KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

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DEPARTMENT OF FOOD SCIENCE AND TECHNOLOGY

EXPOSURE ASSESSMENT OF LEAD IN RICE

BY

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DECLARATION

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

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ABSTRACT

The Asante Akim Central municipality, with Konongo as its capital is known for its small scale mining activities. It was expected that human and commercial activities, as well as deposition of heavy metals in the environment that may lead to contamination of the food chain with heavy metals. The main occupation of the inhabitants is farming which include rice farming, hence the need to perform exposure assessment of lead (Pb) in rice in the area. The main objective of this research was to evaluate lead exposure and potential health risk of consuming local rice produced in the Asante- Akim area. The levels of Pb were compared with that of the WHO/FAO recommended values. Pb content in rice ranged from 0.06 to 0.70 mg/Kg with a mean of 0.235 mg/kg. With 70 % of the samples, the concentration of Pb was below the recommended values proposed by the WHO/FAO guidelines. The chronic daily intake (CDI) of Pb was calculated based on the rice consumption data to be 1.72857×10^{-5}mg/Kg bw/day for adults. The exposure assessment in mean levels showed that health risk associated with Pb through the consumption of rice was present. Even the 5th percentile which represents the lowest exposed consumers showed that there is significant risk associated with Pb through rice consumption. It is recommended that consumer wash rice thoroughly and cook before consuming since these practices help reduce heavy metal content.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AIC: Akaike Information Criterion

FAO: Food and Agriculture Organization

WHO: World Health Organization

ATSDR: Agency for Toxic Substances and Disease Registry

MAC: Maximum allowable concentrations

LOD: Limits of Detection

EPA: Environmental Protection Agency

USEPA: United State Environmental Protection Agency

PTWI: Provisional Tolerable Weekly Intake

JECFA: Joint FAO/WHO Expert Committee on Food Additives

CDI: Chronic Daily Intake

ADI: Acceptable Daily Intake

IARC: International Agency for Research on Cancer

NTP: National Toxicology Program

B.D.H: British Drug House pH:

Hydrogen Ion Concentration

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Risk assessment as one of the three main stages in risk analysis, is the scientific evaluation of the probability of occurrence of a known or potential adverse health effect. It is a science-based task of measuring and describing the nature of the risk being analyzed and is performed during the risk assessment phase of risk analysis (Ofosu, 2014). Risk is therefore, the possibility that an event will occur and adversely affect the health of humans. Risk assessment should then be carried out to ensure the Health and
Safety of humans. Risk assessment consists of four main steps which include Hazard Identification, Hazard Characterization, Exposure Assessment, and Risk Characterization.

Pollution within mining communities of Ghana by heavy metals has been extensively studied by previous researchers, (Armah *et al.*, 2010; Owusu-Donkor, 2011; Zango *et al.*, 2013; Anane-AcheampongOsisiadan, *et al*., 2013; Kyeremateng, 2013).

It is a known fact that the problem of soil contamination by heavy metals actually exist in some parts of the Ashanti region. This includes Zn, Cu, Fe, Cd, Pb and Mn of which high levels above permissible limits set by FAO/WHO have been reported for Cd and Pb in soils in the Asante Akim North area (Owusu-Donkor, 2011).

Chemicals used for mining may pollute water bodies in mining areas due to the mining activities, and pollution of water sources by mining poses danger to the health of the local communities, for example damnification of the central nervous system, reproduction disorders and mortality in even the communities nearby and some extended ones also. As a result of pollution from mining activities, biodiversity may also be decreased (AnaneAcheampong Osisiadan *et al.*, 2013).

Minerals extracted through mining activities are of immense importance to a country since it contributes greatly to socio-economic development in the nation. However, the exploitation of minerals such as gold puts immense stress on air, water, soil and vegetation and also poses potential and real hazards to human health. This is due to the production of wastes which are deposited in landfills adjacent to farmlands. Mine wastes may contain heavy metals which are safe for consumption by man and animals at permissible levels in crops. Mining activities and many industrialized processes give rise to contamination of heavy metals such as cadmium (Cd), arsenic (As), zinc (Zn) and lead (Pb) in soil, water and air. The contaminants can be accumulated and transferred into plants and crops such as rice (Huang *et al.*, 2013).

A number of studies have already shown that mining activities can emit appreciable quantities of heavy metals into the atmosphere, and the deposition of emitted metals can result in increased metals concentrations in surface soils in farmlands nearby the mines and thus enters the food chain eventually.

Rice is a major commodity in world trade, and it is known to provide about 20 % of the world's dietary energy supply. It is utilized mostly at the household level, where it is consumed as boiled or fried with stew.

Minerals like calcium, magnesium and phosphorus are present along with some traces of iron, copper, zinc and manganese in rice but an increase in the level of the heavy metals needed in trace amounts could be dangerous to health (Udedi, 2003; Ogwuegbu and Muhanga, 2005).

Consequently, heavy metals may pose health risk to the inhabitants living closer to the mining areas. In this study, heavy metal content of rice which is caused by mining, human and other commercial activities within the catchment of the Asante Akim area is being investigated and the potential health risk of heavy metals to the indigenes of the area in relation to the consumption of local rice, evaluated.

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1.2 STATEMENT OF PROBLEM

Rice is one of the most widely consumed foods in the world and also one of nature's great scavengers of metallic compounds. In Ghana, contamination of sediments and surface water bodies has particularly been encountered in communities where gold is mined (Kuma and Young, 2004). The common methods of growing rice often involves flooding the field, and this increases the formation of soluble metallic compounds that can easily be absorbed by the rice plant. Higher concentrations of lead can potentially be toxic to humans and animals. In view of that, a study on the level of pollution of this metal, lead (Pb) is deemed important, especially in communities where lead contaminated water is used for agricultural purposes.

According to Tatlow (2014), heavy metal intake through food is a long term intoxication process by small amounts, and this means that it is a very slow accumulation process, and the excretion and drainage is even slower.

About a third of these heavy metals absorbed by the human body will concentrate in the kidneys and a quarter in the liver. The damage to human health is formidable, (www.thechristianherald.info).

Lead is toxic even at low levels of exposure, which is able to enter the food chain, and that the levels can build up in the body through consistent exposures and the effects are irreversible (ATSDR, 2012).

Food chain contamination by heavy metals have become a trending issue in recent times because of their potential accumulation in biosystems through contaminated water, air ad soil. Growth media for crops (soil, nutrient solutions, air) serve as their main source of these heavy metals from which the heavy metals are taken up by the roots or the foliage (Lokoshwad and Chandrappa, 2006)

Currently, concerns are being raised about possible contamination of food crops by heavy metals as a result of pollutants that are produced from the mining sector.

There is also increasing fear that, the mining activities are causing significant heavy metal contamination to the environment and plants eventually act as a channel through which pollutants are transferred into the food chain.

Moreover, concerns have been raised recently over levels of heavy metals in the environment where scientists suggest that foodstuff from mining communities may contain toxic amounts of these heavy metals (Anane-Acheampong Osisiadan *et al.*, 2013). Thus the urgent need to evaluate the potential health risk of heavy metals to the local inhabitants of these mining sites in relation to the consumption of local rice and make necessary recommendations for sustainable rice production in Ghana.

1.3 **Main Objective**

The main objective of this project is to evaluate the lead exposure and potential health risk of consuming local rice produced in the Asante- Akim area.

1.4 **Specific objectives**

- To measure the levels of lead (Pb) in rice cultivated within the Asante-Akim Central Area.
- To estimate the magnitude of exposure to lead and the risk of adverse health effect to humans through the consumption of rice cultivated near the mining sites in the area.

1.5 **Justification of the Research**

According to Bridgen *et al.* (2014), a study was conducted to investigate surface soils for metal contamination. The study also sought to determine metal concentrations in water and in rice crops, all in an area where an industrial complex is situated in Hunan Province, China. The industrial complex consisted of facilities that undertake smelting and processing of non-ferrous metals. It was noted that rice that was cultivated in locations closer to the mining complex had high concentrations of lead, cadmium and arsenic. It was also observed that rice that was collected from two control areas contained lower levels of lead and cadmium. They attributed the results to the fact that the two control areas are located a bit farther away from the mining complex, hence the lower levels of lead and cadmium as compared to the test areas that were closer to the complex. Bridgen *et al.*

(2014) again pointed out that, metals such as lead and cadmium are very toxic and are able to bioaccumulate. As a result, exposure to even low levels of these metals can lead to build up in the body. Therefore, rice that contains lead and cadmium at higher concentrations poses health risk to consumers, especially in cases where the concentrations are above the maximum permitted level for human consumption (Bridgen *et al.*, 2014).

Huang *et al.* (2013) frankly stated that, adverse effects of exposure of lead and cadmium to human health had been confirmed. It was also indicated that, Lead (Pb) was also shown to be associated with damage to the central nervous system, which may lead to reduced intelligence quotients in children**.** Another observation was that, the main exposure pathway to the whole population was through intake of food**.**

It was therefore found to be important to state the hypothesis as; rice cultivated near mining sites has high concentrations of lead and therefore has the potential to pose health risk to consumers. However, only a couple of studies have been done on the levels of heavy metals including lead in rice, and exposure assessment in the Asante Akim area which have been reported.

For these reasons, this project has chosen rice cultivated around mining areas in the Asante Akim Central municipality to analyze lead in rice and evaluate the exposure with respect to the daily consumption of rice for inhabitants in the area.

CHAPTER 2

LITERATURE REVIEW

2.1 Background

This chapter reviews some related theoretical and empirical literature regarding the heavy metal exposure and potential health risk of consuming local rice produced. The main concern will also be in relation to the measure of the levels of lead (Pb) in rice cultivated within the Asante-Akim Central Area. It also concentrates on the estimation of the magnitude of exposure to lead to humans through the consumption of rice cultivated near the mining sites in the area. Moreover, it uses this information to assess the potential health risks of lead on consumers of the locally cultivated rice.

2.2 Risk Assessment

Risk assessment as part of risk analysis, is the scientific evaluation of the probability of occurrence of a known or potential adverse health effect. It is a science- based task of measuring and describing the nature of the risk being analyzed and is performed during the risk assessment phase. Risk assessment should then be carried out to ensure the Health and Safety of humans. Risk assessment consists of four main steps which include Hazard Identification, Hazard Characterization, Exposure Assessment and Risk characterization.

