.0%

Field observation and focus group discussions

It was observed that most of the people in the buruli ulcer communities walk bare footed. The non-buruli ulcer community members had footwear. Focus group discussions with community members showed that they were aware of the disease and believed that it was obtained through the drinking of stream water. They also believed that illegal mining or 'Galamsey' and private mining companies' activities might have introduced the disease since the disease was observed after their activities had polluted their surface waters. It was also identified that community members take water from the boreholes to their farms. They however had to resort to stream water when their supplies ran out whilst still in the farm.

Dependence on Sources of Drinking Water in the Study Area

The endemic communities used poorer source of water which include streams and hand-dug wells, unlike non-endemic communities which used better sources of water namely boreholes and pipe-borne water only. (Figure 5.7). In some of the endemic communities, especially Bonsaaso, Edwenase and Yawkasakrom, high concentrations of iron and manganese was evidenced by the reddish colour of water from the boreholes, stained concrete surfaces at the water points and previous analysis by the Millennium Villages Project.

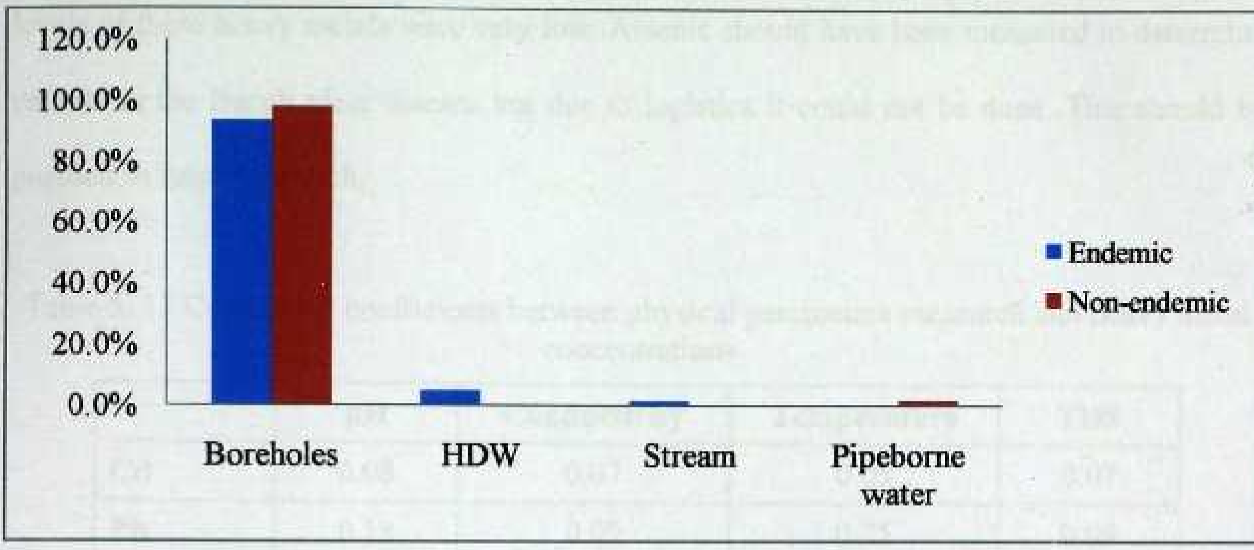

Figure 5.7 Dependency on Sources of Drinking Water in the Study Area

Mwacafe Filters have been installed for the removal of iron and manganese where the concentrations were extremely high (Bonsaaso and Yawkasakrom). In all the other communities however, borehole and well water are not treated before use.

5.2 Discussion

5.2.1 Sources of drinking water

The non-endemic communities generally have better sources of drinking water (boreholes and pipe-borne water) as compared to the endemic communities (boreholes, hand-dug wells and streams).

5.2.2 Physical parameters

There seems to be little or no correlation between the physical parameters measured and the TDS and heavy metal concentrations (Table 5.5). Even though the drinking water samples analyzed were acidic there was also no correlation between heavy metal concentrations and TDS. The low levels of pH are caused by the presence of arsenopyrites (Duker et al, 2004). Such rocks are also low in cadmium and aluminum and even though the water is acidic the levels of these heavy metals were very low. Arsenic should have been measured to determine its role in the Buruli ulcer disease but due to logistics it could not be done. This should be pursued in future research.

