KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY KUMASI

COLLEGE OF SCIENCE

DEPARTMENT OF ENVIRONMENTAL SCIENCE

PESTICIDE CONTAMINATION OF VEGETABLE FARMS ALONG THE ONYASIA STREAM IN GA EAST MUNICIPALITY GREATER ACCRA REGION GHANA

BY

FORDJUOR ARKO LYDIA

JULY, 2011

PESTICIDE CONTAMINATION OF VEGETABLE FARMS ALONG THE ONYASIA STREAM IN GA EAST MUNICIPALITY

GREATER ACCRA REGION GHANA

BY

FORDJUOR ARKO LYDIA

July, 2011

DECLARATION

It is hereby declared that this thesis is the outcome of research work undertaken by the author, any assistance obtained has been duly acknowledged. It is neither in part nor whole been presented for another degree elsewhere.

Signature……………………………………. DATE…………………………….....................

NAME: Lydia Arko Fordjuor (STUDENT)

Signature…………………………………..... DATE………………………………..................

NAME: Eric Agyapong (SUPERVISOR)

Signature…………………………………………… DATE……………………………….

NAME: (HEAD OF DEPARTMENT)

ABSTRACT

The use of pesticides in controlling pests of different types is one of the essential measures of modern agricultural practices. However, the residue resulting from misapplication of pesticides on vegetables is a crucial concern not only to the people of Ghana but the international community at large. The ill-health effect on humans can be minimised to a great extent if the residues are kept below the prescribed maximum residue level, a standard set by the EC. A number of pesticide residues in vegetables were studied in three communities in the Ga East Municipality in the Greater Accra Region of Ghana for a period of nine months. Vegetables produced along the Onyasia Stream were used as samples. A total of 120 fresh vegetables (carrot, lettuce and cabbage) were sampled for the study due to their commercial importance and potential consumption. All samples were taken in accordance with the guidelines of the European Union (EU) (European Commission, 1979); which means that as far as possible the samples were taken at various distributed places throughout the lot. The vegetables were subjected to extraction, SPE, clean up and analysed by Gas Chromatograph Electronic Capture Detector for pesticide residues mainly organo chlorines. The results obtained revealed that most of the vegetables analysed contain residues of the monitored pesticides above the accepted maximum residue level. However some pesticides were not detected in all the vegetable samples. The results obtained showed that 54.2% of the vegetable samples were above the MRL and 45.8% were below the standard. Most vegetables are consumed fresh or slightly cooked and as such intensive vegetable production threatens public health from pesticide dimensions. Standard measures to address this situation would require mass sensitisation and regulations. Education of the farmers to follow strictly label instructions is also essential.

ACKNOWLEDGEMENT

Almighty God, I thank you for seeing me through another hurdle. Unto you be the glory.

I am grateful to Professor Enu Kwesi of the Botany Department of the University of Ghana, Legon whose invaluable contributions, as well as guidance, made this vision a reality.

To my Supervisor, Mr Eric Agyapong of KNUST, without you this dream would not have come to pass, his perfect supervision, direction and constructive criticism kept this work in good shape. God richly bless you.

I am also gratified to Dr Bukari Ali and Dr Bernard Fei Baffoe a senior lecturer and a lecturer respectively at the Department of the Environmental Science for their good counselling and support.

To my sweet heart Mr Isaac Opoku, your support, valuable contribution, and the morale made this piece a success. My prayer is that the Good Lord will grant us long life to enjoy the fruit of our labour.

I am particularly indebted to my Late Father Mr James Kwadwo Fordjuor and siblings; Mrs Adelaide Asibey, Mrs Hannah Acheamfour and Mr James Kwadwo Fordjuor Jnr. who have been the brain behind my success.

I am also grateful to Mr Bempah of the Atomic Energy Commission who opened his doors for me at all times to share his experience, gave me the needed assistance and above all supervised the laboratory work. 'Merci beacoup'

I am thankful to Mr Joseph Elia Arthur of The Forestry Commission of Ghana who spent his time and assisted me with getting the document in this form.

Finally, I wish to express my profound appreciation to my study mates Messrs Alfred Henyo, Michael Asiedu, Divine Ayisa and Agen Ebenzer who supported me in diverse ways to achieve my aim. To all my colleagues, the teaching and non-teaching staff of the College of Science, Department of Environmental Science I will say a big thank you to all.

God richly bless you all.

DEDICATION

This work is dedicated to the entire Fordjuor and Opoku Families.

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

EC	=	European Commission
EU	=	European Union
OC	=	Organochlorine
FAO	=	Food and Agriculture Organisation
LD_{50}	=	Lethal Dose of Fifty
POP	=	Persistent Organic Pollutants
PCB	=	Polychlorinated Biphenyl
DDT	=	Dichloro Diphenyl Trichloroethane
UN	=	United Nations
FFDCA	=	Federal Food Drugs and Cosmetic Act
PIC	=	Prior Informed Consent
HCB	=	Hexachloro Benzene
DDE	=	Dichloro Diphenyl Dichloro Ethylene
SPE	=	Solid Phase Extraction
HPLC	=	High Performance Liquid Chromatography
US	=	United States
MRL	=	Maximum Reside Level
GDP	=	Gross Domestic Product
OP	=	Organophosphate
PP	=	Polyphenols
GC-ECD	=	Gas Chromatography Electron Capture Detector
GC-NCD	=	Gas Chromatography Nickel Capture Detector

LIST OF TERMS AND MEANINGS

Maximum Residue Level - The maximum amount of a pesticide that can be on a raw product when it is used and still be considered safe.

