KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY,

KUMASI

COLLEGE OF SCIENCE

FACULTY OF BIOSCIENCES

DEPARTMENT OF FOOD SCIENCE AND TECHNOLOGY

HEAVY METAL QUALITY AND SAFETY OF PLANTAIN FROM SELECTED MINING TOWNS

by

ESINAM DORKENOO (BSc Hons)

(BSc. Science Laboratory Technology)

MAY 2018

HEAVY METAL QUALITY AND SAFETY OF PLANTAIN FROM SELECTED MINING TOWNS

By

ESINAM DORKENOO BSc. (Hons)

(BSc. Science Laboratory Technology)

A thesis submitted to the Department of Food Science and Technology, Kwame Nkrumah University of Science and Technology, Kumasi in partial fulfilment of the requirements for the award of

MASTER OF SCIENCE IN FOOD QUALITY MANAGEMENT

MAY 2018

DECLARATION

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree or diploma at Kwame Nkrumah University of Science and Technology, Kumasi or any other educational institution, except where due acknowledgment is made in the thesis.

Esinam Dorkenoo (PG 7047916) ....

(Student Name and ID) **Signature**
Date

Certified by

Gloria M. Ankar-Brewoo (PhD) ....

(Supervisor) **Signature** **Date**

Certified by

Faustina Dufie Wireko-Manu (PhD) ....

(Head of Department) **Signature** **Date**

DEDICATION

This work is dedicated to the Almighty God for seeing me through, my parents and siblings for their unflinching support, husband Benjamin and my daughter Baaba for all her laughter during these times.

ACKNOWLEDGEMENT

To God be the glory, greater things He will always do. As always God_s ways are not our ways neither are His thoughts our thoughts but He always makes all things to work together for my good and am forever grateful. My profound gratitude goes to my supervisor Dr. Gloria

Ankar-Brewoo for her cooperativeness and support, also to Abdul Malik and Meinster K. Eduafo for all the help given to me to bring this work to completion.

ABSTRACT

Heavy metal pollution has pervaded many parts of the world especially developing countries such as Ghana. Heavy metals can enter the food chain through industrial mining activities. Plantains (Musa sp) are important staple foods in Ghana. They are rich in dietary energy and also prove good quality diet. The relationship between mining and the presence of these heavy metals in plantain was researched into. The Inductively coupled plasma mass spectrophotometer was used to determine levels of Lead (Pb), Arsenic (As) and the Varian hydride system atomic absorption mass spectrophotometer to determine the level of mercury (Hg) in sixteen samples of plantain in three towns Anyinam, Kwabeng and Kibi in the Eastern region of Ghana. The mean levels in milligram per kilogram of the heavy metals from Anyinam were Pb (0.0025), Hg (0.1194), As (0.0022), from Kwabeng Pb (0.0011), Hg (0.1287), As (0.0010) and from Kibi, Pb (0.0256), Hg (0.1125), As (0.0018).The results indicate presence of mercury in all the samples tested. Only Kibi indicated high levels of Pb which exceeded the Codex recommended levels of 0.01mg/kg in fresh fruits and vegetables. The levels of arsenic were generally low. This study provides an assessment of the levels of mercury, lead and arsenic pollution in mining towns in the Eastern region whiles identifying policy recommendations for standards development in Ghana.

TABLE OF CONTENTS

LIST OF TABLE

LIST OF FIGURES

CHAPTER ONE

INTRODUCTION

1.1 Background

Most of the countries that depend on minerals in Sub-Sahara Africa (SSA) are being placed in jeopardy by a combination of deprivation that is impossible to manage and social poverty. This is evident in present day investigation which recognizes an impregnable and detrimental relationship intervening the level of mineral dependence and its Human Development Index ranking. Because of this the more the countries rely on the exportation of minerals, their standard of living is going to be disastrous due to the variation in wealth distribution together with the adverse environmental consequences within the sector. The plausible negative interrelationship between development and mining is interpreted by the natural resource curse assumptions. With this backdrop it is considered that this natural gifts tends to become a curse as the expected repercussion on the livelihoods of the people on whose lands resources are situated are constantly kept in constant poverty. Governments, non-governmental organisations and mining companies area of growing concern and attention is the detrimental effects of mining on local communities (BaahEnnumh *et al.,* 2017).

Deposits of minerals are limited; because of this mining has a life span. On the other hand agriculture is an economic activity which has been the bedrock for a large population of people in Ghana (Baah-Ennumh *et al.*, 2017). Seventy percent of the labour force is employed within the agricultural sector with only 10 percent of the land unrestricted for other socio-economic activities in the Tarkwa-Nsuaem Municipality for example. This and many others fuel the claim that people within mining communities have suffered a lot of environmental contamination, abuses of power and destruction of farms or are compelled to

give up their land with insufficient resettlement packages or compensation. Thus the social networks and domestic lives within the municipality are directly impacted upon. Wherefore, majority of the artisanal small-medium miners are of the view that the tract of land acquired by large scale mining companies is an encroachment on their sources of livelihood and because of that the only business option left for them is artisanal small medium mining and especially the unsustainable and ecologically unfriendly illegal
―galamsey‖ (Baah-Ennumh *et al.*, 2017).

Like many countries in Africa, Ghana has a history of heavy metal pollution largely arising from industrial effluent discharges and anthropogenic deposits on prevailing winds of pollutants from industrial activities. One of the biggest contributors to pollution in the Ghanaian environment is mineral mining (Hadzi *et al.*, 2017).

The use of primitive techniques within the informal mining activities that mine ores containing gold and process them to recover the gold is given to artisanal gold mining. Deforestation, loss of biodiversity and other natural resources, land and water degradation are some of the dire concerns due to artisanal gold mining despite its important contribution to both the national and local economy. Artisanal gold mining (galamsey) in Ghana has been conducted far and wide over years and which formally involves for the greatest part of a few individuals, especially the youth within rural communities. Recently, with declining preference for employment within the formal sector, the numbers of these miners have increased with most of them operating illegally in and around major streams and rivers that are major sources of drinking water for communities (Attua *et al.*, 2014).

Galamsey, a low-tech, labour-intensive, small-scale mining activity in Ghana, has in recent past come under intense criticism and state policing despite being an essential livelihood source. From research, findings suggest that for most individuals and communities, unemployment, poverty and displacement from agriculture benefits, explain their initial entry into the industry (Afriyie *et al.*, 2016).

Deep mining has been the main form of mining in Ghana till date. One of the largest gold (Au) mines in sub-Saharan Africa located within Obuasi, AngloGold Ashanti mine, augments over 50% of the total annual gold production in the country. About 45% of the total export revenue to the country is obtained from gold. Nevertheless, mining and ore processing have contributed greatly to pollution of the area and environmental degradation. Wastes of mining comprising of fine silts and sand are disseminated into the surrounding environments by wind and surface runoff particles. Farmers living close to the tailings dam of the mining site noticed a decline in their crops when waste materials had precipitated on them. In the year 2005, there were recorded incidents of tailings spillage, each of which resulted in serious environmental problems at Obuasi. Due to heavy metal contaminated water within the area some birds were severely affected after drinking from a pool of arsenic (As) in February. There was a spillage of four million cubic meters of heavy metal contaminated water into the Nyam River and other active farmland. An overflow of tailings treatment retention in that same year ended up in a number of farmlands, settlements and grassland. Different types of toxic contaminants including heavy metals are contained in the tailings from the mines and the probability for the deterioration of the ecosystems around these mines are very high. There is accumulation within higher trophic levels of heavy metals and metalloids that have been discharged into the surrounding environment and subsequently taken up by plants. Heavy metals contamination of agricultural soils, ground and surface water and crops surrounding the mining areas have been identified as one of most intense environmental issues in many countries including Ghana (Bempah *et al.*, 2016). A study conducted by Hayford *et al*. (2008) on the effect of gold mining in soil and staple foods collected around mining communities in Tarkwa showed high levels of some toxic metals including arsenic and mercury (in the soil and staple foods).

Plantain (*Musa paradisiaca*) is a starchy fruit crop grown over all the tropics. It‘s an important staple food in West and Central Africa along with bananas providing millions of people with 25% of calories. Plantain constitutes a predominant source of carbohydrate for a vast majority of people in Africa, Asia, the Caribbean, Latin America and the Pacific (Akinneye *et al.*, 2015).

As a perennial crop, it is able to grow well in a variety of environmental conditions and belongs to the family of *Musaceae* and has been crops of extraordinary importance to human societies. Because of its vast use in beverages, fermentable sugars, cooked food, flavouring and medicines its currently being ranked as the fourth most important food crop in the world after maize, wheat and rice (Falola *et al.*, 2015).

Plantain is ranked third after yam and cassava in the Ghanaian agricultural sector and contributes about 13.1% to the Agricultural Gross Domestic Product. Estimated annual consumption in Ghana is 85 kg per capita (Afriyie *et al.*, 2016).

There were significantly high levels of nitrogen, phosphorus, potassium, magnesium, and calcium in fully ripe plantain pulp, but low levels of Fe, Cu, Zn, and Na. Plantains are also reported to be an important source of vitamins A, B1, B2, B3, B6 and C (Oko, 2015).

This study therefore seeks to determine the levels of heavy metals and mercury that may have been taken up by the plantain from some selected markets in the eastern region of

Ghana. The data from the study will also be used to assess the quality and safety of the plantains being sold on the Ghanaian markets.

1.2 PROBLEM STATEMENT AND JUSTIFICATION

Rural dwellers within the local communities whose main source of living is farming are neglected with little or no consultation when it comes to the granting of leases for largescale mining. Poverty, prostitution, high influx of migrants, poor housing and infrastructure, unemployment and poor health are some of the social conditions that are known in mining communities. Provision of alternative livelihood training programs and social amenities, recruitment of indigenes into menial low paying jobs in the mining companies are some of the effort that have been disregarded by the mining companies to address the problems within the community rather compensation is made to affected land owners (Wilson *et al.*, 2015).

For millions of people around the world a critical poverty reduction strategy is artisanal and small-scale mining (ASM), which is extremely dangerous. Despite the fact that there is realization of the dangers associated with artisanal and small scale mining activities, with the exception of mercury contamination from artisanal gold mining activities, scholarly literature and regulatory bodies in countries where artisanal and small scale mining is prevalent. The largest contributor of mercury contamination by human activity globally has been identified in small scale mining activities. For example in Ghana through the processes of amalgamation, commonly referred to as ―galamsey‖, arsenic and mercury are exposed into the environment. In Ghana the gold bearing ores are highly concentrated with arsenic and they are not extracted and collected in the appropriate manner by these miners. Along the Ghanaian gold belt there have been countless reports of environmental contamination by arsenic, mercury and other such toxic metals. Furthermore within mining communities in Ghana because of the low-level methyl-Hg exposure during infancy which has been as a result of trans-placental acquisition from the mother, breast feeding, or the consumption of fish as a complementary food, there is a high risk of infant‘s exposure to toxic metals (Bansa *et al.*, 2017).This project seeks to ascertain the presence of heavy metals (mercury, lead and arsenic) in fresh plantain from small scale mining towns, determine the levels of these metals and compare them to the required standard.

1.3 OBJECTIVES OF THE STUDY

The objective of the study is to determine heavy metals quality and safety of plantains from selected markets.

Specifically to: Determine the levels of arsenic, lead and mercury in plantains sold at Kibi, Anyinam and Kwabeng markets.