Table 5. 13 Correlation coefficients between physical parameters measured and heavy metal concentrations

	pH	Conductivity	Temperature	TDS
Cd	0.08	0.07	0.05	0.07
Pb	0.18	0.09	0.25	0.09
Al	0.11	0.44	0.01	0.44

5.2.3 Heavy metal concentrations

These low concentrations of cadmium in all the communities show that this heavy metal may not play a significant role in the transmission of Buruli ulcer disease. Similarly, the presence of lead and aluminum may also not play any role because of lack of significant differences between the buruli ulcer endemic and non endemic communities. Instead it could due to arsenic. Literature (Duker et al, 2004) seems to have some correlation of arsenic and buruli ulcer and more studies should be done on arsenic levels. High lead levels identified in the communities should be looked at seriously to identify the source of contamination. This is because high concentrations of lead may lead to memory loss, impotence, brain and kidney damage.

5.2.4 Social characteristics and focus group discussions

Social behaviour has played a major role in the transmission of several diseases in the world. This include water use patterns (Water washed disease such eczema and yaws), walking bare footed (*Ascaris*, helminthiasis,) wading and bathing in infested waters (schistosomiasis) and water borne by drinking water that is contaminated (cholera, guinea worm and others). The endemic communities because of their educational background use good water to avoid water borne disease. This was deduced from focus group discussions. In addition, they had footwear and this would prevent diseases that enter the body directly through poor sanitation. They also avoided swimming and wading in streams. These non endemic communities have protected themselves from most of the possible routes of tropical parasitic diseases. Unlike the endemic communities which have availed themselves to all forms of transmission. This attitudinal behaviour could be a major risk factor in the transmission of the disease. It must be noted here that several diseases could synergistically enhance the morbidity of the buruli ulcer disease. No research work has been done in relation to this and could be an interesting area for investigation. "Galamsey" activities cause the soil disturbance which may release the bacteria which causes buruli ulcer. Thus the observation from the focus group discussion is a confirmation that mining activities could play a role in the proliferation of the disease.

6 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Based on the outcome of the results, the following conclusions were drawn:

Cadmium, Lead and Aluminum may not contribute to the occurrence and transmission of BU. That BU is prevalent in endemic areas may be due to social characteristics such as walking barefoot, wading through surface water, poor education and using poor sources of water for drinking and domestic purposes.

Recommendations

The following recommendations are made:

- The bacterium could be present in either the waters and/or soils around. An avenue for further research would be to determine the abundance of the bacterium in the environment of endemic communities and to identify the source.
- Further research should be done to study the behaviour of the bacterium in Arsenic environments.
- It is also recommended that the people in the study area be educated in order to raise awareness of the identified risk factors such as walking barefooted, and also improve upon their social behaviour.

REFERENCES

Aiga, H., Amano, T., Cairncross, S., Adomako, J., Nanas, O. K., and Coleman, S., (2004): Assessing water-related risk factors for Buruli ulcer: a case-control study in Ghana. American Journal of Tropical Medicine and Hygiene 71, 387–392.

Amofah, G., Bonsu, F., Tetteh, C., Okrah, J., Asamoa, K., Asiedu, K., and Addy, J. (2002): Buruli Ulcer in Ghana: Results of a National Case Search.

Amofah, G. K., Sagoe-Moses, C., Adjei-Acquah, C., and Frimpong, E. H., (1993): Epidemiology of Buruli ulcer in Amansie West district, Ghana. Transactions of the Royal Society of Tropical Medicine and Hygiene 87, 644–645.

Asiedu, K., Etuaful, S., (1998): Socioeconomic Implications of Buruli Ulcer in Ghana: A Three-year Review. American Journal of Tropical Medicine and Hygiene, 59: 1015–1022.

Barker, D. J., (1971): Buruli disease in a district of Uganda. Journal of Tropical Medicine and Hygiene; 74:260-4.