2.2.1 **Hazard Identification**

This involves the determination of whether a particular chemical or biological agent is capable of causing a particular adverse health effect which may be present in a particular food or a group of foods. In the case of chemical agent, the process examines the available scientific data for a given chemical or group of chemicals and develops a weight of evidence to characterize the link between the negative effects and chemical agent. Exposure to an agent may lead to different adverse health effects such as diseases, reproductive defects, formation of tumors, death and other effects (Huang *et al*., 2013).

Sources of data could be clinical studies on humans (statistically controlled), epidemiological studies or data from animal studies. Epidemiological studies are thus appropriate for the research since it involves a statistical evaluation of human populations to examine there is association between exposure to Pb and a human health effect.

2.2.2 **Hazard Characterization**

This is the second step in risk assessment, and can be defined as qualitative and/or quantitative evaluation of the nature of the adverse health effect associated with the biological, physical or chemical agent that may be present in a particular food or groups of foods. Questions asked at this stage include, what are the health problems at different exposures. Dose response is usually performed at this stage. Dose response relationship describes how the likelihood and severity of adverse health effects are related to the amount and condition of exposure to an agent.

The shape of dose response relationship depends on the agent, the kind of response whether tumor, disease etc, and the experimental subject. Generally it is expected that as the dose increases, the measured response also increases. However there may be no response at low doses.

2.2.3 Exposure Assessment

Exposure Assessment which is the third step involves qualitative and/or quantitative evaluation of the nature of the likelihood of intake of biological, chemical or physical agents, either through food or other sources. This stage answers the question, how much of the pollutant are people exposed to during a specific time period, and how many people are exposed. Exposure assessment is the process of measuring or estimating the magnitude, frequency and duration of human exposure to an agent in the environment, or estimating future exposures for an agent that has not yet been released. Some discussions that may be included in exposure assessment are nature, size and types of human populations exposed to the agent and also the uncertainties in them. Although exposure can be measured directly, it is mostly estimated indirectly by considering the measured concentrations in the environment, considering models of chemical transport and the fate in the environment, and also by considering the estimates of human intake over time. Exposure assessment also considers the exposure pathway as well as the exposure route (Sipter *et al*., 2008).

2.2.3 **Risk characterization**

The final stage in risk assessment is Risk characterization whereby the potential chemical/agent intake is compared with the toxicologically acceptable intake limit

(Ofosu, 2014). Risk characterization conveys the risk assessor's judgment as to the nature and presence or absence of risks. Information on how the risk was assessed, where assumptions and uncertainties still exist and also where policy choices may be made are all provided. This final stage answers the question, what is the extra risk of health problems in the exposed population.

Risks to a population are determined by either direct observation or by the use of mathematical models and a series of assumptions to predictor guess correctly the potential risk to humans. Whatever ways risks are defined or quantified, they are precisely expressed as a probability of effects associated with a particular activity. Risk or probability is expressed as a fraction without units from 0 to 1. A probability of 1 is an indication of an absolute certainty that an event or outcome will occur. Scientific notation is generally used to present quantitative risk information. For example 1E-01, 1E-02 etc with 1E-06 being the lowest that risk can be expressed (www.rais.ornl.gov.).

2.3 Soil Pollution

In the course of the exploitation of heavy metal mining, a mining area and its surrounding environment may become affected by serious pollution from heavy metals. Undoubtedly, the heavy emissions of metals can contaminate groundwater and surface water, agricultural soils, and food crops which in turn also pose a health risk to residents near mining areas. Since 1970, mining activities entered a period of rapid development worldwide. Numerous reports indicate that water, soil, vegetables and dust have been heavily polluted by lead (Pb), arsenic (As), copper (Cu), chromium (Cr), zinc (Zn) and cadmium (Cd) near the mining areas (Liu *et al*., 2005). According to the World Health Organisation (WHO, 1993) study of the evaluation of food additives and contaminants, Pb, As, Cu, Cr and Cd are important toxic heavy metals, and have been identified as health risks in several countries. For instance, South China has encountered serious environmental problems posed by these heavy metals in recent years. This emanates from the work of Liu *et al.*, (2005) which noted that the mean concentrations of Pb, As and Cd in the soils of Chenzhou city in South China were 751.98 mg/kg, 459.02 mg/kg, and 6.77 mg/kg, respectively. Other subsequent studies such as Zhuang *et al.* (2009) concluded that the heavy metal concentrations in vegetables (mg/kg, dry weight basis) ranged from

5.0 to 14.3 for Cu, 34.7 to 170 for Zn, 0.90 to 2.23 for Pb, and 0.45 to 4.1 for Cd around Dabaoshan mine in Guangdong, South China.

Moreover, many researchers and authors are of the view that mining, industrial processing, pesticide and chemical fertilizer, and automobile exhaust are the major sources of heavy metal contamination in the environment. Such studies like Sipter *et al*. (2008) and Wang *et al*. (2005) have consented that these metals may accumulate to a toxic concentration level which can lead to impairment in the quality of human life. Also, these threats to human health from heavy metals are associated with exposure to Pb, Cd and Hg. For instance, exposure to Cd may pose adverse health effects, including kidney damage and possibly also bone effects and fractures (WHO, 1993). Similarly, Pb is highly neurotoxic and its adverse effects can be expressed in multiple organ systems throughout the lifespan (WHO, 1990). Long-term exposure to Pb may lead to memory deterioration, prolonged reaction times and reduced ability to understand. According to J¨arup (2003), children may be affected by behavioral disturbances and learning and concentration difficulties. The dangers and hazards of exposure to Cr, Cu and Zn also have revealed by the United States' Environmental Protection Agency in their studies in the year 2000. According that study, Cr, Zn and Cu have non-carcinogenic hazardous effects to human health when exposures exceed the tolerable reference dose.

The other significant source of heavy metal contamination of the soil is disposal of electronic waste. The disposal of electronic and electric waste (E-waste) has caused a serious environmental problem, including the pollution of the soil for the cultivation of crops like rice. For instance, in China, rapidly increasing amount of E-waste from both domestic generation and illegal imports has been cited by United Nation Environmental Programme (UNEP, 2005) as a serious hazard for the development of the country's agriculture. According to Hicks *et al*. (2005), a large amount of E-waste have been dismantled in Taizhou, Zhejiang Province since the 1990s, which is a well-known Ewaste recycling centre in southeast China. In fact, hundreds of small and open specialized E-waste recycling shelters or yards appear in this area and it is believed that many toxic ingredients such as lead, cadmium, beryllium, mercury, polychlorinated biphenyls and brominated flame retardants contained in these E-wastes are deposited in the soil (Schmidt, 2002).

The study by many others reveals that E-waste dismantling sites are usually situated in rural areas, and crops are grown around these areas. In recent times, studies in other jurisdictions have shown that contamination of persistent organic pollutants such as polychlorinated biphenyls and organochlorine pesticides in local food such as rice seeds, hen eggs, and silver carp muscle is worrisome. In the view of many authors, very few studies have investigated the heavy metal contents in crops collected from E-waste dismantling areas and conducted the corresponding risk assessment. According to statistical data from the Food and Agriculture Organization (FAO) (2004), rice nearly provides 30% of the dietary energy supply and 20% of the dietary protein intake around the world. As rice is a staple food for daily consumption in China and other parts of the world, especially in the studied region, heavy metals in rice may contribute a major part to the FAO total daily intake. Therefore, there is an increasing requirement for the study of heavy metal levels in rice sampled from E-waste areas.

As jointly revealed by Gupta and Attreja (1998) and Ja¨rup (2003), soils that have been contaminated by heavy metals from either aerial depositions or irrigation are likely to induce a corresponding contamination in harvested crops. Moreover, their studies have proven that crops in or close to contaminated sites can uptake and accumulate these metals, and then exert potential risk to humans and animals. Malfunction of organs and chronic syndromes may be caused by ingestion of relatively low doses of toxic heavy metals over a long period. The major route for heavy metals exposure to humans is mainly through soil–crop–food pathway. The residual plant components, including hull, straw and the root are partly returned to the soil and partly used as an ingredient in food for livestock, which is also a possible pathway for heavy metals to enter the human body by ingesting contaminated food.

The main route of exposure to these heavy metals into the human body is dietary intake. The other channel is inhalation which can also play an important role in very contaminated sites. This explains why Zhuang *et al*. (2009) asserted that heavy metal concentrations in food products and their dietary intake is very important for assessing their risk to human health. Most research works have focused on the assessment of potential health risks for inhabitants in the vicinity of hazardous sites, such as mines and smelters, because of their exposure to environmental heavy metals via consumption of farm crops which include Zhuang *et al*. (2009), Sipter *et al*. (2008), Cui *et al*. (2004) and

Zheng *et al*. (2007), at least in the last decade. Some researchers have assessed the risk of heavy metals from consuming food grown on soils irrigated with sewage and food chain transfer. In Ghana, the work on the estimation of potential health risks for inhabitants in the vicinity of industrial zone where industrial firms are densely located and there is combined contamination of local grown crops from various industrial is very scanty.

2.4 Heavy Metals in Rice

A number of researches have shown that metal mines can expel significant amounts of metals to the environment and that, the process of depositing the expelled metals can lead to increased metal levels in top soils in the neighborhood of the metal smelters (Douay *et al*., 2009).

Dietary exposure to heavy metals such as lead (Pb), cadmium, zinc, arsenic and copper has been identified as a risk to human health through the consumption of contaminated food (Otitoju *et al.*, 2012).

It has already been noted that rice plants grown in soils that are contaminated by metals can take up metals such as lead among others and especially cadmium. This can lead to increased metal concentrations in the rice grains. The existence of rice with high levels of heavy metals had been reported already in some parts of China by Huang *et al*. (2004). Health risk assessment of heavy metals in rice to the population in Zhejiang, China was a study aimed at analyzing heavy metals in rice from Zhejiang province and evaluating the health risk with respect to daily consumption of rice for adults and children. The researchers of the study noticed a recent concern raised about how likely it is that crops are contaminated by heavy metals. Moreover, the adverse effects of heavy metals exposure to human health had been confirmed**.** The study was undertaken to create awareness of the fact that heavy metals may be accumulated in rice**.** The study was also aimed at providing a platform for comparison of heavy metals in rice in the study area and other regions in

China and beyond. They observed that, the main exposure pathway to the whole population was through intake of food. They therefore found it important to state the hypothesis as, rice has the potential to pose health risk to consumers if it contains heavy metals (Huang *et al.*, 2013). The study showed that after analysis of the rice samples, the highest concentrations recorded for lead (Pb) was 0.220 mg/kg. it was also stated that by comparing the metals in rice with some previous studies showed that, the degree of rice contamination could be evaluated by with the maximum allowable concentrations (MAC) recommended by the Chinese legislation.

