

**SCHOOL OF PUBLIC HEALTH  
COLLEGE OF HEALTH SCIENCES  
UNIVERSITY OF GHANA**



**RESIDUAL HEAVY METALS, PESTICIDES AND THEIR IMPLICATIONS ON  
HUMAN HEALTH OUTCOMES IN CABBAGE PRODUCTION WITHIN THE  
GA-EAST MUNICIPALITY, ACCRA.**

**BY**

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**THIS THESIS IS SUBMITTED TO THE DEPARTMENT OF BIOLOGICAL,  
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REQUIREMENT FOR THE AWARD OF MASTER OF PUBLIC HEALTH  
DEGREE**

**JULY, 2019**

## DECLARATION

I, Charles Yao Ansre, declare that except for other people's investigations which have been duly acknowledged, this research proposal is the result of my own original research undertaken under supervision and that it has neither in whole nor in part been presented for another degree in this university or elsewhere.

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Date: 24<sup>th</sup> June, 2025

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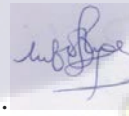
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## DEDICATION

This work is dedicated to my parents, Mr. Livingstone Ansre and Mrs. Margaret Ansre.

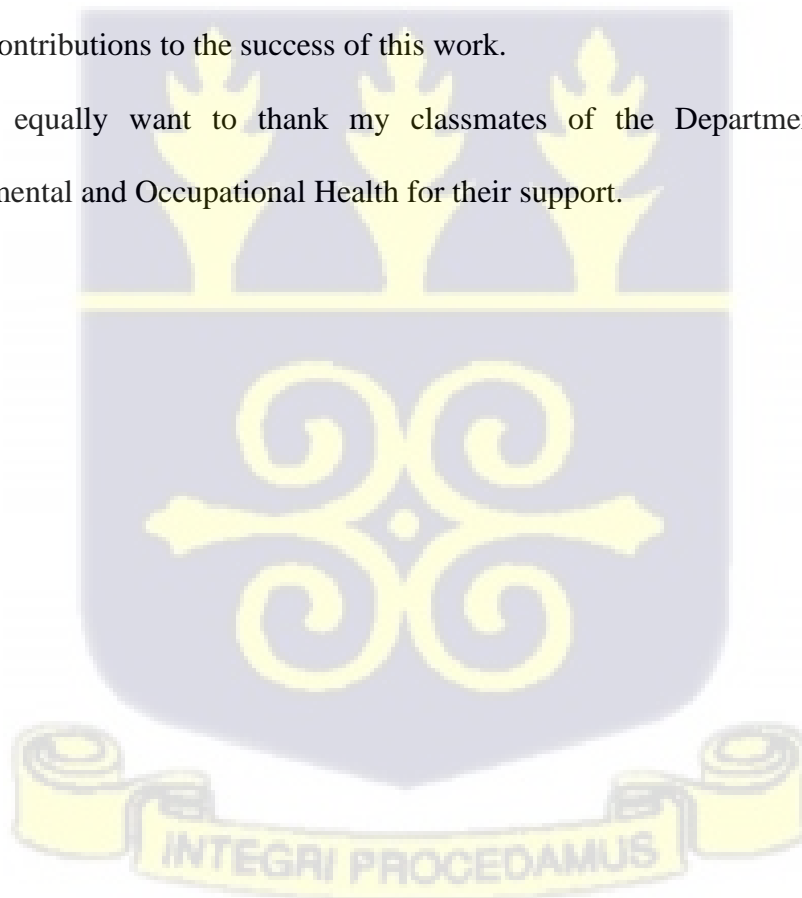


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## LIST OF ABBREVIATIONS

AAS	Atomic Absorption Spectrometer
ADI	Acceptable Daily Intake
BAF	Bio-Accumulation Factor
BNARI	Biotechnology & Nuclear Agriculture Research Institute
DHS	Disodium Hydrogen Citrate Sesquihydrate
EU	European Union
FAO	Food and Agriculture Organization
GAEC	Ghana Atomic Energy Commission
GAP	Good Agricultural Practices
ILO	International Labor Organization
LC/MS	Liquid Chromatograph/Mass Spectrometer
LD <sub>50</sub>	50% Lethal Dose
MOFA	Ministry of Food and Agriculture
MRL	Maximum Residue Limit
NCD	Non-Communicable Disease
PSA	Primary Secondary Amine
RfD	Reference Dose
SPE	Solid Phase Extraction
SRID	Statistics, Research and Information Directorate
TSCD	Trisodium Citrate Dihydrate

USEPA

United States Environmental Protection Agency

WHO

World Health Organization



## ABSTRACT

**BACKGROUND:** Inadequate consumption of vegetables as well as fruits have been linked to an increase in the global incidence of Non-Communicable Diseases (NCDs). The quest for healthy living has thus seen many Ghanaians increasingly including vegetables in their diet. One of the in-demand vegetables, both locally and internationally, is cabbage. A significant threat that can reduce the benefits accrued from cabbage is contamination in the form of either heavy metals, pesticides or microbes. In order to meet the increasing demand for cabbage, farmers have to use pesticides to protect crops from pest attacks. Some of these applications are unregulated thus resulting in higher-than-normal concentrations of these chemicals on the vegetables. Unsuspecting populations get exposed to these chemicals and may suffer adverse health effects. Urbanization, modernization and industrialization have also increased the presence of heavy metals in our environment. Most vegetable farms in peri urban areas are increasingly being exposed to heavy metal contamination due to the above stated phenomena. Heavy metals are also known to have adverse health effects on the population. Thus, there is the need to monitor cabbage farms within peri-urban settlements with the likelihood of being exposed to high levels of pesticides and heavy metals so as to safeguard public health.

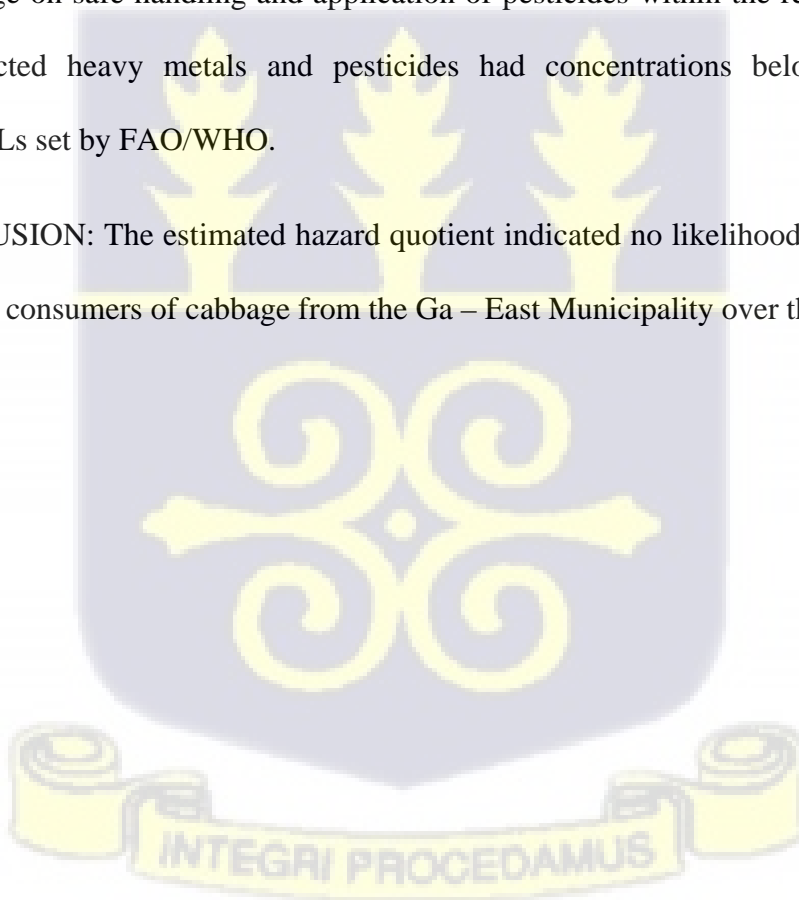
**AIM:** To assess heavy metals and pesticide residues, pesticide usage patterns and their implications on human health outcomes in cabbage production within Ga-East Municipality.

**METHOD:** A questionnaire was used to collect demographic and knowledge on pesticides from the farmers. Standard sampling techniques was used to sample soil, water and

cabbage from the farms. All samples were analyzed for their heavy metals content using Atomic Absorption Spectrometer (AAS) and pesticide content by Liquid Chromatography coupled with a Mass Spectrometer (LC/MS).

**OUTCOME:** Majority (80%) of the respondents indicated that they use recommended doses during pesticides application. With respect to pesticides application routine, 40% of the farmers indicated they applied pesticides at an interval less than a week. The major disposal method for pesticide packages was by burning (52%) while 47% of them observed a pre-harvest interval of 1-3 days. Colleague farmers were the major source of knowledge on safe handling and application of pesticides within the respondents (55%). All detected heavy metals and pesticides had concentrations below recommended ADI/MRLs set by FAO/WHO.

**CONCLUSION:** The estimated hazard quotient indicated no likelihood of adverse health effects to consumers of cabbage from the Ga – East Municipality over the study period.



## CHAPTER ONE

### 1.0 INTRODUCTION

#### 1.1 Background

In an attempt to meet the nutritional requirements of a balanced diet, consumption of vegetables has become an integral part of meals prepared in Ghana. The increasing demand for vegetables (including cabbage) all year round, high youth unemployment rate of 16.9% (Ghana Statistical Service, 2017) as well as the scarcity of agricultural land in peri urban areas have resulted in the conversion of most fallow lands in the proximity of water sources into vegetable farms. The presence of these farms in the midst of heavily populated and urbanized societies makes them susceptible to varied forms of pollution as a result of increased human activities.

The quest for modernization and industrialization has increased the presence of heavy metals in urban soils (Sun et al., 2010). The presence of high levels of heavy metals in soils according to Qing et al. (2015), can result in deterioration in soil ecosystem and threats to human health. Issues of concern regarding contamination of soils by heavy metals relate to the varied sources of heavy metal pollution and properties such as resistance to degradation, toxicity and bio-accumulation potentials (Sharmar et al., 2007; Qing et al., 2015). Typical sources of heavy metal pollution include vehicle emission, industrial and municipal waste discharge, sedimentation of suspended particles in air, coal and fuel combustion , (Li et al., 2001; Qing et al., 2015).

Pesticide application is an integral activity in any cabbage production which is necessitated by the need to maximize productivity (Botwe et al., 2012 ; Fothergill & Abdelghani, 2013)

by killing all forms of organisms that may destroy the vegetables. They are defined by the World Health Organization (WHO, 2008) as chemical compounds used to kill pests and unwanted plants (weeds). Pesticides application under regulated conditions presents numerous benefits (Bempah et al., 2011; Fenik et al., 2011; Tutu, 2011). Notwithstanding the stated usefulness of pesticides, they are inherently toxic and as such are potential hazards to non-target organisms including humans (Yadav & Devi, 2017). The properties which make them potentially dangerous to human health include their widespread use, stability, selective toxicity and bio-accumulation (Fenik et al., 2011).

## **1.2 Problem Statement**

Vegetables are essential components of a healthy diet for humans. The benefits of cabbage production or consumption (as all other types of vegetables) may be classified as either health based or socio-economic based. A significant threat that can reduce the benefits accrued from vegetables is contamination in the form of either heavy metals, pesticides or microbes. Contamination not only reduces the wholesomeness of the cabbages and the associated benefits, but poses significant threat to food security, economic livelihood and human health. The increased and uncontrolled use, coupled with a weak supervisory and monitoring framework for pesticides within the vegetable production sector as a whole, exposes vegetables to varied levels of pesticide contamination.

Modernization through industrialization, urbanization and mechanization, coupled with intense human activities have resulted in increased production of heavy metals especially within peri-urban settlements within major cities (Drechsel & Keraita, 2014). Most vegetable production in Greater Accra goes on within peri-urban settlements and as such

the vegetables are liable to heavy metal contamination as the soils and water used for production get exposed to increased levels of these metals (Lente et al., 2014).

### **1.3 Justification**

Notwithstanding the several benefits of consuming vegetable-inclusive diets, the process of production of these vegetables and the location of these farms can result in the vegetables posing health risk to humans. Cabbage is the vegetable of interest for this study as all of the farmers in this study indicated that they are most attacked by pests. They thus rely heavily on pesticides to protect them, an assertion which is founded by other works (Botwe et al., 2012 ; Osei et al., 2013) . Heavy metals and pesticides are known to be major contaminants in vegetables. The stability of these potential pollutants coupled with their inherent toxicity and bio-accumulative properties make them bio-available in the food chain and thus if their levels exceed safe levels for human consumption, then consuming such vegetables become a potential source of hazard to human health. Anecdotal evidence by way of verbal interview with farmers during a reconnaissance survey to vegetable farms suggested that spraying of cabbage is done every 3 days and at this frequency, excess pesticides may be available for uptake into cabbage tissues as all the pesticides may not have degraded before the next application. All pesticide residues on food crops are classified as either carcinogens or toxins thus the need to reduce them to the lowest levels possible (Zawiyah et al., 2007). Since vegetables are mostly consumed raw or partly-processed, they are susceptible to higher residue levels than other food crops. It's further estimated that there is a 5-fold increase in exposure to pesticide residue through diet than through other routes of exposure with vegetables and fruits contributing 30% (by mass) of

all food consumed (Ronnie et al., 2009). In order to protect public health, continual research aimed at assessing compliance to food safety regulation must be done. Health effects due to consumption of foods contaminated with high levels of heavy metals include kidney damage, neurological effects, skin lesions, reproductive damage and skin cancer (Fu et al., 2008; Jaishankar et al., 2014; Khan et al., 2008) amongst others. Health effects of consuming high levels of pesticides include amongst others: immune disorders, cancers, nervous system damage, and reproductive disorders (Lemaire et al., 2006; Mnif et al., 2011; Nicolopoulou-Stamati et al, 2016).

#### **1.4 Research Questions**

1. What types and concentrations of heavy metals and pesticides are present in cabbage farms in the Ga-East Municipality?
2. What is the bio-accumulation factor for the heavy metals and pesticides in cabbage?
3. Are there health risks associated with consuming cabbage with the measured heavy metals and pesticides from these farms?

#### **1.5 Aim and Objectives**

##### **1.5.1 Aim**

To assess residual heavy metals and pesticides, pesticides usage pattern and their implications on human health outcomes in cabbage production within Ga-East Municipality.

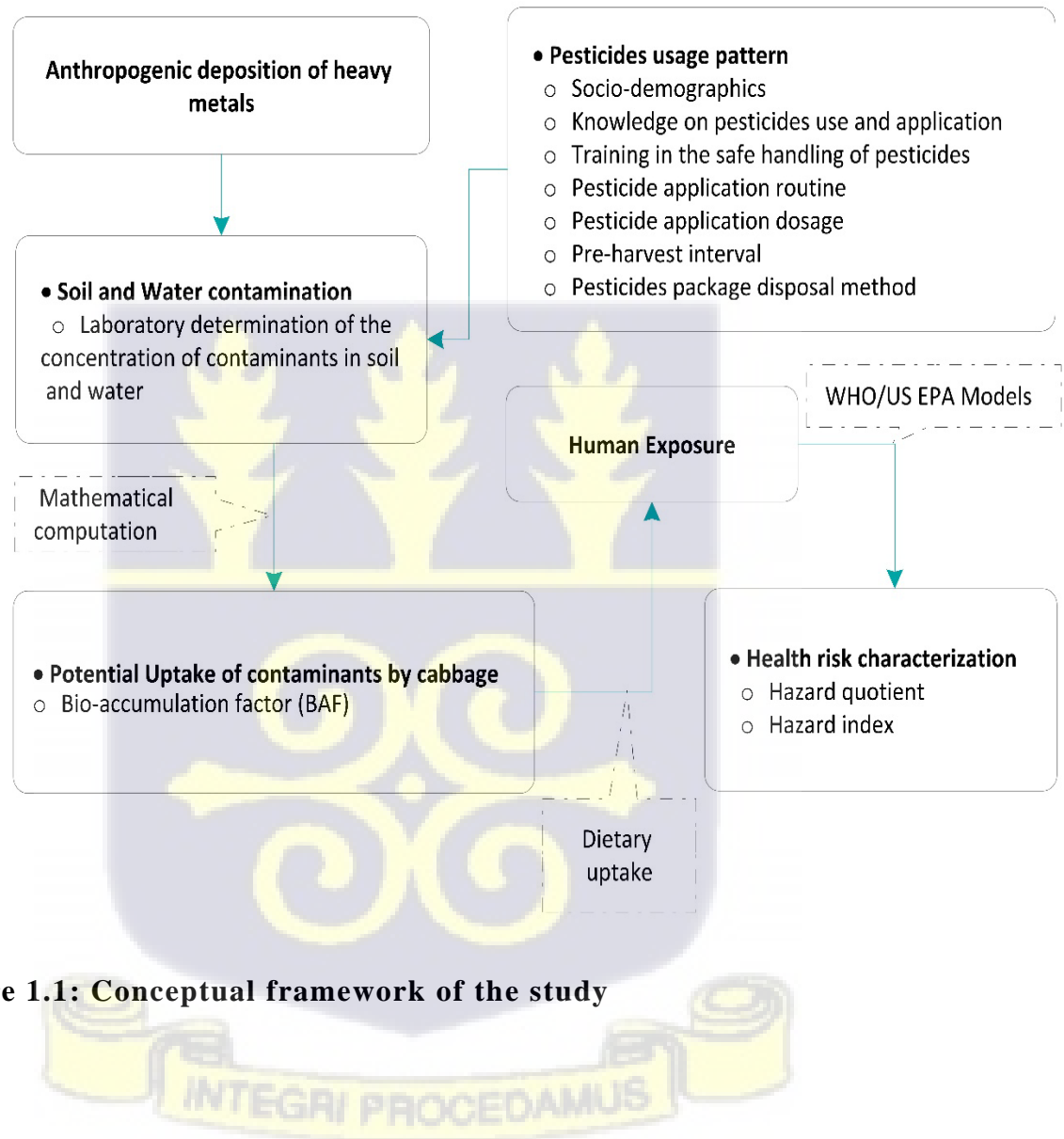
### **1.5.2 Specific Objectives**

1. To determine pesticides usage pattern among vegetable farmers in the Ga-East Municipality.
2. To determine the heavy metal and pesticide concentrations in soil, water and cabbage samples from farms within the Ga-East Municipality.
3. To determine bio-accumulation of heavy metals and pesticides in the cabbage.
4. To estimate the health implication of consuming cabbage with the measured heavy metals and pesticide concentrations on humans.