LD50 – Lethal Dose of fifty is the concentration at which half of the population of the target organisms will be killed/ die

CHAPTER ONE

1.1 ORGANISATION OF THE STUDY

This chapter contains the background of the study, the statement of the research problem, justification, objectives of the study and research questions.

1.2 Introduction

Agriculture is the backbone of Ghana's economy. It contributes 40% to the GDP of Ghana with vegetables forming a sizeable percentage of it. Besides various agronomic crops, dozens of types of vegetables are grown in the country. Vegetables are the most important ingredients of the human diet for the maintenance of good health and prevention of diseases. Ghana also exports quantities of vegetables such as okra and chillies to European countries including Germany, Italy, Belgium and Switzerland (Gyau and Spiller, 2007).

Unfortunately the yield of vegetables is affected by pests, which necessitates the use of insecticides to control the pests. A wide range of pesticides are used for crop protection during cultivation of vegetables due to heavy pest infestation throughout the crop season. Unfortunately the use of pesticides is assuming alarming proportions and calls for thorough studies into it.

Pesticides are used to protect crops before and after harvest from infestation by pests and plant diseases. A consequence of their use may be the presence of pesticide residues in treated products, fruits, vegetables, grains, and other commodities. Even after being washed, stored, processed, and prepared, some residues may remain in both fresh products and processed foods.

About 87% of the farmers who grow vegetables in Ghana use pesticides (Dinham, 2003). Many of these farmers spray the same wide range of pesticides on all vegetables and ignore pre-harvest intervals (Ntow *et al.*, 2006). Sometimes farmers spray pesticides one day before harvest to sell ‘good-looking vegetables. This practice, in particular, exposes consumers to pesticides. Studies conducted by Horna *et al*, (2007), indicated that farmers in Ghana currently use higher than recommended doses of pesticides.

The studies by Ntow *et al*, (2006) showed that residues of OC pesticides are present in environmental samples at Akomadan and in human fluids of its inhabitants. The residues were concluded to have originated from agricultural activities in the area and it is expected that an appreciable build-up of residues with time will occur because of the continuous use of pesticides in the area.

The European Commission has therefore set harmonized Maximum Residue Levels (MRLs) in the Regulation (EC) No 396/2005, in order to avoid that different Member States gave different MRL values for the same pesticide in the same crop, a situation which gave rise to questions from consumers, farmers, and traders.

1.3 Problem statement

Farmers in Ghana do not follow the prescribed dosages for pesticide application, and use pesticides at any stage of crop development without any awareness of the residues and their harmful effects on human health. This is mainly due to lack of education on pesticides usage and their effects on humans and the environment. The treated vegetables are harvested and sold without taking into account the withholding period. Unfortunately most of these vegetables are consumed fresh or slightly cooked. As a result, pesticide residues find their ways into human body as a result of bioaccumulation through food, water and the environment.

According to a recent report, contaminated food and water causes about 700 000 deaths in Africa annually (www.modernghana.com/news/203772/1/contaminated-food-water-causes-700000-deaths-in-af.html).

There have been recent concerns about contaminated vegetables sold on the Ghanaian market Most of the contamination can be attributed to pesticide, fertilizers and water use in irrigated farms. Unfortunately, enough data on the extent of pesticide contamination of vegetables sold on the market is lacking. This study therefore sought to investigate this and add to the existing data.

1.4 Significance of the Study

Pesticides perform an important role in maximizing agricultural production by reducing pest infestation. However, because of their inherent toxicity and widespread use, pesticides also pose a threat to public health, particularly to infants, children and adults as well. The control of pesticide residue in food commodities has become a requirement for compliance with the legislation, ensuring safety of the population and international and national trade.

Epidemiological studies and laboratory studies in animals have shown that exposure to pesticides have adverse health effects including cancer, birth defects, reproductive harm, neurological and developmental toxicity, immunotoxicity and disruption of the endocrine system (Bassil *et al 2007)*

Most major classes of pesticides, including the organochlorine, organophosphorus compounds, carbamate, chlorophenoxy herbicides, and pyrethroids, have shown to adversely affect the developing nervous system of laboratory animals, altering neurological function and causing subtle neuro-behavioural impairments (Longnecker et *al,* 1997).

1.5 General Objective of the study

The main objective was to assess the level of the residue of some commonly used pesticides on vegetables grown under local agro climatic conditions.