It was again stated that, Limits of Detection (LOD) were defined as three (3) times the standard deviation of ten (10) runs of blank measurements, and the LOD of Pb was 0.005 mg/kg. In the survey, the average lead (Pb) was 0.060 mg/kg and ranged from 0.005 to 0.220 mg/kg. Since the current maximum allowable concentration (MAC) is 0.02 mg/kg, 96.4% of the samples were below this figure and therefore acceptable on lead contamination level.

The mean intakes of Pb through the consumption of rice were estimated to be 0.37 mg/kg bw/day for adults and 0.47 mg/kg bw/day for children. It was ascertained that consuming rice cultivated in Zhejiang does not pose any health risk to the population as far as heavy metals are concerned. However, the 97.5th percentile estimates, which represents the highest exposed consumers of Cd and Pb for children and Pb for adults were above the respective safe limits. This is an indication that the inhabitants in metal contaminated areas may experience some adverse health effects (Huang *et al.,* 2013).

According to Bridgen *et al.* (2014), a study was conducted to investigate surface soils for metal contamination. The study also sought to determine metal concentrations in water and in rice crops, all in an area where an industrial complex is situated in Hunan Province, China. The industrial complex consisted of facilities that undertake smelting and processing of non-ferrous metals. In order to determine the concentrations of metals in surface soil, two different soils were used. Soil from regularly cultivated land and what was referred to as uncultivated land; which actually meant soil that was both uncultivated and undisturbed artificially. These lands were found in the neighborhood of the industrial complex with metal smelters and processing facilities.

In determining the significance of water as a carrier of metal contaminants, samples of discharged water from industrial origin, and surface water used for irrigation were analyzed.

In their study, soils from the uncultivated land in areas closer to the complex were found to have higher concentrations of some metals such as Pb, Cd and As among others, compared to the concentrations of metals typically expected in soils from uncultivated areas away from the complex. It was observed that the areas located to the south of the industrial complex and to a lesser extent, the location to the west of the complex had very significant increase in metal concentrations (Bridgen *et al.*, 2004).

It was noted that, the distribution pattern of increased metal concentrations is consistent with atmospheric emissions from the complex. This makes a significant contribution to higher levels of most metals in soils in the areas close to the complex, which includes lead. The results however indicated that there could be other contributing sources of metals to the uncultivated soil in some locations which have not yet been identified. For the following metals; arsenic, cadmium, lead, manganese and zinc, it was observed that, strong correlations of concentrations in uncultivated soils showed a common source. This suggests that, the discharge from the industrial complex may be a major contributory factor to increased concentrations of the metals that were mentioned in uncultivated land in the study area**.** There were similarities observed in the results of soil samples from the fields where rice were cultivated and soil samples from the uncultivated land. There were high concentrations of some metals, especially cadmium as well as lead and zinc. Arsenic and nickel were also found in soils at some locations in some of the rice fields in the neighborhood of the industrial complex. These were considerably higher than the levels that were found in soils samples that were taken from the rice fields in the two control areas which were situated farther away from the complex (Bridgen *et al.*, 2004).

The results also showed that for all the rice field soil samples, which include the ones from the two control areas located approximately 11 km to the southeast and northwest of the complex, the concentrations of the metals were high. Since the concentrations of the metals were high in the soil samples, it could imply that crops including rice that may be cultivated in the areas could also contain high levels of the metals.

In another study by Otitoju *et al.* (2014), the researchers determined the levels of some metals such as cadmium, chromium, arsenic, lead and mercury in locally produced rice samples from the northern region of Nigeria. Ten rice samples were obtained from various locations in Benue, Borno, Kaduna and Nasarawa states. The results showed that the concentrations of lead ranged from 0.311 mg/kg to 0.525 mg/kg in the samples. Average lead (Pb) concentration was 0.260 mg/kg. However, Cd, Cr, As and Hg were not detectable at 0.001 mg/kg. A calculation of weekly intake of rice by an average Nigerian revealed that weekly consumption of lead (Pb) in this locally produced rice exceeded the 0.025 mg/kg WHO/FAO (2002; 2001) provisional tolerable weekly intake of lead (Pb). This is of public health importance as individuals who consume this locally produced rice are at greater risk of lead (Pb) toxicity.

Zazouli *et al.* (2010), in an investigation, surveyed lead and cadmium concentrations of Iranian local rice in the northern part of Iran. In their study, a total of 72 samples were collected from rice farms in Babol region of Mazandaran Province. The rice samples were collected during harvesting of rice in the farms. Two methods were used for cooking; which are Kateh and Pilaw. The grains of raw polished and cooked rice were digested by acid digestion method and then analyzed for Pb and Cd by atomic absorption spectrometry. The results show that average content of Pb in raw polished rice was 11.5 ± 6.4 µg/g dry wt. the minimum and maximum lead (Pb) content in raw polished rice was 2.92 ± 0.8 and 20.26 ± 7.8 µg/g for Tarom Hashemi from Boleh Kola and Fajer from Meson Abad, respectively.

The analysis showed that cadmium was not detectable in all rice samples. The average content of Pb in Pilaw was lower than Kateh in all samples. It was noted that the average content of lead (Pb) was above the FAO/WHO guidelines. This could be attributed to the fact that some amount of Pb was retained in the water that was used to par-boil the rice samples in the pilaw method, and since the water was drained, this could lead to the reduction of Pb content in the rice. In order to assess the safety of dietary intake, weekly intake of lead (Pb) by rice was calculated based on daily consumption of rice, and dietary in (PTWI) established by the JECFA (WHO/FAO). The results showed that the weekly intake lead (Pb) was less than the maximum weekly intake recommended by WHO/FAO. Since the contents of Pb were low, it was expected for the weekly intake to be low as was observed.

In China, some prior studies have shown that residents eating various vegetables will potentially incur major risks to their health through the intake of Pb and Cd contained in the vegetables; the risk to the health of children is higher than that for adults, and the risk for residents of mining areas is much higher than that for residents of a control area (Sun *et al.*, 2013). Other studies have shown that for residents in Japan and Korea, exposure to Cd primarily from a diet that is heavy in rice accounts for 40% and 23% of their total intake of Cd, respectively (Nakadaira and Nishi, 2003). This indicates that arable land near mining areas is easily affected by mining; the surrounding soil can be polluted by sewage irrigation and falling dust.

Data from the United States Integrated Risk Information Database (US IRIS) and WHO show that Pb can damage the brain and nervous system, causing neurological disorders and high blood pressure, and can lead to a slowing of growth in children, hearing impairment, headaches, reduction in learning ability, and abnormal behaviors (USEPA, 2004). The intake of As can cause cancer in internal organs (such as liver, kidney, lung, bladder), and can increase the risk for skin cancer (USEPA, 1993). With regard to the eating habits of residents in the study area, rice is the main cereal crop in Suxian County, and residents treat it as their staple food. The vast majority of local residents grow their own crops as a source of food in the study area, greatly increasing their health risks.

However, because heavy metals have the characteristic that they tend to accumulate and persistent in an environment, the risk of other heavy metal contamination still exists.

Related departments should pay increased attention to the situation, and they should take appropriate measures to address the problem of soil contamination and industrial dust emissions in Suxian County to reduce the harmful effects of heavy metals on people in the area, especially children.

2.5 Lead

Lead is another common heavy metal and it makes headlines as well. According to the International Agency for Research on cancer (IARC), lead is a probable human carcinogen (Group 2A). The National Toxicology Program (NTP) also rates lead as reasonably anticipated to be human carcinogen. Lead has been described as a heavy, low melting, bluish-gray metal that occurs naturally in the earth's crust. It is however seldom found as a metal. It is normally found combined with two or more other elements to form lead compounds (Patil *et al.*, 2006).

Weathering of rocks, chipping of lead-based paints from buildings, bridges and other structures as well as lead that falls to the ground from air in the atmosphere, are the main sources of lead in dust and soils. Industrial activities such as manufacturing of ammunitions, and battery production may also deposit waste that contains lead at landfills. Also disposal of lead ore mining waste and other lead-containing products contribute to lead at landfills in municipalities (ATSDR, 2013).

However, most of the high levels found throughout the environment come from human activities. Lead can enter the environment through emissions from lead mining and other metals, and also from factories that make or use lead, lead toys or lead compounds. It is also established that lead is also released into the air during burning of coal, oil or waste (Singh and Jin, 2014).

For example, lead is found in lipsticks, paints, children's toys and drinking water. Like other metals, lead occurs mainly in the environment through pollution in different ways. It is dispersed throughout the soil, plants, water, air, paints, fuels and other media. Lead has been known to be toxic and therefore needs attention from the regulatory authorities.

Lead can also accumulate in plant products and children's play toys and other materials used by people. Lead is known to be capable of being one of the factors responsible for damaging the human central nervous system. In adults, lead can cause high blood pressure and hypertension (Madyiwa, 2006).

Lead is also known to be toxic even at low levels of exposure, and it is able to enter the food chain and when it does, the levels can build up in the body through repeated exposure and the effects are irreversible (ATSDR, 2012).

It has also been stated that, exposure to Pb can have so many different effects o children's development and behavior as well. In children, even small levels of lead exposure can make them appear inattentive, hyperactive and irritable. When children are exposed to high levels of lead, they may also have problems with reading and learning, delayed growth and hearing loss. Lead is said to be able to cause permanent brain damage and even death at high levels in children (ATSDR, 2007).

Acute high level lead poisoning has been associated with hemolytic anemia. Lead induces anemia through diminishing red blood cell survival in chronic lead poisoning (ATSDR), and lead also has a direct nephropathic effect on the kidney. There has also been evidence of an association between lead exposure and hypertension (Patrick, 2006).

2.6 Mode of Action of Pb

Mode of action is a sequence of key events and processes, which starts with the interaction of an agent and a cell, and continues through operational and anatomical changes, and finally results in cancer formation. Mode of action analysis is based on physical, chemical and biological information that helps to explain the key events in an agent's influence on tumor development. The effect of an agent may be experienced through more than one mode of action (Holstege, 2015).