### **1.6 Conceptual Framework**

To ensure that the nutritional benefits from consuming cabbage profits the consumers and does not adversely affect health, farms and produces from these farms should be regularly examined for contaminants. The quest for modernization and industrialization has increased the presence of heavy metals in urban soils (Sun et al., 2010). Pesticide application is an integral activity in any cabbage production which is necessitated by the need to maximize productivity (Botwe et al., 2012; Fothergill & Abdelghani, 2013) by killing all forms of organisms that may destroy the vegetables. The Source-Pathway-Receptor model proposed by Suter (2007), explains that contaminants such as heavy metals and pesticides through crops (pathway) are able to affect human (receptor) health. Heavy metals and pesticides, ones released into the environment, contaminate the soils in which these crops grow as well as the water that is used to irrigate these farms. Cabbage grown in contaminated soils is able to absorb these contaminants, which degrade slowly and have the potential for bio-accumulation, primarily through the roots (Guerrieri, Mazzini, &

Borgonovo, 2024). Human exposure to heavy metals and pesticides that have been absorbed by cabbage is through dietary ingestion of the contaminated cabbage. The health risk associated with consuming contaminated cabbage is estimated using hazard indices or quotients as detailed by organizations such as WHO and US EPA models.



**Figure 1.1: Conceptual framework of the study**

## CHAPTER TWO

### 2.0 LITERATURE REVIEW

#### 2.1 Vegetable Production in Ghana

Growth in Ghana's domestic vegetable sector is largely attributed to an increase in the middleclass population with an increasing awareness of the health benefits of consuming vegetables. An estimated 45.8% of the total households in Ghana are agricultural households (Ghana Statistical Service, 2013). Of a total 9.7 million acres of land under cultivation, about 227,758 acres is used in vegetable production. The major vegetables cultivated are tomato, pepper, garden eggs, okro and onion/shallots (Ghana Statistical Service, 2013). Among the top twenty (20) ranked crops and livestock in Ghana, five vegetables were included namely cocoyam, dried chilies, green chilies, tomato and okra (Gonzalez et al., 2014). Year-round production of vegetables is made possible by weather conditions and irrigation though most waters for irrigation are untreated or waste waters. Production and consumption of vegetables is estimated to have grown to 12% in 2011 (Netherlands-African Business, 2014). It is estimated that 2000 farmers, 5300 street food sellers and 800,000 daily consumers benefit from urban vegetable production within Ghana's major cities (Drechsel & Keraita, 2014).

#### 2.2 Economic Value of Ghana's Vegetable Sector

Two major factors have been identified as the reasons underlying the surge in Ghana's vegetable export value. These factors were highlighted by the sector minister in a publication as being the conduciveness of the prevailing climate for production of tropical vegetables and the nearness of Ghana to many European markets (Gonzalez et al., 2014).

Vegetable exportation is classified as an agricultural non-traditional export. In 2010, the total volume of all non-traditional agricultural exports was 2,999.5 million metric tons (MT) with the vegetable sector contributing 3,685MT (0.12%) of this volume (MOFA & SRID, 2011). In terms of revenue, the value of all non-traditional agricultural exports was \$164.9 million with the vegetables sector contributing \$2.067 million (1.25%) of the total value (MOFA & SRID, 2011). The domestic vegetable market is estimated to have grown at about 10% with an export potential of \$250 million based on a report by Netherlands-African Business (2014). The overall turnover of the vegetable sector is estimated at \$800 million (Netherlands-African Business, 2014).

### **2.3 Health Benefits of Vegetable Consumption**

In Ghana, a report by Food and Agriculture Organization (Owolabi et. al., 2018) has revealed that on average, national consumption of vegetables is 2.3% portion daily compared to recommended levels of 4% - 6%. The World Health Organization (WHO, 2003) recommends consuming about 400 g of vegetables a day as fruits and vegetables are known to prevent chronic diseases such as obesity, diabetes and heart diseases. Fruits and vegetable consumption has also been stated to prevent Non-Communicable Diseases (Oguntibeju et al., 2013). A joint FAO/WHO expert consultation (WHO, 2003) attributes 2.8% (1.7 million) of global deaths, 14% of gastrointestinal cancer deaths, 11% of ischemic heart disease deaths and 9% of stroke deaths to insufficient intake of fruits and vegetables.

## **2.4 Challenges to Ghana's Vegetable Sector**

The vegetable production and supply chain consist of a number of contributing factors to which a challenge to any of these factors results in a challenge to the whole supply chain system. Issues related to Maximum Residue Limits (MRLs) of pesticides and Good Agricultural Practices (GAP) are some of the factors resulting in the decline in vegetable exportation from Ghana (Netherlands-African Business, 2014). Urbanization in major cities have been stated as a challenge to vegetable production as it reduces the available farm lands. It was established that Accra and Tamale had 36%-50% decline in urban vegetable farming areas between the years 2006 to 2014 (Drechsel & Keraita, 2014). Pathogenic load of water used for urban irrigation in Ghana as reported by Amoah et al. (2005) far exceeds recommended levels set by WHO for unrestricted irrigation. Contamination of vegetables by pathogens is another challenge facing the vegetable sector as illustrated in work done by Amoah et al. (2005). It has been stated that exports of vegetables from Ghana to the European Union (EU) are at times rejected due to the presence of some organisms that are on the EU list of harmful organisms and this resulted in a ban on several high value export vegetables in 2014 for instance (Gonzalez et al., 2014).

## **2.5 Heavy Metals**

Metals with specific weight higher than  $5 \text{ g/cm}^3$  or atomic number greater than 20 and toxic at relatively high concentrations are said to be heavy metals (Barlos et al., 1989; Jarup, 2003). They are naturally occurring in varying concentrations and exist either in their elemental state or as compounds (Dean et al., 2003). Anthropogenic factors are said to have

changed the biochemical cycles, abundance and fate of these heavy metals in the food web (Dean et al., 2003). Some heavy metals such as Iron (Fe), Nickel (Ni), Copper (Cu) and Zinc (Zn) in trace amounts are needed for optimal functioning of biological systems (Bharti, 2012). Others such as Lead (Pb), Arsenic (As), Cadmium (Cd) and Mercury (Hg) have no established benefits in humans and no known homeostasis mechanism for them (Morais et al., 2012).

### **2.5.1 Sources of Heavy Metals**

Although heavy metals are known environmental pollutants with adverse health effects, their production and emission globally has been on the increase (Jaishankar et al., 2014). Natural and anthropogenic sources are responsible for the environmental availability of heavy metals. Specific sources of heavy metals include soil erosion, weathering, vehicular emission, mining, urban run-off, sewage discharge, disease control agents/pesticides, industrial production and use, volcanic eruption, agricultural use of metal containing compounds amongst others (Morais et al., 2012; Tchounwou et al., 2012).

### **2.5.2 Routes of Exposure**

Heavy metals find their way into the human body through food, water, air and absorption through the skin during agricultural, industrial or residential processes (Bharti, 2012). In children, ingestion is said to be the major route of exposure whereas industrial exposures are the commonest route of exposure in adults (Bharti, 2012).

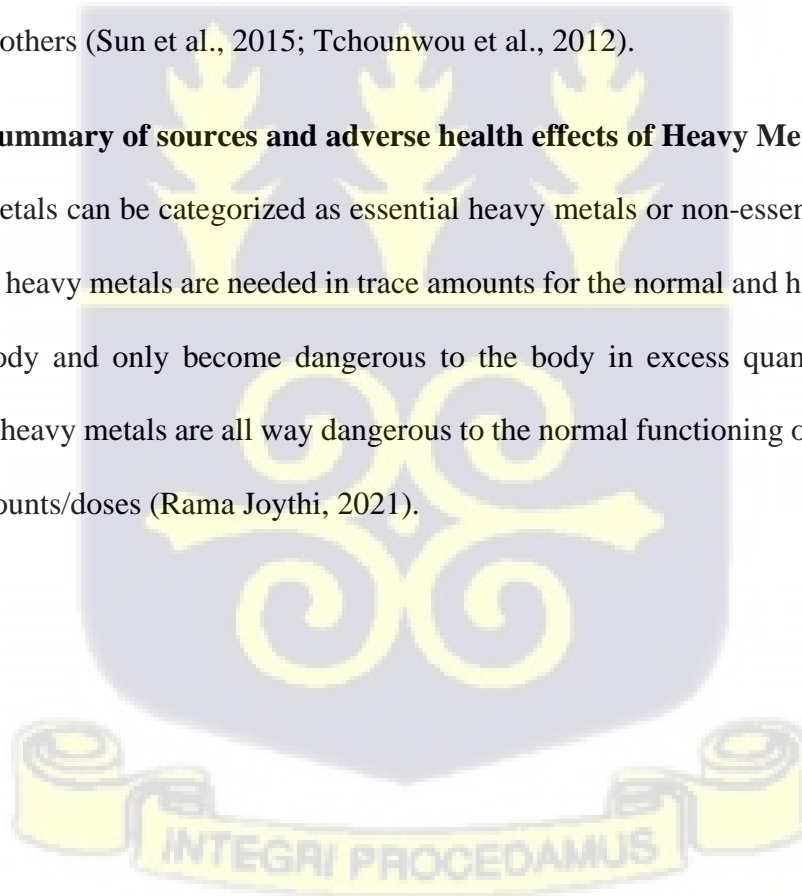
### **2.5.3 Toxicity of Heavy Metals**

The concentration of heavy metals in any media is said to be the primary determinant of its toxicity (Appenroth, 2010; Barlos et al., 1989). Since there is no clear metabolic pathway for these metals (Morais et al., 2012), they accumulate in soft tissues and become

toxic (Bharti, 2012). Other factors said to influence the toxicity of heavy metals include route of exposure, age, gender, genetic of exposed person as well as the chemical species of the heavy metal (Sun et al., 2015; Tchounwou et al., 2012). The underlying mechanism of heavy metal toxicity is their ability to bind to protein sites by displacing the original metals at these sites resulting in cell malfunctioning as well as their ability to escape the body's control mechanisms of homeostasis, transportation, compartmentalization and binding to appropriate sites (Sun et al., 2015). Health effects associated with the exposure to heavy metals include systemic health effects as they affect different organs, neurological effects, teratogenic effects, cancers, cardiovascular effects and pulmonary disorders amongst others (Sun et al., 2015; Tchounwou et al., 2012).

#### **2.5.4 Summary of sources and adverse health effects of Heavy Metals**

Heavy metals can be categorized as essential heavy metals or non-essential heavy metals. Essential heavy metals are needed in trace amounts for the normal and healthy functioning of the body and only become dangerous to the body in excess quantities/doses. Non-essential heavy metals are all way dangerous to the normal functioning of the body even in trace amounts/doses (Rama Joythi, 2021).



**Table 2.1: Sources and adverse health effects of Heavy Metals**

<b>Categorization</b>	<b>Heavy metal</b>	<b>Sources</b>	<b>Adverse Health effect</b>
<b>Essential Heavy metals</b>	Zinc (Zn)	Oil Refining; Plumbing; Brass manufacturing	Gastrointestinal disorders; Kidney & Liver abnormal functioning
	Copper (Cu)	Copper polishing; Plating; Printing	Abdominal disorders; Metabolic activity abnormalities
	Iron (Fe)	High intake of iron supplements & oral consumption	Vomiting; Diarrhea; Abdominal pain; Dehydration & Lethargy
	Cobalt (Co)	Hip alloy replacement case	Hematological, Cardiovascular, Hepatic & Endocrine disorders
<b>Non-essential Heavy metals</b>	Chromium (Cr)	Steel fabrication; Electroplating; Textile	Lung disorders (bronchitis, cancer); Renal and Reproductive system disorders
	Lead (Pb)	Batteries; Coal combustion; Paint industry	Serious effect on mental health (Alzheimer disease); Nervous system disorders
	Arsenic (As)	Atmospheric deposition; Mining; pesticides	Highly effects dermal region (Cancer); Brain & Cardiac problems
	Mercury (Hg)	Coal combustion; Fish; Mining; Paint industry; Paper industry; Volcanic eruption	Sclerosis; Blindness; Minamata disease; Deafness; Gastric problems; Renal disorders
	Cadmium (Cd)	Plastic Fertilizers pesticides	Osteo related problems; Prostate cancer Lung diseases; Renal issues

### 2.5.5 Studies on Heavy Metals in Vegetables in Ghana

Several studies on heavy metals in different media and sites have been conducted over the years in Ghana. One particular area of interest regarding heavy metals is their concentration

and health risk in relation to food consumption. Specific studies involve heavy metals in vegetables, water, soil, dairy products and cash crops amongst others (Addae, 2015; Addo et al., 2010; Bempah et al., 2011; Lente et al., 2014). Lead (Pb) concentrations in selected vegetables from parts of Accra irrigated with waste water were found to be above WHO/FAO recommended levels while all other studied heavy metals were found to be below the recommended WHO/FAO levels (Lente et al., 2014). Health risk assessment of toxicity from consuming such vegetables showed that there may be no risk to consumers with the exception of toxicity due to lead (Lente et al., 2014). A study conducted in Kumasi with respect to heavy metals in commonly used spices showed higher Pb concentrations as compared to recommended levels whereas all other heavy metals were within the recommended levels (Nkansah & Amoako, 2010). Another study conducted by Bempah et al. (2011) reported that heavy metals studied in selected vegetables and fruits from selected markets in Accra were below permissible levels set by WHO/FAO. It is of interest to state that all of these studies recommend continuous monitoring of heavy metals in all media especially food products.

## **2.6 Pesticides**

Pesticides by the definition of FAO (1989) are all substances or mixture of substances intended for destroying, controlling or preventing any pest, including vectors of human or animal disease, unwanted species of plants or animals causing harm during or otherwise interfering with the production, processing, storage, transport, or marketing of food, agricultural commodities, wood and wood products, or animal feedstuffs, or which may be administered to animals for the control of insects, arachnids or other pests in or on their

bodies. The term includes substances intended for use as a plant growth regulator, defoliant, desiccant, or agent for thinning fruit or preventing the premature fall of fruit, and substances applied to crops either before or after harvest to protect the commodity from deterioration during storage and transport. Thus by definition, pesticides are inherently toxic and deliberately released into the environment (Zacharia, 2011). Historically, the intensive use of pesticides followed the success story of Dichlorodiphenyltrichloroethane (DDT) coupled with the era of “green revolution” which was a global drive to increase grain yields to meet the demands of the rapidly growing population (Zacharia, 2011). Pesticides have been of benefit to humans however their unregulated use possess health and environmental risks since they are inherently designed to be toxic thus, they have the ability to affect both target and non-target organisms.

### **2.6.1 Classification of Pesticides**

Pesticides are generally classified into 4 classes:

- Classification based on their chemical nature
- Classification based on the target pest they affect
- Classification based on their mode of action
- Classification based on their toxicity

#### **2.6.1.1 Classification based on chemical nature**

This is said to be by far the most important basis of pesticide classification to researchers and it involves classifying the pesticide based on the chemical nature of the active compound/ingredient. This scheme thus gives indication of the chemical and physical properties as well as the efficacy of the pesticide, providing essential details on which its application and precautions for use is based (Zacharia, 2011). Based on their chemical

nature, they are classified into groups such as: Organochlorines, Organophosphates, Carbamates, Phenoxy and Pyrethroids (Garcia et al., 2012; Zacharia, 2011).