CDC: Emerging Infectious Diseases, Vol. 8, No. 2 [Http://www.cdc.gov/ncidod/eid/vol8no2/01-0119.htm]. Accessed (6/11/2008).

Clancey, J. K., Dodge, O. G., Lunn, H. F., Oduori, M. L., (1961): Mycobacterial skin ulcers in Uganda. Lancet; ii: 951-4.

Duker, A. A., Carranza, E. J. M., and Hale, M. (2005): Spatial relationship between arsenic in drinking water and Mycobacterium ulcerans infection in the Amansie West district, Ghana. Mineralogical Magazine, October 2005, Vol. 69(5), pp. 707 - 717.

Duker, A. A., Portaels, F., and Hale, M. (2005): Pathways of Mycobacterium ulcerans infection: A review.

Duker, A., Carranza, E., and Hale, M., (2004): Spatial dependency of Buruli ulcer prevalence on arsenic-enriched domains in Amansie West District, Ghana: implications for arsenic mediation in Mycobacterium ulcerans infection. International Journal of Health Geographics 3, 19.

Eddyani M., Ofori-Adjei D., Teugels G., De Weirdt D., Boakye D., Meyers W. M., and Portaels F., (2004): Potential Role for Fish in Transmission of Mycobacterium ulcerans Disease (Buruli Ulcer): an Environmental Study. Applied and Environmental Microbiology, Sept. 2004, p. 5679–5681

Exner, K., and Lemperle, G., (1987): Buruli ulcer–necrotizing infection of the hand of a plastic surgeon. Handchir Mikrochir Plast Chir, 19: 230–232.

Eaton, A. D., Clesceri, L. S., Rice, E. W., and Greenberg, A. E., (2005) Standard Methods for the Examination of Water and Wastewater, 21st edition. American Public Health Association (APHA), American Water Works Association (AWWA), Water Environment Federation (WEF).

Järup, L. (2003): Hazards of Heavy Metal Contamination. British Medical Bulletin 68:167-182 (2003)

Johnson, P. D., Stinear, T. P., and Hayman, J. A., (1999): Mycobacterium ulcerans – a mini-review. Journal of Medical Microbiology 48, 511–513.

Marsolliers, L., Robert, R., Aubry, J., Saint Andre, J. P., Kouakou, H., Legras, P., Manceau, A., Mahaza, C., and Carbonnelle, B., (2002): Aquatic insects as a vector for Mycobacterium ulcerans. Applied Environmental Microbiology 2002, 68(9):4623-4628.

Marston, B. J., Diallo, M. O., Horsburgh, C. R., et al. (1995): Emergence of Buruli ulcer disease in the Daloa region of La Côte d'Ivoire. American Journal of Tropical Medicine and Hygiene 52, 219–224.

Oluwasanmi, J. O., Solankee, T. F., Olurin, E. O., Itayemi, S. O., Alabi, G. O., and Lucas, A. O., (1976): Mycobacterium ulcerans (Buruli) skin ulceration in Nigeria. American Journal of Tropical Medicine and Hygiene 25, 122–128.

Phillips, Rl, Horsfield, C., Kuijper, S., et al. (2005) Sensitivity of PCR Targeting the IS2404 Insertion Sequence of Mycobacterium ulcerans in an assay using punch biopsy specimens for diagnosis of Buruli ulcer. Journal of Clinical Microbiology 43, 3650–3656.

Portaels, F., Chemlal, K., Elsen, P. et al. (2001): Mycobacterium ulcerans in wild animals. Revue Scientifique et Technique 20, 252–264.

Portaels, F., Elsen, P., Guimaraes-Peres, A., Fonteyne, P-A., and Meyers, W. M., (1999): Insects in the transmission of Mycobacterium ulcerans infection (Buruli ulcer). Lancet, 353:986.

Portaels, F., Fonteyne P-A., De Beenhouwer, H., De Rijk, P., Guedenon, A., Hayman, J., and Meyers, W. M., (1996): Variability in 3` end of rRNA sequence of Mycobacterium ulcerans is related to geographical origin of islolates. J Clinical Microbiology, 34:962-965.