1.5.1 Specific Objectives

- To determine the residue levels of some selected pesticides on vegetables.
- To evaluate the residual concentrations of the selected pesticides in vegetables on different farms.
- To make some comparisons between the concentrations of identified pesticides in vegetables with international standards.

1.6 Hypothesis

The null and the alternate hypotheses for the study are stated as below:

1.6.1 Null hypothesis (H_o):

There are no chemical residues found in vegetables grown and harvested for market along the 'Onyasia Stream' in the Ga East area in the Greater Accra region of Ghana.

1.6.2 Alternate hypothesis (H_1):

There are chemical residues found in vegetables grown and harvested for market along the 'Onyasia Stream' in the Ga East area in the Greater Accra Region of Ghana.

1.7 Research Questions

The following research questions were asked to guide the objectives.

- What types of pesticides are used to control pests by the farmers in the study area?
- What is the concentration of pesticide residue found in the vegetables?
- What threats do these pesticides residue levels pose to consumers?
- Which of the vegetables have the highest pesticide residue?

- Is there waiting time for pesticides to degrade before harvesting?
- Do the farmers adhere strictly to the labelling instructions?

CHAPTER TWO

LITERATURE REVIEW

2.0 Overview

Ghana is growing to become a large consumer of pesticides as a result of the recent introduction of agrochemicals into the Ghanaian market (Amoah, *et al*, 2006). Due to tropical climatic conditions, proliferation of insects is very high; pesticides have therefore become an inevitable tool in controlling the pests of various field crops. Quite a number of pesticides are used on fruits and vegetable crops. Their persistent use leads to build up of toxic residues on crop produce, which may exert adverse effect on human health in addition to disturbing the ecosystem. This problem is more serious in case of vegetables as they are often consumed raw, and occasionally with little processing.

As a background to the study there is the need for a review of existing information on pesticide contamination of vegetables and the environment. This chapter therefore looks at pesticides currently in use, and their effect on public health and the environment.

2.1 Definition of Pesticide

Food and Agriculture Organization (FAO) has defined pesticide as; any substance or mixture of substances intended for preventing, destroying or controlling 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 substances 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. Also, pesticides are used as substances applied to crops either before or after harvest to protect the commodity from deterioration during storage and transport (FAO, 2002).

From the above definition, a pesticide can be described as a natural or man-made preparation used to kill or control an insect population, control weeds or diseases in plants and animals including humans.

2.2 Types of pesticides

Pesticides are classified based on the following:

- the target pest
- their mode of action and
- The major compound making up the chemical.

2.2.1 Classification based on target pest

Based on the target pest there are about 9 main groups of pesticides and these are:

a. Insecticides: used for insect control e.g. Karate, Cymbush, Comfidor, etc.

b. Acaricides / miticides used for mites, ticks, spiders etc., e.g. Dimethoate

c. Molluscides for the control of snails and slugs e.g. Phorate

d. Fungicides for the control of fungi e.g. Dithane M-45, Kocide

e. Bactericides for the control of pathogenic bacteria e.g. Streptomycin

f. Herbicides for the control of weeds e.g. Glyphosate, Gramoxone

g. Rodenticides for the control of rodents such as mice, rats e.g. Klerat

h. Nematicides for nematodes e.g. Methyl-bromide or Diethyl-Dibromide

i. Avicides for birds e.g. DRC 736, DRC 1327 (not available in this country)

2.2.2 Classifications based on their mode of action

2.2.2.1 Stomach poison

These are pesticides that are toxic to organisms when ingested, usually with their food, and takes effect through the alimentary canal. Their use is limited to surface-eating pests with chewing mouth parts e.g. leaf-eating insects and rodents.

2.2.2.2 Contact pesticides

These kill by direct contact at the time of application, with the external part of the pest organism. They may be used for both chewing and sucking pests which must be present at the time of application to be killed, unless there is a residual effect. Herbicides are also contact pesticides in their action e.g. Gramoxone.

Residual contact pesticides are contact pesticides with extended residual toxicity. Direct body contact with pests at the time of application is not essential for control to be achieved. It can be applied to walls in stores or on leaves of plants.

2.2.2.3 Fumigants

These are pesticides with high vapour pressure, naturally or heat induced, to produce lethal concentrations of vapour which enter primarily through the respiratory system of the pest organism. They are used in enclosed spaces or in soil to destroy the pests present, e.g. Phostoxin, Methyl dibromide.

2.2.2.4 Systemic pesticides

These are pesticides that are soluble enough to be absorbed harmlessly by plants through their seed, roots, stems, trunk or foliage and can be Trans located by sap to the points of attack to destroy the plant feeding organisms. They could function as stomach poisons on sap-sucking pests such as aphids, mites, scale insects, and chewing insects such as leaf miners. Systemic effectiveness may last from a few weeks up to a few months.

2.2.2.5 Repellents

These are compounds that do not usually kill but are distasteful or irritating enough to keep pests from attacking plants. It drives away pests when applied to plants e.g. neem extracts.

2.2.2.6 Attractants

These are chemicals that act as lures for pests. They are added to other chemicals to lure especially insect pests to plants so they can be killed. They can be used to detect early infestation, survey and sample pest populations, reduce target pest population, delineate area of infestation and to determine timing of control.