#### **2.6.1.2 Classification based on target pest species**

This classification is based on the pest species for which the pesticide is formulated to eradicate/affect. This system thus groups pesticides as rodenticides, insecticides, herbicides, fungicides, bactericides, avicides amongst others (Zacharia, 2011).

#### **2.6.1.3 Classification based on mode of action**

This is the classification of pesticides based on the mechanism by which they effect the desired effects in the target organisms. Under this system, there are 2 broad categories of pesticides namely: systemic and non-systemic (contact) pesticides. Systemic pesticides are those that are effectively translocated within the plants vascular system whereas non-systemic pesticides do not effectively penetrate the plants but will have the desired effect when it comes in direct contact with the target organism (Zacharia, 2011).

#### **2.6.1.4 Classification based on toxicity**

This system was primarily designed by the WHO to categorize pesticides into more and less hazardous forms. This category is based on the acute oral and dermal toxicity (LD<sub>50</sub>) of the pesticides to rat resulting in the following groups of pesticides: Extremely hazardous, Highly hazardous, moderately hazardous, Slightly hazardous and Unlikely to present acute hazards (WHO, 2010).

#### **2.6.2 Sources and Routes of Exposure**

Majority of pesticides are synthetic chemicals, which implies they are produced by man and deliberately released into the environment and intended to achieve a desired result.

Agricultural, industrial and public health usage are the major sources of environmental pesticides (Alewu & Nosiri, 2011; Garcia et al., 2012). Once released to act on a target organism, everything in the vicinity of the target pest (air, water, soil, food, fauna, flora, etc.) becomes exposed to the pesticide and in themselves become sources of exposure of pesticides to the human population. The routes of exposure to pesticides are ingestion, inhalation, dermal absorption and transplacental (Laborde, 2008).

### **2.6.3 Toxicity of Pesticides**

Pesticides are deliberately synthesized to be toxic and as consistent with all chemicals, the primary determinant of toxicity is the dose/concentration. The physical and chemical properties, duration of exposure as well as the type of formulation and the route of exposure to the pesticide also play critical roles in determining its toxicity. Individual specific characteristics such as age, gender and body weight to some extent influence the toxicity of a pesticide in an individual. Based on the effects induced by pesticides, they can be grouped as: teratogens, carcinogens, mutagens and systemic toxicants. All pesticides can induce acute or chronic effects in any population (Alewu & Nosiri, 2011; Garcia et al., 2012). Table 2.2 shows a summary of health effects of specified pesticides active ingredients.

### **2.6.4 Summary of health effects of specified pesticides active ingredients**

Pesticides active ingredients are responsible for a variety of adverse health effects in humans. The severity of the health effects vary based on several factors including toxicity, dose, route of exposure and individual immune dynamics. Summarised below are the health effects associated with some of the identified active ingredients.

**Table 2.2: Health effects of specified pesticides active ingredients**

<b>Active ingredient</b>	<b>Adverse Health Effect</b>	<b>Reference</b>
<b>Glyphosate</b>	Liver disorders; kidney disorder; Lung disorder; possibly carcinogenic, mutagenic, and estrogenic	Galli et al., 2024
<b>Acetamiprid</b>	Nausea; Hypotension; Neuromuscular paralysis; Tachycardia	Nauen & Denholm (2005); Imamura et al., 2010
<b>Chlorpyrifos</b>	Cognitive defects in infants; Nausea; Neurodevelopmental disorders	<a href="https://www.ncbi.nlm.nih.gov/books/NBK594644/">https://www.ncbi.nlm.nih.gov/books/NBK594644/</a> National Pesticides Information Centre (toxicslink.org)
<b>Emamectin benzoate</b>	Gastrointestinal upset; CNS distress; multi-organ disfunction	Lalmalsawmi et al., 2024; Ankita Kathri (2022)
<b>Imidacloprid</b>	Abdominal discomfort; CNS disfunction; Hypertension; Tachycardia; Apoptosis	Mundhe (2017); Wei (2024)

### **2.6.5 Research on Pesticides in Agriculture in Ghana**

Due to the toxicity and adverse health effects associated with exposure to pesticides, several research have been done and are still underway to monitor the presence and quantities of pesticides especially in the agricultural sector as it is the main source of environmental exposure (Avicor et al., 2011; Bempah et al., 2011; Darko & Akoto, 2008; Miensah et al., 2015). Avicor et al. (2011) conducted research among 60 vegetable and cotton farmers in Accra and Upper East regions of Ghana and found that 25% of these farmers use pesticides above the recommended levels. They further stated that most of these farmers lack basic protective equipment from exposure to these pesticides. It has been recommended in all past literature of the need for continued monitoring and education on pesticides as to safeguard public health.

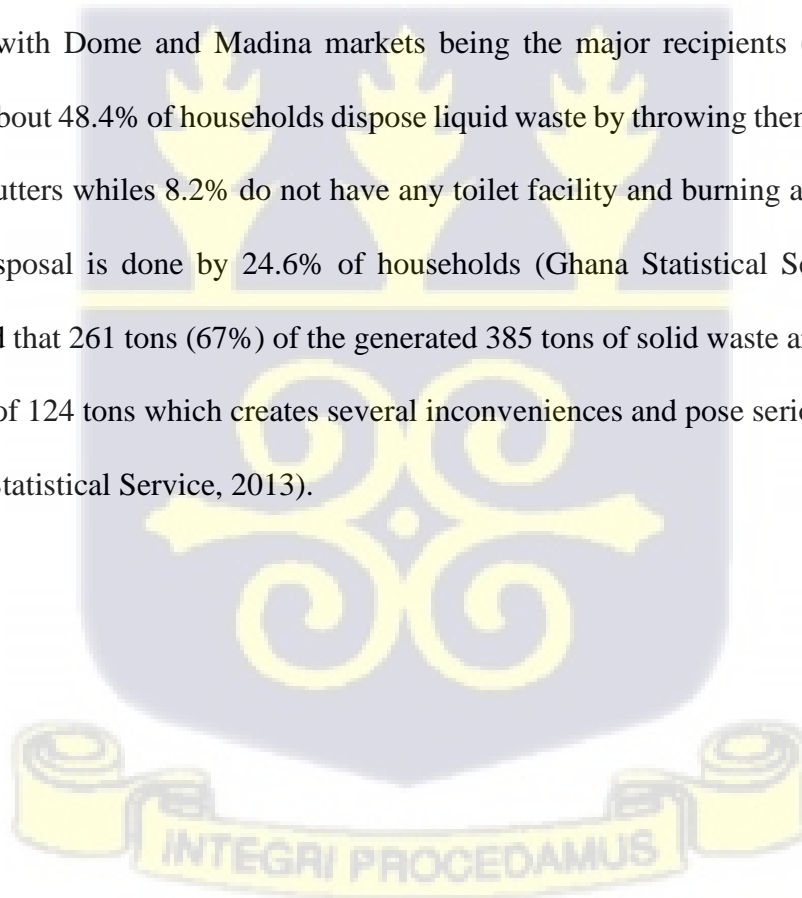
## CHAPTER THREE

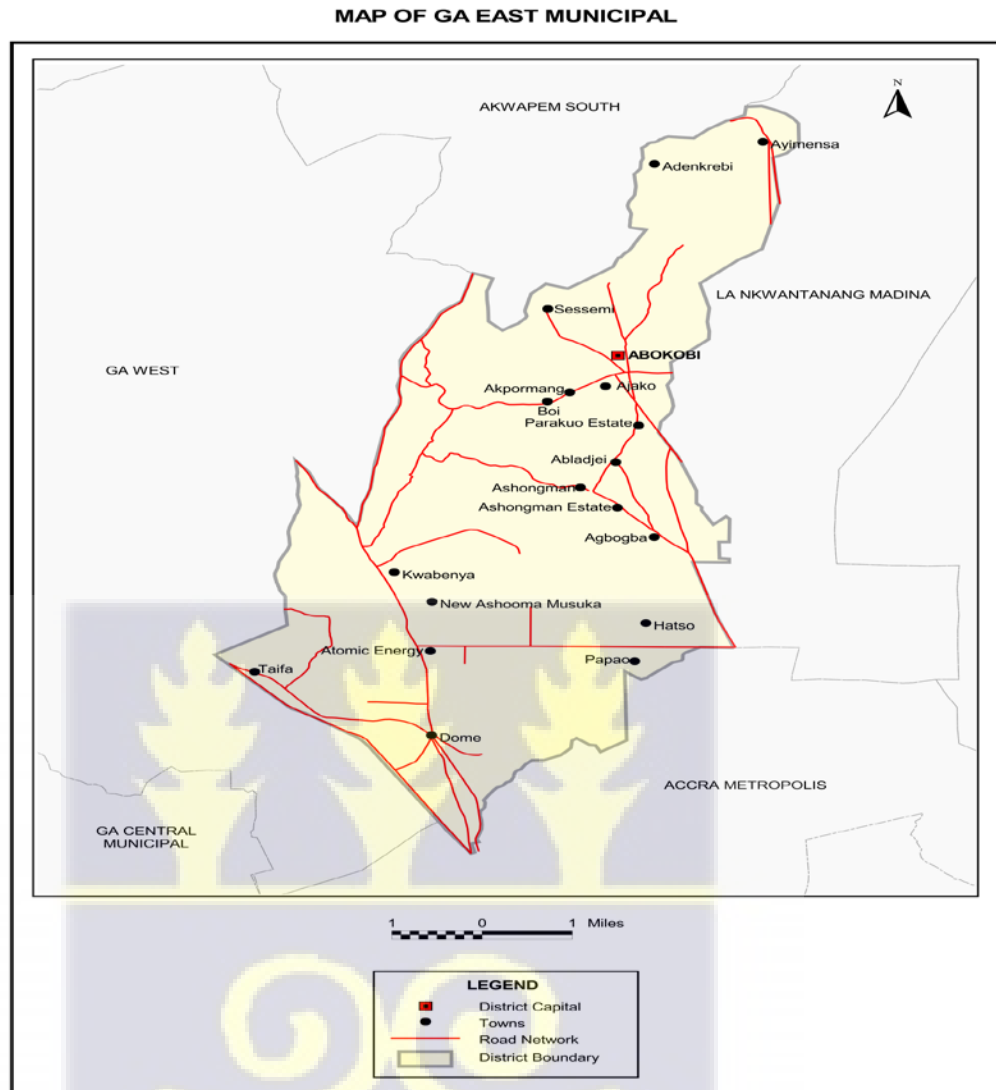
### 3.0 MATERIALS AND METHODS

#### 3.1 Site Description

The study area is Ga-East municipality with a total land size of 166 sq. km of which 107.9 sq. km is for agricultural production. The municipality experiences a bi-modal rainfall pattern and lies within the savanna ecological zone. Several soil types exist within the municipality and these include amongst others fete consociation, Nyigbanye – Haatso complex association, Danfa-Dome association, Fete Bediesi complex and Oyarifa – Manfe complex association (MOFA & SRID, 2011). Vegetable farms with a minimum land size of one acre in the following communities within the municipality was considered in this study: Musuko and Atomic as these are the known large-scale sites for vegetable farming within Ga-East Municipality according to MOFA & SRID (2011). Ga-East, specifically University of Ghana and its surrounding communities have been identified as one of the nine major sites within Greater Accra where large scale irrigated vegetable farming is done. Urbanization has however reduced the areas available for these farms especially within the urban areas leaving the peri-urban communities with the available space for these farms (Danso et al., 2014). Aside the categorization of the area as one of the nine major irrigated vegetable sites, there is unavailable literature on vegetable production (trends, volume, practices, contamination, risk analysis, pesticide usage etc.) within this municipality. Most research on vegetables in Greater Accra is centered on the central business district, the largest open markets and areas experiencing unprecedented urbanization and worrying environmental pollution (Addae, 2015; Danso et al., 2014; Mattah et al., 2015) to the

detriment of other areas which are further from the central business district but are also increasingly experiencing rapid urbanization and environmental pollution. Farmers within the municipality rely on agricultural inputs (improved seeds, agrochemicals and machinery) predominantly from a local agro-input shop (AGRIMAT) as well as from ten (10) other small agrochemical shops within the municipality (MOFA & SRID, 2011). The population as at 2010 census was 147,742 (Ghana Statistical Service, 2013). An estimated 80.2 % of households are engaged in crop farming. The predominant agricultural produce are vegetables, cash crops and livestock. Most of the agricultural produce from this municipality finds their way into one of these four markets: Dome, Taifa, Haatso and Madina with Dome and Madina markets being the major recipients (MOFA & SRID, 2011). About 48.4% of households dispose liquid waste by throwing them onto compounds or into gutters while 8.2% do not have any toilet facility and burning as a means of solid waste disposal is done by 24.6% of households (Ghana Statistical Service, 2013). It is estimated that 261 tons (67%) of the generated 385 tons of solid waste are collected with a backlog of 124 tons which creates several inconveniences and pose serious health hazards (Ghana Statistical Service, 2013).





**Figure 3.1: Map of Ga-East Municipality (Source: Ghana Statistical Service, GIS 2010).**

### **3.2 Study Design**

The study was designed as a cross-sectional study.

### **3.3 Study Population**

The study involved questionnaire administration to farmers within the stated study site.

### 3.4 Inclusion Criteria

The study included farmers who were aged 18 years and more as at the time of administration of question. Only cabbage farms that were under irrigation and with a land size equal to or greater than 1 acre were considered for the study. Only cabbage samples at farm-gate level was used for analysis. Soil samples at depth of 0 cm to 15 cm was collected for analysis.

### 3.5 Exclusion Criteria

Farmers younger than 18 years as well as cabbage that were not at farm-gate level were excluded from the study. Soil samples at depths greater than 15 cm was excluded from collection for analysis.

### 3.6 Sample Size Determination

#### 3.6.1 Sample size calculation for soil and cabbage sampling

The sample size was determined under the assumption: a simple random sampling gives everyone an equal chance of selection.

$$n = \frac{N}{1+N(e)^2} \dots\dots\dots \text{Yamane (1967)}$$

Where n – sample size      N – Study population      e- Precision = 5%

The study population (N) refers to the number of farms under irrigation with a land size equal to or greater than one acre; N = 20

Thus, the calculated sample size (number of farms to consider for the purpose of soil and

vegetable sampling is:

$$n = \frac{20}{1+20(0.05)^2} \Rightarrow n = 20$$

### **3.7 Data Collection**

To address the objectives set out in this work, two data collection tools/techniques were deployed: 1) Structured Questionnaire, and 2) Sampling of water, cabbage and soil for the laboratory determination of the heavy metal and pesticide concentrations.

#### **3.7.1 Questionnaire Administration**

A structured self-administered questionnaire which was earlier pre-tested was administered to farmers. The questions were based on the stated objectives of the study. The questionnaire had two (2) sections: 1) socio-demographic data, 2) knowledge of pesticide use and application. The socio-demographic section elicited responses regarding the age, sex, educational level, marital status and number of years in vegetable farming. The section of the questionnaire that examined the knowledge of farmers on pesticide use and application sought to find out the types of pesticides used by the farmers, their knowledge of the protocols regarding the safe use of the pesticides as well as the sources of their information on the safe use and handling of the pesticides.

The questionnaire was administered to two farmers per each sampled farm as more than one farmer tended each farm due to the acreage.

#### **3.7.2 Sampling**

##### **3.7.2.1 Soil Sampling**

Systematic unaligned grid sampling technique was used to collect three (3) replicate soil samples at a depth of 0-15 cm using an auger per farm into plastic buckets. The samples from each farm were mixed and a composite soil sample obtained for each of the 20 vegetable farms.

### **3.7.2.2 Water Sampling**

Two replicate water samples each was collected from ten different sections of the stream (water source) which serves the purpose of irrigation into 100 ml pre-rinsed polyethylene bottles. One set of 10 replicates was fixed with 1 ml nitric acid to prevent utilization of heavy metals by microbes and analyzed for their heavy metals' concentration. The other set of 10 replicate samples was analyzed for its pesticide content.

### **3.7.2.3 Vegetable Sampling**

Cabbage is the vegetable of interest for this study. Only farm gate (harvested for the market) or potential farm gate (ready for harvesting for the market) vegetables will be sampled. Three (3) replicates will be collected from each of the 20 farms. The replicates from each farm will be rinsed with water and freeze dried at 80°C to obtain a constant weight (freeze drying is not required for pesticide analysis). The samples from each farm will be crushed, sieved through a 2 mm mesh sieve and thoroughly mixed to obtain a composite sample for each farm. Each composite will be analyzed for the heavy metals and pesticides concentrations.

## **3.8 Sample Analysis**

### **3.8.1 Heavy Metal Analysis of Soil Samples.**

Heavy metal content of samples was analyzed using Atomic Absorption Spectrophotometer, preceded by acid digestion of samples. Each composite soil sample from the farms was separately air dried, crushed and sieved through a 2 mm mesh sieve. One gram (1 g) of each sample was measured into a 100 ml borosilicate beaker and a 20 ml of a ternary mixture (500 ml HNO<sub>3</sub> + 50 ml H<sub>2</sub>SO<sub>4</sub> + 20 ml HClO<sub>4</sub>) was added. The

beaker was covered with a cling film, place on the hot plate and digested for 3 hours at a temperature of 90°C. Twenty milliliters (20 ml) of water was then added and the mixture further heated for one hour. The digestate was then allowed to cool, sieved with a 125-micron Whatman filter paper and transferred into test tubes and topped-up with distilled water to make a volume of 20 ml for analysis using VARIAN AA 240FS- Atomic Absorption Spectrometer under recommended instrument parameters (Appendix E). Blanks and duplicates of samples were digested under the same conditions as the samples. These served as internal quality control measures.