Stienstra, Y., van der Graaf, W. T. A., Asamoa, K., and van der Werf, T. S., (2002): Beliefs and Attitudes toward Buruli Ulcer in Ghana. American Journal of Tropical Medicine and Hygiene, 67(2), 2002, pp. 207–213.

The Uganda Buruli Group (1971): Epidemiology of Mycobacterium ulcerans infection (Buruli ulcer) at Kinyara, Uganda.

WHO Country Office, Ghana, Annual Report, 2005

World Health Organization (2005): Buruli ulcer disease-(Mycobacterium ulcerans infection). Fact sheet No.199. World Health Organization.

World Health Organization (2000): Buruli ulcer-Mycobacterium ulcerans infection. Geneva: World Health Organization. WHO/CDS/CPE/GBUI/2000.1. 118 p.

World Health Organisation (WHO): BURULI ULCER: Mycobacterium ulcerans infection Edited by: Asiedu, K., Scerppbier, R., and Raviglione, M. WHO/CDS/CPE/GBUI/I.WHO, Geneva; 2000.

APPENDICES

APPENDIX A

Table A. 1 Results of Field Measurements and Laboratory Analysis in Endemic Communities

Community	Water Point code	Physical Parameters				Cadmium		Lead		Aluminum	
		pH	Conductivity (µS)	Temperature (°C)	TDS (ppm)	Concentration (µg/L)	SD	Concentration (µg/L)	SD	Concentration (µg/L)	SD
1	2	3	4	5	6	7	8	9	10	11	12
Keniago	Kg1	5.6	169	29.5	84.5	3	0.7	0	0	1	0.7
	Kg2	5.8	233	29.9	116	1	2.1	0	13.3	0	2.1
	Kg3	6.1	185	29.5	92.4	0	1.6	0	13.9	0	0.1
	Kg4	6.1	182	30.1	90.8	2	1.3	0	19.9	0	2
	Kg5	5.8	93	29.6	46.1	3	0.8	0	16.3	0	0.2
	Kg6	5.8	113	30.1	56.7	3	2	0	13.9	0	1.7
	Kg7	4.8	170	29.9	85	2	0	0	3.8	1	0.3
	Kg8	6.0	152	29.4	75.7	0	0.3	0	10.4	0	0.8
Ayiem	Ay1	5.1	151	27.6	75.2	1	1.6	0	9	0	0.1
Essienkyem	Es1	6.2	302	29.7	150	3	0.8	6	10.5	0	0.2
	Es2	6.2	262	30	131	4	0.8	0	7.2	2	0.9
	Es3	4.6	160	29.7	79.9	0	0.4	0	14.3	0	0.3
	Es4	4.7	289	30.2	144	1	2.1	0	0	0	0.1
	Es5	3.3	581	30.1	290	2	2.4	0	6.3	0	2
Datano	Dt1	5.0	114	28	56.8	0	1.1	36	14.8	1	1.5