2.2.2.7 Anti-feedants

These chemicals inhibit feeding in insects and other pests. They do not merely drive away insects but prevent them from feeding on plants. In laboratory tests, insects such as locusts and army worms have remained on treated plants indefinitely and eventually starved to death without eating leaves. Neem seed extracts have been observed to have such anti-feedant property.

However chemical control results in undesirable consequences such as:

- resurgence of pest attack.
- environmental pollution
- progressive build-up of residue in the bodies of non- target organism in the food chain with the consequence of threatened health and or population extinction.

2.3 Classification based on the major compound making up the chemical

2.3.1 Inorganic insecticides

Some inorganic compounds have insecticidal properties. They were widely used to control insect pests before the discovery of synthetic organic compounds such as DDT. They are not fat soluble and act only as stomach poisons. Hence, they are effective against chewing insects. These compounds were marketed as salts of toxic elements such as arsenic, fluorine, thallium and mercury, e.g. Calcium arsenate, Lead arsenate, Paris green (Copper acetate + copper arsenate).

2.3.2 Natural insecticides (Botanicals)

These are derived from plant chemicals toxic to pest. They have been in use for insect pest control, since ancient times. Their popularity has increased in the recent years because

- they are environmentally friendly.
- they break down readily on exposure to sunlight and air.
- generally except nicotine, they have low mammalian toxicity
- they require no residue tolerance
- hardly is pest resistance developed against them

They act chiefly as direct contact insecticides, but some act as residual contact and stomach poisons.

2.3.2.1 Nicotine

This is derived from tobacco. Its vapour enters the tracheae of insects, paralyzing the nervous system.

2.3.2.2 Pyrethrin and Pyrethroids

Pyrethrin is derived from chrysanthemums. They act primarily on the nervous system causing drastic disruption. They affect both the peripheral and central nervous system of treated insects, causing paralysis. They also have a rapid knock-down effect. They have low mammalian toxicity; are easily applied and effective in aerosol form. Because of these desirable characteristics, synthetic analogues called **Pyrethroids** have been produced with the result that there are several available with greater light stability, longer residual action and of greater toxicity to insect pests. Examples of these insecticides are Cypermethrin (Cymbush), Deltamethrin and Permethrin. Recent pyrethroids include acrinathrin (Rufast), imiprothrin (Pralle) registered in 1998.

2.3.2.3 Rotenone

This chemical is derived from the following plant species: Derris *sp*., Lonchocarpus *sp*., Tephrosia *sp*. The mode of action of this chemical is obscure. It is observed that death follows paralysis, the symptoms of which are depressed respiration and heartbeat.

2.3.2.4 Azadirachtin

These, which include other chemicals such as salanin, meliantrol, etc., are derived from the neem tree, all of which have insecticidal properties. The chemical acts as an antifeedant, repellent, growth regulator, anti-ovipositor etc.

2.4 Organic (synthetic) Insecticides

2.4.1 Organochlorine (Chlorinated hydrocarbons)

These groups of chemicals typically contain carbon, chlorine, hydrogen and oxygen. They were first synthesized in 1874 but its insecticidal properties were discovered in 1939.

The organochlorines are a broad-spectrum and very persistent group of chemicals which usually kill both by contact and as stomach poison. They are highly stable, have low solubility in water, moderate solubility in organic solvents and liquids and low vapour pressure. They are generally non-phytotoxic and have pre-harvest interval of two weeks. They are moderately toxic to mammals. The LD_{50} ranges between 67 mg/kg and 113 mg/kg body weight. Examples are DDT, hexachloro Benzene (BHC/Lindane), Aldrex 50, Aldrin, Heptachlor, Endosulfan, etc. Due to their persistent nature in the environment a lot of these organochlorines have been banned Dewailly *et al.* (1999) and Toft *et al.* (2004).

2.4.2 Organophosphates

These are a large group of versatile pesticides derived from ortho phosphoric acid. They are formulated as esters containing varying combinations of oxygen, carbon, sulphur and nitrogen attached to phosphorus. They are non-persistent, have greater selective toxicity and are therefore widely used as a replacement for the persistent organochlorine. They kill by direct residual contact, as stomach poison or by fumigant action.

The organophosphates act as insecticides, acaricides or nematicides. They are generally non phytotoxic. However, some are generally much more toxic to mammals than the organochlorine with LD_{50} ranging from 3.7 mg/kg to 12 mg/kg body weight, with the exception of Malathion which has an LD_{50} of 2800 mg/kg. They break down readily and therefore have shorter pre-harvest interval of about four days if crops are to be eaten direct and seven (7) days for crops to be processed. They are effective against aphids, thrips, leaf hoppers, spider mites, mealy bugs, scale insects, beetles and caterpillars. Examples are

Sumithion, Perfekthion, Malathion, Monocrophotos, Karate phosmet (Imidan) and azinphos-methyl (Guthion) and azinphos-ethyl (Casida and Quiestad,1998).