### **3.8.2 Heavy Metal Analysis of Water Samples.**

Forty milliliter (40 ml) of each water sample was measured into a 100 ml borosilicate beaker and a 20 ml of a ternary mixture (500 ml HNO<sub>3</sub> + 50 ml H<sub>2</sub>SO<sub>4</sub> + 20 ml HClO<sub>4</sub>) was added. The beaker was covered with a cling film, place on the hot plate and digested for 3 hours at a temperature of 90°C. Twenty milliliters (20 ml) of water was then added and the mixture further heated for one hour. The digestate was then allowed to cool and transferred into test tubes and topped-up with distil water to make a volume of 20ml for analysis using VARIAN AA 240FS- Atomic Absorption Spectrometer under recommended instrument parameters (Appendix E). Blanks and duplicates of samples were digested under the same conditions as the samples. These served as internal positive controls.

### **3.8.3 Heavy Metal Analysis of Cabbage Samples.**

Two grams (2 g) of each sample was measured into a 100 ml borosilicate beaker and a 20 ml of a ternary mixture (500 ml HNO<sub>3</sub> + 50 ml H<sub>2</sub>SO<sub>4</sub> + 20 ml HClO<sub>4</sub>) was added. The beaker was covered with a cling film, place on the hot plate and digested for 3 hours at a temperature of 90°C. Twenty milliliters (20 ml) of water was then added and the mixture

further heated for one hour. The digestate was then allowed to cool, sieved with a 125-micron Whatman filter paper and transferred into test tubes and topped-up with distilled water to make a volume of 20 ml for analysis using VARIAN AA 240FS- Atomic Absorption Spectrometer under recommended instrument parameters (Appendix E). Blanks and duplicates of samples were digested under the same conditions as the samples. These served as internal positive controls.

#### **3.8.4 Extraction and Clean-Up for Pesticides Analysis in Water**

After filtration, 1 L of the water sample was transferred into a 2 L separatory funnel and 30 ml of concentrated sodium chloride (NaCl) solution added. Partitioning of the solution was achieved by adding 100 ml of dichloromethane, shaking the funnel vigorously for 2-3 minutes and releasing the pressure intermittently each time. The layers were allowed to separate and the dichloromethane extract layer drained by allowing the solution in the funnel to stand for about 8 minutes. The partitioning and separation process was repeated thrice.

Extract purification/clean-up was achieved using Silica SPE cartridge which has a 2 g layer of sodium sulfate on top with 10 ml of dichloromethane. The extract was concentrated and loaded onto the cartridge and allowed to run. The eluent was collected into a 100 ml round bottom flask. The column was then eluted with 20ml dichloromethane and the eluent concentrated to dryness using a rotary evaporator at a temperature less than 40°C. The concentrated eluent was re-dissolved by adding 1 ml of acetonitrile. The extract was then transferred into a 2 ml standard vial for quantification using the LC/MS.

### **3.8.5 Extraction and Clean-Up for Pesticides Analysis in Cabbage**

The cabbage samples were rinsed under running water, chopped into smaller sizes and a FOSS homogenizer 2096 was then used to homogenize the composite samples. Ten grams (10 g) of the homogenized sample was weighed into a 50 ml centrifuge tube and 10 ml each of cold deionized water and acetonitrile added. The mixture was then vortexed for one minute using a Thermolyne maxi mix plus. A mixture of QuEChERS salts was then added [4 g anhydrous MgSO<sub>4</sub> plus 1 g NaCl, 1 g Trisodium Citrate Dihydrate (TSCD), and 0.5 g disodium hydrogen citrate sesquihydrate (DHS)]. The mixture was further vortexed for one minute and then centrifuged for five minutes at 3000 U/min.

Dispersive SPE was used in cleaning-up the extract by transferring 6 ml of the aliquot into a PP centrifugation tube which contained 150 mg PSA and 900 mg magnesium sulphate. The tube was closed, vigorously shaken for 30 seconds and centrifuged for 5 minutes at 3000 U/min. The aliquot was then transferred into a 2 ml standard vial for quantification using the LC/MS.

### **3.8.6 Extraction and clean-up for pesticide analysis in soil**

Ten grams of the composite soil samples was weighed into a 100 ml separatory flask and 10 ml acetonitrile added to it. The flask was corked and sonicated for 5 minutes. An additional 10 ml of acetonitrile was then added and the flask corked and placed on a horizontal shaker to shake for 30 minutes. The mixture was allowed to stand for 10 minutes for the layers to separate, 10 ml of the aliquot was pipetted into a round bottom flask and evaporated to 2 ml.

Extract purification was achieved by loading 2 ml of the extract onto a silica cartridge which had 2 cm thickness layer of anhydrous magnesium sulphate on top and 10 ml of

acetonitrile. The eluent was concentrated below 40 °C on the rotary evaporator to dryness. The concentrated eluate was re-dissolved in 1 ml acetonitrile and transferred into a 2 ml standard vial for quantification using the LC/MS.

### **3.9 Data Processing and Analysis**

Quantitative data was entered into Microsoft Excel 2016 for processing and analysis. The response rate of the administered questionnaires was 100% as research assistants were present on the farms with the farmers to explain the questions to each of them and waited on them to fill and submit the questionnaires. Data was presented using descriptive analysis of tables, and frequencies. Laboratory analysis of soil, water and cabbage samples provided the results needed to answer the second objective of this study and presented as tables. Mathematical equations were used to determine the Bio-Accumulation Factor (BAF) and the Hazard Quotient/Index (HQ/HI) of the measured heavy metals and pesticides and presented as tables. The calculated BAF and HQ/HI were compared with established references by the FAO/WHO to answer the third and fourth objectives of this study.

### **3.10 Mathematical Computations**

#### **3.10.1 Bio-Accumulation Determination**

This expresses the ability of the vegetable to accumulate a particular heavy metal or pesticide with respect to its concentration in the soil. Bio-Accumulation Factor (BAF) is computed as a ratio of the concentration in biota (soil) and the concentration in the cabbage as expressed below:

$$\text{BAF} = C_{\text{veg}}/C_{\text{soil}} \text{ (Balkhair \& Ashraf, 2016)}$$

$C_{veg}$ : concentration of heavy metals/pesticides in vegetables.

$C_{soil}$ : concentration of heavy metals/pesticides in soil.

Interpretation of BAF (US EPA, 2000):

$BAF < 1000$  implies no/low probability of bio-accumulation

$1000 < BAF < 5000$  implies moderately bio-accumulative

$BAF < 5000$  implies highly bio-accumulative

### 3.10.2 Health Implication Determination

This is determined by establishing the Hazard Quotient and Hazard Index (HQ & HI) of the measured heavy metals and pesticides. The HQ is a ratio of the average Daily Intake/daily life exposure dose to the Reference Dose (RfD)/Acceptable Daily Intake (ADI). Comparing the computed Hazard quotient to values established by WHO helps to establish the Hazard Index. An HQ greater than 1 implying the exposed population is likely to experience adverse effects during their lifetime whereas a ratio less than 1 implies the unlikelihood of adverse effects on an exposed population.

$$HQ = \frac{\text{average Daily Intake}}{RfD/ADI} \quad (\text{Miensah et al., 2015})$$

$$\text{average daily intake/daily life exposure dose} = \frac{C_{veg} * IR_{veg}}{BW} \quad (\text{Addae, 2015})$$

$C_{veg}$ : Concentration of heavy metal/pesticide in vegetables

$IR_{veg}$ : Ingestion rate of vegetables by population (Arora et al., 2008)

BW: Average body weight of population

RfD: Levels set by Codex Alimentarius Commission (Codex Alimentarius, 2007)

ADI: Acceptable Daily Intake levels (FAO/WHO, 2011).

Assumptions:

- a) Hypothetical body weight of 15 kg for children (0 - 6 yrs), 30 kg for children (7 - 13 yrs) and 60 kg for people older than 13 years.
- b) Maximum absorption rate of 100% and a bioavailability rate of 100% (US EPA, 1998).

### **3.11 Quality Assurance**

The questionnaires were pre-tested on five farmers within the Dome-Kwabinya Constituency who were also engaged in vegetable farming. The necessary corrections were made to questions that had to be modified while questions that were ambiguous were rephrased for clarity. Two research assistants were trained to assist in the data collection and validation before entries were made.

### **3.12 Ethical Consideration**

Ethical approval was sought and received from the Ghana Health Service Ethics Review Committee. The Ethics Review number for approval of the conduct of this study was GHS-ERC 057/05/19. An approval letter from the University of Ghana, School of Public Health also served as validation for the conduct of the study.



## CHAPTER FOUR

### 4.0 RESULTS

#### 4.1 Socio-Demographic Characteristics of Respondents (Cabbage Farmers)

All farmers involved in the study were males, representing 100% of respondents. The mean age of the study population was 32 years with 85% of the respondents aged 20 – 49 years. Thirty-three respondents, representing 82.5% of respondents have spent less than 20 years in vegetable cultivation. The average years spent in vegetable farming by respondents was 11 years. Eighteen of the respondents, representing 45% of respondents were married whereas sixteen of the respondents, representing 40% were single. Thirteen respondents, representing 32.5%, had no form of formal education whiles twenty-seven respondents, representing 67.5%, had a form of formal education. Table 3 shows the description of the socio-demographic characteristics of respondents.

**Table 4.1: Socio-demographic characteristics of respondents**

Variable	Number of respondents (%)
<b>Sex</b>	
Male	40 (100%)
Female	0 (0%)
Total	40 (100%)
<b>Age</b>	
0 -19	4 (10%)
20 – 29	12 (30%)
30 - 39	13 (32.5%)

40 - 49	9 (22.5%)
50 and above	2 (5%)
Total	40 (100%)

---

**Years spent in vegetable farming**

< 10	17 (42.5%)
10 - 19	16 (40%)
20 - 29	6 (15%)
30 and above	1 (2.5%)
Total	40 (100%)

---

**Marital status**

Married	18 (45%)
Single	16 (40%)
Divorced	6 (15%)
Total	40 (100%)

---

**Highest Educational Level**

No formal education	13 (32.5%)
Primary	11 (27.5%)
Junior Secondary	8 (20%)
Senior Secondary	8 (20%)
Total	40 (100%)

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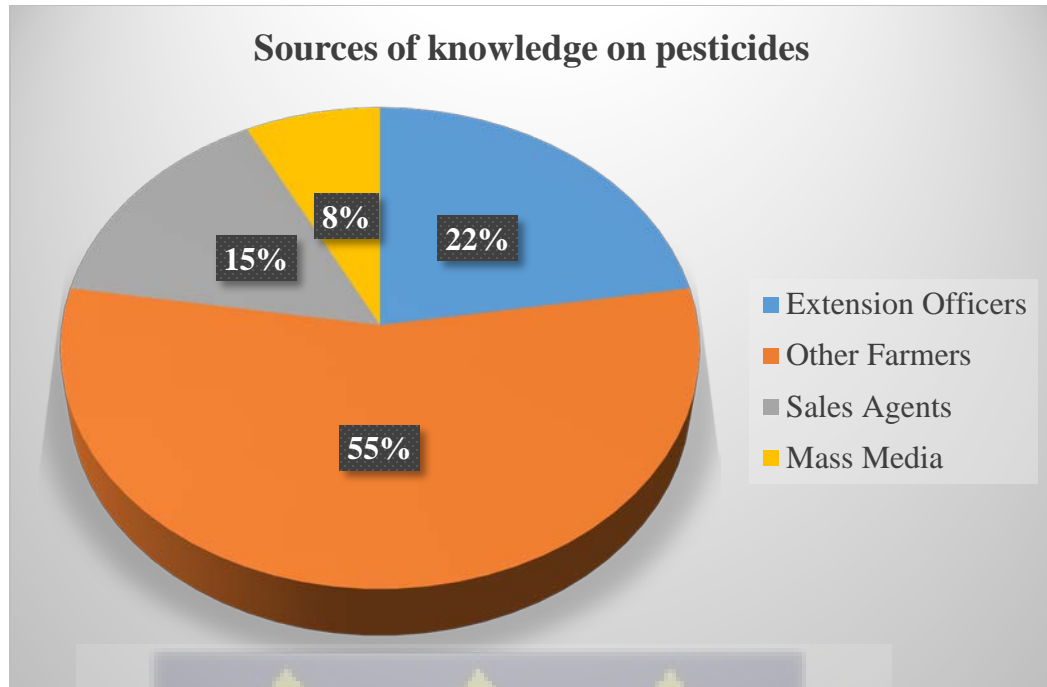
## 4.2 Pesticide Usage Pattern Among Vegetable Farmers in the Ga-East Municipality

### 4.2.1 Knowledge on Pesticide Use and Application

All responders attested to having been trained in safe handling of pesticides and agreed that vegetable production cannot be done without pesticide use shown in Table 4. From the study, the sources of knowledge on pesticides by farmers was from extension officers, representing 22.5% of respondents; other farmers, representing 55% of respondents; sales agents, representing 15% of respondents; and mass media representing 7.5% of the respondents as shown in Figure 4.1. All the responders indicated that they read and understood the instructions on the pesticide labels.

**Table 4.2: Training in the safe handling of pesticides and the perceived importance of pesticides in vegetable production.**

Variable	Number of respondents (%)
<b>Have you been trained in the safe handling of pesticides?</b>	
Yes	40 (100%)
No	0 (0%)
Total	40 (100%)
<b>Can vegetable production be done without the use of pesticides?</b>	
Yes	40 (100%)
No	0 (0%)
Total	40 (100%)

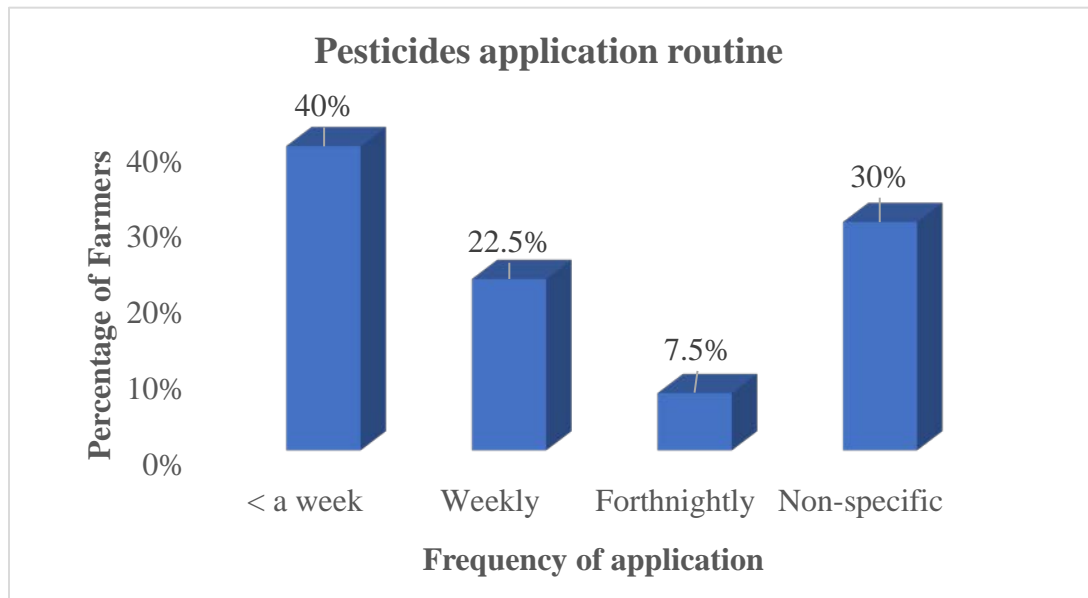


**Figure 4.1: Sources of knowledge on pesticides**

#### **4.2.2 Pesticide application routine**

Generally majority of the farmers, representing 67% of respondents applied pesticides weekly to their vegetables. More specifically 16 farmers, representing 40% of respondents applied pesticides with a duration less than 1 week. There were 9 farmers who indicated that they applied pesticides on a weekly bases, representing 22.5% of respondents. The number of respondents who applied pesticides fortnightly and those without a specific application routine were 3 (7.5%) and 13 (22.5%) respectively. The pesticides application routine is shown in Figure 4.2.