CHAPTER TWO

LITERATURE REVIEW

2.0 THE ADVENT OF SMALL SCALE MINING IN GHANA

The informal gold mining sector took an unusual turn in Ghana in the global rush to grab mineral resources (Crawford and Botchwey, 2017).The artisanal and small scale mining (ASM) by law been‘ reserved for Ghanaian citizens‘, but with the increase in gold prices during 2008 and beyond, there was an invasion of foreign miners, especially irregular migrants from China, who entered into the small scale mining (ASM) sector. An out of control situation which was characterized by a culture of impunity ensued which was used to describe an astonishing illicit, free for all over the access to gold between Chinese and Ghanaian miners at its height between 2012 and 2013. Within a short space of time the Chinese miners in particular, over thousands, introduced mechanization and new technology, which resulted into irrevocable changes to this traditional economic sector. Subsequently, the increase of mining activities caused incalculable environmental damage to both water and land bodies. Government appeared very slow to respond, despite increasingly negative media coverage of _illegal Chinese miners‘ that focused on local conflicts between Chinese and Ghanaian miners, resulting in deaths and injuries on both sides, and on the large-scale environmental destruction. Finally, on 15 May 2013,

President John Dramani Mahama, ex- president of the republic of Ghana established an Inter-Ministerial Task Force aimed at _flushing out‘ illegal miners, a military-style operation with the deportation of 4592 Chinese nationals, along with few other foreign nationals from Niger, Russia Togo (Crawford and Botchwey, 2017).

Artisanal small scale mining has been an indigenous and traditional activity for decades, dating back at least to the fifteenth century when gold extraction was done using mercury for the first time and it has continued to use rudimentary means of extraction, at least up to the past decade. Artisanal small scale mining takes both licensed and unlicensed forms, as in other African countries with the unlicensed forms predominating, such illicit miners in Ghana are known as _galamsey‘, an adulterated version of the English phrase _gather them and sell‘. ASM in Ghana in present times has become an increasingly significant means of employment for many rural dwellers, often turning to mining to augment or replace farming incomes.

Although widely practiced in Ghana until 1989 artisanal small scale mining was formally illegal. The Small-Scale Gold Mining Law 1989 (PNDCL 218) attempted to regulate and legalise ASM by introducing a registration and licensing process. This was then incorporated into the current Minerals and Mining Act 2006 (Parliament of the Republic of Ghana, 2006). This formalization process enabled artisanal miners to apply to the Minerals Commission for a concession of 25 acres maximum in designated mining areas and then to acquire a license to mine. This process however was criticized as being lengthy, with payments of official and unofficial fees, very expensive and bureaucratic. Galamsey activities thus have continued to increase due to the fact that most low-income miners have been prevented from registering (Crawford and Botchwey, 2017).

2.1.1 ENVIRONMENTAL DEGRADATION

The mechanization and intensification of mining has been on a larger-scale, thus environmental degradation in areas of alluvial mining, inclusive of both water and land bodies. The rush to acquire land for mining has meant that large tracts of arable land have been destroyed, most notably where illegal mining has entailed sites being abandoned without any reclamation, and will remain unusable for farming for generations. The countries foreign exchange earnings and food security have been adversely affected due to the loss of farmlands which has affected food crop and cocoa production. Abandoned pits that become flooded because they have been left uncovered pose a danger to local residents and children especially with reports of some deaths. With the introduction of dredging mining in the rivers by Chinese miners which has been copied by the Ghanaians, there has been a destruction of river bodies which is a new and catastrophic form of environmental degradation. Loss of aquatic life, increased in water turbidity levels and contamination of drinking water are the main forms of pollution in the main rivers. There has been an increase in the cost of chemical treatment to make waters from such sources potable because of the degree of pollution which has a very severe repercussions for local communities (CSI) (Crawford and Botchwey, 2017).

Deforestation and forest degradation, especially in developing countries, accounts for some 18% of global carbon dioxide emissions. Most of the accessible rainforests in Ghana are shrinking due to the combined effect of logging, forest fires, agricultural colonization, mining activities, wild land fires and other development projects. From the country's original forest cover of 8.2 million hectares at the beginning of the 20th century only an estimated 1.6 million hectares remain.

The activity of illegal miners in reserved forests is observed as a major threat to sustainable forest management and impact on livelihoods of communities. The Offin shelterbelt forest reserve in Ghana has been bedeviled by illegal mining since the year 2010. Currently information on the extent of mining driven deforestation and degradation of forest reserves, as well as its impacts on livelihoods is limited. Also, the estimated cost incurred in flushing out illegal miners and the sustainability of such operations has not been well document (Boadi *et al.*, 2016).

2.1.2 EFFECTS OF GALAMSEY ON THE ECONOMY

The illegal artisanal small scale gold mining and processing cycle is well known which includes discovery, migration and relative economic prosperity which are subsequently followed by economic destitution, outmigration and economic destitution. Frequent repercussions of disordered livelihoods at galamsey sites include prostitution, disease, and degradation of moral standards, drugs, alcohol abuse and gambling. The economic benefits obtained by the miners apparently does not justify for the deplorable socio-economic conditions left to surrounding communities. Sites are abandoned after exploitable gold reserves are depleted, and there is extreme poverty and legacies of devastation to the environment to those who remain to contend with (Mantey *et al.*, 2016).

Despite the increase in total gold production, significant revenue collection opportunities are being lost by the state through unlawful mining. It‘s been suggested that gold is being smuggled out of the country because it has become difficult to trace how gold is traded and exported. Both the unlawful galamsey operators and illegal foreign miners pay no taxes because a knowledgeable respondent at national level stated that this is _a widely-held view‘ while a licensed concession holder who had worked with Chinese miners in Dunkwa-on-Offin alleged that _gold was sent direct to China‘ with _so many ways‘ of doing so (Crawford and Botchwey, 2017).

The activity of artisanal and small-scale gold mining has become an important source of income and employment for miners and their dependents and in doing so has contributed to the country‘s gross domestic product (GDP). With Ghana‘s annual gold mining production artisanal small scale gold mining represents a relatively small proportion (~10%), it is a sector that is growing and affecting the livelihood of large numbers of people each year. Two local mining companies (Precious Minerals and Marketing Corporation and Asap Vasa) in 2011, bought and sold approximately 245,000 ounces of gold extracted by ASGM activities. At the average annual 2011 price of U.S. $1568 per ounce , representing about $386 million generated by ASGM, not including an unknown—but estimated to be substantial—revenue from sales through informal markets and non-traditional means. ASGM production rose by 43% to 357,493 ounces the following year, which, at the 2012 average annual price of $1669 per ounce, represented about $597 million of ASGM gold, a one-year increase of more than 64% in market value

ASGM production.

2.2.0 HISTORY AND DESCRIPTION OF PLANTAIN

Plantains and bananas plants are crops which originated from Southeast Asia, belonging to the genus *Musa*; they are giant perennial herbs. They are monocotyledonous plants, belonging to the section Eumusa within the genus *Musa* of the family *Musaceas*e and the order *Scitamineae*. By natural hybridization between the two species, *M. acuminate* (contributing genome A) and *M. balbisiana* (contributing genome B) these cultivars evolved (Swennen and Oritz, 1997).

Almost all important bananas and all plantains are triploid. Triploid cultivars have a genome combination of AAA, AAB, and ABB. Most plantain and banana hybrid cultivars are of tetraploid type i.e. AAAA, AABB, and ABBB (Ajani, 2011).

One of the leading producing countries of plantain in Africa is Ghana. Other countries include Uganda, Rwanda, Nigeria and Cote d'Ivoire.

In the Americas, Cuba, Peru, Venezuela, Ecuador and Colombia are the leading producing countries of plantains. In Asia, Sri Lanka and Myanmar are the only leading plantain producers. Other countries that produce plantain include the Thailand, India, Southern United States, Puerto Rico, Hawaii, Bolivia, Brazil, Cameroon, Egypt, Taiwan, Indonesia, Malaysia, Philippines and Northern Australia (Ajani, 2011). Environmental conditions have profound influence on plantain production. Three main conditions are needed to enable good growth for plantain production; they are soil temperature and moisture. Plantains grow best between temperature of 20°C and 30°C. The optimum temperature for the dry matter accumulation is about 20°C and 30ºC for the appearance of new leaves. The growth of plantain plant stops with temperatures above 38ºC but under irrigation, this is prevented. An average of 100 mm amount of rainfall per month would supply the required amount of moisture needed for the growth of plantain plant.

Plantains can be grown on a wide variety of soils provided there is good drainage and adequate fertility. The best soils are usually deep, well drained, water retentive loams with high humus content. Soil pH of 5.5 – 6.5 is desirable. Various constraints in plantain production include diseases, pests, weeds, soil fertility, lodging, finance and marketing (Ajani, 2011).

2.2.1 MORPHOLOGY OF PLANTAIN

The plantain plant consists of basically the roots, pseudo-stem, leaves and inflorescence. The roots system is made up of primary, secondary and tertiary roots. Secondary roots are those that develop on primary roots, while tertiary roots develop on the secondary roots. The primary roots have the explorer roots and the feeder roots. The explorer roots are mainly for anchorage and are thicker than feeder roots. Feeder roots take up water and nutrients and usually grow from explorer roots (Swennen and Oritz, 1997).

Pseudo-stem is the cylindrical structure growing from the corm and carrying the foliage. The pseudo-stem is not wood because plantain crops are giant herbs, not trees. The pseudo-stem consists of tight packing of overlapping leaf sheaths. The pseudo-stem offers support for the inflorescence. The function of the pseudo-stem is purely connective and provides vascular connection between roots, leaves on one hand and the inflorescence on the other. The inflorescence, also known as the bunch, is the collection of the plantain fingers (fruits) on a fruit stalk. There are types of inflorescence, and this depends on the type of variety.

2.2.2 NUTRITIONAL VALUES OF PLANTAIN

Calories as high as 125 per cup are obtained in plantains. One cup of cooked plantain produces a trace of fat, 26 mg folate, 10.9 mg vitamin C, 465 mg potassium, 2.3 g dietary fiber, 909 IU vitamin A and 32 mg magnesium. They are known to be a great source of vitamins A, B1, B2, B3, B6, C, calcium and minerals such as phosphorus and potassium (Ajani, 2011).

Plantains are important in the management of high blood pressure and heart diseases in patients because they are low in sodium, very little fat and no cholesterol. Because they do not contain substances that give rise to uric acids they tend to be ideal for patients with gout or arthritis (Dzomeku *et al.*, 2007).

2.2.3TYPES OF PLANTAIN

Plantains can be classified into four (4) groups and are mostly differentiated by number of hands and weight of fingers, presence of neutral flowers, completeness of inflorescence at maturity and male bud at maturity (Swennen and Oritz, 1997). These groups are French plantain, French horn plantain, False horn plantain and True horn plantain. The French plantain has a complete inflorescence at maturity. This type can achieve a height of about 2.5 m and circumference of 600 mm. It produces between 30-38 leaves before fruiting and takes 12 months to produce a mature bunch. The bunch carries as many as 6-12 hands and 60-170 small fingers (Ajani, 2011).The False Horn plantain group has smaller number of hands as compared to the French plantain but larger fingers. This type of bunch can carry as many as 5-12 hands and 25-80 fingers. There are neutral flowers and no male bud at maturity. The inflorescence is incomplete. The True Horn plantain variety usually has 1-5 hands. The fingers are few in number between 1 and 50. This variety of plantain is longer and stouter than the False Horn plantains (Ajani, 2011).