2.4.3 Organosulphurs

These few materials have very low toxicity to insects and are used only as acaricides (miticides). These include tetradifon (Tedion), propargite (Omite, Comite), and ovex (Ovotran) (Casida and Quistad, 1998; Peter and Cherian, 2000).

2.4.4 Carbamates

They are derived from carbamic acid and act as stomach poisons and to a lesser extent, residual contact pesticides, on a fairly broad spectrum of plant pests. Some are effective systemically on insects, mites and nematodes (Casida and Quistad, 1998; Peter and Cherian, 2000).

2.5 Persistent organic Pollutants (POP)

These are a group of toxic chemical substances that persist in the environment, bioaccumulate along the food chain, and are a risk to human health. Twelve substances were initially classified as POPs under the Stockholm Convention, namely; aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, mirex, toxaphene, polychlorinated biphenyls (PCBs), hexachlorobenzene, dioxins and dibenzofurans.

2.6 Common pesticides used in Ghana

In Ghana DDT is banned whereas lindane and endosulfan are restricted for the control of capsids on cocoa, stem-borers in maize and pests on coffee. However, research has showed that these potent agrochemicals are used in vegetable production (Ntow, et al., 2008).

In Ghana vegetable growers mix several pesticides for use in order to increase their potency. Several pesticides especially chloropyrifos are widely used by vegetable producers in Ghana.

This corresponds to studies conducted by Okorley and Kwarteng (2002) and was confirmed by Johnson (2002) who reported evidence of chloropyrofos in Rice and Beans popularly known as 'waakye'.

2.7 Health Effects of Pesticides

To analyse the possible side effects of pesticide use on human health, a distinction has to be made between occupational health hazards and pesticide residues in food products and drinking water. Pesticides may cause acute and delayed health effects in those who are exposed (US EPA, 2007). Pesticide exposure can cause a variety of adverse health effects. These effects can range from simple irritation of the skin and eyes to more severe effects such as affecting the nervous system, mimicking hormones causing reproductive problems, and also causing cancer. A 2007 systematic review found that "most studies on non-Hodgkin lymphoma and leukaemia showed positive associations with pesticide exposure" and thus concluded that cosmetic use of pesticides should be decreased (Bassil et al., 2007). Strong evidence also exists for other negative outcomes from pesticide exposure including neurological, birth defects, foetal death (Sabon et al., 2007) and neuro-developmental disorder (Jurewicz and Hanke, 2008).

The American Medical Association recommends limiting exposure to pesticides and using safer alternatives (Council on Scientific Affairs, American Medical Association, 1997). Particular uncertainty exists regarding the long-term effects of low-dose pesticide exposures. Current surveillance systems are inadequate to characterize potential exposure problems related either to pesticide usage or pesticide-related illnesses.

The World Health Organization and the UN Environment Programme estimate that each year, three million workers in agriculture in the developing world experience severe poisoning from pesticides and about eighteen million die (Miller, 2004).

One study found pesticide self-poisoning the method of choice in one third of suicides worldwide, and recommended, among other things, more restrictions on the types of pesticides that are most harmful to humans (Gunnell et al., 2007).

These costs of externalities include the effects on human health and the related costs of treatment in cases of pesticide poisoning, contamination of food and water, development of resistance to pesticides and loss of bio-diversity. These side effects of pesticide use therefore involve costs which are external to the pesticide user and which have to be included in an economic analysis aimed at achieving the social optimum for pesticide use.

Clarke undertook a field study to examine the extent of pesticide-associated symptoms in farmers involved in irrigation projects in Ghana (Clarke 1995, 1997). About 36% of the interviewed farmers had experienced negative side effects such as headache, dizziness, fever, blurred vision, and nausea / vomiting after applying pesticides. Clarke showed furthermore that there were direct linkages between knowledge and / or the protective equipment of farmers on the one hand and the extent of negative side effects on the other hand.

A long-term study on possible poisoning caused by pesticides was carried out by researchers of the Ghana Standards Board and the Department of Pathology of the University of Ghana (Adetola et al., 1999). A number of cases were tested positive for chemical poisoning which were directly related to the misuse of pesticides. The main causes for deaths were carbamates, organophosphorous pesticides and organochlorines. The most serious problems farmers associated with pesticide use were general ill health after spraying and acute poisoning.

2.8 Theoretical Overview

The main concepts which emerge from the theoretical framework of pesticides usage are farming practices, food contamination, the environment and public health.