2.6.1 Mechanism of toxicity

Lead has many adverse mechanisms of toxicity. Lead is particularly toxic to multiple enzyme systems since it has a very high affinity for sulfhydryl groups. Lead toxicity also leads to inhibition of cellular functions that require calcium, since lead binds to calcium activated proteins with higher affinity than calcium (Gillis *et al.*, 2012).

The concentration of lead and calcium ions determines the interaction of lead and calcium with cellular sites. Lead and calcium ions compete at the plasma membrane for transport systems, and this affects their entry or exit. Lead disturbs intracellular calcium homeostasis at the mitochondria, and the endoplasmic reticulum. At the mitochondria, lead interacts with calcium-dependent effector mechanisms such as calmodulin and protein kinase C in the plasma membrane and in neurotransmitter release. Also alteration of protein kinase C compromises second messenger systems within the cell, and leads to further changes in gene expression and protein synthesis.

Lead also has an effect on heme biosynthesis and this leads to anemia at high blood levels and microcytosis at low blood levels as well as increase in the number of red blood cells (Patil *et al.*, 2006). When lead binds to the sulfhydryl group of proteins irreversibly, it causes impaired function. Two key enzymes are compromised by lead; delta aminolevulinic acid dehydratase, which catalyses the formation of porphobilinogen ring, and ferrochelatase, which catalyses the incorporation of iron into the protoporphrin ring. If ferrochelatase is inhibited as in the case of lead toxicity, zinc is substituted for iron and zinc protoporphirin concentrations increase. The result of this is decreased circulating levels of hemoglobin. The inhibition of these enzymes may begin with lead levels as low as 5 µg/dL (Holstege, 2015).

Lead accumulation in bone cells also has toxic effect on the bone status. There are four different types of cells that determine skeletal development and the regulation of skeletal masses. These are the osteoblasts, osteoclasts, lining cells and osteocytes. These cells line and penetrate the mineralized matrix and are responsible for matrix formation, mineralization and bone resorption. All these activities are controlled by both systemic and local factors. Systemic regulators include the parathyroid hormone, 1,25dihydroxyvitamin D-3 and calcitonin. The local regulators include the cytokines and the growth factors.

Lead toxicity may directly or indirectly alter many aspects of bone cell function. In the first instance, lead may indirectly alter bone cell function through changes in the circulating levels of hormones such as 1,25-dihydroxyvitamin D-3 which modulate bone cell function. Secondly, bone cell function may be altered by lead, where it inhibits the ability of bone cells to respond to hormonal regulation. Lead also impairs the ability of cells to synthesize or secrete other components of the bone matrix such as collagen. Finally, lead may directly substitute for calcium in the active sites of the calcium messenger system, resulting in loss of physiologic regulation (Gupta and Attreja, 1998).

2.6.2 ABSORPTION OF LEAD

Lead may be absorbed through the skin; dermal absorption. Absorption of lead through the skin is limited, less than 1% is absorbed. The amount of lead absorbed through the skin is dependent on the physical characteristics of the lead, and the integrity of the skin. Inorganic lead is not absorbed through intact skin. However, organic lead compounds are absorbed (Patrick, 2006).

Lead may be absorbed directly through the lungs if fine particles are inhaled. Inhaled lead particles may also be carried through to the throat where it is swallowed and absorbed through the gastrointestinal tract. The amount of lead particles that is absorbed through the respiratory system depends on the particle size, the patient's respiratory volume, and the amount of deposition. Almost 100% of the lead inhaled as fumes or vapor is absorbed directly through the lungs (Holstege, 2015).

2.6.3 Gastrointestinal absorption

According to Holstege (2015) the average blood lead concentration has been reported at 0.03 mg/L in children and 0.11 mg/L in adults. Lead absorption in children is greater than in adults. In general, approximately 30 – 50% of lead ingested in children is absorbed, and about 10% of lead ingested by adults is absorbed. The percentage of lead that may be absorbed through the gastrointestinal (GI) tract is not constant. Lead absorption depends on several factors. This includes the physical form of lead the particle size ingested, the GI transit time and the nutritional status of the person ingesting the lead.

Lead absorption is inversely proportional to the particle size; the smaller the particle, the more completely the lead is absorbed. Thus an individual who is exposed to lead dust is at a higher risk of absorption than an individual exposed to equivalent amount of lead from chips of lead paint.

Lead absorption is high in persons with deficiencies of iron, zinc and calcium. Generally, malnutrition has been associated with increased lead absorption, as well as low-energy (calorie) intake and high-fat intake. However, lead absorption decreases with the presence of vitamin C, vitamin E, phosphorus and riboflavin (Cui *et al.*, 2004).

2.6.4 Lead Distribution

Lead absorbed is exchanged primarily among 3 compartments; blood, soft tissues and mineralizing tissues.

2.6.4.1 Blood

Absorbed lead enters the blood compartment. Lead is mostly found in the red blood cells (about 99%), which serves as the initial receptacle of absorbed lead and distributes lead throughout the body to other tissues or for excretion. The remaining 1% of absorbed lead is found in the blood plasma, which transfers lead between the different compartments.

The elimination half-life of lead in adults' blood has been estimated to be one (1) month and ten (10) months in children. Lead exposure is mostly measured using blood lead level (BLL).

2.6.4.2 Soft Tissues

Soft tissues include the liver, kidneys, lungs, brain, spleen, muscles and heart. Lead moves quickly in and out of soft tissues after the blood distributes it. Animal studies indicate that the liver, lungs and kidneys have the greatest soft tissue lead concentrations immediately after acute exposure. Children retain more lead in soft tissues than adults do. Selective brain accumulation may occur in the hippocampus, this leads to the brain damage in children. The half-life of lead in soft tissues is approximately 40 days (Zheng *et al.*, 2007).

2.6.4.3 Mineralizing Tissues (Bones and teeth)

Most retained lead in the human body is deposited in the bones. The bones and teeth of adults contain more than 90% of their total lead body burden, and that in children is approximately 75%. Lead in mineralizing tissues is not uniformly distributed, with accumulation in bone regions undergoing the most active calcification at the time of exposure.

Bone is seen as a double compartment with relatively shallow compartment (trabecular bone) with elimination half-life of 90 days, and a deep inert compartment (cortical bone) where the elimination half-life may be 10-30 years. Lead in the inert component may be stored for decades. The body can mobilize lead stores in bone in times of physiologic stress, thereby increasing blood lead level. Since the inert pool serves as an endogenous source of lead that can maintain BLLs long after exposure, it poses a special risk**.** Bonetoblood lead mobilization is increased in pregnancy lactation, menopause, chronic disease, hyperthyroidism, kidney disease, fractures, advanced age and is exacerbated by calcium deficiency (Gupta and Attreja, 1998).

2.6.5Excretion

Most of the lead that is absorbed into the body is excreted either through renal clearance or biliary clearance in faeces. A number of factors determine the percentage of lead excreted and also the timing of excretion. Excretion of lead may take several months or even years.

2.7 Heavy Metals in Soil in Ghana

Owusu-Donkor (2011) also conducted a study in some selected districts in Ashanti region on heavy metal contents of soil and citrus grown in the areas. The study area included the Asante Akim North (now Central) municipality, in Ghana where it was realized that, there have been recent concerns raised on the levels of heavy metals in the environment and scientists suggested that foodstuff from mining communities may contain toxic amounts of these heavy metals. Thus, there was an urgent need to characterize the heavy metal contents of mining and non-mining sites and correlate these with the heavy metal content of fruits grown in these sites and make the necessary recommendations for sustainable citrus production in Ghana. The aim of the research work was undertaken to characterize mining sites as against non –mining sites in terms of heavy metal content.

Mining activities, use of agrochemicals in agriculture production and vehicle exhaust fumes were proposed as the main sources of heavy metals. The accumulation of these metals in these municipalities were in the order Obuasi>Sekyere West > Asante Akim North >Ejisu-

Juaben. There were significant differences in the selected metals contents in citrus fruits and soils from the four districts.

It was observed that, though the heavy metal load of soils from all the four municipalities were below the permissible limit set by the Dutch standards for soil contamination assessment, the levels of citrus fruit Zn and Pb of all the four districts were above the permissible limits set by FAO/WHO while Cd in citrus fruit from Obuasi, Asante Akim North and Sekyere West were above the permissible limit. This could be due to the low pH of the soils in the Asante Akim study area, and as a result, the citrus fruits with high acid contents absorb more of the heavy metals than the soil could retain. It was therefore concluded that consumption of citrus fruit from the selected districts could pose health hazards to humans as at the time of the study.

The assertion that lead (Pb) and other metals other than calcium is readily taken up by plants in soils of low pH is emphasized in another study by Chamannejadian *et al.* (2013). It was noted that, lead solubility and plant availability decreased in calcareous soils of higher pH. This was attributed to metal carbonate precipitation and calcium competition with other metal cations for plant uptake. This means that, the other metal cations like lead would rather be taken up readily in soils of low pH since the competition with calcium is reduced under such conditions.

2.8 Heavy Metals in Water in Ghana

Armah *et al.* (2010) conducted a study at Tarkwa, a mining community in the western region of Ghana. Multivariate Statistical Analysis was used to interprete data from surface water as well as groundwater. In all, twelve parameters which consisted of trace elements and physico-chemical parameters were studied. The trace elements included Pb, Cd, Mn, Fe, Cu, As, Hg and Zn, while the physico-chemical parameters included conductivity, pH, total dissolved salts and turbidity. A total of 49 sampling sites of both surface and underground water were selected. The data was analyzed using factor analysis (FA).

The results indicated that most of the water bodies in the study area had elevated mean levels of As, Fe, Hg, Zn and Pb which were above the WHO and Ghana EPA guideline values (Armah *et al.*, 2010). Therefore, there is the possibility that crops that are irrigated with these water bodies could contain high levels of these heavy metals.