2.2.4 FARMING SEASONS

There are generally two main farming seasons in Ghana; the rainy season and the dry season. The rainy season begins in April and ends in October whiles the dry season is from November and ends in late March (Ajani, 2011).

Rainfall determines largely the type of agricultural enterprise carried out in the various agro ecological zones. The rain forest, deciduous forest, transitional and coastal zones experience bimodal rainfall pattern which gives rise to major and minor farming seasons. Unimodal rainfall distribution in the Guinea savannah and Sudan savannah of the northern zone gives rise to a single farming season. The bimodal regions in Ghana include Eastern, Western,, Ashanti, Brong Ahafo and parts of Central and Volta region. The major farming season is between the months of March and July with the minor farming season between September and November. The single farming season in the northern zone is between May and September (Biederlack and Rivers, 2008).

2.2.5 FARMING CONSTRAINTS

Yields losses in plantain production may be classified as soil, biological and climate related (Dzomeku *et al.*, 2007).

2.2.6 BIOLOGICAL CONSTRAINTS

Plantains are susceptible to a wide variety of diseases and pests. Some pest and diseases are highly aggressive, very contagious and they spread easily. They are persistent and practically difficult to eradicate once established. Some of these diseases affecting plantain production in Ghana include witting, black sigakota, pseudostem rot, nematodes and heart

rot.

When fungi clogs the plant's vascular system it is called witting and this reduces the plant's ability to transpire and grow. A leaf spot disease Black Sigakota (*Mycosphaerella fijensis*) is also caused by a fungus. Pseudostem rot is another fungal disease which affects the pseudostem and may cause it to fall prematurely. The rot lowers the fibre quality through discolouration. Nematodes are parasitic to the plantain plants and are detrimental to the plant's health. Heart rot is another fungal disease that causes the decay of the plantain plant.

Pests that lower the yields in plantain production can be grouped into two, major and minor pests. The major pests include termites, black ants, mealy bugs, grasshoppers, banana weevils and rhinoceros beetle. The minor pests include monkeys, birds and rodents (Ajani, 2011).

2.2.7 CLIMATE CONSTRAINTS

The single climate constraint that affects the plantain production is wind. Winds of 15 m/s and above can topple the plants especially when they carry plantain bunch. Height has a dramatic effect on wind tolerance. Steady winds cause significant leaf drying and shredding and also the distortion of the crown. In case of extreme winds, complete or partial toppling of the entire plant occurs. Wind causes more damage if the underground corm is weakened by diseases or insects. Leaf tearing due to winds also reduces bunch weight by 50% (Nelson *et al.*, 2006).

2.2.8 SOIL RELATED CONSTRAINTS

One major factor that influences the yields in plantain production is soil fertility. Majority of farmers perform intercropping of plantain over a long period and do not practice any soil fertility maintenance on the farms. This gradually reduces the fertility of the soil. Some ways to maintain the soil fertility is the use of fertilizer or green manure (Dankyi *et al.*, 2007).

2.3.0 MERCURY

Under its organometallic form (methylmercury—MeHg -CH_3Hg^+) mercury (Hg) is one of the main components of toxic metals in the aquatic environments because it‘s able to biomagnify in food chains. The main exposures to organic mercury in humans are via consumption of aquatic food, while that of inorganic and/or elemental mercury occurs mostly through the inhalation of gaseous elemental Hg. Exposure to the inorganic form of mercury occurs when miners who handle it directly burn amalgam at their mining sites as well as persons living close by the mining activities (Niane *et al.*, 2014).

Mercury (Hg) is used in gold mining to extract gold from ore by forming ―amalgam‖—a mixture composed of approximately equal parts mercury and gold. In developing countries about 15 million people, including approximately 3 million women and children take part in artisanal small-scale gold mining. ASGM produces about 37% of global air emissions of Hg. The amalgam is heated; the Hg is evaporated from the mixture, leaving the gold. This method of gold extraction is used in the mining communities because it is easy and quick, can be used by one person independently and also cheaper than most alternative methods

(Gibb and O'Leary, 2014).

2.3.1 PRESENCE IN THE ENVIRONMENT/USES

Both anthropogenic and natural processes aid in the distribution of Mercury throughout the environment. The toxicity of Hg has resulted in widespread public health concerns (Endo *et al*, 2015). Mercury (Hg) can be found in various environments and has the ability to transform among different species in nature. As a global pollutant it's found in various environmental media and the chemical form which it's found is related to its toxicity level. Methyl mercury (MeHg) which is the most toxic mercury compound is able to accumulate in the aquatic food web making fishes at higher trophic levels with mercury concentrations 106 times higher than its surrounding water.

The main methyl mercury exposure pathway to local residents in a province of China, Guizhou was through the consumption of rice grown at mercury mining areas, a current study showed. Potential toxicity, bioavailability and mobility are the different matrix phases that determine the form in which mercury can be found in the soil. Hg in soil occurs in various forms that can be bound to different matrix phases and these phases vary upon bioavailability, mobility and potential toxicity (Meng *et al.*, 2013). In determining the environmental and toxicological hazard within soil suspected to be contaminated, total mercury (THg) has been found to be a poor indicator. The methylation if insoluble mercury (IHg) is achieved by the water soluble form since it forms the main substrate; it is easily available to biota and highly soluble. Total mercury levels of up to 130,000 mg/kg were detected in local soil which has been contaminated with Hg in recent studies in Wansham (Meng *et al.*, 2013).

Elemental mercury, a liquid with high volatility is the form of mercury that is usually used in the amalgamation of gold at low temperature (Gibb and O'Leary, 2014). Because of insufficient use in artisanal gold mining communities when mercury is used for the processing of gold alluvial deposits it then becomes the main source of mercury pollution. During such processes, mercury escapes into the atmosphere and are subsequently deposited in aquatic ecosystems and surrounding soils. Furthermore, leaching and soil erosion processes can also mobilize mercury to aquatic systems. It can be bio transformed by microorganisms into MeHg once in the aquatic systems, especially in anoxic bottom sediments thus reaching top predators through its bioaccumulation and bio magnification in the food chain (Castilhos *et al.,* 2015). Countries in sub –Sahara Africa, reports have been made for artisanal small scale gold mining concerning mercury's effects on health and the environment. Large volumes of mercury are discharged into river and soil systems within the surrounding environment during such processes. Environmental consequences are already noticeable in the abundance use of mercury by artisanal small scale gold mining activities after about ten years. There has been an evaluation of the future health and environmental effects of these activities (Niane *et al.*, 2014).

The World Health Organization (WHO) limits for public exposure of mercury vapors of 1.0ug/m^3 in the air are always exceeded at the burning sites of amalgam during its processing. Anaerobic microorganisms transform this vaporized mercury into methyl mercury as it eventually settles in the sediments of oceans, rivers, bays, lakes and soil

(Gibb and O'Leary, 2014).

2.3.2 ECONOMIC BENEFITS

Respiratory and neurological systems damage may be caused by exposure to mercury vapor in human. Several researchers traditionally utilize the presence of mercury in the blood as a sign of recent exposure whiles mercury vapor exposure are detected in the urine. Teratogenic and neurotoxic damages which are irreversible are some of the effects observed in methyl mercury elation over a chronic period of time (Castilhos *et al.*, 2015). Brains of fetuses are usually highly sensitive thus exposure through the placenta is very dangerous. When this occurs, memory loss, delayed development, language disorders, hearing and vision loss, seizures and mental retardation are some of the neurological symptom's observed. Chronic mercury exposure results in acrodynia, a syndrome characterized by painful and red extremities in children (Gibb and O'Leary, 2014).

2.4.0 LEAD

Lead, a soft and malleable metal which is prepended to be a heavy metal belonging to the carbon group. , also known as Plumbum (Pb). It has a half-life of approximately thirty days when it finds its way into the blood stream; it's eliminated from the body through bile and urine at 1 to 3mL clearance rate. Lead ultimately concentrates in the bones after the rest binds to the red blood cells and diffused throughout soft tissues of the body. Lead that has been deposited in the bones has a period of 20-30 half-life (Mason *et al.*, 2014).

2.4.1 PRESENCE IN THE ENVIRONMENT/USES

Human activities such as battery manufacturing, mining and smelting are to a greater extent the cause of the presence of Lead contamination in the environment though it occurs naturally. Food is the main source of lead introduction into the body, and this can be on the account of its bioaccumulation in the edible parts of vegetables since there's an uptake of lead through surface deposition of particulate matter, direct foliar uptake and the roots and translocation within the plant, and this poses a possible risk for the population. Leads strong adsorption to the soil makes its less available to plants. The reduction in amount of organic matter and pH increases the availability of Lead in the soil (Beccaloni *et al.*, 2013).

Soil to plant transmission of heavy metals is the main source of human exposure to contaminated soil. The concentrations and uptake of heavy metals in the soil determines their presence in food, this is because both elemental nutrients and toxic elements are present in the soil from which crops take these through adsorption by the roots thus making the soil the major connection within the food chain. Heavy metal uptake and accumulation is different for each plant and also there are variations within tissues of the same plant. The highest concentrations are said to be in the roots of the plant, the stem then the lowest is in the fruit or grains (Rai *et al.*, 2015).

2.4.2 ECONOMIC BENEFITS

Lead is a cumulative toxic metal that can affect various functions at relatively low levels leading to hematological, gastrointestinal, neurological, renal and cardiovascular disorders (Nascimento and Reis Martinez, 2015). Interference with other systems in the body that support the function of the nervous system is responsible for indirect effects on the nervous system. There is an increased risk of various detrimental effects of the nervous system such as preterm birth, hypertension, impaired thyroid function, vitamin D deficiency when there's an exposure to Lead (Mason *et al.*, 2014).

High doses of Lead exposure within weeks develops into lead encephalopathy, which is a serious neurological effect , this leads to increase in headache, memory loss, irritability, hallucinations, tremor, mental dullness and difficulty in paying attention. Delirium, convulsions, death, coma or paralysis are some of the symptoms observed when the situation worsens. At low Lead doses there's the development of Lead encephalopathy in children than adults (Mason *et al.,* 2014).

2.5.0 ARSENIC

A metalloid which has the ability of being both a metal and a non-metal. Widely dispersed in the air, soul, rocks and water. Inorganic arsenic is the widest spread of all the naturally occurring forms of arsenic. Arsenic is ubiquitous in the environment due to geological and human activities (Hong *et al.,* 2014).

As in the soil is taken up by plants, it is accumulated in the edible parts (such as rice grains), which is further consumed by humans and other organisms higher in the food chain (Li and Song, 2015). Different types of arsenic compounds are formed from reactions between arsenic that occurs naturally with oxygen or molecules in water, soil or air since it cannot be destroyed (Hong *et al.,* 2014).

2.5.1 PRESENCE IN THE ENVIRONMENT\USES

Soil is the most significant avenue for circulation and concentration of arsenic, as compared to water and the atmosphere. The adsorption and holding power of the soil to arsenic is very strong. Arsenic is said to have a half-life of between 1000-3000 years in the soil compared to the atmosphere which is much shorter. Precipitation, an important form of conveying arsenic that has been liberated by upstream mining activities enters into the soil via water. Surface runoffs produce arsenic found in downstream soils. Because of adsorption – desorption reactions with soil matrix water soluble arsenic is able to drift into soils (Li *et al.*, 2016).