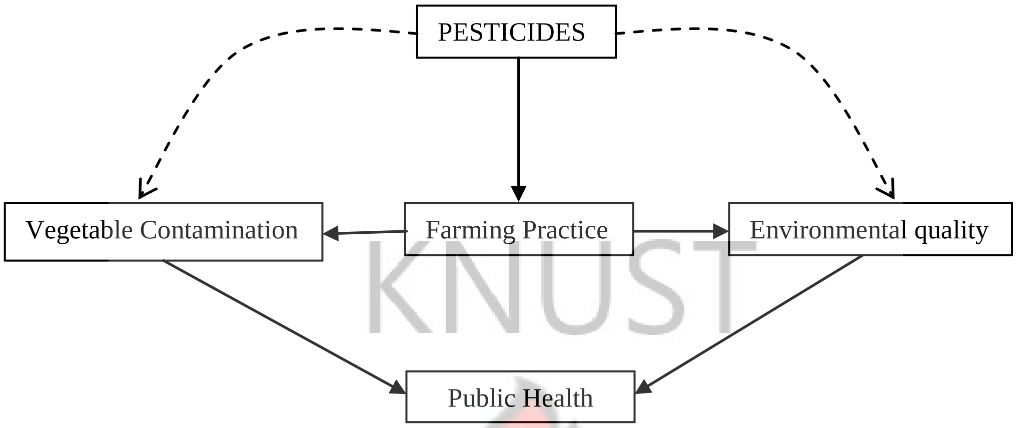


Fig 2.1: A flow chart indicating the links among pesticides application by vegetable farmers and its effect on public health and the environment.

2.8.1 Explanation of the flowchart

The contamination of agricultural produce by pesticides is often a direct or indirect consequence of farming practices. Some sources of anthropogenic contamination of vegetable crops include the application of manures, sewage sludge, fertilizers and pesticides to soils, with a number of studies identifying the risks in relation to increased soil metal concentration and consequent crop uptake (Whatmuff, 2002).

Literature (Mukherjee and Gopal, 1996; Dogheim et al., 1996; Elliion et al., 2000) reveals that vegetables may contain remnants of insecticides above the prescribed maximum residue levels (MRL), which may pose health hazard to the consumers.

Environment is defined as the components of the earth and includes but is not limited to: land, water and air, including all the layers of the atmosphere; organic and inorganic matter and living organisms; and the interacting natural systems (Mackenzie, 1995).

Ellen and Marc (2001) define 'Environmental quality' as the balance of nature, being composed of animals, plants, natural resources and man-made objects which is for the benefit of subsistence of mankind and the sustenance of human-being and nature.

Over the last few decades there has been remarkable increase in food production. This is attributable to various factors including expansion of croplands, introduction of new high-yielding seeds and heavier applications of fertilizers and pesticides.

Local farming practices concerning the application of pesticides and subsequent harvest of treated crops may have effects on the consumers and for that matter public health. The position therefore is that crops may contain remnants of insecticides above the prescribed maximum residue levels (MRLs), which may pose health hazard to the consumers and affect environmental quality.

2.9 Pesticide use and Regulation

In most countries, pesticides must be approved for sale and use by a government agency. For example, in the United States, the Environmental Protection Agency (EPA) is responsible for regulating pesticides. Regulation is done by the EPA to ensure that these products do not pose adverse effects to humans or the environment (EPA, 2007).

Some pesticides are considered too hazardous for sale to the general public and are designated restricted use pesticides. Only certified applicators, who have passed an exam, may purchase or supervise the application of restricted use pesticides. Though pesticide regulations differ from country to country, pesticides and products on which they were used are traded across international borders. To deal with inconsistencies in regulations among countries, delegates to a conference of the United Nations Food and Agriculture Organization adopted an International Code of Conduct on the Distribution and Use of Pesticides in 1985 to create voluntary standards of pesticide regulation for different countries (Food and agriculture organization of the United Nations, 1986). The Code was updated in 1998 and 2002 (FAO, 2007). The FAO claims that the code has raised awareness about pesticide hazards and decreased the number of countries without restrictions on pesticide use.

2.10 Pesticide Residue Tolerances

A tolerance is the maximum amount of a pesticide that can be on a raw product when it is used and still be considered safe. Before EPA can register a pesticide for crop protection, it must grant a tolerance. Tolerances are based upon use of the pesticide product in accordance with good agricultural practices. Tolerances are established under conditions that maximize the potential for residues. Controlled field trials use the maximum rate permitted on the label, the maximum number of applications, and the minimum pre-harvest interval (the number of days between the last application and harvest). The FFDCA requires EPA to establish these residue tolerances based upon the specific uses of a pesticide product.

2.11 Agriculture and Pesticide Use in Ghana

Agriculture is the main sector of the Ghanaian economy. According to political and social strategies, accelerated growth of the agricultural sector is necessary in boosting overall economic development. The share of agricultural products in the export earnings is high. The population is mainly in rural areas, depending to a large extent on small-scale farming.

Ghana’s agricultural policy is based on five main objectives. The predominant goals are:

- To ensure food security and adequate nutrition for all the people in the country,
- To promote the supply of raw materials and inputs to other sectors of the economy, and
- To contribute to export earnings (MoFA, 1998).

These goals were defined in the early days of independence and have not been changed substantially. Furthermore, agricultural development aims at:

- Increasing employment opportunities and income for the rural population and
- Generating resources for general economic development (Nyanteng, 1997).