**Figure 4.2: Pesticides application routine**

#### 4.2.3 Pesticide dosage application

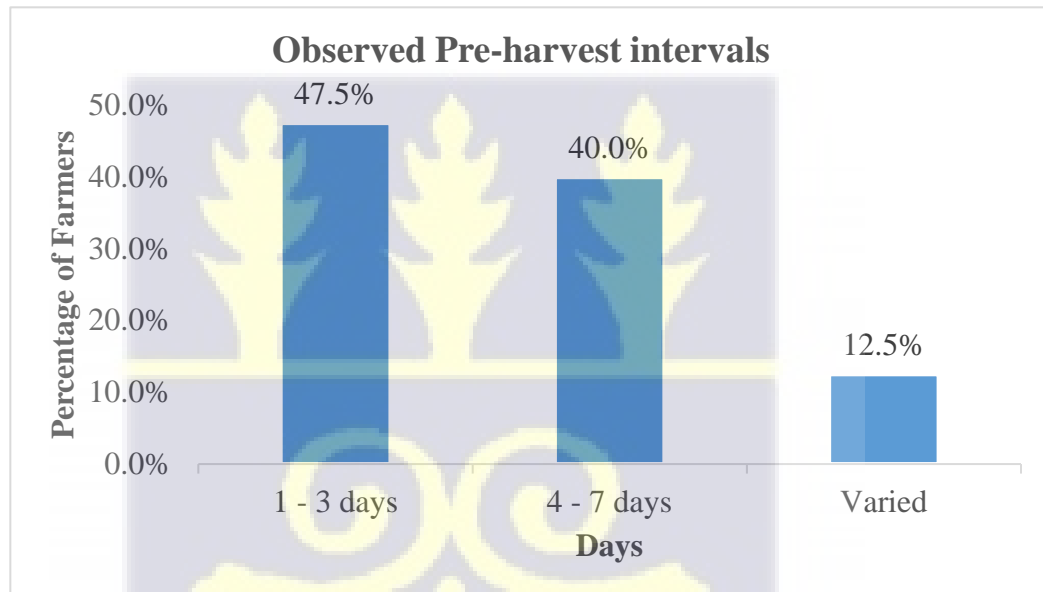
During a single application period, thirty-two (32) of the farmers, representing 80%, asserted to using the recommended dosage whereas 8 of them, representing 20%, indicated varied application doses as shown in Table 5, which is based typically on the spread of the disease.

**Table 4.3: Pesticides dosage application rate**

Variable	Number of respondents (%)
<b>What dosage of pesticides do you apply to your crops?</b>	
Recommended dose	32 (80%)
Below recommended dose	0 (0%)
Above recommended dose	0 (0%)
Varied dose	8 (20%)
<b>Total</b>	<b>40 (100%)</b>

#### 4.2.4 Observed pre-harvest interval

All respondents indicated they have knowledge on pre-harvest interval with 87% of the respondents indicating an interval of a day to a week. Specifically, nineteen (19) respondents, representing 47.5%, observed a pre-harvest interval of 1 – 3 days. A pre-harvest interval of 4 – 7 days was observed by 16 respondents, representing 40%. The remaining 5 respondents, representing 12.5%, observed a varied pre-harvest interval which was based on the type of vegetable. The observed pre-harvest intervals are presented in Figure 4.3.



**Figure 4.3: Duration of pre-harvest interval**

#### 4.2.5 Pesticide package disposal

The widely used method for disposing pesticides package was burning. The proportion of farmers who used this method was 21 (52.5%). Pesticides package disposal by throwing away was the next commonly used method with 17 respondents, representing 42.5%, using this method. A small proportion of respondents, 5%, discarded their pesticides packages using other means than the two methods earlier stated. The pesticides package disposal methods are presented in Table 4.4.

**Table 4.4: Pesticides package disposal**

Variable	Number of respondents (%)
<b>Which method do you use to dispose your pesticides package?</b>	
Thrown-away	17 (42.5%)
Burning	21 (52.5%)
Neither thrown-away nor burnt	2 (5%)
<b>Total</b>	<b>40 (100%)</b>

### **4.3 Heavy Metal and Pesticide Concentration in Soil, Water and Cabbage Samples from Vegetable Farmers Within the Ga-East Municipality.**

#### **4.3.1 Heavy Metals Concentration**

##### **4.3.1.1 Concentration of Heavy Metals in Soil**

The heavy metal content of sampled soils from 20 sites/farms were determined and it was realized that concentrations of Cupper (Cu), Cobalt (Co) and Cadmium (Cd) were below the detection limits of the atomic absorption spectrometer (AAS) in use. The statistical summary of the measured heavy metal concentrations is presented in Table 4.5.



**Table 4.5: Summary of heavy metals concentration in soil**

<b>SITE</b>	<b>As (mg/kg)</b>	<b>Fe (mg/kg)</b>	<b>Zn (mg/kg)</b>	<b>Mn (mg/kg)</b>	<b>Pb (mg/kg)</b>	<b>Ni (mg/kg)</b>	<b>Cr (mg/kg)</b>	<b>Cu (mg/kg)</b>	<b>Co (mg/kg)</b>	<b>Cd (mg/kg)</b>
<b>A1</b>	ND	0.024	0.024	1.010	0.282	0.030	0.090	ND	ND	ND
<b>A2</b>	ND	0.023	0.078	0.767	0.332	0.042	0.042	ND	ND	ND
<b>B1</b>	ND	0.024	0.023	0.694	0.294	0.059	0.033	ND	ND	ND
<b>B2</b>	ND	0.025	0.195	0.810	0.249	0.074	0.032	ND	ND	ND
<b>B3</b>	ND	0.024	0.047	0.652	0.274	0.057	0.031	ND	ND	ND
<b>C1</b>	ND	0.024	0.023	0.663	0.281	0.046	0.011	ND	ND	ND
<b>C2</b>	ND	0.024	0.025	0.531	0.275	0.058	0.011	ND	ND	ND
<b>C3</b>	ND	0.024	0.062	0.526	0.254	0.048	0.010	ND	ND	ND
<b>C4</b>	ND	0.023	0.020	0.582	0.269	0.053	0.016	ND	ND	ND
<b>D1</b>	ND	0.024	0.055	0.693	0.279	0.052	0.030	ND	ND	ND
<b>D2</b>	ND	0.025	0.047	0.810	0.274	0.053	0.089	ND	ND	ND
<b>D3</b>	ND	0.024	0.023	0.531	0.294	0.047	0.031	ND	ND	ND
<b>E1</b>	ND	0.024	0.024	1.010	0.252	0.073	0.011	ND	ND	ND
<b>E2</b>	ND	0.024	0.062	0.524	0.277	0.052	0.042	ND	ND	ND
<b>E3</b>	ND	0.024	0.023	0.581	0.331	0.043	0.011	ND	ND	ND
<b>F1</b>	ND	0.024	0.020	0.767	0.278	0.046	0.032	ND	ND	ND
<b>F2</b>	ND	0.023	0.025	0.696	0.249	0.031	0.031	ND	ND	ND
<b>F3</b>	ND	0.024	0.078	0.692	0.268	0.060	0.016	ND	ND	ND
<b>G1</b>	ND	0.024	0.055	0.665	0.281	0.060	0.016	ND	ND	ND
<b>G2</b>	ND	0.024	0.196	0.652	0.281	0.068	0.032	ND	ND	ND
<b>Mean</b>	-	0.024	0.055	0.693	0.279	0.052	0.031	-	-	-
<b>SD</b>	-	0.001	0.052	0.141	0.022	0.012	0.023	-	-	-

ND: Not detected SD: Standard deviation

#### 4.3.1.2 Concentration of Heavy Metals in Water

A total of 10 sites/locations along the river which serves as the source of water for irrigating the farms was sampled. The heavy metals content of the sampled water was determined and it was realized that concentrations of Cupper (Cu), Cobalt (Co) and Cadmium (Cd) were below the detection limits of the atomic absorption spectrometer (AAS) in use. The statistical summary of the measured heavy metal concentrations is presented in Table 4.6 below.

**Table 4.6: Summary of heavy metals concentration in water.**

<b>SITE</b>	<b>As (mg/kg)</b>	<b>Fe (mg/kg)</b>	<b>Zn (mg/kg)</b>	<b>Mn (mg/kg)</b>	<b>Pb (mg/kg)</b>	<b>Ni (mg/kg)</b>	<b>Cr (mg/kg)</b>	<b>Cu (mg/kg)</b>	<b>Co (mg/kg)</b>	<b>Cd (mg/kg)</b>
<b>AW0</b>	ND	0.024	0.005	0.029	0.285	0.038	0.057	ND	ND	ND
<b>AW1</b>	ND	0.045	0.006	0.023	0.305	0.036	0.035	ND	ND	ND
<b>AW2</b>	ND	0.022	0.007	0.025	0.268	0.037	0.028	ND	ND	ND
<b>BW1</b>	ND	0.045	0.006	0.036	0.247	0.059	0.095	ND	ND	ND
<b>BW2</b>	ND	0.017	0.005	0.047	0.237	0.060	0.040	ND	ND	ND
<b>CW0</b>	ND	0.058	0.004	0.031	0.222	0.027	0.025	ND	ND	ND
<b>CW1</b>	ND	0.038	0.008	0.010	0.242	0.035	0.011	ND	ND	ND
<b>CW2</b>	ND	0.014	0.005	0.068	0.239	0.042	0.012	ND	ND	ND
<b>DW0</b>	ND	0.002	0.003	0.036	0.217	0.026	0.011	ND	ND	ND
<b>EW0</b>	ND	0.013	0.003	0.035	0.301	0.054	0.089	ND	ND	ND
<b>Mean</b>	-	0.028	0.005	0.034	0.256	0.041	0.040	-	-	-
<b>SD</b>	-	0.018	0.002	0.015	0.032	0.012	0.031	-	-	-

ND: Not detected SD: Standard deviation

### 4.3.1.3 Concentration of Heavy Metals in Cabbage

The heavy metal content of cabbages from 20 sites/farms were determined and it was realized that concentrations of Copper (Cu), Cobalt (Co) and Cadmium (Cd) were below the detection limits of the atomic absorption spectrometer (AAS) in use. The statistical summary of the measured heavy metal concentrations is presented in Table 4.7 below.

**Table 4.7: Summary of heavy metals concentration in cabbage.**

<b>SITE</b>	<b>As (mg/kg)</b>	<b>Fe (mg/kg)</b>	<b>Zn (mg/kg)</b>	<b>Mn (mg/kg)</b>	<b>Pb (mg/kg)</b>	<b>Ni (mg/kg)</b>	<b>Cr (mg/kg)</b>	<b>Cu (mg/kg)</b>	<b>Co (mg/kg)</b>	<b>Cd (mg/kg)</b>
<b>A1</b>	ND	0.341	0.079	0.193	0.007	0.010	0.043	ND	ND	ND
<b>A2</b>	ND	0.182	0.068	0.298	0.007	0.011	0.095	ND	ND	ND
<b>B1</b>	ND	0.193	0.070	0.185	0.005	0.007	0.121	ND	ND	ND
<b>B2</b>	ND	0.122	0.048	0.315	0.005	0.009	0.123	ND	ND	ND
<b>B3</b>	ND	0.147	0.063	0.354	0.005	0.008	0.143	ND	ND	ND
<b>C1</b>	ND	0.148	0.061	0.306	0.007	0.010	0.161	ND	ND	ND
<b>C2</b>	ND	0.216	0.088	0.360	0.005	0.012	0.092	ND	ND	ND
<b>C3</b>	ND	0.142	0.060	0.308	0.007	0.020	0.137	ND	ND	ND
<b>C4</b>	ND	0.118	0.049	0.274	0.007	0.011	0.147	ND	ND	ND
<b>D1</b>	ND	0.155	0.050	0.304	0.005	0.008	0.150	ND	ND	ND
<b>D2</b>	ND	0.248	0.072	0.342	0.007	0.015	0.157	ND	ND	ND
<b>D3</b>	ND	0.183	0.064	0.295	0.005	0.011	0.124	ND	ND	ND
<b>E1</b>	ND	0.341	0.074	0.298	0.007	0.010	0.095	ND	ND	ND
<b>E2</b>	ND	0.182	0.059	0.315	0.007	0.011	0.143	ND	ND	ND
<b>E3</b>	ND	0.193	0.050	0.354	0.007	0.009	0.161	ND	ND	ND
<b>F1</b>	ND	0.216	0.088	0.360	0.005	0.008	0.137	ND	ND	ND
<b>F2</b>	ND	0.155	0.079	0.308	0.005	0.012	0.147	ND	ND	ND
<b>F3</b>	ND	0.248	0.068	0.304	0.007	0.011	0.150	ND	ND	ND
<b>G1</b>	ND	0.148	0.063	0.342	0.005	0.020	0.157	ND	ND	ND
<b>G2</b>	ND	0.142	0.072	0.185	0.005	0.020	0.123	ND	ND	ND
<b>Mean</b>	-	0.191	0.066	0.300	0.006	0.011	0.130	-	-	-
<b>SD</b>	-	0.063	0.012	0.054	0.001	0.004	0.030	-	-	-

ND: Not detected    SD: Standard deviation

### 4.3.2. Pesticides Concentration

#### 4.3.2.1 Commonly used pesticides

A total of 28 pesticides are used by these farmers and they include insecticides (18), herbicides (8), nematicides (1) and fungicides (1). The pesticides indicated all fall within class II (61%) and III (39%) classification of pesticides based on their hazardousness. Most of the pesticides had different trade names (common names) but contained the same active ingredients either in the same concentration or slightly different concentrations. The typical active ingredients in the herbicides were glyphosate (63%), paraquat dichloride (24%) and pendimethaline (13%). Mancozeb and carbofuran were the active ingredients in the fungicide and nematicide respectively. The active ingredients present in the insecticides were: abamectin (6%), acetamiprid (6%), cypermethrin (6%), lambda cyhalothrin + acetamiprid (6%), parisrapae granulosis + *Bacillus thuringensis* (6%), chlorpyrifos ethyl (17.5%), emamectin benzoate (17.5%), imidacloprid (17.5%) and lambda cyhalothrin (17.5%).

**Table 4.8: Commonly used pesticides by the farmers**

Type of pesticide	Pesticide common name	Active ingredient	Proportion (%)	Hazard Class	Number of users
<b>Herbicide</b>	Adwumapa	Glyphosate	29%	III	2
	Adwumawura	Glyphosate		III	9
	Condemn	Glyphosate		III	2
	Roundup	Glyphosate		III	11
	Weedout	Glyphosate		III	6
	Gramoquat	Paraquat dichloride		III	1
	Gramozone	Paraquat dichloride		III	1
	Stomp	Pendimethaline		II	2

	Bormic	Abamectin		II	1
	Golan	Acetamiprid		III	1
	Conpyrifos	Chlorpyrifos ethyl		II	6
	Dursban	Chlorpyrifos ethyl		II	11
	Sunpyrifos	Chlorpyrifos ethyl		II	1
	Polythrine-C	Cypermethrin		II	1
	Attack	Emamectin benzoate		II	10
	Control	Emamectin benzoate		II	3
	Protect	Emamectin benzoate		II	5
<b>Insecticide</b>	Antie Atta	Imidacloprid	60%	II	8
	Confidol	Imidacloprid		II	1
	Consider	Imidacloprid		II	2
	Clear	Lambda cyhalothrin		III	1
	Karate	Lambda cyhalothrin		II	1
	Lambda	Lambda cyhalothrin		II	6
	K-optimal	Lambda cyhalothrin +		II	3
		Acetamiprid			
	Bypel	Perisrapae Granulosis + <i>Bacillus thuringensis</i>		II	11
	<b>Fungicide</b>	Agrithane		Mancozeb	7%
Benco		Mancozeb	III	3	
<b>Nematicide</b>	Furadan	Carbofuran	4%	II	9

#### 4.3.2.2 Pesticides concentration in Soil, Water and Cabbage

The following active ingredients were determined as the active ingredients in most of the pesticides used by farmers in the municipality and thus, they were considered as the active ingredients of focus for this study: acetamiprid, chlorpyrifos, emamectin benzoate,

glyphosate and imidacloprid. In soil and water samples, the concentrations of the stated active ingredients were below the detection limit of the LC/MS and thus could not be detected. In cabbage samples, glyphosate was the only pesticide active ingredient that was detected with mean concentration of 0.014 mg/kg. The statistical summary of the measured pesticides active ingredient concentrations in cabbage is presented in Table 4.9.