Pentavalent arsenate and trivalent arsenite are inorganic forms of arsenic compounds. In alloys, glassware, wood preservatives and semiconductors production, Arsenic is used. In medicine, the treatment of yaws, amoebic dysentery, syphilis and currently in leukemia, the utilization of Arsenic has been authenticated. Respiratory, dermal and oral routes are the main forms of exposure of arsenic in humans. Oral exposure from contaminated fish and agricultural products, soil and water are the major exposure pathways to individuals who are not likely to be exposed to arsenic in their work environment (Hong *et al.,* 2014). Activities in mining, worldwide are responsible for pollution related to arsenic. There are serious repercussions on human health which is caused by the mining process through pollution of the atmosphere. Susceptibility of humans to other diseases including lung cancer is the consequences when a large amount of arsenic enters the respiratory system.

The pollution thus easily affects both water and soil (Li *et al.*, 2016).

2.5.2 ECONOMIC BENEFITS

Lung and skin cancers in humans were used to confirm the carcinogenic effects of Arsenic. There is likely to be a further reduction in the concentration of Arsenic permitted in drinking water by the US Environmental Protection Agency, although it was reduced from 50 to 10 ppb. In South Korea there are various metal mines with high arsenic levels in the soil that have been abandoned and these pose as a risk of arsenic contamination in the environment. Nails, skin, hair, muscle, liver, kidneys and bones serve as deposit sites for arsenic after it bind with red blood cells; urine is the main route through which it is gotten rid of. The activities of numerous enzymes that are responsible for glutathione metabolism, cellular respiratory and DNA synthesis, are suppressed by inorganic arsenic compounds, thus the development of the fetus nervous system is affected since it may be transported across the placenta (Hong *et al.,* 2014).

Arsenic is the carcinogen which is known to cause cancer via gastrointestinal and respiratory exposure. The International Agency for Research on Cancer (IARC) registered it after it was formally determined as a carcinogenic substance in the 1980‘s.Further research was carried out in Argentina, Chile, United States, Bangladesh, India and Taiwan after the confirmation of Arsenic exposure and it being a carcinogen to examine further their association, and the results obtained confirmed the former reports. Inorganic arsenic compounds can be classified as being clear carcinogens (group1) or potential carcinogens (group2), this was proven from epidemiological and animal studies results.

Neurobehavioral distortions in adults and neurobehavioral abnormalities during puberty in childhood are induced in the body when there is arsenic accumulation. These effects may escalate after exposure to lead therefore care must be taken. The peripheral nerves of the sensory functions are affected by aggravation of arsenic toxicity called Neuritis.

Deficiency's in verbal intelligence quotient and long term memory in children from Mexico in a study attest to its association with exposure to arsenic (Hong *et al.*, 2014).

2.5.3 UPTAKE OF ARSENIC BY PLANTS FROM THE SOIL

Contamination of soil by As occurs in the usage of insecticides, wood preservatives, and waters contaminated with arsenic which are being used for irrigation and mining activities.

A food safety problem arises as a result of arsenic uptake by plants enormously. Research studies shown the efficiency of arsenic uptake from paddy soils by rice (*Oryza sativa*), this results in high concentrations of arsenic in rice grains at ranges that pose a health risk consumers of huge quantities of rice in their meals (Zhao *et al.*, 2008)

Bedrocks rich in arsenic or its downstream forms soils that have extremely high levels of naturally occurring arsenic. Within its mineral structure, silicate (IV), titanium (IV), phosphorus (V), iron (III) and aluminum (III) can be replaced chemically with arsenic since it occurs in numerous rock forming minerals (Pushon *et al.,* 2016).

The concentrations of arsenic in soil reduces as the distance from the mine sites increases, this is because soil arsenic contamination exists at the particular locations where mining and smelting activities occurs. A peculiar problem is the particulate fine matter which is wind

dispersed, thus contamination to farther distances from the sites of the mine. Leafy material mainly with large surface areas and plant materials are contaminated with these fine materials which are not thoroughly removed by washing. Home gardeners and residents within the areas with compelling arsenic contamination of the soil surface are at risk. Generally a good link was observed between soil and total plant arsenic concentrations from a correlation of concentrations of arsenic in vegetables cultivated in
South West England (historic mining activity site) and those from a natural site in North West Scotland. Soil arsenic levels ranging from 120-1130 mg/kg resulted in increased arsenic levels in produce from South West England. Leafy greens such as lettuce, kale and spinach had high levels of arsenic, other vegetables that were unpeeled (swedes, carrots, potatoes) had higher levels of arsenic compared to its peeled ones, and in both scenarios attests to the fact that soil adhesion to below biomass and windblown particles from the soil were responsible for the contamination rather than the uptake by roots (Pushon *et al.*, 2016).

Uptake of arsenic by plants is for the most parts through absorption by roots, arsenic is also absorbed from water through their leaves by plants that are submerged. Methylated arsenic dimethylarsinic acid (DMA) and monomethylarsonic acid (DMA), arsenite (As III) and arsenate (As V) are the three predominate forms of arsenic available to plants that are found in the soil. Arsenic can be found in the soil in varied forms at the same time. Arsenic species are converted to As (V) to As (III) by microorganism‘s present in the soil, and later to MMA and DMA. Particular arsenic species are selectively taken up by roots of plants through definite pathways and transporters (Li and Song, 2015).

Arsenite>Arsenate>DMA>MMA is the arrangement in which arsenicals are taken up by plants from the soil. The different species of arsenic enter through divergent root membrane transport proteins within the plasma membrane of the roots which allows molecules and ions to cross with varied levels of selectivity, or target specificity. Entry into cells of roots of arsenite and silicic acid and arsenate and phosphate is controlled by their chemical structure similarities. Phosphate transporters (the Phosphate Transporter 1 family of proteins; PHT1) are the routes in which arsenate enters into cells of roots (Pushon *et al.*, 2016).

2.5.4 TOXICITY TO PLANTS

No particular type of arsenic is usually more toxic, arsenic in general is lethal to plants. At arsenic levels exceeding 1 mg/kg in tissues, yields of soybean are affected, for cotton yields its 4mg/kg, whiles there is inhibition of growth at levels of 20 mg/kg in barleys. At 1000 mg/kg in tissues of roots and 20-100 mg/kg in above ground biomass of arsenic, there is an increased in the yield limits in rice. Whereas arsenic levels of 290 mg/kg in soil did not affect inhibition to growth in potatoes (*Solanumtuberosum L.*). Inorganic forms of arsenic are less toxic compared to the organic form in some plants, example is smooth cordgrass (*SpartinaalternifloraLoisel*) (DMA = MMA >arsenite>arsenate) and rice (order of toxicity: MMA >arsenite> arsenate = DMA).There are differences to the levels at which plants can tolerate levels of arsenic and the response to stress varies for each species of arsenic. Phosphates in ATP, a biomolecule, (adenosine triphosphate, a molecule that is utilize for intercellular energy transfer), are easily replaced by arsenic because of the similarities in the chemical structure between arsenate and phosphate, when this happens there is a negative effect on metabolism and growth (Pushon *et al.*, 2016).

CHAPTER THREE

MATERIALS AND METHODS

3.1.0 MATERIALS

All the reagents and chemicals used were of analytical grade from Merck (Darmstadt, Germany). Concentrated 65% HNO_3 and 30% H_2O_2 were of spectroscopic grades.

Standard stock solutions of concentrations (1000 mg/l) for mercury (Hg), Lead (Pb) and Arsenic (As) were procured from Aldrich. Palladium (Pd) stock standard solution modifier (3.00 gL-1), was prepared from Pd 99.999% and used for both Lead (Pb) and Arsenic (As) analysis.

3.1.1 METHODS

3.1.2 SAMPLING

This study was carried out in the Eastern Region of Ghana in selected towns known for artisanal small and medium scale mining activities. Sixteen samples were obtained from

Anyinam, Kwabeng and Kibi township on market days within a three-week period. Six different locations in Anyinam and Kwabeng and four from Kibi. The samples were transported in ice chest from the markets to the laboratory. The samples were then peeled, diced, blended and stored in a refrigerator prior to analysis.

3.1.3SAMPLE PREPARATION

About one (1) gm of the stored sample was weighed into teflon vessel of the milestone microwave digester (Milestone start D, 2010, Italy) and 5 mls of 47% nitric acid and 3mls of hydrogen peroxide were added to the sample in the vessels enclosed with a shield. The samples were subsequently placed in the microwave digester and digested for one hour at a temperature of 170 ^{o}C. The cooled samples were filtered into a 50ml graduated centrifuge tubes and made up to 25 ml mark.

3.2.0 DETERMINATION OF LEAD

The concentration of lead (Pb) in the samples was analysed in duplicates using the (British Standard European Norm) BS N14084:2003 and the graphite furnace technique of the inductively coupled plasma mass spectrometer (ICP) (Agilent Technologies 7700x series, Germany). Calibration standards of 5 µg/L, 10 µg/L and 15 µg/L were prepared from a bulk stock standard solution of 20 µg/L. The bulk standard solution was prepared from a 1000 mg/L stock solution by serial dilution using the dilution formula ($C_1V_1=C_2V_2$). The standards were prepared using 0.1% nitric acid solution. A linear graph was plotted with four calibration points (0, 25, 50,100 ug/L).

3.3.0 DETERMINATION OF ARSENIC

Arsenic analysis in the plantain samples was carried out using the (British Standard European Norm) BS 14084:2003 and the inductively coupled plasma mass spectrometer (ICP) (Agilent Technologies 7700x series, Germany) for analysis which was done in duplicates. Serial dilution of a stock standard solution of concentration 1000 mg/L was carried out to prepare a bulk standard solution of 100 µg/L using the dilution formula ($C_1V_1 = C_2V_2$) with 0.1% nitric acid solution. A linear graph was plotted with calibrations points 0, 25 µg/L, 40 µg/L and 100 µg/L before analysis of the samples.

3.4.0 DETERMINATION OF MERCURY

The cold vapour technique of the Varian Hydride System Atomic Absorption Spectrophotometer (VGA 77, 2010, Australia and British Standard European Norm BS EN 13806:2002) was used to analyse mercury in duplicates. Calibration standard solutions of 10 µg/L, 20 µg/L and 30 µg/L was prepared from a stock standard solution of 1000 mg/L by serial dilution using the dilution formula (C1V1 = C2V2) with 0.1% nitric acid solution. Thus a linear calibration graph was plotted with points 0, 10, 20 and 30 ug/L.

3.5.0 DATA ANALYSIS

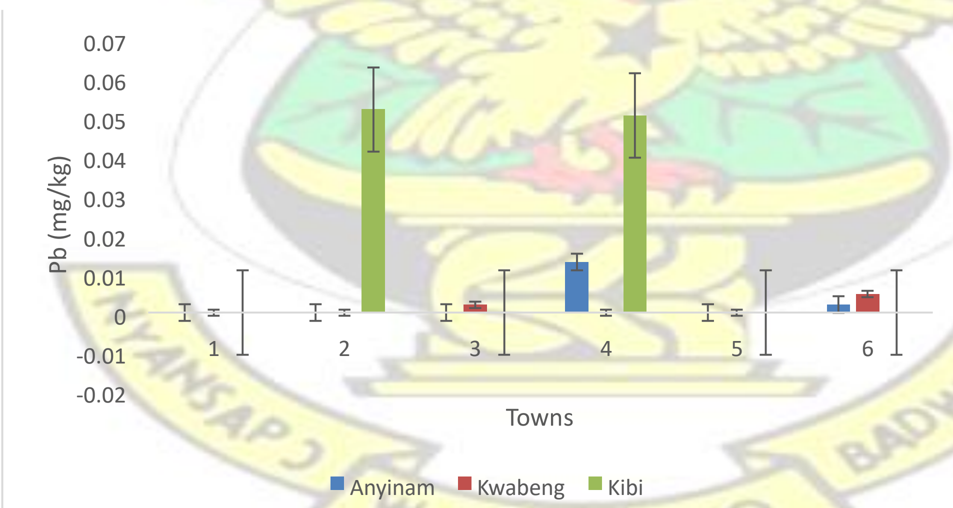
Bar graphs using excel were used for each sampling points. This was used to compare levels within all the sampling sites. The values obtained were compared to the relevant standard where available. A similar one was also used for the mean values of the metals detected. The standard deviation and coefficient of variation were also calculated for each metal. Significant level was also determined.