Kyerematen (2013) also conducted a study of heavy metals, and Arsenic that was deposited in the sediments and water from streams in the Damang Mine Concession was investigated. To evaluate the contamination levels in sediments and water, 15 water and sediment samples were collected from different sampling points and analyzed for Arsenic, Calcium, Cadmium, Copper, Iron, Manganese, Lead and Zinc contents under laboratory conditions. By the investigation, the mean concentrations of heavy metals in water samples were 11.31 mg/L for As, 462.64 mg/L for Ca, 0.04 mg/L for Cd, 10.87 mg/L for Cu, 16919 mg/L for Fe, 101.89 mg/L for Mn, 115.36 mg/L for Pb, 14.62 mg/L for Zn. Pb concentration in water was detected to be above the permissible limit. The findings by these researchers is a proof of the fact that water bodies around these study areas are polluted with heavy metals and consequently crops such as rice that are irrigated by these water bodies may contain high levels of these heavy metals. Per the results of the study, it is therefore important to evaluate the heavy metal, particularly lead content in food crops such as rice.

2.9 Metal Toxicity

Metal toxicity is an uncommon diagnosis with the possible exceptions of acute iron toxicity from intentional or unintentional ingestion and suspected lead (Pb) exposure. Physicians are rarely alerted to the possibility of metal exposure. Moreover, heavy metal exposure can result in significant morbidity and mortality if unrecognized or inappropriately treated. Many of the heavy metals have no known benefits for human physiology and examples include lead, mercury and cadmium which are toxic, yet other metals are essential to human biochemical processes, such as zinc being an important cofactor for many enzymatic reactions in the human body (Gupta and Atrejja, 1998).

As stated by the ATSDR, the toxicity of heavy metals depend on a number of factors, which include the metal in question, the total dose absorbed, the route of exposure and whether the exposure is acute or chronic. The age of the person can also influence toxicity (ATSDR 2007, 2012). For example, children are more susceptible to the effects of lead exposure because they absorb more of these metals than adults when they are exposed for the same amount of time. Children's developmental processes may also be affected even when they are exposed over a relatively short time because their brains are immature and more plastic. People may be exposed to metals through food consumption, from medicines and also from the environment or even in the course of work or in a child's play. In cases where heavy metal toxicity is suspected, a full dietary and lifestyle history may help to unearth other unknown ways through which humans are exposed to metals (Soghoian, 2001). Heavy metals tests in food and for that matter rice are therefore critical to this research.

2.10 Rice Production in Ghana

There have been several studies on rice production in the Ghana in many respects. Among them is improving rice production by Monica *et al.* (2016) in the Ahafo Ano North District, rice production and marketing by Agbanyo (2012). In fact, such studies have been necessitated by the escalation of rice consumption in recent times all over the world. The trend of rice consumption has no exception in the Sub-Saharan Africa (SSA) where rice has become a major staple among the people in these stated. Though rice consumption is on the increase, domestic production is disproportionate to consumption demands (Agbanyo, 2012). This calls for an urgent state and private interventions aimed at improving rice production in terms of quality and quantity in order to make up for the deficit in supply and also to cater for the health implications associated with it.

According to statistics revealed by Nakano *et al*. (2011), the Sub-Saharan Africa account for a third of global rice imports which is approximately US$4.3 billion per year. This figure is very significant in the sense that the said amount could otherwise be used in other areas development. In Ghana for instance, annual per capita rice consumption on the average increased from 17.5 kg during 1999-2001, to 22.6 kg during 2002-2004. By estimation, per capita rice consumption would increase to 63.0 kg in 2015 if the trend remains the same (MOFA-NRDS, 2009).

It is no doubt that specific policy documents on the rice sector reveal strategies which seek to promote rice production to address food security and poverty reduction. Among such is the Food and Agriculture Sector Development Policy Two (FASDEP II), which is the current Agricultural Sector Development Policy guideline (2008 – 2010) The guideline records rice as one important crop/commodity whose production must be given extra attention to ensure increased food security and import substitution.

Rice production in Ghana has been on large scale and small scale levels which are also either indigenous rain-fed rice production or improved seed under modern irrigation system. However, large scale production has been on the decline in recent times according to Agbanyo (2012) but a significant number of smallholders also depend upon inputs and scientific prescriptions which still exist. The study identified two distinct ways of cultivating rice in Ghana, to wit: indigenous and improved methods continue to exist. In the Volta Region, cultivation of many different varieties of rice occurs. These include indigenous upland and swamp glaberrima varieties, and improved sativa varieties. Agbanyo (2012) asserted that at Avatime, no farmer applies synthetic inputs, and rice cultivation is bound with a complex cycle of rituals. On the irrigation project at Weta on the other hand, the majority of farmers use improved varieties and synthetic inputs. Thus by comparing these two as Weberian ideal types of rice cultivation, we can contrast the impact of different farming styles in order to understand what effects they have in the relative position of farmers in the food value chain – the extent to which they can exercise choice or how dependent they can be.

Monica *et al*. (2016) reveals that local rice production has not been able to meet the increases in demand triggered by population growth, rapid urbanization and change in consumer habits. The fast-growing demand for rice is driving interest in expanding

Ghana’s own rice production. This has made it necessary, the adoption of certain interventions to boost domestic rice production. Among all the several efforts geared towards increase in rice production, the development and strengthening of rice value chain appear to be the most remarkable. Food and Agricultural Sector Development Policy for 2009-2015 (FASDEP II) recognizes the importance of supporting agricultural growth through value chain development (Monica *et al*., 2016).

On top of the developmental agenda of Ghana is self-sufficient rice production. In this regard, the Ghana's rice value chain initiative emphasizes on the creation and strengthening of both horizontal and vertical linkages of the chain. According to Monica *et al.* (2016), the government believes that the development of rice value chain will increase competitiveness, increase production, contribute to food security and address what past initiatives failed to acknowledge - end markets and private sector actors. This will enable producers can gain access to modern markets so that there is an interaction of poor rural men and women producers with the end market under the new initiative. In fact, there are a lot of benefits which have been documented in the literature to be associated with the development of rice value chain. Demont and Rizzotto (2012) believe that, rice value-chain development and upgrading have significant implications for food security, poverty alleviation and overall economic development. The emergence of rice value chain development constitutes a fundamental change in the rice sector by organising the sector into a sustainable and competitive one (Loosvelt and Defoer, 2010).

The value chain development generates higher profits and creates mutually beneficial outcomes for all stakeholders involved, especially the rural population and entrepreneurs (Hobbs *et al*., 2000).

Surprisingly, there still persist the deaths of empirical evidence to show the effect of the rice value chain development initiative on domestic rice production. The work of Monica *et al*. (2016) has the objective of the analysing the effect of rice value chain development initiative on domestic rice production in the Ahafo Ano North district of Ghana. Specifically, this recent study has analysed the current status of rice value chain initiative, identify constraints of rice value chain development in Ghana and more importantly identify the role of stakeholders in the development of rice value chain in Ghana as well as assessing the effect of rice value chain development initiative on domestic rice production. The debate on how to create and develop rice value chain in a sustainable way, based on appropriate strategies and policies is still unfolding, and the empirical context the study provides will enhance the discussions.

In talking about rice production in Ghana, it is important to note that agricultural production in Ghana has generally declined for several reasons. Among them include slow adoption rate of improved technologies, continuous use of traditional implements not suited to large scale production, advanced age of subsistence farmers, coupled with the youth migrating to the cities, lack of credit facilities, inadequate infrastructure development, marketing and inappropriate policy measures. General agricultural policies by governments since independence have focused on large scale production of food to meet public demand.

During the Second World War (1939-1945), efforts by the colonial government were mounted to increase food production in the north of the country, as well as elsewhere, in order to eliminate the growing need for food imports, principally in the south Ghana, which was becoming a food deficit area. The investment in peasant farming was cut back after independence in 1957. During 1959-61, president of the first Republic, Kwame Nkrumah, focused on a socialist strategy of import-substitution, industrialisation, mechanised agriculture and direct public interventions in production and marketing by means of a plethora of large-scale state farms, marketing boards, public enterprises and other parastatal institutions. This policy led to a growing need for government revenues and foreign exchange in order to finance the ambitious investments and capital/input intensive imports and also resulted in a substantial investment programme to open up the shallow river valleys of the Northern regions for the commercial mechanised farming of rice to feed the southern markets.

After Nkrumah, the Military National Liberation Council (NLC, 1966-69) and its elected civilian successor, the Busia regime of the Progress Party (PP, 1969-72) tried to liberalize the economy. The number of state farms was reduced substantially and more room was created for the private sector to participate in the development process. Succeeding military and civilian regimes between the early 1970's and mid - 1980's further encouraged the dualism in agricultural sectors as they all tended to favour large-scale and capital intensive modes of production over labour intensive farming by small-holders. The potential land for the development of lowland rice exceeds 400,000 ha. Only a small proportion of this is currently under cultivation. There are a number of constraints to be overcome for full utilization of the available land. Among them are the high climatic risks due to inadequate water control measures and consequently non-intensive cropping practices and therefore low yields and low profitability (Dapaah, 1995). Again, the agronomic practices employed which essentially include ploughing broadcasting of seed, harrowing and harvesting of the crop under these practices land preparation is inadequate, little or no fertilizer is applied and little weed control is done thus promoting the rapid build-up of noxious weeds which soon make the land unusable after a few years of cultivation are other challenges. The use of mixed and unimproved varieties possessing different colours and shapes which when milled give poor quality grain spurned by most consumers who then turn to imported rice is another identified problem. Moreover, inadequate extension on rice production and processing, poor processing techniques and the use of unimproved milling machines such as the Englebert type rice huller, which compounds the poor outturn in the milling process, the lack of credit to farmers to enable them purchase inputs for farming is another bottleneck for increased production of rice. Allied to this is the current high interest rate and other lending requirements, which are disincentive for farmers in their acquisition of loans.

In line with Ghana's objective of becoming a middle-income country by the year 2020, the overall GDP is to grow at an annual economic rate of 8% compared with the Structural Adjustment period. Under the vision 2020 programme, the agricultural sector is targeted to grow at annual growth rate of 5-6% in order to ensure food security and adequate nutrition for all Ghanaians, to supply raw materials and other inputs to other sectors of the economy, to contribute to an improvement in balance of payment and to provide producers with incomes comparable to earnings outside agriculture.

The Ministry of Food and Agriculture, in line with the objective of vision 2020 has launched an Accelerated Agricultural Growth and Development Strategy (AAGDS) which has been designed to generate sectoral growth of about 5-6% from the current 2-3% and thereby fuel an increase in Ghana's annual GDP growth rate to 8% (Ofori, 2000). The policies and programmes designed to achieve the objectives of the strategy are based on five elements. These are:

- Improve access to market for the promotion of production and export of selected commodities.