**Table 4.9: Summary of active ingredient concentration of commonly used pesticides by farmers in cabbage production.**

SITE	Acetamiprid (mg/kg)	Chlorpyrifos (mg/kg)	Emamectin benzoate (mg/kg)	Glyphosate (mg/kg)	Imidacloprid (mg/kg)
A1	ND	ND	ND	0.013	ND
A2	ND	ND	ND	0.015	ND
B1	ND	ND	ND	0.013	ND
B2	ND	ND	ND	0.014	ND
B3	ND	ND	ND	0.013	ND
C1	ND	ND	ND	0.012	ND
C2	ND	ND	ND	0.013	ND
C3	ND	ND	ND	0.016	ND
C4	ND	ND	ND	0.013	ND
D1	ND	ND	ND	0.014	ND
D2	ND	ND	ND	0.013	ND
D3	ND	ND	ND	0.013	ND
E1	ND	ND	ND	0.016	ND
E2	ND	ND	ND	0.013	ND
E3	ND	ND	ND	0.015	ND
F1	ND	ND	ND	0.013	ND
F2	ND	ND	ND	0.014	ND
F3	ND	ND	ND	0.013	ND
G1	ND	ND	ND	0.012	ND
G2	ND	ND	ND	0.015	ND
<b>Mean</b>	-	-	-	0.014	-
<b>SD</b>	-	-	-	0.001	-

ND: Not detected    SD: Standard deviation

#### **4.4 The Bio-Accumulation Factor of Heavy Metals and Pesticides in Cabbage Samples from Vegetable Farms Within the Ga-East Municipality**

##### **4.4.1 Bio-accumulation factor of heavy metals in cabbage.**

The bio-accumulation factor of heavy metals in cabbages sampled from the 20 sites were determined based on the measured metal concentrations in the soil and vegetables from these sites. The bio-accumulation factor was determined for all elements with the exception of As, Cd, Cu, and Co. The trend observed and presented in Table 12 shows that the BAF of the measured heavy metals was Fe (7.966) > Cr (4.238) > Zn (1.202) > Mn (0.433) > Ni (0.219) > Pb (0.022).



**Table 4.10: Summary of bio-accumulation factor of heavy metals in cabbage samples.**

<b>SITE</b>	<b>Fe</b>	<b>Zn</b>	<b>Mn</b>	<b>Pb</b>	<b>Ni</b>	<b>Cr</b>
<b>A1</b>	14.270	3.362	0.191	0.025	0.317	0.480
<b>A2</b>	7.745	0.871	0.389	0.021	0.253	2.289
<b>B1</b>	7.971	3.111	0.267	0.017	0.119	3.708
<b>B2</b>	4.887	0.247	0.389	0.020	0.122	3.889
<b>B3</b>	6.001	1.344	0.543	0.018	0.132	4.689
<b>C1</b>	6.153	2.630	0.462	0.025	0.220	14.636
<b>C2</b>	9.118	3.592	0.678	0.018	0.198	8.714
<b>C3</b>	5.970	0.967	0.585	0.028	0.421	13.650
<b>C4</b>	5.162	2.513	0.471	0.026	0.210	9.188
<b>D1</b>	6.464	0.903	0.438	0.018	0.155	4.934
<b>D2</b>	9.935	1.548	0.422	0.026	0.285	1.756
<b>D3</b>	7.707	2.783	0.555	0.017	0.235	4.000
<b>E1</b>	14.511	3.101	0.295	0.028	0.130	8.636
<b>E2</b>	7.563	0.956	0.601	0.025	0.202	3.429
<b>E3</b>	8.054	2.162	0.608	0.021	0.212	14.375
<b>F1</b>	8.828	4.422	0.469	0.018	0.165	4.239
<b>F2</b>	6.717	3.160	0.442	0.020	0.369	4.820
<b>F3</b>	10.377	0.871	0.438	0.026	0.183	9.344
<b>G1</b>	6.120	1.134	0.514	0.018	0.336	9.781
<b>G2</b>	5.844	0.368	0.284	0.018	0.294	3.864
<b>Mean</b>	7.966	1.202	0.433	0.022	0.219	4.238
<b>SD</b>	2.664	1.222	0.126	0.004	0.086	4.244

#### **4.4.2 Bio-accumulation factor of pesticides in cabbage**

The BAF for pesticides could not be determined since the concentration of the pesticides active ingredients couldn't be determined (were below the detection limit of the LC/MS) in soil. The bio-accumulation factor is a ratio of the active ingredient concentration in cabbage samples to the active ingredients' concentration in soil samples.

#### **4.5 The Health Implications of Consuming Cabbage with The Measured Heavy Metals and Pesticides Concentration on Human**

##### **4.5.1 Health Risk Associated with Measured Heavy Metals Consumption**

Presented in Tables 4.11, 4.12 and 4.13 are the Hazard Quotients (HQ) and Health Risks (HR) to people of different age groups associated with consuming cabbage containing the measured heavy metals concentrations. The Hazard Quotient is obtained mathematically as defined in section 3.10.2. The Health Risk associated with consuming cabbages with the measured heavy metals concentration is obtained by comparing the HQ to the value 1. An HQ value that is greater than 1 is interpreted to mean that there is the likelihood of adverse health effects from consuming cabbages containing the measured heavy metals concentration during the lifetime of the individual. An HQ value that is less than 1 is interpreted to mean that there is no likelihood of adverse health effects from consuming cabbages containing the measured heavy metals concentration during the lifetime of the individual. From the tables, it is observed that all the HQ values for all the age categories were less than 1, thus implying that there was no likelihood of adverse health effects from consuming cabbage with the measured heavy metals concentrations during the lifetime of the individual.

**Table 4.11: Hazard Quotient and Health Risk to adults (Age >13yrs; Average weight = 60kg).**

SITE	Fe		Zn		Mn		Pb		Ni		Cr	
	HQ	HR	HQ	HR	HQ	HR	HQ	HR	HQ	HR	HQ	HR
<b>A1</b>	3.27E-05	NO	3.03E-05	NO	5.53E-04	NO	1.34E-04	NO	2.73E-04	NO	1.08E-04	NO
<b>A2</b>	1.74E-05	NO	2.59E-05	NO	8.57E-04	NO	1.34E-04	NO	3.02E-04	NO	2.38E-04	NO
<b>B1</b>	1.84E-05	NO	2.68E-05	NO	5.32E-04	NO	9.58E-05	NO	2.01E-04	NO	3.01E-04	NO
<b>B2</b>	1.17E-05	NO	1.84E-05	NO	9.06E-04	NO	9.58E-05	NO	2.59E-04	NO	3.06E-04	NO
<b>B3</b>	1.40E-05	NO	2.40E-05	NO	1.02E-03	NO	9.58E-05	NO	2.16E-04	NO	3.58E-04	NO
<b>C1</b>	1.41E-05	NO	2.32E-05	NO	8.80E-04	NO	1.34E-04	NO	2.88E-04	NO	4.03E-04	NO
<b>C2</b>	2.07E-05	NO	3.37E-05	NO	1.03E-03	NO	9.58E-05	NO	3.31E-04	NO	2.29E-04	NO
<b>C3</b>	1.36E-05	NO	2.28E-05	NO	8.84E-04	NO	1.34E-04	NO	5.75E-04	NO	3.41E-04	NO
<b>C4</b>	1.13E-05	NO	1.88E-05	NO	7.88E-04	NO	1.34E-04	NO	3.16E-04	NO	3.68E-04	NO
<b>D1</b>	1.48E-05	NO	1.9E-05	NO	8.73E-04	NO	9.58E-05	NO	2.30E-04	NO	3.74E-04	NO
<b>D2</b>	2.38E-05	NO	2.76E-05	NO	9.83E-04	NO	1.34E-04	NO	4.31E-04	NO	3.91E-04	NO
<b>D3</b>	1.75E-05	NO	2.45E-05	NO	8.47E-04	NO	9.58E-05	NO	3.16E-04	NO	3.10E-04	NO
<b>E1</b>	3.27E-05	NO	2.82E-05	NO	8.57E-04	NO	1.34E-04	NO	2.73E-04	NO	2.38E-04	NO
<b>E2</b>	1.74E-05	NO	2.26E-05	NO	9.06E-04	NO	1.34E-04	NO	3.02E-04	NO	3.58E-04	NO
<b>E3</b>	1.84E-05	NO	1.9E-05	NO	1.02E-03	NO	1.34E-04	NO	2.59E-04	NO	4.03E-04	NO
<b>F1</b>	2.07E-05	NO	3.37E-05	NO	1.03E-03	NO	9.58E-05	NO	2.16E-04	NO	3.41E-04	NO
<b>F2</b>	1.48E-05	NO	3.03E-05	NO	8.84E-04	NO	9.58E-05	NO	3.31E-04	NO	3.68E-04	NO
<b>F3</b>	2.38E-05	NO	2.59E-05	NO	8.73E-04	NO	1.34E-04	NO	3.16E-04	NO	3.74E-04	NO
<b>G1</b>	1.41E-05	NO	2.4E-05	NO	9.83E-04	NO	9.58E-05	NO	5.75E-04	NO	3.91E-04	NO
<b>G2</b>	1.36E-05	NO	2.76E-05	NO	5.32E-04	NO	9.58E-05	NO	5.75E-04	NO	3.06E-04	NO
<b>Mean</b>	1.83E-05		2.53E-05		8.62E-04		1.15E-04		3.29E-04		3.25E-04	
<b>SD</b>	6.07E-06		4.62E-06		1.56E-04		1.97E-05		1.18E-04		7.44E-05	

**Table 4.12: Hazard quotient and Health risk to children (Age: 7-13yrs; Average weight = 30kg).**

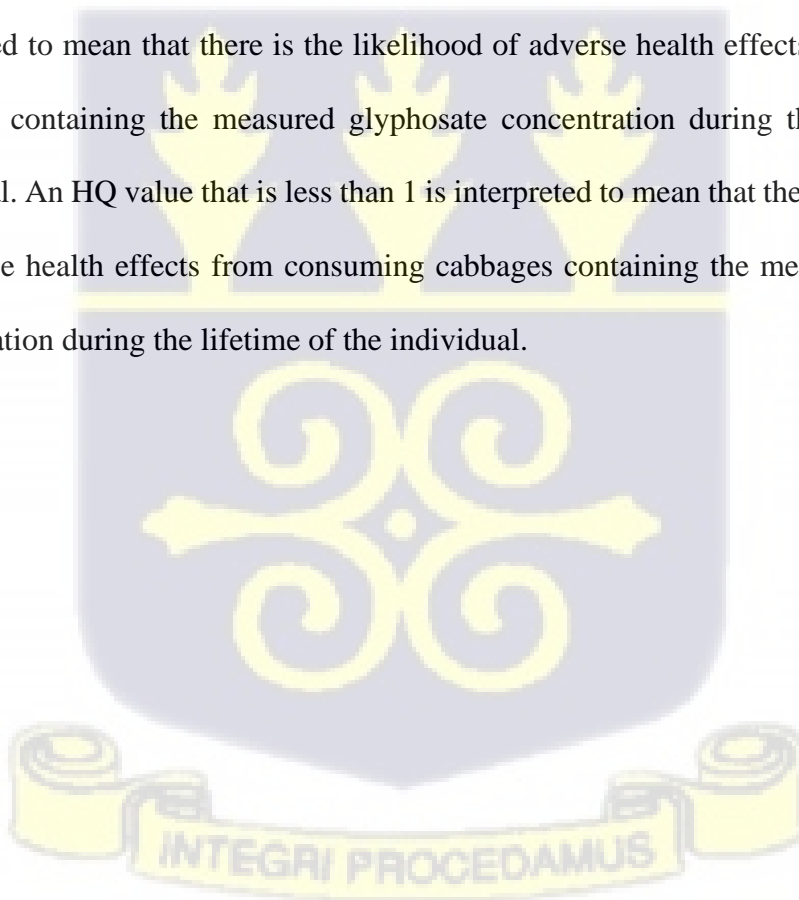
SITE	Fe		Zn		Mn		Pb		Ni		Cr	
	HQ	HR	HQ	HR	HQ	HR	HQ	HR	HQ	HR	HQ	HR
<b>A1</b>	4.4E-05	NO	4.07E-05	NO	7.44E-04	NO	1.80E-04	NO	3.67E-04	NO	1.45E-04	NO
<b>A2</b>	2.34E-05	NO	3.48E-05	NO	1.15E-03	NO	1.80E-04	NO	4.06E-04	NO	3.19E-04	NO
<b>B1</b>	2.48E-05	NO	3.61E-05	NO	7.15E-04	NO	1.29E-04	NO	2.71E-04	NO	4.05E-04	NO
<b>B2</b>	1.57E-05	NO	2.47E-05	NO	1.22E-03	NO	1.29E-04	NO	3.48E-04	NO	4.12E-04	NO
<b>B3</b>	1.89E-05	NO	3.22E-05	NO	1.37E-03	NO	1.29E-04	NO	2.90E-04	NO	4.81E-04	NO
<b>C1</b>	1.9E-05	NO	3.12E-05	NO	1.18E-03	NO	1.80E-04	NO	3.87E-04	NO	5.41E-04	NO
<b>C2</b>	2.78E-05	NO	4.54E-05	NO	1.39E-03	NO	1.29E-04	NO	4.45E-04	NO	3.08E-04	NO
<b>C3</b>	1.83E-05	NO	3.07E-05	NO	1.19E-03	NO	1.80E-04	NO	7.73E-04	NO	4.59E-04	NO
<b>C4</b>	1.52E-05	NO	2.53E-05	NO	1.06E-03	NO	1.80E-04	NO	4.25E-04	NO	4.94E-04	NO
<b>D1</b>	1.99E-05	NO	2.55E-05	NO	1.17E-03	NO	1.29E-04	NO	3.09E-04	NO	5.03E-04	NO
<b>D2</b>	3.2E-05	NO	3.71E-05	NO	1.32E-03	NO	1.80E-04	NO	5.80E-04	NO	5.26E-04	NO
<b>D3</b>	2.35E-05	NO	3.3E-05	NO	1.14E-03	NO	1.29E-04	NO	4.25E-04	NO	4.17E-04	NO
<b>E1</b>	4.4E-05	NO	3.79E-05	NO	1.15E-03	NO	1.80E-04	NO	3.67E-04	NO	3.19E-04	NO
<b>E2</b>	2.34E-05	NO	3.04E-05	NO	1.22E-03	NO	1.80E-04	NO	4.06E-04	NO	4.81E-04	NO
<b>E3</b>	2.48E-05	NO	2.55E-05	NO	1.37E-03	NO	1.80E-04	NO	3.48E-04	NO	5.41E-04	NO
<b>F1</b>	2.78E-05	NO	4.54E-05	NO	1.39E-03	NO	1.29E-04	NO	2.90E-04	NO	4.59E-04	NO
<b>F2</b>	1.99E-05	NO	4.07E-05	NO	1.19E-03	NO	1.29E-04	NO	4.45E-04	NO	4.94E-04	NO
<b>F3</b>	3.2E-05	NO	3.48E-05	NO	1.17E-03	NO	1.80E-04	NO	4.25E-04	NO	5.03E-04	NO
<b>G1</b>	1.9E-05	NO	3.22E-05	NO	1.32E-03	NO	1.29E-04	NO	7.73E-04	NO	5.26E-04	NO
<b>G2</b>	1.83E-05	NO	3.71E-05	NO	7.15E-04	NO	1.29E-04	NO	7.73E-04	NO	4.12E-04	NO
<b>Mean</b>	2.46E-05		3.4E-05		1.16E-03		1.55E-04		4.43E-04		4.37E-04	
<b>SD</b>	8.17E-06		6.22E-06		2.09E-04		2.64E-05		1.58E-04		1.00E-04	

**Table 4.13: Hazard quotient and Health risk to children (Age: 0-6yrs; Average weight = 15kg).**

SITE	Fe		Zn		Mn		Pb		Ni		Cr	
	HQ	HR	HQ	HR	HQ	HR	HQ	HR	HQ	HR	HQ	HR
<b>A1</b>	8.79E-05	NO	8.15E-05	NO	1.49E-03	NO	3.61E-04	NO	7.35E-04	NO	2.89E-04	NO
<b>A2</b>	4.68E-05	NO	6.96E-05	NO	2.30E-03	NO	3.61E-04	NO	8.12E-04	NO	6.39E-04	NO
<b>B1</b>	4.96E-05	NO	7.22E-05	NO	1.43E-03	NO	2.58E-04	NO	5.41E-04	NO	8.10E-04	NO
<b>B2</b>	3.14E-05	NO	4.95E-05	NO	2.44E-03	NO	2.58E-04	NO	6.96E-04	NO	8.24E-04	NO
<b>B3</b>	3.78E-05	NO	6.44E-05	NO	2.73E-03	NO	2.58E-04	NO	5.80E-04	NO	9.62E-04	NO
<b>C1</b>	3.80E-05	NO	6.24E-05	NO	2.37E-03	NO	3.61E-04	NO	7.73E-04	NO	1.08E-03	NO
<b>C2</b>	5.56E-05	NO	9.07E-05	NO	2.78E-03	NO	2.58E-04	NO	8.89E-04	NO	6.15E-04	NO
<b>C3</b>	3.66E-05	NO	6.14E-05	NO	2.38E-03	NO	3.61E-04	NO	1.55E-03	NO	9.18E-04	NO
<b>C4</b>	3.04E-05	NO	5.05E-05	NO	2.12E-03	NO	3.61E-04	NO	8.51E-04	NO	9.89E-04	NO
<b>D1</b>	3.98E-05	NO	5.10E-05	NO	2.35E-03	NO	2.58E-04	NO	6.19E-04	NO	1.01E-03	NO
<b>D2</b>	6.39E-05	NO	7.42E-05	NO	2.64E-03	NO	3.61E-04	NO	1.16E-03	NO	1.05E-03	NO
<b>D3</b>	4.71E-05	NO	6.60E-05	NO	2.28E-03	NO	2.58E-04	NO	8.51E-04	NO	8.34E-04	NO
<b>E1</b>	8.79E-05	NO	7.58E-05	NO	2.30E-03	NO	3.61E-04	NO	7.35E-04	NO	6.39E-04	NO
<b>E2</b>	4.68E-05	NO	6.08E-05	NO	2.44E-03	NO	3.61E-04	NO	8.12E-04	NO	9.62E-04	NO
<b>E3</b>	4.96E-05	NO	5.10E-05	NO	2.73E-03	NO	3.61E-04	NO	6.96E-04	NO	1.08E-03	NO
<b>F1</b>	5.56E-05	NO	9.07E-05	NO	2.78E-03	NO	2.58E-04	NO	5.80E-04	NO	9.18E-04	NO
<b>F2</b>	3.98E-05	NO	8.15E-05	NO	2.38E-03	NO	2.58E-04	NO	8.89E-04	NO	9.89E-04	NO
<b>F3</b>	6.39E-05	NO	6.96E-05	NO	2.35E-03	NO	3.61E-04	NO	8.51E-04	NO	1.01E-03	NO
<b>G1</b>	3.8E-05	NO	6.44E-05	NO	2.64E-03	NO	2.58E-04	NO	1.55E-03	NO	1.05E-03	NO
<b>G2</b>	3.66E-05	NO	7.42E-05	NO	1.43E-03	NO	2.58E-04	NO	1.55E-03	NO	8.24E-04	NO
<b>Mean</b>	4.92E-05		6.81E-05		2.32E-03		3.09E-04		8.85E-04		8.75E-04	
<b>SD</b>	1.63E-05		1.24E-05		4.19E-04		5.29E-05		3.17E-04		2.00E-04	

#### 4.5.2. Health Risk Associated with Measured Pesticides Consumption

The health risk due to consuming cabbage with the measured active ingredient concentration was estimated for glyphosate only as it was the only active ingredient that recorded values above the detection limit of the LC/MS. Presented in Table 4.14 is the Hazard Quotient (HQ) and Health risk (HR) to people in different age groups associated with consuming cabbage containing the measured glyphosate concentrations. The Hazard Quotient is obtained mathematically as defined in section 3.10.2. The Health Risk associated with consuming cabbages with the measured glyphosate concentration is obtained by comparing the HQ to the value 1. An HQ value that is greater than 1 is interpreted to mean that there is the likelihood of adverse health effects from consuming cabbages containing the measured glyphosate concentration during the lifetime of the individual. An HQ value that is less than 1 is interpreted to mean that there is no likelihood of adverse health effects from consuming cabbages containing the measured glyphosate concentration during the lifetime of the individual.