Linked to the intensification and structural changes in agricultural production is the potentially increased use of pesticides. To policy makers, the increased use of inputs like fertilizers and chemical pesticides often seems to be one of the most effective ways to increase production and food supply, since a good part of produce is lost through diseases, pests and weeds in the field and in storage. However, to reach a sustainable development of the agricultural sector, it is necessary to do more than just increase input use. Within the context of efforts to intensify agricultural production on a sustainable basis, crop protection policies play a crucial role. However, there is no comprehensive crop protection policy in place in Ghana, especially for pesticide use. Current crop protection approaches have been primarily shaped by technical expertise without taking economic arguments into proper consideration.

In addition, implementations of legal instruments are currently inadequate for controlling and mitigating negative side effects of pesticides. Specific effects of pesticides, e.g. the risks to human health and the environment, have been partly taken into account by government decisions and are receiving in general the necessary attention.

Moreover, farmers' knowledge and practices in crop protection are not sufficiently known to provide a sound basis for policy and extension planning. Handling and application of pesticides at farmers' and retailers' level are not satisfactory in terms of effectiveness, safety, the health of farmers, the prevention of side-effects on consumers and the environment. However, EPA (2007) reported that the current level of pesticide use is generally low, in spite of overuse on some crops. Due to the government strategy of intensified agricultural production, it can be expected that pesticide use will increase in the near future.

2.12 Pesticide Management and Control Policies in Ghana

Several governmental institutions are currently involved in policy formulation, pesticide management and control and execution. Ghana's Pesticide Control and Management Act (528) of 1996 was promulgated to ensure an effective control and management of pesticides. The Act requires the registration of all dealers of agrochemicals and pesticides. Requirements for registration are not defined in the Act itself. It is left to EPA to specify these requirements as legal instruments.

Act 528 of 1996 defines four classes of pesticides: (1) general use, (2) restricted use, (3) suspended pesticide and (4) banned pesticide. Pesticides in classes (2), (3) and (4) are subject to the Prior Informed Consent (PIC) procedure as laid down in the international procedures for exchanging information. A pesticide may be suspended or restricted if its application may cause unreasonable adverse effects on people, animals or the environment (EPA 1994, 1997).

Table 2.2a: Provisional List of Banned Pesticides in Ghana

Name	Active Ingredient	Reason for Ban
Aldrex T	Aldrin and Parathion	persistent, highly toxic
Aldrin	Aldrin	Persistent
Dieldrin	Dieldrin	Persistent
E-605 Combi	Parathion	highly toxic
Parathion Methyl	Parathion Methyl	highly toxic
Heptachlor C10	Heptachlor	not in use
DDT	Dichloro Diphenyl Trichloro Ethane	safer alternatives
EDIB	Ethylene Dibromide	highly toxic
D-D	Dichloropropane	banned internationally
Bidrin	Dicrotophos	banned internationally

Source: EPA of Ghana

Currently, ten pesticides have been banned in Ghana (Table 2.2a). The reasons for the ban are either the persistence of the pesticide in the environment or high toxicity. This list is in line with international conventions. Eight more pesticides have restricted application (Table 2.2b). Among this group are Unden and Lindane insecticides registered for capsid control in cocoa. According to COCOBOD, alternatives with the same effectiveness for capsid control are not yet available, which justifies the decision not to ban the two pesticides as has been done in other countries. Six of the eight restricted pesticides can be found on the market in considerable quantities (Table 2.2b).

Table 2.2b: Provisional List of Severely Restricted Pesticides in Ghana

Product Name	Active Ingredient
Azodrin	Monocrotophos
Unden	Propoxur
Lindane	Gamma BHC
Elocron	Dioxacarb
Gramaxone	Paraquat
Furadan	Carbofuran
Thiodan	Endosulfan
Atrazine	Atrazine

Source: EPA of Ghana

2.13 Integrated Pest Management (IPM)

A system in which populations of any pest(s) are maintained at or below the level that causes damage or loss, and which minimizes adverse impacts on society and environment as a whole. This system is very effective and an environmentally sensitive approach to pest management. It combines natural predators, pest-resistant plants, and other methods to preserve a healthy environment in an effort to decrease reliance on harmful pesticides.

Whatever the objectives of IPM are, they are achieved through the allocation of resources to improve efficiency, substitution, and system redesign. These objectives are achieved in either of the following ways.

- Improving the efficiency of current measures - e.g. by the use of monitoring techniques to ensure that pesticides are only used when necessary

- Substitution - e.g. by replacing pesticides with bio-control, bio-pesticides, or transgenic varieties
- System redesign - e.g. by adopting crop rotation practices, through area-wide management schemes or by alternating direct seeding with transplanting.

The economic threshold concept is most relevant for decisions that are made when the level of pest attack can be assessed through monitoring. Various measures can be used to assess the level of pest attack, such as the number of pest insects per ten (10) plants, the percentage of diseased plants in a crop, or the number of weeds per m^2. The economic threshold, defined in terms of the level of pest attack, is the level of attack where the estimated benefits of treatment cover the cost of that treatment. If the level of attack is below the threshold, the cost of treatment would exceed the benefits and the farmer would incur a loss by applying the treatment.