CHAPTER FOUR

RESULTS AND DISCUSSION

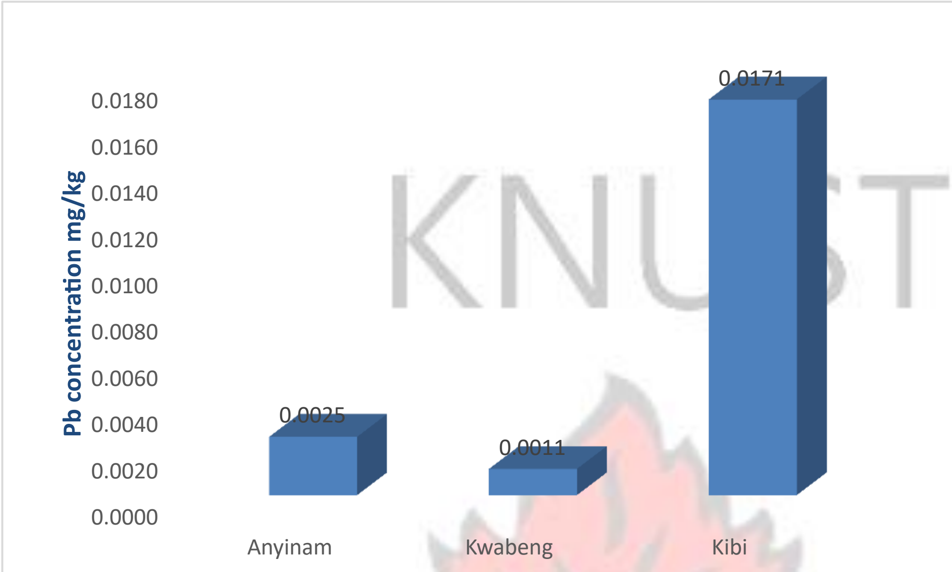
4.0 RESULTS AND DISCUSSION

Results from the study shows that fresh plantains from Kibi had highest concentrations of Lead (0.0520 mg/kg) and Anyinam had lowest concentrations of 0.0020 mg/kg. Out of the sixteen samples analysed lead was not detected in ten of the samples, four from both Anyinam and Kwabeng and two from Kibi as can be seen from Figure 4.1.



Source: field survey

Figure 4.1 Lead content within the three towns



Source: field survey

Figure 4.2 Average lead concentrations between the three towns

Some parts of Kibi recorded the highest level of lead among all the sampling sites with a concentration of 0.052 and 0.0505 mg/kg, followed by one location in Anyinam which recorded a level of 0.013 mg/kg (Figure 4.1). All these levels exceeded the allowable Codex standard level of 0.01 mg/kg. The rest of the sampling point‘s recorded very low values whiles with others it was not detected.

Lead was detected in two points out of the six locations in Anyinam with the lowest being 0.0021 mg/kg and the highest being 0.0130 mg/kg which is higher than the Codex Standard of 0.01 mg/kg. In Kwabeng Pb was detected in two places out of six locations and they were all below the Codex Standard.

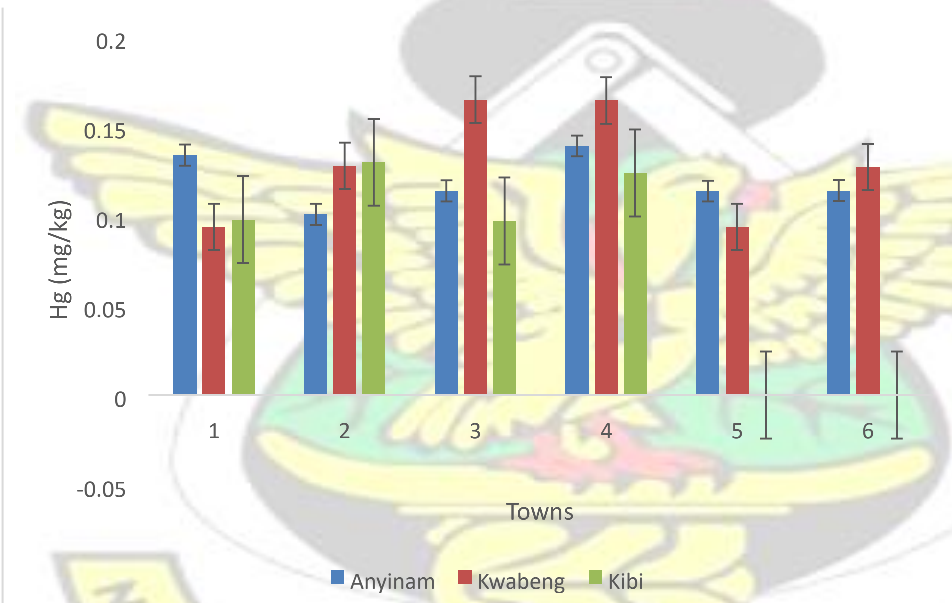
Pb was detected in two places out of the four points sampled in Kibi. The values were 0.0505 and 0.0520 mg/kg which was higher than the recommended level of 0.01 mg/kg of Codex Standard for fresh fruits and vegetables (Standard 193: 1995).

Over 80% of lead consumed constantly can be attributed to dust, food and soil. The quantities of lead in plants and soil in the environment is determined by the nature and range of leads source, with part of the highest concentrations located around smelters and mines, current research documented exposure to lead within the African populace with other mining sources included (WHO, 2015). Lead largely persists in contaminated environment and may result in reduced growth and learning disability in children. It‘s been reported that 59% of urban and 81% of rural areas total lead intake could be attributed to dietary exposure. Furthermore, neurological and developmental effects in children are well known in literature (Molina-Villalba *et al.*, 2014).

Exposure to very low as well as high concentrations of lead has deleterious effects on health. Repercussions such as socio behavioral problems (delinquency, aggression), learning problems and decline in intelligence scores and hearing loss arises as a result of exposure to low concentrations of lead from a general agreement. There are enormous presumptions for the society and individual, such as low lifetime earnings and accomplishments and educational feats, and also sub optimal economic expectation at the district levels. In Africa about 98.2million IQ points are misplaced annually due to exposure to lead a current economic study on health has estimated, this translates to US$ 134.7 billion in economic losses. An important determinant of lead poisoning and exposure in children from Africa is poverty, as depicted intensely and harrowingly in Kabwe, Zambia and Zamfara State, Nigeria an artisanal mining settlement. (WHO, 2015). A study carried out by Bortey-Sam *et al*. (2015) in thirteen settlements in Tarkwa, Ghana to evaluate the degree of metalloid and heavy metal accumulation in soils for agriculture in food crops (Musa*paradisiaca*, plantain and M.*esculenta*, cassava) and also assess the human health risk in connection with utilization of such foods. Levels of lead from the studies showed 30% of cassava samples analysed exceeded the standard levels in the Codex Alimentarius Commission.

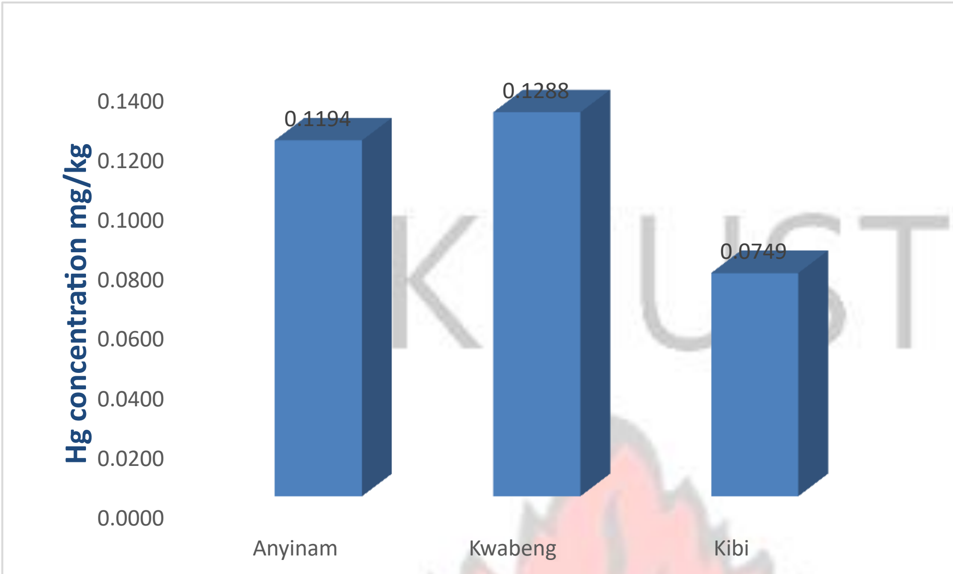
The World Health Organisation (WHO) designated levels for As, Pb and Hg of 0.01 mg/kg was exceeded in two small scale mining settlements in the northern parts of Ghana, (Tinga and Nangodi) when As, Zn, Pb, Cd and Hg levels were tested in their drinking water. Serious health risks may arise when inhabitants of these communities engaged in mining consume water containing increased levels of Cd, As and Hg (Cobbina *et al.*, 2015).

In Figure 4.3 which shows the mercury content within the three towns, Kwabeng recorded both the highest concentration of 0.1650 mg/kg and the lowest of 0.0939 mg/kg.