**Table 4.14: Hazard Quotient (HQ) and Health Risk (HR) across all age groups due to consuming cabbage with the measured glyphosate concentrations.**

SITE	0 - 6 YEARS		7 - 13 YEARS		ADULTS (> 13 years)	
	HQ	HR	HQ	HR	HQ	HR
<b>A1</b>	2.01E-04	NO	1.01E-04	NO	6.98E-05	NO
<b>A2</b>	2.32E-04	NO	1.16E-04	NO	8.05E-05	NO
<b>B1</b>	2.01E-04	NO	1.01E-04	NO	6.98E-05	NO
<b>B2</b>	2.17E-04	NO	1.08E-04	NO	7.51E-05	NO
<b>B3</b>	2.01E-04	NO	1.01E-04	NO	6.98E-05	NO
<b>C1</b>	1.86E-04	NO	9.28E-05	NO	6.44E-05	NO
<b>C2</b>	2.01E-04	NO	1.01E-04	NO	6.98E-05	NO
<b>C3</b>	2.47E-04	NO	1.24E-04	NO	8.59E-05	NO
<b>C4</b>	2.01E-04	NO	1.01E-04	NO	6.98E-05	NO
<b>D1</b>	2.17E-04	NO	1.08E-04	NO	7.51E-05	NO
<b>D2</b>	2.01E-04	NO	1.01E-04	NO	6.98E-05	NO
<b>D3</b>	2.01E-04	NO	1.01E-04	NO	6.98E-05	NO
<b>E1</b>	2.47E-04	NO	1.24E-04	NO	8.59E-05	NO
<b>E2</b>	2.01E-04	NO	1.01E-04	NO	6.98E-05	NO
<b>E3</b>	2.32E-04	NO	1.16E-04	NO	8.05E-05	NO
<b>F1</b>	2.01E-04	NO	1.01E-04	NO	6.98E-05	NO
<b>F2</b>	2.17E-04	NO	1.08E-04	NO	7.51E-05	NO
<b>F3</b>	2.01E-04	NO	1.01E-04	NO	6.98E-05	NO
<b>G1</b>	1.86E-04	NO	9.28E-05	NO	6.44E-05	NO
<b>G2</b>	2.32E-04	NO	1.16E-04	NO	8.05E-05	NO
<b>Mean</b>	2.11E-04		1.06E-04		7.33E-05	
<b>SD</b>	1.83E-05		9.14E-06		6.34E-06	

## CHAPTER FIVE

### 5.0 DISCUSSION

#### 5.1 Socio-Demographics

Typically, agriculture is a male dominated profession in Ghana and majority of the population usually engaged in it are within the age group 20 – 50 years (Ghana Statistical Service, 2013), it comes thus as a surprise that 100% of the respondents were males with 70% of them within this age group and is similar to results obtained by Ninsin et al., (1997). The proportion of respondents decreased with increasing educational level thus indicating that vegetable farming within the district was less enticing for people with higher educational levels. This phenomenon can have implications on general productivity as well as safe application and handling of pesticides as most instructions are written in English. The highest educational level attained by respondents was SHS (20%) and those without any form of formal education was 33%. The district has majority of the population within the ages 30 – 60 years being married (Ga-East Municipality, 2013) and this is similar to results obtained in the study where the mean age of respondents was 32 years and most of them were married (73%).

#### 5.2 Commonly Used Pesticides

Insecticides and herbicides were the major groups of pesticides used by farmers. These indicate that the major concern of the farmers in relation to pests were weeds and insects. Insecticides were predominantly used to kill insect pest that attacked the vegetables while herbicides are typically used to control weeds during pre-emergence state of seedlings and

immediately after emergence of seedlings. This is because the seedlings are very vulnerable to mechanical control of weeds. The other stage in which herbicides are used is after the emergence of fruits or maturity of the vegetables so as not to damage the vegetables that will soon be harvested for the market if mechanical means are to be used for weed control. The other groups of pesticides used by farmers was nematicides and fungicides. With respect to the hazard classification of the pesticides, all pesticides used by the respondents were either class II (moderately hazardous) or III (slightly hazardous) chemicals. These results were consistent with results obtained in a work by Mattah et al. (2015). Further credence to the wide spread use of insecticides and herbicides is evident in the fact that of all imported pesticides into Ghana, the major groups are insecticides and pesticides (Diarra and Tasie, 2017).

### **5.3 Pesticides Usage Pattern**

All respondents attested to having been trained in the safe handling and application of pesticides. This is in line with requirements to ensure that maximum benefits are obtained from the use of these pesticides while protecting producers and consumers from the deleterious effects inherent in these pesticides. In consonance with a work by Avicor et al. (2011) the respondents indicated that their crops were attacked by pests and as such they predominantly use chemical agents to control the pest. In effect, they attested that vegetable farming cannot be done without the use of chemicals. The sources of knowledge on pesticides was similar to that obtained by a research by Mattah et al. (2015) though the proportions to which each identified source contributed to the respondents' knowledge on pesticide was varied. The varied sources of pesticide knowledge of respondents is likely to

impact their use and handling of pesticides due to the fact that each source of knowledge will have to deal with a form of conflict of interest. Information from sales agents may likely focus on providing efficacy of pesticide as opposed to the possible adverse effects while mass media may focus more on the possible adverse effects of pesticide usage as opposed to the possible benefits on increasing output. Extension officers may be more likely to provide a near balanced and accurate information on pesticides use as opposed to the sources earlier stated. In effect, the sources of respondents knowledge on pesticides influences everything relating to their use of pesticides including the disposal method of pesticide packages, the dosage of pesticides, the frequency of application of the pesticides as well as the observed pre-harvest intervals by respondents as exemplified by other studies though to different extent/proportions (Avicor et al., 2011; Mattah et al., 2015).

#### **5.4 Heavy Metals Concentration in Soil, Water and Cabbage**

The heavy metal concentration in soil based on mean value showed Mn>Pb>Zn>Ni>Cr>Fe as the observed trend whereas the observed trend in cabbages was Mn>Fe>Cr>Zn>Ni>Pb. A similar study conducted on agricultural soils and cabbage within the same locality reported elevated heavy metal concentrations for both the dry and wet seasons than results of this study (Addae, 2015). Relative to EU guidelines on heavy metal concentration in agricultural soils, all the measured concentrations in this study were below the EU recommended levels (European Commission, 2002). The trend in water (based on mean value) was Pb>Ni>Cr>Mn>Fe>Zn. The measured levels in water were similar to results obtained by a work by Lente, Brimah & Atiemo (2014) in Ghana. Comparative to FAO/WHO (2007) standards, the results obtained were below the recommended levels.

The low levels of heavy metals recorded for this study can be attributed to the absence of the major anthropogenic sources of these metals within the municipality or its immediate environs. Heavy metals whose major sources are from industrial processes such as mining, tanning, municipal waste, sewage sludge, electroplating and pyro-metallurgy typically recorded lower levels than metals whose primary sources included burning of fossil fuel (typically from vehicular emission) such as Pb. In the absence of major anthropogenic sources of these metals within the study area, the heavy metal concentrations likely depend on the natural abundance of these metals within the study with the exception of concentrations obtained for water where factors along its entire catchment area up to the sampled sites can influence the concentration. To a limited extent, the measured heavy metal concentrations can give an indication of the pollution load and sources of the heavy metals within the municipality.

### **5.5 Bio-Accumulation of Heavy Metals in Cabbage**

Bio-accumulation of metals in plants depends on several factors including: solubility of metal, pH, soil type, soil particle size, organic matter, concentration of metal in soil and vegetable species (Gebrekidan et al., 2013).

The bio-accumulation factor for heavy metals in cabbage, which was a factor obtained based on the concentration of heavy metals in cabbage relative to the concentration of heavy metals in soil showed a trend as:  $Fe > Cr > Zn > Mn > Ni > Pb$ . This factor is explained to mean that for a unit measure of heavy metal in soil, there would be the BAF fold increase of the measured soil concentration in the cabbage. BAF is typically indicative of the heavy metals' contamination in the environment (Khan et al., 2008). Generally, an inverse

relationship exists between BAF and heavy metal concentration of soil and thus the trends observed for these two measures should likewise depict this inverse relationship. With respect to this work, inverse relationship in terms of trend between BAF and soil concentrations was generally observed with the exception of Mn which significantly skipped the trend. It is worth mentioning that in the event that the difference between the concentration of two or more heavy metals in the soil is small relative to the difference in their measured concentration in cabbage, the concentration in the cabbage typically determines the trend that will be observed between these metals as shown in the BAF trend observed for Ni and Zn. The Bio-accumulation, within acceptable levels, of Fe, Zn, Mn and Ni which are essential elements/ micronutrients for plants, animals and humans in cabbages within this municipality ensures that dependents on these cabbages are not deficient of these essential elements.

#### **5.6 Health Risk Associated with Measured Heavy Metals Consumption in Cabbage**

The health risk to consumers of cabbage containing the measured heavy metals concentration was estimated based on the calculated Hazard Quotient (HQ). The HQ is the ratio of the potential exposure of a substance and the level at which no adverse effect is expected. By way of interpretation, an HQ of at least 1 indicates the possibility of adverse effects whereas a value less than 1 suggest no likelihood of experiencing an adverse effect due to exposure to the measured substance. The indication of the likelihood or not of an adverse effect is the Health Risk (HR). The results obtained in this study indicated an HQ less than 1 for all the measured concentrations across all the three age categories thus indicating that there is no likelihood of adverse effect due to consuming cabbage from this

municipality with the measured heavy metals content. The results of this study was similar to results obtained in other works in which health risks due to heavy metal contamination of fruits and vegetables from farms and markets in Ghana was studied. (Addae, 2015; Bempah et al., 2011; Lente et al., 2014).

### **5.7 Pesticides Concentration in Soil, Water and Cabbage**

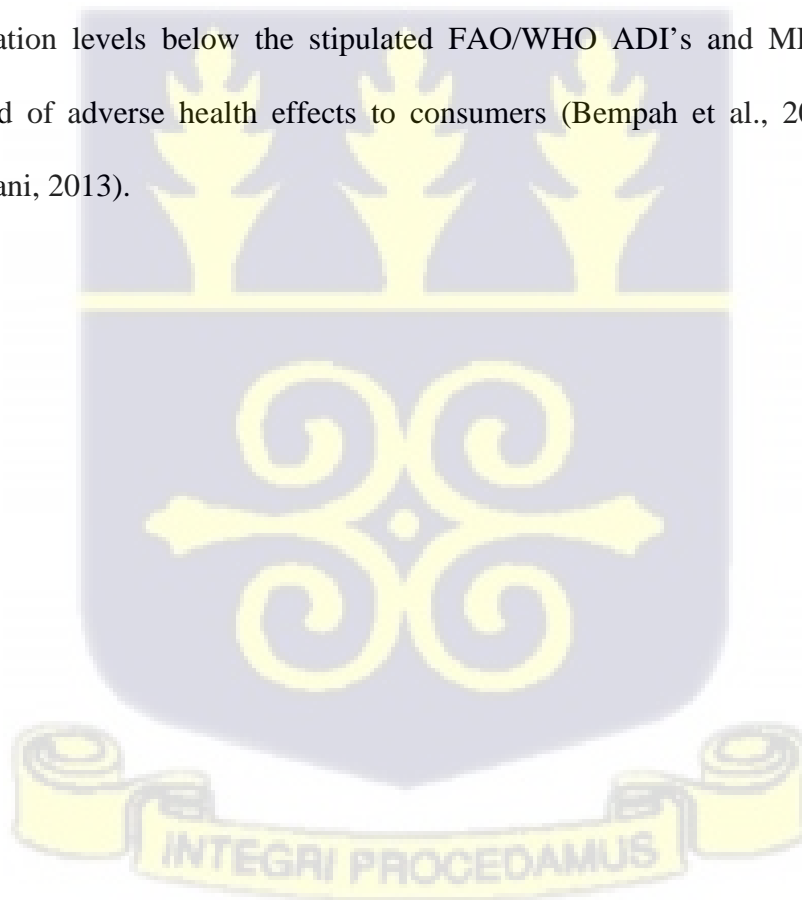
All other active ingredients with the exception of glyphosate were undetected as their concentrations were below the detection limit of the LC/MS in all of the three media. Glyphosate was the only active ingredient of the list of active ingredients of focus for this study, whose concentration was detected in only cabbage out of the three media of interest. The detection limit of the LC/MS is 0.005 mg/kg, indicating that all the undetected active ingredients of interest had concentrations below this level. Generally, the low concentration of active ingredients across soil, water and cabbage can be best explained by the following reasons: All the farmers indicated they understood and observed pre-harvest intervals, which is the minimum time from application of pesticides on crops to its harvesting within which the pesticide should degrade to acceptable levels that wouldn't pose health risk to consumers. Of the total respondents, 87% of them indicated they observed a pre-harvest period of 1 – 3 days and 4 – 7 days cumulatively. Majority of the farmers (80%) indicated that they apply recommended doses of pesticides to their crops. Using recommended dose during application not only ensures effectiveness of the pesticide but also reduces contamination and accumulation in environmental matrices (soil, water and cabbage). A good pesticide application routine further buttresses the advantages of using recommended doses as it allows for the degradation of pesticides. As indicated in the results, 27% of the

farmers apply pesticides once in a week while 40% of them apply pesticides for a maximum of 2 -3 times a week. Information regarding the safe use and application of pesticides as displayed on labels are mostly written in English. This thus requires that users should be able to read and understand English as used on these labels. Majority of farmers in this study (67%) had a form of formal education and thus indicated they read and understood instructions in the pesticide labels. The remaining proportion of the farmers also indicated their understanding of instruction on the labels based on their ability to interpret the symbol and diagrams which come with the labels though they had no formal education. This is possible as all farmers indicated they have training in the safe use of pesticides and interpreting diagrams and symbols on labels forms part of the training. The major source of knowledge on pesticides was attributed to extension officers and colleague farmers. Farmers within the study area belong to a cooperative association and they thus engage in regular stakeholder meetings, workshops and trainings. They indicated that colleagues are sent to attend such trainings and workshops, which includes safe usage and handling of pesticides, and they in-turn are mandated to train other farmers within their association. Most of the farms are on the land belonging to the Ghana Atomic Energy Commission (GAEC) whose Biotechnology and Nuclear Agriculture Research Institute (BNARI) also organizes trainings and workshops for these farmers. The concentration of glyphosate in cabbage though detected, was very low and largely due to the same reasons as stated to be responsible for the non-detection of the other active ingredients. Glyphosate is the active ingredient in most of the herbicides which are applied to control weeds throughout the life cycle of cabbage (from nursery bed preparation to harvest) thus the possibility of accumulating in the cabbage to detectable levels as compared to the other

active ingredients which are insecticides and have a shorter interaction time with the life cycle of cabbage.