1	2	3	4	5	6	7	8	9	10	11	12
	Dt2	3.5	172	28	85.9	0	0.6	5	1.5	0	1.7
	Dt3	4.7	37	28.1	18.3	2	1.2	0	20.5	0	1.1
	Dt4	5.5	160	28.1	79.9	2	1.1	13	14.3	0	1.3
	Dt5	6.2	249	28.1	124	1	1	37	22.5	1	0.7
	Dt6	6.2	196	28	97.8	1	2.1	25	17.3	0	2.1
Watreso	Wt1	5.4	167	27.5	83.6	1	0.4	0	7.5	0	0.2
	Wt2	6.2	194	27.6	96.7	5	4	36	12.3	0	0.1
	Wt3	6.1	155	27.5	77.5	1	1.7	6	14.6	0	0.1
Akyerekyerekrom	Ak1	6.7	357	27.5	178	2	0.4	27	3.9	2	2
	Ak1'	6.4	313	27.8	157	2	0.9	16	15.2	0	0.4
	Ak2	6.3	259	27.4	130	2	1.1	21	10.8	0	1.4
	Ak3	5.7	149	27.7	74.6	0	1.1	31	11.4	1	0.2
	Ak4	3.8	106	27.8	53	0	2.3	25	4.4	1	1.7
Dunhura	Dh1	6.0	263	27.6	132	2	1	0	12.4	0	0.2
	Dh2	3.8	289	27.8	145	1	0.2	0	8.8	1	0.2
Yawkasakrom	Y1	6.6	229	27.5	114	1	1.5	30	1	0	0.3
	Y1'	6.2	175	27.5	87	2	0.6	46	8	0	0.8
	Y2	6.0	151	27.6	75.6	2	1.2	25	8.1	1	1.8
Bonsaaso	Bn1	6.5	257	28	128	2	2.2	0	4.6	0	0.1
	Bn1'	6.2	177	28.2	88.5	2	1.7	0	7.5	4	0.1
	Bn2	6.6	402	28.1	201	1	1.8	0	14.8	0	0.2
Tontokrom	Tk1	5.4	61	27.8	30.5	6	0.8	32	4.8	0	0.9
	Tk2	6.1	188	27.7	94.1	0	1.2	0	10.9	1	0.3

1	2	3	4	5	6	7	8	9	10	11	12
	Tk3	6.0	185	27.9	92.4	1	1.5	0	7.2	0	0.1
Afraso	Af1	5.8	144	27.9	72	1	1.5	15	18.7	0	0.4
	Af2	5.6	83	27.9	41.3	0	1.9	0	11.4	0	0.8
	Af3	5.4	125	28	62.6	1	2.2	13	3.7	0	0.2
Adagya No. 1	Ad1	6.3	254	27.6	127	1	2.1	17	0	0	2.1
	Ad2	5.6	89	27.5	44.4	2	0.8	33	0.9	0	0.8

Table A.2 Results of Field Measurements and Laboratory Analysis in Non-Endemic Communities

Community	Water Point code	Physical Parameters				Cadmium		Lead		Aluminum	
		pH	Conductivity (µS)	Temperature (°C)	TDS (ppm)	Concentration (µg/L)	SD	Concentration (µg/L)	SD	Concentration (µg/L)	SD
1	2	3	4	5	6	7	8	9	10	11	12
Bensaaso	Bn1	6.3	244	27.7	122	0	1.4	19	14.2	0	0.2
Besease	Bs1	5.8	1334	27.7	67.1	1	0.9	0	13.1	1	0.1
Mpranease	Mp1	3.7	455	27.7	228	0	1.1	8	15.5	2	0.1
	Mp2	5.9	174	27.8	86.8	0	1.3	25	2.9	1	0.3
Nanhin	Nh1	6.1	198	27.7	99.1	1	0.4	0	13.8	0	0.1
	Nh2	6.3	291	27.8	146	2	1.3	0	15.6	0	0.1
	Nh3	6.2	241	27.7	120	2	2.4	13	10.9	0	0.6
Nyadieya	Nd1	6.4	333	27.6	166	0	0.8	32	1.7	1	5
	Nd2	6.3	318	27.7	158	1	1.2	39	5.8	0	1.1
Asarekrom	Ar1	6.3	294	27.8	147	0	1.2	21	13.7	0	3
	Ar2	6.1	263	27.7	131	1	0.4	18	4.4	0	1
	Ar3	6.2	271	27.8	135	0	1.4	3	9.5	2	0.2
Nsiana	Ns1	5.6	95	27.6	47.4	5	0.5	0	8	1	0.1
	Ns2	5.6	141	27.8	70.3	1	1.5	35	13.4	0	0.1
	Ns3	5.3	228	27.9	114	2	0.5	0	15.6	1	0.1
	Ns4	5.9	180	27.8	90.1	2	2.5	0	5.9	0	0.1