Source: field survey

Figure 4.3 Mercury content within the three towns



Source: field survey

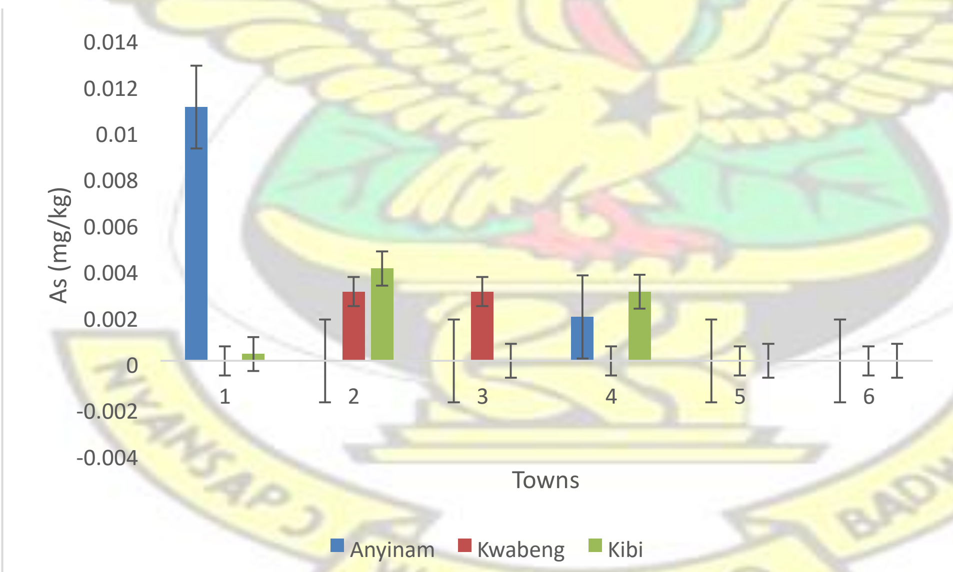
Figure 4.4 Average mercury concentrations between the three towns

From Figure 4.4 it can be observed that mercury was detected in all the samples analysed. The highest and lowest concentrations of 0.1650 and 0.1645 mg/kg respectively coming from Kwabeng township. Mercury was detected in all the sixteen samples analysed. The concentrations of mercury range from 0.0939 – 0.1650mg/kg all within Kwabeng township and also it having the highest and least levels compared to the other towns. Mercury levels in Anyiman were within the ranges of 0.1010- 0.1392 mg/kg. Kibi recorded between 0.0972-0.1300 mg/kg of mercury. This can be confirmed through observation of the mining activities going on within all the towns. The mercury levels observed in all the samples can be attributed to the small scale mining activities being carried out in the study areas of the various towns since Hg is used to amalgamate gold from ore. Amalgam, which is formed when mercury binds with gold and this gold mercury amalgam, is easily burnt off due to the low vapour pressure of mercury leaving the precious gold in its wake. Local scale towns and villages located at sites where the vapour is emitted experiences serious effects from mercury during the amalgam burning process, and globally if it‘s transported to greater distances before its redeposit as inorganic mercury on the countryside after the mercury vapour has entered the global atmospheric pool.(Rajee *et al.*, 2015). And these activities can be observed visually with its accompanying adverse environmental effects. A research carried out to investigate the effect of small scale mining on the quality of water for irrigation from some selected sites along a river in Asante Akim Central Municipality of Ghana indicated that Hg was higher than FAO permissible limits for irrigation water. The detection of some level of heavy metals in the water should be a major concern to stakeholders in the Municipality as continuous influx of small scale miners in the area could increase heavy metal concentration beyond the acceptable thresholds.

Allowable mercury levels in natural mineral water using the Codex standard gives a maximum limit of 0.001mg/kg thus when compared to this study the levels of mercury far exceeds this limit. A study carried out in thirteen communities in Tarkwa, Ghana to assess the extent of heavy metals and metalloid accumulation in agricultural soils and foodstuffs (cassava and plantain) and to estimate the human health risk associated with the consumption of these foodstuffs. The concentrations of arsenic, lead, mercury and other metals were measured. The results indicated that 30% of cassava samples collected contained higher concentrations of Pb when compared to Codex Alimentarius Commission standard values (Bortey-Sam *et al*., 2015). Another study carried out by Doke and relatively low average level of MeHg (~0.1 μg/g), although higher levels are seen in rivers in the gold mining regions (0.25 (±0.23)) using USEPA health values.

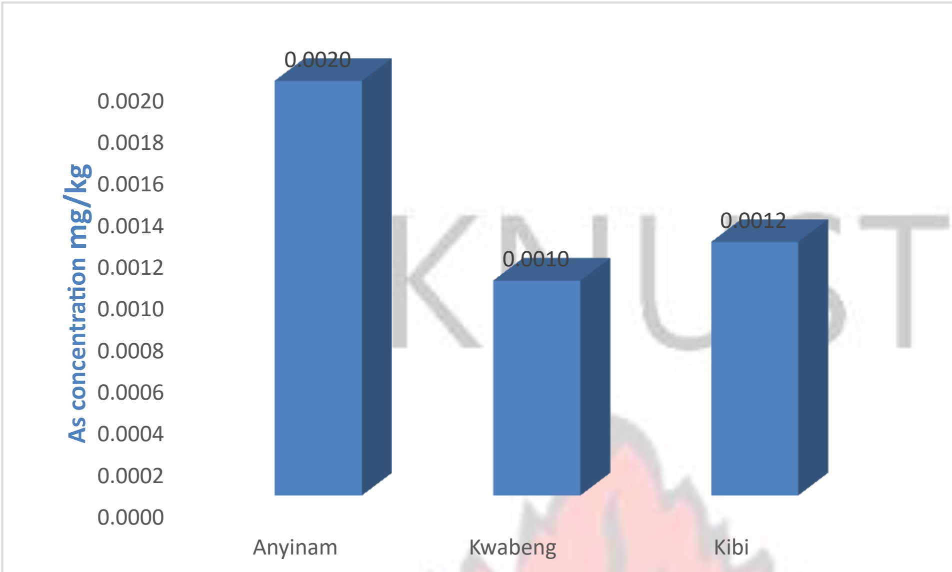
The results showed concentrations of these metals compared to the standards for drinking water to be higher, and there was increased accumulation of Arsenic above the usual level in the vegetable samples tested. For the vegetables grown on soils from Sanso, the bioaccumulation factors of heavy metals were found to be seriously higher. The hazard quotient and average daily intake in drinking water for arsenic, lead and mercury exceeded allowable levels in the vegetable samples. Within the vegetable samples tested for arsenic, mercury and lead, there was an unacceptable non-cancer health risk levels detected. Also a similar risk was also detected in the consumption of vegetables, drinking of groundwater and within the soil. Consumption of vegetables cultivated around the sites of sampling poses a very high health risk to heavy metal pollution since the hazard index for these vegetables was greater than one (Bempah and Ewusi, 2016).

Anyiman recorded the highest arsenic concentration of 0.0110 mg/kg whiles Kibi recorded the lowest of 0.0003 mg/kg as can be seen from Figure 4.5. None was detected in nine out of the sixteen samples.



Source: field survey

Figure 4.5 Arsenic content within the three towns



Source: Field data

Figure 4.6 Average arsenic concentrations between the three towns

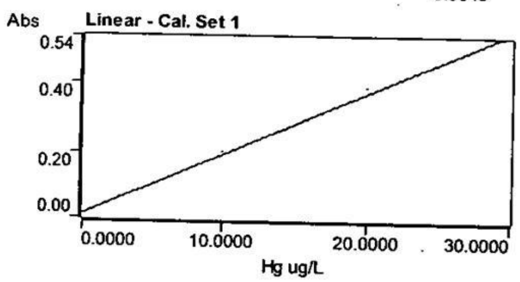
Arsenic was detected in seven out of the sixteen locations of the sampling sites. The highest was from Anyinam with a level of 0.011 mg/kg and the lowest from Kibi with a level of 0.0003 mg/kg. In general, the arsenic levels detected were very low though there are no standards to compare with. Arsenic was detected in two locations at Anyinam and Kwabeng and three locations in Kibi. From Figure 4.5 the highest arsenic concentration was at Anyinam (0.0110 mg/kg) and the lowest in Kibi (0.0003 mg/kg). Comparing with Codex standard limit for natural mineral water of 0.01mg/kg conclusion can be made in that all the levels detected were acceptable.

Arsenic, a naturally occurring metal within the earth crust and it's extensively dispersed in the environment. Interference of humans has intensified its pollution although natural actions of microorganisms and mineralization augment its movement within the environment. Different concentrations of lead, arsenic etc. (inorganic parameters) are mostly made to go through tailings after the extraction of the valuable metals from the ores, and these tailings are later made bare to the climatic conditions leading to the circulation of other compounds and the metals in association with the processing of the ore into water bodies nearby.

Consumption of soil materials and ground and surface sources of water containing elevated concentrations of arsenic from mine waste is the primary point of exposure to arsenic to the population in general. Arsenic is discharged in elevated levels from oxidized minerals of sulphide during activities of mining, this leads to elevated concentrations in vegetation, soil, ground and surface waters. Land deterioration through soil erosion, loss of vegetation cover, contamination of soil and water with arsenic from poor management of tailings of processed ores and waste from mines are the effects of mining in Ghana. School compounds, farm lands and communities around mining sites, elevated arsenic levels have been recorded within Obuasi, Ghana, a mining (Kumi-Boateng, 2007).

Cancer of the liver and bladder, circulatory problems, skin and lung lesions is some of the effects on human health due to exposure to arsenic. A study in parts of Amansie west in the Ashanti region of Ghana showed Buruli Ulcer prevalence in the settlements along arsenic enriched drainage channels and farmlands. Considerable groups of citizens from Ghana and Bangladesh whose drinking water contains arsenic have exhibited these signs (Kumi-Boateng, 2007).

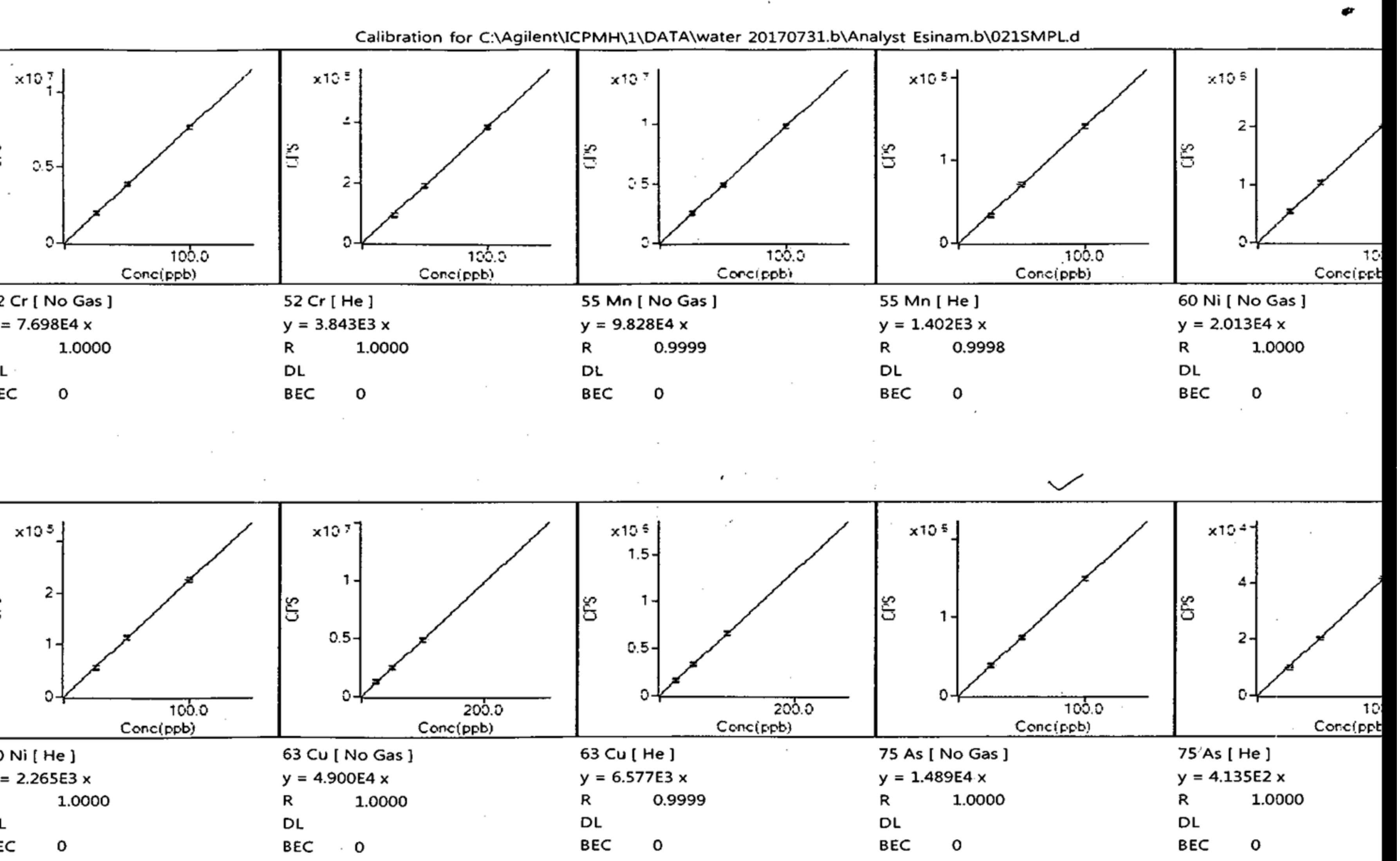
	0.1944	0.2002	8/2/2017	8:58:20 AM	
STANDARD 2	20.0000	0.9	0.3852	0.0061	
	Readings				
	0.3820	0.3851	0.3886	8/2/2017	8:59:44 AM
STANDARD 3	30.0000	0.5	0.5367	0.0063	
	Readings				
	0.5340	0.5372	0.5390	8/2/2017	9:01:12 AM