- Facilitate access to agricultural technology for sustainable natural resource management.
- Improve access to rural finance.
- Improve rural infrastructure and utilities.
- Build institutional capacity.

The strategy is consistent with two basic orientations of the Government of Ghana namely; Privatisation - reliance on private sector to lead investment, and Decentralization - devolution of significant responsibilities from central Government to District Assemblies (Ofori, 2000).

CHAPTER 3

MATERIALS AND METHODS

3.1 **Materials**

Rice (Jasmine 85 variety) was procured from farmers at their farms at the study area. Transparent plastic bags were purchased from the Konongo market at the study area.

Trioxonitrate (V) acid (70% W/V) (B.D.H) was obtained from Sigma-Aldrich chemicals Company. Hydrochloric acid (37%) B.D.H was also obtained from Sigma-Aldrich chemicals Company.

3.2 **Description of study area**

The Asante Akim central municipal, formerly Asante Akim north municipal assembly is one of the 30 districts in the Ashanti region. It has Konongo as its Capital Town and is about 45 km east of Kumasi and is noted for its small scale mining activities. The municipality is located in the eastern part of Ashanti region and lies between 60 30’ north and 70 30’ north and longitude 00 15’ west and 10 20’ west. The municipality covers a land area of 300 square kilometers with an estimated population of 169,976 in 2010, (projection from 2000 population census). The municipality shares boundaries with Asante Akim North District on the north, Asante Akim South on the east and south and Sekyere East and Ejisu-Juaben on the west. At the south-western corner, it shares boundary Bosome-Freho district.

A total of 5 sites in the Asante Akim Central municipality were included in this study. The variety of rice mostly grown by farmers in this locality is the Jasmine 85 and the Agra varieties. Ten farms were selected from the 5 sites, that is, two farms from each site in Asante Akim Central municipality. The farms selected were Kusasi and Amoh farms at Ohene-Nkwanta, Felix and Rasta farms at Patrensa, Oppong and Boakye farms at Dwease, Dani and Osei farms at Odumasi and Sule and Frimpong farms at Konongo.

Figure 1: Map of the Asante Akim Central Municipality

Source: www.statsghana.gov.gh/docfiles/2010_District_Report/Ashanti/ASHANTI

3.3 **Sampling and Sample Preparation**

There are a total of 5 communities within the study area. Two farms were randomly selected from each community and a total of 10 locally cultivated rice samples (polished) were collected (one sample per farm). The Jasmine 85 variety of rice, which is the predominant variety grown in these communities, was used for this project. Samples were collected during harvesting period of rice in the farms (between August and September, 2014). About

50g of polished rice were collected from each farm and put in plastic bags for further analysis.

3.3.1 Metal Analysis

In the determination of heavy metals, a portion of the raw rice grains were cleaned and 2 g of each sample was weighed and dried at 110 °C for 24 h. Glassware were cleaned with aqua regia (nitric acid: hydrochloric acid ratio, 3:1) by filling the glass tubes with enough volume of the aqua regia. The tubes were agitated and allowed to stand for 30 min. The tubes were then washed thoroughly with soap and rinsed with copious amount of water. The tubes were rinsed again with distilled water and dried in the oven.

3.3.2 Digestion of samples

Two grams each of the 10 dried rice samples was weighed into the clean digestion tubes and 10 ml of aqua regia was measure out into each of the tubes containing the 2 g of the samples. The content in the digestion tubes were allowed to stand for 1h. The tubes were later placed in boiling water bath set at 100 ^{o}C and left over night to complete digestion. Digested samples were quantitatively transferred into 50 ml Ependorf tubes and topped up with distilled water up to the 50 ml mark and vortexed, ready for metal analysis. A standard protocol was followed.

Concentrations of Pb in the filtrate of digested rice samples were estimated by using a Perkin Elmer atomic absorption spectrophotometer (Model 2380, USA).

The instrument was fitted with the specific lamp of lead (Pb). The instrument was calibrated using manually prepared standard solution of lead as well as drift blanks. All samples were prepared and analyzed in duplicate. Concentrations were expressed in terms of mg/100 g on a dry weight basis. Precision and accuracy of analysis were assured through repeated analysis of samples against standard reference materials.

3.3.3 Rice Consumption Data

The rice consumption data were extracted from the food consumption survey that was conducted in Asante Akim Central municipality, Ghana. The representative sample of participants included 300 people, who were interviewed by the use of questionnaires about their rice consumption per day, and also per week in order to obtain a rice consumption profile that represents the population. The socio-demographic characteristics of respondents were included in the questionnaire. The body weights of individual participants were also taken.

3.4 Exposure Estimates

The exposure from rice was obtained using the consumption data and lead (Pb) concentrations in rice samples and then dividing by the average body weight. The mean and 95th percentile of the daily exposure levels was used to represent the dietary exposure for average and high level consumers respectively.

In order to assess the safety of dietary intake, weekly intake of lead (Pb) through rice was estimated based on daily consumption of rice. Weekly Pb intake was also calculated by multiplying lead contents in rice by weekly rice consumption.

Whenever possible, monitoring data from dietary intake studies are to be compared with acceptable or tolerable levels recommended by the Joint FAO/WHO Expert committee on food additives. Hence the total dietary exposure levels of Pb determined in this study were compared with the provisional tolerable weekly intakes (PTWIs) by the JECFA to assess potential health risks faced by consumers (Mohammad *et al.*, 2008).

For food toxicants such as lead that may accumulate in the body, the tolerable intakes are expressed on a weekly basis as this allows for daily variations in intake levels. This is because the actual concern is on prolonged exposure to the contaminants (Ziarati *et al.*, 2013).

To assess the risk, a probabilistic approach was used by applying a Monte-Carlo simulation. This statistical probabilistic tool was used to predict the magnitude of the expected impact of toxicant as well as the uncertainty and variability involved in these estimates, hence it produces a distribution or range of values instead of one fixed or point estimate value.

The chronic daily intake (CDI) was calculated based on the formula;

$$CDI = \frac{C \times CR \times EFD}{BW * AT} \qquad \text{equation (1)}$$

From equation 1, C is the Average exposure concentration over the period. CR is the contact rate, and it refers to the amount of contaminated medium contacted per unit time. EFD is the exposure frequency and duration (assumed to be 5 yrs). BW refers to the average body mass over the exposure period expressed in kg. AT is the Averaging time (70 yrs), and it refers to the period over which the exposure averaged.

Risk was calculated based on the formula;

$$Risk = PF\ (CDI\text{-}RfD) \qquad \text{equation (2)}$$

From equation 2 PF represents the potency factor, whereas CDI is the chronic daily intake. R_fD represents the reference dose.

However, since Pb is a group 2A carcinogen (IARC), the reference dose was absent. This means that if a little of lead availability is assumed to have a risk, then there will be no level of which it is assumed to be safe for consumption, therefore $R_fD = 0$. Hence equation (2) becomes Risk = PF(CDI)   equation (3).

Risk was calculated according to the formula given, using the potency factor of 5 µg/day. Simulation was run at 10,000 iterations. Cumulative ascending order of graph output was selected with the 5^{th} and 95^{th} percentile risk inserted and all axes labeled.

3.5 Statistical Analysis

The various data sets were first fitted to their unique distributions. Lead (Pb) concentrations were fitted as continuous data, and ranked according to AIC and the topmost distribution selected. Distributions were fitted accordingly for the total consumption of rice per day and exposure durations fitted as discrete data. However, the body weight variable was fitted as continuous data since the values obtained were randomized data. The various distributions were fitted as presented in the table 3.1.

Statistical distributions of dataset used in the computation for lead (Pb) in *Asante Akim* area**.**

Table 3.1: The different distributions fitted.

Variables	**Statistical distributions**
Lead ingestion	**Expon, 0.24924, shift (0.060206)**
Contact rate	**Uniform (5.8049, 83.7240**
Body weight	**Normal (69.682,11.190)**

CHAPTER 4

RESULTS AND DISCUSSION

4.1 **Results**

Table 4.2: The distribution of respondents as to age group and sex.

	Respondents % (n = 300)
Female	42 (127)
Male	58 (173)
Age group	
18-30	38 (114)
31-44	36 (108)
45-64	24 (72)
65-80	2 (6)

As shown in table 4.2, out of the 300 respondents, 127 were female and this represented 42% of the population. The percentage of males was 58 and that is 173 out of the 300 respondents. About 75% of the total respondents belonged to the younger age group (1830 and 31-44) while only a 25% of the respondents belonged to the older age group.

The lead content in rice from the ten farms is presented in Table 4.3. The mean concentrations (mg/kg) of lead in rice ranged between 0.06–0.66 with the average mean of 0.235 mg/kg. Rice lead content was highest in rice from RFO3 (0.66 mg/kg) followed by RFO4 (0.615 mg/kg), both at Odumasi. Of the ten samples that were analyzed, three of them had lead content higher than the maximum permitted level (0.3 mg/kg) proposed by the JECFA.

Table 4.3: Mean Pb content of rice

Sample identity	Mean±SD (mg/Kg)
RFO-1	0.09±0.01
RFO-2	0.08±0.00
RFP-1	0.08±0.00
RFP-2	0.06±0.00
RFD-1	0.08±0.00
RFD-2	0.18±0.02
RFO-3	0.66±0.02
RFO-4	0.62±0.02
RFK-1	0.13±0.02
RFK-2	0.365±0.01

The results are presented as the mean of two replicates ± SD. RFO represents rice farm in Odumasi; RFP represents rice from Patrensa; RFD represents rice from Dwease; RFK represents rice from Konongo.

Rice lead content was lowest in rice from RFP2 (0.0625 mg/kg) at Patrensa, (Table 4. 3).The mean concentration of Pb in rice was estimated to be 0.235 mg/kg.

The chronic daily intake (CDI) of Pb by the population was estimated to be 1.72857×10^{-5} mg/kg bw/day. The 95thpercentile level was used to represent 5% of the population who are the highest exposed consumers of the distribution, while the 5thpercentile was used to represent 5% of the population who are the least exposed consumers of the distribution. The results for the analysis of data are presented in figures 2, 3 and 4.