1	2	3	4	5	6	7	8	9	10	11	12
Antoakrom	An1	4.8	158	27.8	79.2	3	1.4	0	7.1		0.1
	An2	6.0	318	27.6	159	2	1	0	66.8	0	0.1
	An3	6.2	221	27.6	110	1	2	2	6.7	0	0.2
Akropong	Ag1	6.2	293	27.8	146	0	0.6	4	8	0	0.1
	Ag2	6.2	234	27.9	117	2	1.1	29	26.5	1	0.2

APPENDIX B

Table B. 1 Comparison of Cadmium Concentration

SUMMARY

Groups	Count	Sum	Average	Variance
Endemic	12	0.0186	0.0016	2.74E-07
Non-endemic	10	0.0090	0.0009	8.1E-07

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2.31E-06	1	2.31E-06	4.494605	0.046703	4.351243
Within Groups	1.03E-05	20	5.15E-07			
Total	1.26E-05	21				

Table B. 2 Comparison of Lead concentrations

SUMMARY

Groups	Count	Sum	Average	Variance
Column 1	12	0.1372	0.011433	0.00014
Column 2	10	0.11725	0.011725	0.000121

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	4.64E-07	1	4.64E-07	0.003536	0.953174	4.351243
Within Groups	0.002625	20	0.000131			
Total	0.002625	21				

Table B. 3 Comparison of Aluminum concentrations

SUMMARY

Groups	Count	Sum	Average	Variance
Column 1	12	0.004283	0.000357	1.54E-07
Column 2	10	0.005567	0.000557	2.4E-07

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2.18E-07	1	2.18E-07	1.130158	0.30041	4.351243
Within Groups	3.85E-06	20	1.93E-07			
Total	4.07E-06	21				

APPENDIX C

Table C. 1 Buruli Ulcer Cases in the Amansie West District

	Community	2002		2003		2004		2005		2006		2007		2008	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Pop.	No. of cases	Pop.	No. of cases	Pop.	No. of cases	Pop.	No. of cases	Pop.	No. of cases	Pop.	No. of cases	Pop.	No. of cases
1	Keniago		0		0		0	2475	0	2544	0	2646	2	2826	2
2	Dawusaso		3		1		9	1491	8	1539	8	1594	2	1703	1
3	Fahiakobo		3		0		2	759	0	783	0	811	0	867	0
4	Kobiriso		1		1		1	640	2	660	0	684	0	730	0
5	Hiamankwa		0		0		0	163	0	168	0	175	0	186	0
6	Edwenase		0		0		0	596	0	615	0	637	0	680	0
7	Ayiem		0		0		0	388	0	401	0	415	0	443	1
8	Domi Assamang		3		3		4	1359	1	1402	1	1453	0	1552	0
9	Esienkyem		0		1		1	432	4	446	5	462	1	494	1
10	Datano		1		3		2	2413	0	2491	0	2580	6	2635	2
11	Wonipaninadue		0		0		0	300	0	310	0	321	0	328	0
12	Watreso		1		1		5	2502	3	2582	4	2675	29	2731	1
13	Adagya No. 1		0		1		0	582	1	601	1	623	0	636	0
14	Brichakrom		0		0		0	159	0	164	0	170	0	173	0

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
15	Dwumako		0		0		1	291	0	301	0	311	0	318	0
16	Nyamebekyere		0		1		0	287	0	296	0	307	0	313	0
17	Aboaboso		0		1		1	1977	0	2040	0	2113	0	2158	0
18	Apenimadi		1		2		2	1024	0	1056	0	1094	0	1117	0
19	Nkrumakrom		0		0		0	331	0	341	0	354	0	361	0
20	Manukrom		0		1		0	344	0	355	0	368	1	376	0
21	Taabosere		0		0		0	247	0	255	0	264	0	270	0
22	Groso		1		5		4	331	0	341	0	354	0	361	0
23	Akyerekyerekrom		1		3		6	684	0	706	1	731	7	747	7
24	Dunhura		0		2		0	234	1	241	1	250	0	255	2
25	Yawkasakrom		0		2		0	415	2	428	1	443	0	453	1
26	Kojonsiakrom		0		0		0	128	0	132	0	137	0	140	0
27	Bonsaaso		0		3		7	1182	1	1220	1	1264	6	1291	1
28	Tontokrom		3		4		4	2056	2	2122	4	2198	1	2244	0
29	Dadease		0		0		3	882	0	911	0	943	0	963	0
30	Takroase		1		0		0	2118	0	2186	0	2264	0	2312	0
31	Afraso		0		0		1	644	0	665	0	689	0	703	1