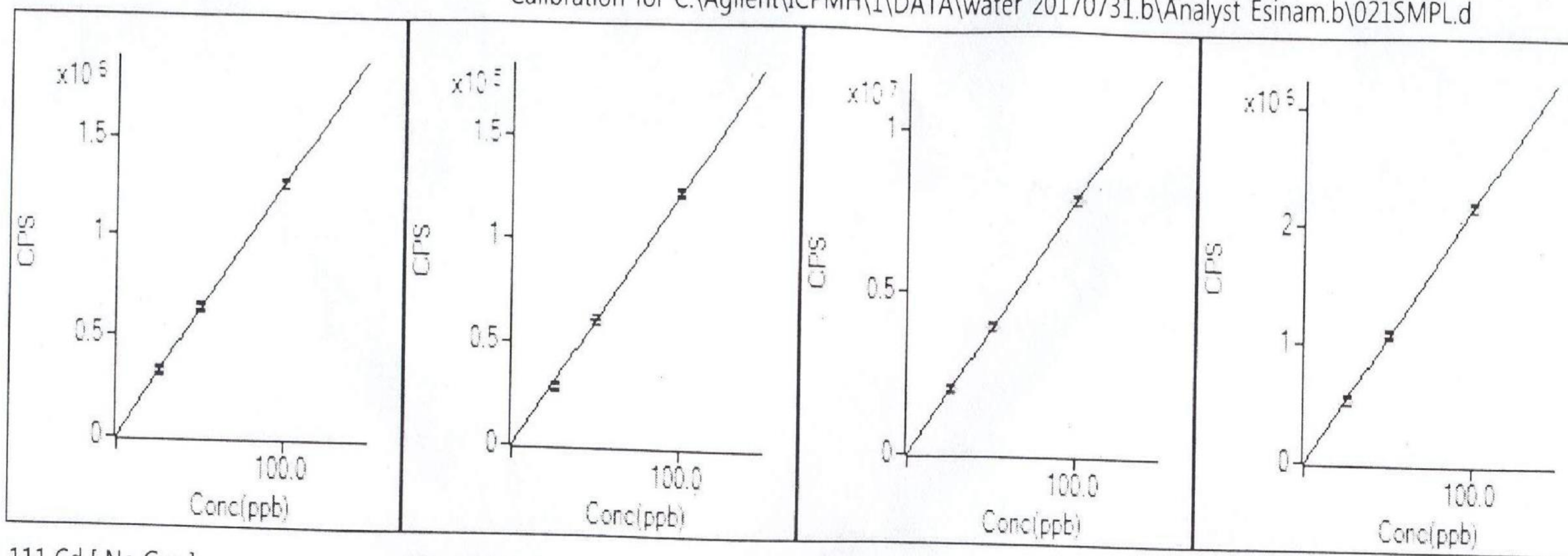
Curve Fit = Linear
Characteristic Conc = -0.4384 ug/L
r = 0.9985
Calculated Conc = -0.5125 10.3438 20.8498 29.3188
Residuals = 0.5125 -0.3438 -0.8498 0.6812

Abs = 0.01789 x C + 0.01224

Cleaning	-0.1816	23.6	0.0090	0.0006	
	Readings				
	0.0109	0.0093	0.0067	8/2/2017	9:05:02 AM
water	-0.3746	9.2	0.0055	0.0004	
	Readings				
	0.0051	0.0055	0.0061	8/2/2017	9:06:06 AM
Acid blk	-0.3212	3.7	0.0065	0.0004	
	Readings				
	0.0068	0.0063	0.0064	8/2/2017	9:07:24 AM
Sample blk	-0.2218	11.9	0.0083	0.0010	
	Readings				
	0.0075	0.0094	0.0080	8/2/2017	9:11:32 AM
10ppb Hg std	10.8926	2.2	0.2071	0.0024	
	Readings				
	0.2018	0.2094	0.2102	8/2/2017	9:17:12 AM
water	-0.3155	4.9	0.0066	-0.0003	
	Readings				
	0.0069	0.0065	0.0063	8/2/2017	9:20:10 AM
Dorm 4	10.4411	2.6	0.1990	0.0041	
	Readings				
	0.1942	0.1985	0.2043	8/2/2017	9:21:54 AM
water	-0.3498	9.0	0.0060	0.0035	
	Readings				


Calibration for C:\Agilent\ICPMH\1\DATA\water 20170731.b\Analyst Esinam.b\021SMPL.d
2 Cr [No Gas]
= 7.698E4 x
1.0000
L
EC 0
52 Cr [He]
y = 3.843E3 x
R 1.0000
DL
BEC 0
55 Mn [No Gas]
y = 9.828E4 x
R 0.9999
DL
BEC 0
55 Mn [He]
y = 1.402E3 x
R 0.9998
DL
BEC 0
60 Ni [No Gas]
y = 2.013E4 x
R 1.0000
DL
BEC 0
) Ni [He]
= 2.265E3 x
1.0000
L
EC 0
63 Cu [No Gas]
y = 4.900E4 x
R 1.0000
DL
BEC 0
63 Cu [He]
y = 6.577E3 x
R 0.9999
DL
BEC 0
75 As [No Gas]
y = 1.489E4 x
R 1.0000
DL
BEC 0
75 As [He]
y = 4.135E2 x
R 1.0000
DL
BEC 0
Conc(ppb)
CPS

Calibration for C:\Agilent\ICPMH\1\DATA\water 20170731.b\Analyst Esinam.b\021SMPL.d



111 Cd [No Gas]	111 Cd [He]	208 Pb [No Gas]	208 Pb [He]
y = 1.268E4 x	y = 1.218E3 x	y = 7.818E4 x	y = 2.154E4 x
R 1.0000	R 0.9999	R 1.0000	R 0.9999
DL	DL	DL	DL
BEC 0	BEC 0	BEC 0	BEC 0

✓

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.0 CONCLUSION

In conclusion the safety and quality of fresh plantains from these three locations leaves much to be desired. This is because mercury was detected in all the samples analysed this makes consumption of fresh plantains from these areas unsafe (taking into consideration the adverse effects of mercury consumption) since it should not have been` there in the first place. And also the level of lead exceeded the recommended standards at certain locations. The levels of arsenic detected in all the samples were acceptable.

5.1.0 RECOMMENDATION

The predestination of mercury in effect is unknown in the environment and the total amount of mercury used for gold recovery cannot be accounted for. For now the government has instituted a task force to these mining towns to stop the operation of these illegal small scale mining activities. There is the need for an immediate attention to lessen and halt lead and mercury dispersion, treatment and circulation to presently sites that are not contaminated to prevent a massive environmental health disaster that may proceed through the continual discharge into the ecosystem.

From the above conclusion it‘s recommended that:

1. The government is to intensify their operation to stop the illegal mining through education of indigenes and involvement of chiefs and stakeholders in such towns.

2. Since the presence of these heavy metals take a long time to decay in the environment and artisanal mining is a major problem the country is battling with now, the regulatory bodies have to set standards for the limits of these metals in fresh plantain.
3. A research to be carried out on the process or procedure to reclaim lands that have been used for such mining processes.

REFERENCES

Afriyie, J. K., Bart-Plange, A. and Asiedu, E. (2016). Effects of degree of ripeness, moisture content and temperature on thermal conductivity of _apantu‘ variety of plantain. Journal of Engineering and Applied Science, Asian Research Publishing Network (ARPN), VOL. 11, NO. 1, ISSN 1819-6608 Pp 1-4.

Afriyie, K., Ganle, J. K., and Adomako, J. A. A. (2016). The good in evil: a discourse analysis of the galamsey industry in Ghana. *Oxford Development Studies*, P1.

Ajani, A. I. (2011). Mechanical properties of plantain pseudostem. Pp. 6-15.

Akinneye, J. O. and Aringbangba, R. O. (2015). Effects of Packaging Materials on Proximate, Mineral and Physicochemical Properties of Plantain Chips *(Musaparadisiaca*) in Storage. *FUTA Journal of Research in Sciences*, Vol. 11, Pp. 55-59.

Attua, E. M., Annan, S. T. and Nyame, F. (2014). Water quality analysis of rivers used as drinking sources in artisanal gold mining communities of the Akyem-Abuakwa area: A multivariate statistical approach. *Ghana Journal of Geography*, *6*(1), Pp.24-41.

Ayanwale, A.B, Fatumbi A.O and Oja M. (2016) Innovation Opportunities in Plantain Production in Nigeria. Guide Book 1. *Forum for Agricultural Research in Africa (FARA), Accra Ghana*. Pp. 2-10

Baah-Ennumh, T. and Forson, J. A. (2017).The impact of artisanal small-scale mining on sustainable livelihoods: A case study of mining communities in the TarkwaNsuaem municipality of Ghana. *World Journal of Entrepreneurship, Management and Sustainable Development*, *13*(3), Pp1-3.

Bansa, D. K., Awua, A. K., Boatin, R., Adom, T., Brown-Appiah, E.C., Amewosina, K.K., Diaba**,** A., Datoghe, D. and Okwabi, W. (2017).Cross-sectional assessment of infants' exposure to toxic metals through breast milk in a prospective cohort study of mining communities in Ghana. *BMC public health*, *17*(1), P2.

Beccaloni, E., Vanni, F., Beccaloni, M. and Carere, M. (2013). Concentrations of arsenic, cadmium, lead and zinc in homegrown vegetables and fruits: estimated intake by population in an industrialized area of Sardinia, Italy. *Microchemical Journal*, *107*, Pp190.

Biederlack, L. and Rivers, J., 2009. *Comprehensive Food Security & Vulnerability Analysis (CFSVA): Ghana*. United Nations World Food Programme.

Bempah, C. K. and Ewusi, A. (2016). Heavy metals contamination and human health risk assessment around Obuasi gold mine in Ghana. *Environmental monitoring and assessment*, *188*(5), Pp 2-3.

Bill and Melinda Gates Foundation (2014). Multi crop value chain phase II Ghana plantain. Available at https://agriknowledge.org/files/dr26xx473 [Accessed on May 31, 2017].