4.2 **Discussion**

The results indicate the presence of lead in all the rice samples. Rice from RFO-3 recorded the highest Pb content (0.66 mg/kg), followed by rice from RFO-4 (0.62 mg/kg), both at Odumasi and this result could be attributed to the nearness of the farms to the mining sites. However, "galamsey" operators in personal communications with this researcher claim to use other heavy metals such as mercury in mining. Hence, the high levels of lead in rice from these areas could be due to the high rate of deposition of lead from dust, car exhaust and gases from different industrial sources. It could also be due to the low pH of soils in these particular sites where the samples were picked from.

Chamannejadian *et al.* (2013) also conducted a study and noted that in calcareous soils, lead (Pb) solubility and plant availability decreased due to metal-carbonate precipitation in higher pH and calcium competition with other metal cations for plant uptake. Thus, in calcareous soils with higher pH, calcium is readily taken up by plants. This does not allow for other metals to be absorbed in higher amounts, hence the competition for metal uptake. On the other hand, when the pH of calcareous soils is low, thus acidic, calcium is unable to compete for metal uptake and other metal cations take over and become readily available for plant uptake.

The results from a previous study of heavy metal contents of soil in the study area by Owusu-Donkor (2011) also showed a relation between soil pH and soil lead content. It was noted that the soil lead content was 2.70 mg/kg. Of the four districts that were studied, the highest top soil lead (3.20 mg/kg) was recorded for the Asante Akim area.

Moreover, the highest citrus fruit lead content was highest in the study area. The soils in the area also had the highest soil pH of 4.71. The results stated above could be due to the inverse relationship between the soil pH and plant availability for heavy metals. He also attributed the high lead content to the nearness of soil to the mines. Thus, the higher the lead content in a soil with low pH, the higher the lead levels in food crops since plant availability for lead is increased under such conditions.

Similar levels were reported in another study by Bridgen *et al.* (2014) in Hunan Province, China, where the highest Pb content in rice was 0.237 mg/kg. They attributed their results to a link between elevated levels of lead in rice and in farmed soils for the two areas which are located close to the western side of the industrial area where metal smelting and processing is done.

Rice from RFP-2 at Patrensa had the least Pb content, 0.0625 mg/kg. Comparatively, the distance from the mining sites to Patrensa is farther than from the mines to Odumasi. Actually the mine is situated at Odumasi as well as many “galamsey” operators, therefore the proximity of the mine to these farms could account for the relatively high content of Pb in rice from Odumasi. Comparatively, Odumasi is busier than Patrensa, in terms of human and other commercial activities such as mechanic shop, movement of many vehicles as Odumasi is along the main Kumasi – Accra highway. These reasons could account for the lower levels of Pb in rice from Patrensa.

The average content of Pb in raw polished rice at the Asante Akim area was estimated to be 0.235 mg/kg dry weight. The Joint FAO/WHO Experts Standards Program Codex

Alimentation Commission (JECFA) had proposed a maximum level of lead as 0.3 mg/kg in rice (Zazouli *et al.*, 2010). Based on this, the average content of lead (Pb) in this study is below the maximum permitted level of rice as compared with the FAO/WHO codex.

As shown in Table 4.1, Pb contents are very different in the same varieties that were grown in the different farms. This could be attributed to the nature of the soil and other factors because heavy metals contents in rice depend on soil moisture, pH, redox potential, weather conditions, and use of fertilizer, water and contamination rate. Solubility of metals is known to increase with a decrease in soil pH and hence plant metal uptake is higher in calcareous soils. Reduced pH in soils in the farms could raise metal availability and metal uptake by plants, which could also increase health risk (Mohammad *et al.*, 2008).

Furthermore, a previous study of Pb in rice by Forson (2009) showed that generally Pb content in rice around the study area was low. This is because of the thirteen samples that were analyzed; only three of the rice samples had Pb content above the FAO/WHO permissible limit of 0.3 mg/kg. They attributed the high levels of Pb in these three samples to the low pH of the soil in the area.

From the above discussion, it could be deduced that, the high lead content in three (3) out of the ten samples analysed in this research, could also be attributed to the acidic soils in the study area. This has been clearly stated above by Forson (2009) who conducted similar research in the study area. This assertion is further emphasized by Chamannejadian (2013) who attributed high metal levels in rice to soils of low pH. Similar levels compared to the data in this study were reported in a study by Bridgen, *et al.* (2014) in Hunan Province, China. In the report, the highest Pb content in rice was

0.237 mg/kg, which is although below the maximum permitted level by the JECFA, yet it exceeds the allowable level for rice (0.2 mg/kg) in China (Ministry of Health, China 2012). They attributed their results to a link between elevated levels of lead in rice and in farmed soils for the two areas which are located close to the western side of the industrial area.

Another study in China, Zhejiang by Huang, *et al.* (2013) reported the Pb content in rice to be 0.060 mg/kg which is below the maximum permitted level for rice compared with the FAO/WHO codex, and attributed the findings to the pollution status of the soils in the study area.

As already mentioned, the contamination rate at Patrensa (RFP-2) was expected to be low, since it is farther away from the mine as well as the busy commercial area in the municipality. It is also known that, there is a linear relationship between metal availability and organic matter content (Zazouli *et al.*, 2010).

In a study in Nigeria by Otitoju, Otitoju and Ogbonna (2014), the Pb content (0.777 mg/kg) in the rice samples was found to be above the FAO/WHO guidelines, and

attributed the results to the species of the rice samples, total content of heavy metal, soil chemical and physical properties; which could affect the bioavailability of heavy metals in plants.

To assess the safety of dietary intake, weekly intake of lead (Pb) through rice consumption was calculated based on daily consumption of rice and dietary intake compared with the Provisional Tolerable Weekly Intake (PTWI) established by the JECFA (WHO/FAO). Based on the survey, an individual whose weight is 70 kg is bound to absorb and accumulate about 0.024 mg/kg/week of lead content. On comparing the levels of lead concentration (mg/kg/week) consumed by an individual with the PTWI which is 0.025

mg/kg, the results indicated that weekly intake of lead was less than the PTWI recommended by WHO/FAO. This also implies that, the weekly intake of lead is acceptable and therefore, the rice at the study area is good for consumption.

In another study by Othman (2011), the average weekly dietary intake of lead and cadmium from cereal foods which included rice ranged from 0.95 – 3.06 μg/kg bw/week which was below the PTWI and subsequently the intake of these heavy metals was found to be below the ADI which then indicated that the dietary intake of lead on daily basis was acceptable. The results according to Othman (2011) also showed that Pb contamination in rice had a lesser potential to pose health risk to the consumers, for all the rice samples.

As shown in figure 2, Pb concentration has a very strong positive correlation with the risk. This means that, as the Pb content increases**,** the lifetime risk also increases. The linear correlation coefficient is 0.73 which is very close to +1. The number of days that rice is consumed and the amount of rice eaten also has a positive correlation but not as strong as Pb concentration, which means that increasing these variables will slightly increase the lifetime risk. However, weight has a negative correlation with linear coefficient of -0.15, which means that a negative (inverse) correlation exists between the two; weight and risk. This means that an individual's weight does not affect the possibility of one being at risk of lead contamination and the subsequent adverse effects.

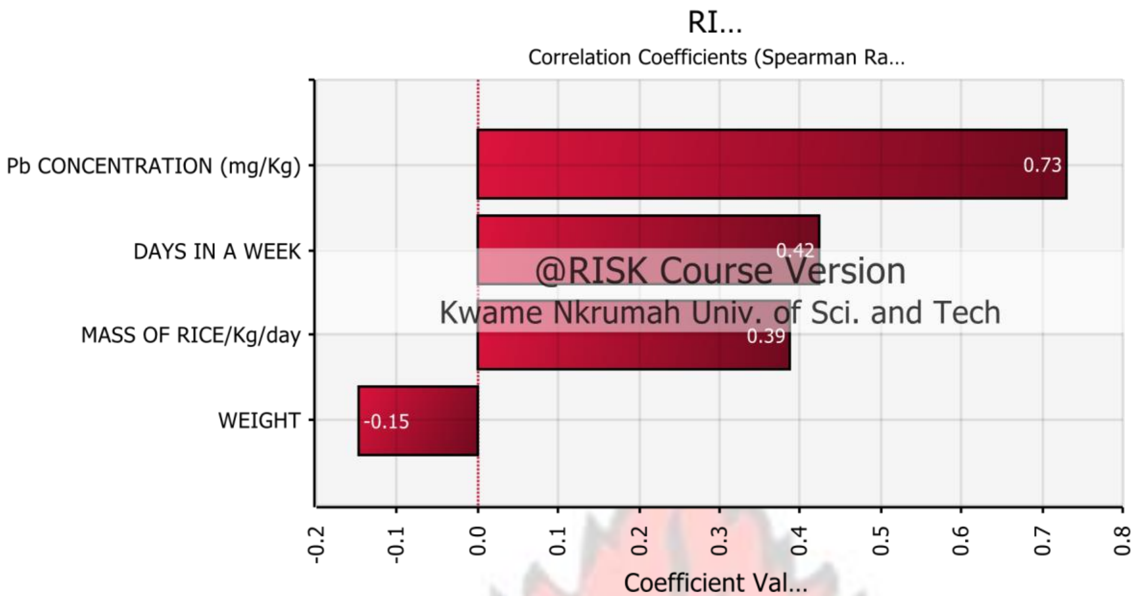

Figure 2: Correlation between Pb concentrations in rice and the risk associated with rice consumption.

In figure 3, the regression graph indicates that lead (Pb) concentration has a greater effect on the risk. This means increasing the concentration of lead will greatly increase the risk by a factor of 1, considering the regression equation; Risk = C+ 0.01CR, where C represents the concentration of lead Pb, CR represents contact rate = gram rice × servings per day. Contact rate has an effect on the risk but very small almost insignificant since its coefficient is 0.01. Body weight does not have any effect on the risk associated with consuming rice from the study area. Hence the risk is approximately 100% on the lead (Pb) concentration.