### **5.8 Health Risk Associated with Measured Pesticide Consumption in Cabbage**

The estimated hazard quotients and health risk indicated that there is no likelihood of adverse health effects from consuming cabbage with the measured pesticides concentration. This is as a result of the low levels of pesticides in cabbage below the Acceptable Daily Intake (ADI) or the Maximum Residue Levels (MRLs) levels as set by the FAO/WHO. The results of this study were consistent with works in which pesticide concentration levels below the stipulated FAO/WHO ADI's and MRLs presented no likelihood of adverse health effects to consumers (Bempah et al., 2011; Fothergill & Abdelghani, 2013).



## CHAPTER SIX

### 6.0 CONCLUSION AND RECOMMENDATION

#### 6.1 Introduction

Presented in this chapter is the conclusion arrived at from this study as well as recommendations. The limitations as observed have also been stated.

#### 6.2 Conclusion

Out of ten heavy metals of interest, the concentrations of six were detected in all of the three media of interest (soil, water and cabbage). As, Co, Cu, and Cr were not detected in all of the three media. All of the detected heavy metals and pesticide active ingredients in soil, water and cabbage was below the recommended levels set by FAO/WHO.

The pesticides usage pattern as ascertained from the study revealed that most farmers used recommended doses in pesticide application. Having been trained in the safe use and application of pesticides, the farmers largely observed the appropriate pre-harvest interval and application routine.

The bio-accumulation factor indicated low pollution load and translocation potential of heavy metals and glyphosate in the study area. Some of the heavy metals (Mn, Zn and Fe) are known micronutrients/essential elements thus needed in trace amounts for normal biological functioning. The accumulation of these micronutrients below ADI/MRL indicates that these cabbages can serve as a source of these micronutrients/essential elements for consumers. As estimated by the hazard quotient, under normal consumption rate, no adverse health effects is expected to occur among the population who consume cabbage from these farms relating to heavy metals and pesticides contamination.

With the exception of glyphosate, all the other pesticide active ingredients of interest (acetamiprid, chlorpyrifos, emamectin benzoate and imidacloprid) were below the detection limit of the LC/MS in all of the three media.

### **6.3 Recommendation**

The following have been identified as recommendations following the results of this study:

- 1) Similar studies using different research tools such as Cloze Test; Achievement Test and Socratic Seminars could provide better understanding of the pesticide's usage pattern.
- 2) Similar studies on heavy metals and pesticides should be done on other vegetables within the study area.
- 3) Government and other regulatory bodies should ensure that similar studies are regularly conducted across the major vegetable producing farms and markets in the country.
- 4) Medical screening should be conducted on farmers to assess health effects of long-term exposure to the pesticides and heavy metals.

### **6.4 Limitation**

The identified limitations of this study are:

- 1) The farming and pesticide application history of each farm was not ascertained. This is important as it can help to further explain the results obtained.

- 2) The variety of cabbage that was cultivated was also not considered in this study as different varieties may accumulate different amounts of heavy metals and pesticides.



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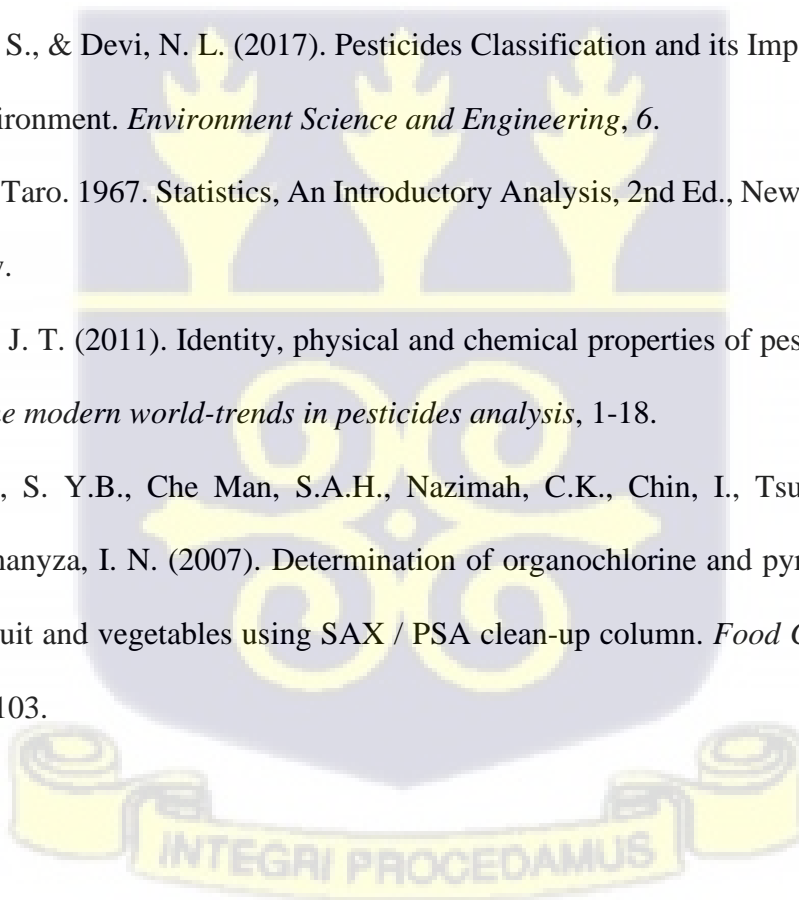
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## APPENDICES

### APPENDIX A: Participants Information Sheet

STUDY TITLE: RESIDUAL HEAVY METALS, PESTICIDES AND THEIR IMPLICATIONS ON HUMAN HEALTH OUTCOMES IN CABBAGE PRODUCTION WITHIN THE GA-EAST MUNICIPALITY, ACCRA.

Dear participant, I am Charles Yao Ansre, an MPH student at the School of Public Health University of Ghana Legon.

In order to meet the increasing demand for vegetables globally, farmers have to use pesticides to protect crops from pest attacks. Some of these applications are unregulated thus resulting in higher-than-normal concentrations of these chemicals on the vegetables. Unsuspecting populations get exposed to these chemicals and may suffer adverse health effects. Urbanization, modernization and industrialization have also increased the presence of heavy metals in our environment. Most vegetable farms in Accra are increasingly being exposed to heavy metal contamination due to the above stated phenomena. Heavy metals are also known to have adverse health effects on the population. The aim of this study is to assess heavy metals and pesticide residues and their implications on human health outcomes in vegetable production within GA-East municipality.

If you agree to participate in this study, you may be required to answer some questions on vegetable production and pesticides application. The questions will require approximately 15- 20 minutes for completion.

This study is self-sponsored and participation in this study will be at no cost to you. There is minimal risk involved in this study as you may be uncomfortable with answering some of the questions. If such a situation happens, you can skip those questions or withdraw from the study without penalty and without having to give any reasons. There is no compensation or direct benefit from your participation in this study. However, the information obtained from this study will be used to help farmers improve their knowledge on safe pesticide application.

The study will be conducted in accordance with guidelines stipulated by the Ethics Review Committee (ERC). Participation in this study is voluntary and decision to participate, stay or withdraw from study is at the discretion of the participant and will be of no consequence. All the information collected from the study participants will be kept confidential and will not be traceable to the participants. Data will be under lock and key and electronic versions will be password protected with only the P1 having access to them. The data will be used for research and academic purposes only and will be destroyed by burning questionnaires after five (5) years. Ethical clearance will be sought again should the need arise for reuse of the data.

You will not be identified by name in any dissemination reports or publications resulting from this study. You will be given a copy of the information sheet and Consent form after it has been signed to keep.

Additional Information:

Any questions or additional information should be directed to the Principal Investigator (PI) Charles Yao Ansre, Department of Biological, Environmental and Occupational Health, School of Public Health, University of Ghana.

Phone contact: 0242306796, Email: [ansrecharlesyao@gmail.com](mailto:ansrecharlesyao@gmail.com) or

Miss Hannah Frimpong, of the Ethics Review Committee (ERC) of the Ghana Health Service (GHS), Phone Contact: 0507041223, Email: [hannah.frimpong@ghsmail.org](mailto:hannah.frimpong@ghsmail.org) or [ghserc@gmail.com](mailto:ghserc@gmail.com)



**APPENDIX B: Consent Form**

**PARTICIPANTS' STATEMENT**

I acknowledge that I have read or have had the purpose and contents of the Participants' Information Sheet read and satisfactorily explained to me in a language I understand (language: .....). I fully understand the contents and any potential implications as well as my right to change my mind (i.e. withdraw from the research) even after I have signed this form.

I voluntarily agree to be part of this research.

Name or Initials of Participant .....

ID Code .....

Participants' Signature.....

Date .....

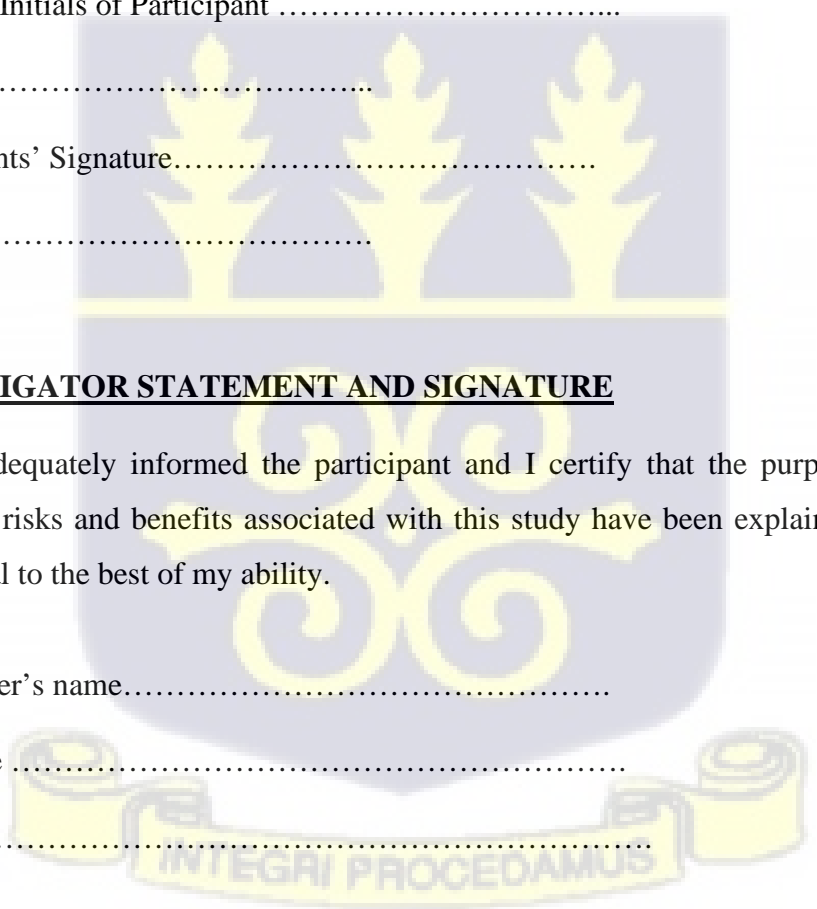
**INVESTIGATOR STATEMENT AND SIGNATURE**

I have adequately informed the participant and I certify that the purpose, procedures, potential risks and benefits associated with this study have been explained to the above individual to the best of my ability.

Researcher's name.....

Signature .....

Date.....



**APPENDIX C: Questionnaire**

**SECTION A: DEMOGRAPHIC INFORMATION**

Please kindly provide answers to the underlisted questions. Respond to the items by **ticking** (✓) or **writing** in the spaces provided.

1. Age as at last birthday. (                      )

2. Sex: (a) male (     )                      (b) Female (     )

3. Marital status

A) Single                      b) Married                      c) Divorced

d) Co-habiting                      e) Widowed

4. Highest level of education

a) None                      b) Primary                      c) JHS

d) SHS                      e) Tertiary

5. How long have you been engaged in farming? (                      )

6. How long have you been engaged in vegetable farming? (                      )

7. Which vegetables do you cultivate?

a)                                      b)                                      c)

d)                                      e)                                      f)

8. Do you have an alternative source of livelihood?

(a) Yes (     )                      (b) No (     )



**SECTION B: KNOWLEDGE ABOUT PESTICIDE USE AND APPLICATION**

Please kindly provide answers to the underlisted questions. Respond to the items by **ticking (√)** or **writing** in the spaces provided.

9. Are your vegetables attacked by pest?

a) Yes ( ) (b) No ( )

10. Do you take measures to control the pests that attack your vegetables?

a) Yes ( ) (b) No ( )

11. If No, why don't you control the pests which attack your vegetables?

.....  
.....

12. Which method(s) do you use in controlling pests on your vegetables?

(a) Chemical (b) Biological  
(c) Cultural (d) Mechanical

13. If you use chemicals, what type of chemicals do you use in controlling pests on your vegetable farm?

a) Synthetic/Inorganic (b) Biopesticides (c) Natural/Organic

14. How frequently do you apply these pesticides to the vegetables?

a) Daily (b) Weekly (c) Forth nightly (d) Monthly  
e) Varied (please specify)

.....  
.....

15. What do you use as a sign to apply pesticides?

a) Calendar basis  
b) When I detect the presence of pest/disease  
c) Others (specify) .....

16. What is the major reason that influences your choice of pesticides?

- a) Availability
- b) Effectiveness
- c) Cost
- e) Other reasons (please specify)

.....  
.....

17. Do you know of the term “pre-harvest interval” and its importance?

- a) Yes ( )
- (b) No ( )

18. What duration of “pre-harvest interval” do you observe?

- a) Same day
- b) 1 day to 3 days
- c) 4 days to 7 days
- d) 8 days to 14 days
- e) Varied (please specify)

.....  
.....

19. How much (dosage) of the pesticide do you apply during a single application period.

- a) Below recommended
- b) Recommended
- c) Above recommended

20. Where do you store your pesticides?

- a) In rooms at home
- b) In barns
- c) On the farm
- d) Others (please specify)

.....  
.....

21. By what method(s) do you dispose-off the pesticide containers?

- a) Sold
- b) Thrown away
- c) Buried in the soil
- d) As storage containers

22. If your answer to the question above is **d**), what do you store in the containers?

.....

23. What is/are your source(s) of knowledge about pesticide use?

- a) Extension officers
- b) Other famers
- c) Sales agents
- d) Media (radio, TV, newspaper)
- e) Others (please specify)

.....

.....

24. Do you read the labels on pesticide containers?

- a) Yes ( )
- (b) No ( )

25. Do you understand the instructions and symbols on the pesticide containers?

- a) Yes ( )
- (b) No ( )

26. Have you ever received training in safe handling and application of pesticides?

- a) Yes ( )
- (b) No ( )

27. Do you know that residues of pesticides can stay on vegetables?

- a) Yes ( )
- (b) No ( )

28. Do you think vegetable production can take place without the use of pesticides?

- a) Yes ( )
- (b) No ( )

29. Please provide reason(s) for your respective answer to Q27.



**SECTION C: IDENTIFICATION OF COMMONLY USED PESTICIDES**

Please kindly provide answers to the underlisted questions. Respond to the items by **ticking** (✓) or **writing** in the spaces provided.

30. What are the names/types of pesticides you use on your farm?

<b>PESTICIDE COMMON NAME</b>	<b>TICK</b>	<b>PESTICIDE COMMON NAME</b>	<b>TICK</b>
AGRAZINE		CLEAR	
ADWUMAPA		DURSBAN	
ADWUMAWURA		FURADAN	
ACTELIC		GRAMOQUAT	
BUFFALO		GOLAN	
BYPEL		KARATE	
CONPYRIFOS		K-OPTIMAL	
CONTROL		LAMBDA	
CONSIDER		POLYTHRINE C	
ROUNDUP		WEEDOUT	
<b>OTHERS</b>		<b>OTHERS</b>	
<b>THANK YOU FOR YOUR PARTICIPATION</b>			

**APPENDIX D: Ethical Approval**



**APPENDIX E: AAS Recommended Instrument Parameters**

<b>ELEMENT</b>	<b>WAVELENGTH nm</b>	<b>LAMP CURRENT Ma</b>	<b>SLIT WIDTH nm</b>	<b>FUEL</b>	<b>SUPPORT</b>
Fe	248.3	5	0.2	ACETYLENE	AIR
Mn	279.5	5	0.2	ACETYLENE	AIR
Pb	217.0	5	1.0	ACETYLENE	AIR
Ni	232.0	4	0.2	ACETYLENE	AIR
Cr	357.9	7	0.2	ACETYLENE	AIR
Cu	324.7	4	0.5	ACETYLENE	AIR
Co	240.7	7	0.2	ACETYLENE	AIR
Cd	228.8	4	0.5	ACETYLENE	AIR
As (by hydride)	193.7	10	0.5	ACETYLENE	Nitrous oxide
Zn	213.9	5	0.1	ACETYLENE	Air