Boadi, S., Nsor, A. C., Antobre, O. O. and Acquah, E. (2016). An analysis of illegal mining on the Offin shelterbelt forest reserve, Ghana: Implications on community livelihood. *Journal of Sustainable Mining*, Vol. 15(3), Pp.115-119.

Bortey-Sam, N., Nakayama, S.M., Akoto, O., Ikenaka, Y., Fobil, J.N., Baidoo, E., Mizukawa, H. and Ishizuka, M., (2015). Accumulation of heavy metals and metalloid in foodstuffs from agricultural soils around Tarkwa area in Ghana, and associated human health risks. *International journal of environmental research and public health, 12(8),* Pp.8811-8827.

Bortey-Sam, N., Nakayama, S. M., Ikenaka, Y., Akoto, O., Baidoo, E., Yohannes, Y. B. and Ishizuka, M. (2015). Human health risks from metals and metalloid via consumption of food animals near gold mines in Tarkwa, Ghana: Estimation of the daily intakes and target hazard quotients (THQs). *Ecotoxicology and environmental safety*, *111*, Pp.160-161.

Bortey-Sam, N., Nakayama, S. M., Akoto, O., Ikenaka, Y., Fobil, J. N., Baidoo, E., Mizukawa, H. and Ishizuka, M. (2015). Accumulation of heavy metals and metalloid in foodstuffs from agricultural soils around Tarkwa area in Ghana, and associated human health risks. *International journal of environmental research and public health*, *12*(8), Pp. 8811-8827.

BS EN 13806:2002 Foodstuffs- Determination of trace elements- Determination of mercury by cold vapour atomic absorption spectrometry (CVAAS) after pressure digestion.

BS EN 14084:2003 Foodstuff- Determination of trace elements-Determination of lead, cadmium, zinc, copper and iron by atomic absorption spectrometry (AAS) after microwave digestion.

Castilhos, Z., Rodrigues-Filho, S., Cesar, R., Rodrigues, A. P., Villas-Bôas, R., de Jesus, I., Lima, M., Faial, K., Miranda, A., Brabo, E. and Beinhoff, C. (2015). Human exposure and risk assessment associated with mercury contamination in artisanal gold mining areas in the Brazilian Amazon. *Environmental Science and Pollution Research*, *22*(15), Pp.1-2.

Codex Alimentarius, International food standards (1993). General standard for contaminants and toxins in food and feed. Codex Standard 193-1995, Pp. 49.

Cobbina, S. J., Duwiejuah, A. B., Quansah, R., Obiri, S. and Bakobie, N. (2015) Comparative Assessment of Heavy Metals in Drinking Water Sources in Two Small-Scale Mining Communities in Northern Ghana. *International journal of environmental research and public health*, Vol *12*(9), Pp. 10620-10634.

Crawford, G. and Botchwey, G. (2017). Conflict, collusion and corruption in small-scale gold mining: Chinese miners and the state in Ghana. *Commonwealth & Comparative Politics*, Pp.1-2.

Dankyi, A.A., Dzomeku, B.M., Anno-Nyako, F.O. and Adu-Appiah, A., Gyamera-Antwi. 2007. Plantain production practices in the Ashanti, Brong-Ahafo and Eastern regions of Ghana. *Asian Journal of Agricultural Research*, *1*(1), Pp.1-9.

Doke, D. A. and Gohlke, J. M. (2014). Estimation of human health risk from exposure to methylmercury via fish consumption in Ghana. *Journal of Health Pollution*, Vol. *4*(6), Pp.18-25.

Dzomeku, B.M., Bam, R.K., Abu-Kwarteng, E. and Ankomah, A.A., 2006. Comparative study on the nutritional values of FHIA-21 (Tetraploid Hybrid) and apem (Triploid french plantain) in Ghana. J. *Plant Sci*, *1*, Pp.187-191.

Endo, T., Hayasaka, M., Ogasawra, H., Kimura, O., Kotaki, Y. and Haraguchi, K. (2015). Relationships among mercury concentration, and stable isotope ratios of carbon and nitrogen in the scalp hair of residents from seven countries: Effects of marine fish and C4 plants consumption. *PloS one*, Vol. *10*(6), P.e0128149.

Falola, A. O., Olatidoye, O. P., Adesala, S. O. and Daramola, O. (2011). Effect of Different Processing Methods on Proximate, Functional and Pasting Properties of Plantain Flour. *Pakistan Journal of Nutrition 13,(12)*Pp 432

Gibb, H. and O'Leary, K. G. (2014). Mercury exposure and health impacts among individuals in the artisanal and small-scale gold mining community: a comprehensive review. *Environmental health perspectives*, *122*(7), Pp.667.

Hadzi, G. Y., Essumang, D. K. and Adjei, J. K. (2015). Distribution and Risk Assessment of Heavy Metals in Surface Water from Pristine Environments and Major Mining Areas in Ghana. *Journal of Health and Pollution*, Pp. *5*-9.

Hong, Y.S., Song, K.H. and Chung, J.Y., 2014. Health effects of chronic arsenic exposure. *Journal of preventive medicine and public health*, *47*(5), P.245.

Kumi-Boateng, B. (2007). Assessing the spatial distribution of arsenic concentration from goldmine for environmental management at Obuasi, Ghana. *International Institute for Geoinformation Sciences and Earth Observation: Enschede, The Netherlands*.

Li, N., Wang, J. and Song, W. Y. (2015). Arsenic uptake and translocation in plants. *Plant and Cell Physiology*, *57*(1), Pp.4-13.

Mason, L. H., Harp, J. P. and Han, D. Y. (2014). Neurotoxicity: neuropsychological effects of lead toxicity. *BioMed research international*, *2014*.

Mantey, J., Nyarko, K. and Owusu-Nimo, F. (2016). Costed reclamation and decommissioning strategy for galamsey operations in 11 selected MDAs of the Western region, Ghana. P1. Available at https://www.theigc.org/wpcontent/uploads/2017/01/Mantey-et-al-2016-Final-report.pdf [Accessed on May 7, 2017].

Meng, M., Li, B., Shao, J. J., Wang, T., He, B., Shi, J. B., Ye, Z.H. and Jiang, G. B. (2013). Accumulation of total mercury and methylmercury in rice plants collected from different mining areas in China. *Environmental Pollution*, vol. 184 Pp.179180.

Molina-Villalba, I., Lacasaña, M., Rodríguez-Barranco, M., Hernández, A.F., GonzalezAlzaga, B., Aguilar-Garduño, C. and Gil, F., 2015. Biomonitoring of arsenic, cadmium, lead, manganese and mercury in urine and hair of children living near mining and industrial areas. *Chemosphere*, *124*, Pp.83-91.

Nascimento, C. R. B. and dos Reis Martinez, C. B. (2015). Daily intake of lead in Wistar rats at different ages: Biochemical, genotoxic and physiological effects. *Environmental toxicology and pharmacology*, Vol. *41*, Pp. 132.

Nelson, S. C., Ploetz, R. C. and Kepler, A. K. (2006). Species profiles for Pacific island agroforestry. *Morinda Citrifolia,15* Pp. 5.

Niane, B., Guédron, S., Moritz, R., Cosio, C., Ngom, P. M., Deverajan, N., Poté, J. (2015). Human exposure to mercury in artisanal small-scale gold mining areas of Kedougou region, Senegal, as a function of occupational activity and fish consumption. *Environmental Science and Pollution Research*, *22*(9), Pp. 1-2.

Nukpezah, D., Rahman, F.A. and Koranteng, S.S., 2017. The Impact of Small Scale Mining on Irrigation Water Quality in Asante Akim Central Municipality of Ghana. *West African Journal of Applied Ecology, 25(2),* Pp.49-67.

Oko, A. O., Famurewa, A. C. and Nwaza, J. O. (2015). Proximate composition, mineral elements and starch characteristics: Study of eight (8) unripe plantain cultivars in Nigeria. *British Journal of Applied Science & Technology*, *6*(3).

Punshon, T., Jackson, B. P., Meharg, A. A., Warczack, T., Scheckel, K. and Guerinot, M. L. (2016). Understanding arsenic dynamics in agronomic systems to predict and prevent uptake by crop plants. *Science of the Total Environment*,*581*, Pp. 211-212.

Rai, S., Gupta, S. and Mittal, P. C. (2015). Dietary intakes and health risk of toxic and essential heavy metals through the food chain in agricultural, industrial, and coal mining areas of northern India.*Human and Ecological Risk Assessment: An International Journal*, *21*(4), Pp. 916.

Rajaee, M., Obiri, S., Green, A., Long, R., Cobbina, S.J., Nartey, V., Buck, D., Antwi, E. and Basu, N., 2015. Integrated assessment of artisanal and small-scale gold mining in Ghana—Part 2: Natural sciences review. *International journal of environmental research and public health,* 12(8), Pp.8971-9011.

Swennen, R. and Ortiz, R. (1997). *Morphology and growth of plantain and banana*. International Institute of Tropical Agriculture (IITA) Pp2-6

WHO (2015). Lead exposure in African children contemporary sources and concerns. Available at http://apps.who.int/iris/bitstream/10665/200168/1/9780869707876.pdf [Accessed on June 8, 2017].

Wilson, M. L., Renne, E., Roncoli, C., Agyei-Baffour, P. and Tenkorang, E. Y. (2015). Integrated assessment of artisanal and small-scale gold mining in Ghana—Part 3:

Social sciences and economics. *International journal of environmental research and public health*, *12*(7), Pp. 1-2.

Zhao, F. J., Ma, J. F., Meharg, A. A. and McGrath, S. P. (2008). Arsenic uptake and metabolism in plants. *New Phytologist*, *181*(4), Pp. 1-2.

APPENDIX

Table 1: Heavy metal concentrations of the various locations within the towns are given in the table below.

Area code	Lead mg/kg	Mercury mg/kg	Arsenic mg/kg
ANYINAM 1	-	0.1340	0.011
ANYINAM 2	-	0.1010	-
ANYINAM 3	-	0.1140	-
ANYINAM 4	0.0130	0.1391	0.0019
ANYINAM 5	-	0.1139	-
ANYINAM 6	0.0021	0.1142	-
Mean	**0.0025**	**0.1194**	**0.0022**
Standard deviation	**0.005204**	**0.014326572**	**0.004401704**
Coefficient of variation	**206.7817**	**12.00215**	**204.7304**
KWABENG 1	-	0.0940	-
KWABENG 2	-	0.1280	0.0030
KWABENG 3	0.0020	0.1650	0.0030
KWABENG 4	-	0.1645	**-**
KWABENG 5	-	0.0939	**-**

KWABENG 6	0.0048	0.1273	-
Mean	**0.0011**	**0.1287**	**0.0010**
Standard deviation	**0.00196638**	**0.031676074**	**0.001549193**
Coefficient of variation	**173.5045**	**24.59641**	**154.9193**
KIBI 1	-	0.0980	0.0003
KIBI 2	0.0520	0.1300	0.0040
KIBI 3	-	0.0972	-
KIBI 4	0.0505	0.1240	0.0030
Mean	**0.0256**	**0.1123**	**0.0018**
Standard deviation	**0.02959554**	**0.017153037**	**0.00198053**
Coefficient of variation	**115.4948**	**15.2743**	**108.5222**

Significant differences between the towns

Metal	**p-value**
Pb	0.1807
Hg	0.0723
As	0.7679

Because these values are greater than 0.05 the null hypothesis is not valid or in other the words there is no difference in the concentration of the metals in the three towns (level of metals occur in the same quantity in those three environs)