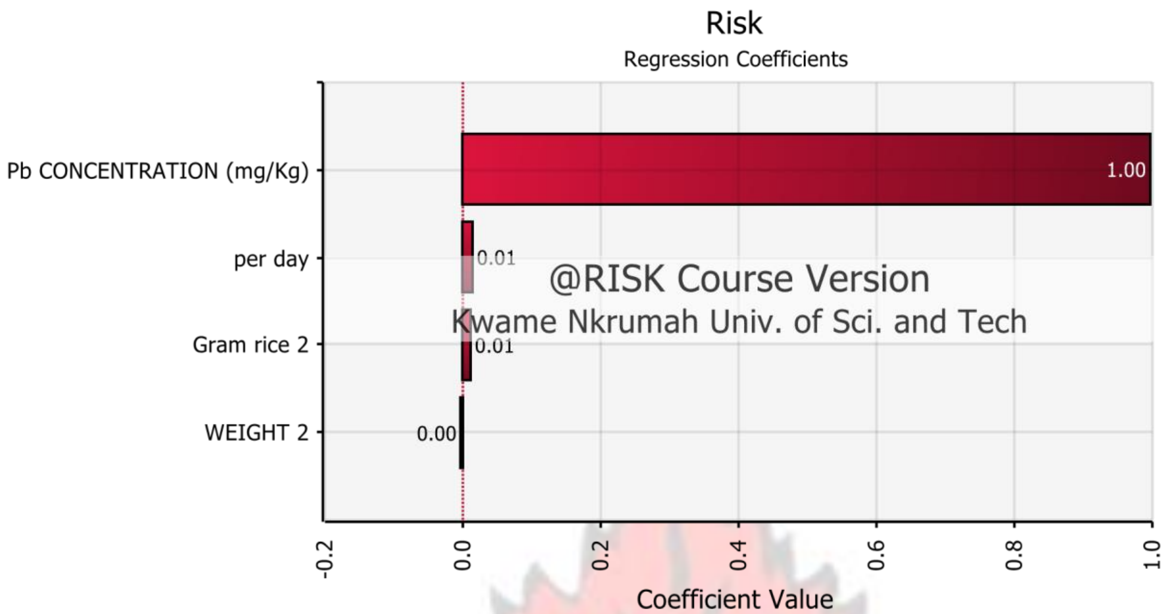

Figure 3: Regression between Pb concentrations in rice and the risk associated with rice consumption.

Regression analysis shows how risk is affected by the age, weight of consumers as well as the concentration of lead (Pb) and all the other variables as represented in figure 3.

The Probability distribution in figure 4 shows that there is significant risk associated with consuming the locally cultivated rice from the study area. Risk values equal to1×10^{-6} is said to present the lowest risk, and it represents one in a million. The 50th percentile was estimated to be 0.000519 and represented 50% of the consumers who are the average exposed consumers. The average exposed consumers are individuals who consume two servings of rice per day for four days in a week. However the 50th percentile value which represents 5 out of 10,000 is greater than the deminimis of (1×10^{-6}), and it indicates a significant risk to the average exposed consumers of rice cultivated in the study area.

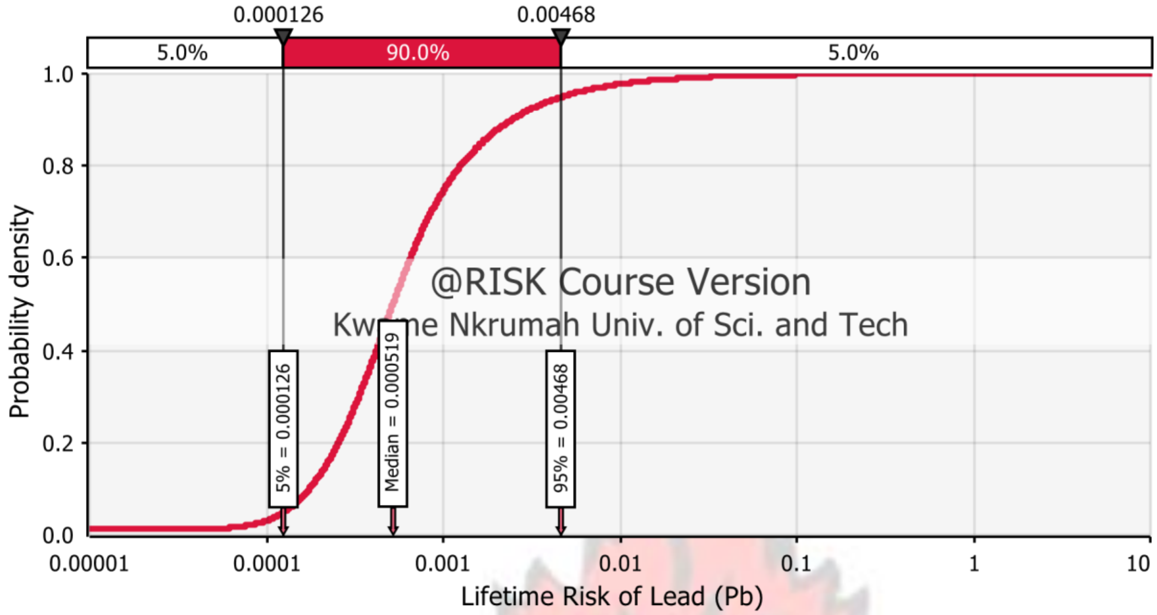

Figure 4: Cumulative frequency curve of lead Pb content in rice cultivated in the *Asante Akim* Central municipality.

The 95th percentile represented 5% of the consumers who are the highest exposed consumers of the distribution. The highest exposed consumers are individuals who consume two servings of rice per day for all the seven days in a week. The 95th percentile level was estimated to be 0.00468 (4.68×10^{-3}). This means 5 out of 1000 consumers are at risk of consuming rice from the study area. This value is greater than the 10^{-6} value which is known to represent the lowest risk that a chemical can pose to human health. The 5th percentile was estimated to be 0.000126 and represented 5% of the consumers who are the least exposed consumers of the distribution. The least exposed consumers are individuals who consume two servings of rice per day twice in two week. This means that for 5% of the consumers 1 out of 10,000 consumers are at risk of consuming the rice in their lifetime. These values further confirm that, there is significant risk associated with the consumption of locally cultivated rice in the Asante Akim central municipality as far as lead is concerned in an individual's lifetime.

CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

The mean Pb content in the rice samples was found to be lower than the maximum permitted level for rice compared with FAO/WHO codex.

The estimated weekly intake of Pb was below the PTWI recommended by FAO/WHO. However, the risk it poses is significant. This means that, the probability of occurrence of adverse health effects posed by Pb contamination of rice is significant.

The health risk associated with Pb intake may increase in the future in Asante Akim municipality and this risk will increase with consumption of other food crops cultivated in the area if mining activities continue to contaminate water sources and soils in the area. Therefore, mining activities in the area should be well regulated, since consumption of heavy metal polluted rice could lead to several health hazards such as cardiovascular diseases, cancers, diabetes, hypertension, arthritis, and poor development of the grey matter in children.

It can be concluded that, even though mining, commercial and other human activities that may cause lead contamination are present at the study area, yet the lead concentrations in rice were low. However the health risk that these concentrations pose is not negligible.

5.2 RECOMMENDATIONS

Since the actual intake of Pb was found to be less than the PTWI, the risk associated with consuming the locally cultivated rice may be lower but the estimated intake is just for rice consumption. Other media for exposure to lead contamination also exist. It is therefore recommended that, more food crops be studied to determine their levels of contamination by heavy metals in the area. This might help create a clear picture of the risk posed by heavy metals through food consumption in the area.

Periodic monitoring of the rate of contamination and consumption is necessary to assess the overall exposure level in the community.

Repetitive washing of the rice can greatly reduce the level of heavy metal contents. Cooking the rice grains also reduced the content of heavy metals. This was also emphasized in an investigation of lead and cadmium content in rice in Iran. Consumers could be educated on proper ways of washing and cooking rice since these can reduce heavy metal contents in rice as mentioned by different researchers.

Health risk assessment application on the bioavailability of other heavy metals in rice is also suggested.

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http://en.wikipedia.org/wiki/Lead_poisoning

APPENDICES

APPENDIX A

Sample Identity and Sources

Sample identity	Source
RFO-1	Rice farm at Ohene-Nkwanta 1
RFO-2	Rice farm at Ohene-Nkwanta 2
RFP-1	Rice farm at Patrensa 1
RFP-2	Rice farm at Patrensa 2
RFD-1	Rice farm at Dwease 1
RFD-2	Rice farm at Dwease 2
RFO-3	Rice farm at Odumase 1
RFO-4	Rice farm at Odumase 2
RFK-1	Rice farm at Konongo 1
RFK-2	Rice farm at Konongo 2

APPENDIX B

Interview Questionnaire

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

DEPARTMENT OF FOOD SCIENCE AND TECHNOLOGY

STUDY ON RISK ASSESSMENT OF HEAVY METALS IN RICE

INTERVIEW SCHEDULE FOR LOCAL RICE CONSUMERS

Identification

Investigator: ________________ Date: _____________ Tel:____________________________________

Location of the bussiness____

Interviewer's Declaration

My name is Portia Asare, a master's student in the above mentioned institution. I am doing an academic research on riskassessment of heavy metals in rice. I need your response to some few questions to enable me complete my thesis.

Of course, we will treat your information confidential and it will not be shared with other people. The data will only be used for academic purposes. If you don't want to give the answer to any particular question please mention it along the conduction of the survey.

Personal Profile Questions

Questions
1. Age
_________________ years
2. Gender
Male
Female

3. Weight
....
4. Religious affiliation

Christian

Muslim

Traditionalist

Others(Specify) ……………………………………..

5. What is your highest educational level?

a. Tertiary b. Training college

c. Tech/voc

d. Secondary

e. Middle School/ JHS

f. Primary

g. None

6. Which ethnic group do you belong to

a. Ewe

b. Akan

c. Hausa

d. Ga/Adangbe

e. Guan

f. other (specify)…………………………………………

7. **Do you eat rice**?

Yes

No

8. **If yes, Which type of rice do you prefer**?

Locally cultivated rice

Imported rice

9. **Why do you prefer either type of rice**?

10. **Where do you get your rice from**? from farmers market tenders shops/stores others (specify)

11. **In the past four weeks, have you eaten rice at all?**

Yes

No

12. **How many days in an average week do you eat rice?**

One day

Two days

Three days

Four days

Five days Six days

Everyday

13. **Onaverage how many servings of rice do you eat per day**? (1/4 cup of dry rice equates to 1 cup of rice When cooked. 1cup of rice equates to two servings of grains)

Less than one serving per day

1 serving

2 servings

3 servings

4 or more servings

Don't know

THANK YOU