APPENDIX D

D.1 Sample Questionnaire

QUESTIONNAIRE ON WATER SOURCES AND QUALITY IN BURULI ULCER ENDEMIC AND NON-URULI ULCER ENDEMIC AREAS

ALL OF THE PERSONAL INFORMATION GIVEN WILL BE TREATED AS CONFIDENTIAL. PLEASE ANSWER ALL OF THE QUESTIONS BY TICKING THE APPROPRIATE OPTION.

Questionnaire No: ………………… Town/Village: ……………………………………

A. Demographics of Household Members

1. Gender: Male [ ] Female [ ]
2. Age: Below 10 [ ] 10-20 [ ] 20-40 [ ] Above 40 [ ]
3. Level of education:
   None [ ] Primary [ ] Secondary [ ] Post Secondary [ ]
4. Ethnic Group: ____________________________
5. Religion: Christian [ ] Muslim [ ] Traditionalist [ ] Other [ ]
6. Occupation: ____________________________

B. Community Understanding of Disease

1. Distance of house from health facility:
   Less than 100m [ ] 100-500m [ ] More than 500m [ ]
2. Have you experienced any of these symptoms?
   Painless swelling [ ] Lesion [ ] Deformity [ ] None [ ]
3. If yes, what part of the body?
   Lower limb [ ] Upper limb [ ] Other (specify) ……………………………
   ……………………………………………………………………………………
   ……………………………………………………………………………………

C. Sources and Treatment ~~of Drinking~~ Water

1. What source of water do you use now and what are the uses?

Source	Uses			
Stream [ ]	Cooking [ ]	Washing [ ]	Bathing [ ]	Drinking [ ]
Borehole [ ]	Cooking [ ]	Washing [ ]	Bathing [ ]	Drinking [ ]
Well [ ]	Cooking [ ]	Washing [ ]	Bathing [ ]	Drinking [ ]
Pipe borne [ ]	Cooking [ ]	Washing [ ]	Bathing [ ]	Drinking [ ]
Other [ ] ……	Cooking [ ]	Washing [ ]	Bathing [ ]	Drinking [ ]

2. Distance of house from water source:

Source	Distance		
Stream [ ]	Less than 100m [ ]	100-500m [ ]	More than 500m [ ]
Borehole [ ]	Less than 100m [ ]	100-500m [ ]	More than 500m [ ]
Well [ ]	Less than 100m [ ]	100-500m [ ]	More than 500m [ ]
Pipe borne [ ]	Less than 100m [ ]	100-500m [ ]	More than 500m [ ]
Other [ ]……	Less than 100m [ ]	100-500m [ ]	More than 500m [ ]

3. Do you treat the water before using? Yes [ ] No [ ]
4. If yes, what method and material are used for treatment?

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

5. Have you always used this source? Yes [ ] No [ ]
6. If no, what source did you use before? Stream [ ] Well [ ] Other [ ]
7. Why did you stop using this source(s)?

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

D. Activities Carried Out Close to Drinking Water Sources

1. What activities are carried out close to the drinking water source?
   Farming [ ] Swimming [ ] Washing [ ] Mining (Galamsey) [ ]
2. What water do you use when you go to the farm?

………………………………………………………………………………………………

D.2 Focus Group Discussion

1. What do you think causes the disease?

   Poor hygiene [ ] Unclean environment [ ] Contaminated food [ ]

   Drinking water [ ] Other (specify) …………………

2. Do you think it is contagious?

   Yes [ ] No [ ]

3. If yes, how?

   Contact with infected person [ ] Eating together [ ] Sharing of clothing [ ]

   Other ……………………

4. What is your perception about the disease now?

   Reduced occurrence [ ] Increasing occurrence [ ] Eliminated [ ]

5. Why do you think so?