A simple way of looking at economic thresholds is to start with the cost of treatment. If you can estimate what it costs to apply a pest management treatment, you can then try to estimate what benefit - in terms of reduced yield loss - you would need to gain for treatment to be worthwhile.

2.14 Review of previous studies

Several researchers have studied the occurrence of pesticide residues in crops. In the annual report of Pesticide Regulatory Committee (2008) in the United Kingdom, 4129 samples of vegetables were tested individually for many different pesticides. Of the samples tested it was found that: 53.8% of samples contained no residues tested for; 45% of samples contained residues below the MRL; and 1.2% of them contained residues above the MRL.

In Venezuela studies conducted on pesticide residue in vegetables cultivated in Jose´ Marı´a Vargas County on seven organophosphorus pesticides (methamidophos, diazinon, chlorpyriphos, parathion-methyl, dimethoate, Malathion and tetrachlorvinphos), in some vegetables like potato, lettuce, tomato, onion, red pepper and green onion cultivated, showed that 48.0% of the samples were contaminated with some of the pesticides studied. Methamidophos was found in the vegetables in the rank of 6.3%–65.5%. The results showed that 16.7% of the samples tested have residues higher than the maximum limits permitted.

In Poland a research conducted by Sadło et al, (2007) on surveillance of pesticide residues in fruits and vegetables on 747 samples of 39 different types of fresh fruits and vegetables analyzed for their pesticide residue contents gave the following results: The highest resides found were: bupirimate residues (2.19 mg/kg), captan residues (1.82 mg/kg), ethylenebisdithiocarbamate residues (1.6 mg/kg), tolylfluanid residues (1.44 mg/kg), procymidone residues (1.19 mg/kg) and chlorpyrifos residues (1.01 mg/kg). In 27 samples, 3.6% residues exceeded national MRLs (Polish Journal of Environmental Studies. Vol. 16, No. 2 (2007), 313-319).

In India, studies conducted by Battu *et al,* (2005) revealed widespread contamination of vegetables, fruits, and cereals with insecticide residues. Kumari *et al,* (2001) monitored sixty market samples of six seasonal vegetables to determine the magnitude of pesticide contamination. The estimation of insecticide residues representing four major chemical groups i.e. organochlorine, organophosphorous, synthetic pyrethroid and carbamate, was done by adopting a multi-residue analytical technique employing GC-ECD and GC-NPD systems with capillary columns. The tested samples showed 100% contamination with low but measurable amounts of residues. Among the four chemical groups, the organophosphates were dominant followed by organochlorines, synthetic pyrethroids and carbamates. About

23% of the samples showed contamination with organophosphorous compounds above their respective MRL values.

Ntow in 2008 assessed the accumulation of persistent organochlorine contaminants in milk and serum of farmers in Ghana. The study revealed concentrations of persistent organochlorines such as DDT and its metabolites, HCH isomers, HCB and Diedrin in samples of human breastmilk and serum collected from vegetable farmers in Ghana in year 2005. The levels of the pesticides in the milk samples were found to correlate positively with the age of the milk sample donors.

Similar to the study done by Ntow in 2008, another study was conducted by Ntow in 2001 on organochlorine pesticide levels in a farming community in Ghana. A total of 208 samples of water, sediment, tomato, and human breast milk were collected from the environs of Akomadan, a prominent vegetable-farming community in Ghana. Endosulfan sulfate was the most frequently occurring (78%) OC in water with a mean of 30.8μg/L. Lindane was detected in 38 samples (76% of analysed samples). The concentration was highest in sediment for lindane (mean 3.2 μg/kg) and least for β-endosulfan (mean 0.13μg/kg). Heptachlor epoxide was present at a quantifiable level in tomato (mean 1.65μg/kg fresh weight) and in sediment (means 0.63μg/kg dry weight). HCB was detected in 55% and DDE in 85% of all samples analyzed. For milk samples, 95% indicated quantifiable amounts of HCB, whereas 80% showed DDE. The mean values of HCB and p, p-DDE in blood were 30μg/kg and 380μg/kg, respectively. The mean values of HCB and p, p-DDE in milk were 40μg/kg fat (1.75μg/kg whole milk) and 490μg/kg fat (17.15μg/kg whole milk), respectively. The study confirmed that residues of some pesticides are present in areas of highly intensive agricultural production.

Another study by Amoah *et al*, (2006) on analysis of pesticide and pathogen contamination of vegetables in Ghana's urban markets, revealed that, of a total of 180 vegetable samples randomly purchased from Accra, Kumasi and Tamale, chlopyrifos (Dursban) was detected on 78% of the lettuce, lindane on 31%, endosulfan on 36%, lambdacyhalothrin (Karate) on 11%, and DDT on 36%. The report showed that most of the residues measured exceeded the maximum residue limit.

CHAPTER THREE

METHODOLOGY

3.0 Introduction

This chapter describes the procedures for sample collection, preparation, treatment and analysis. It also gives a brief description of the study area, namely Musuko, Haatso and Kwabenya in the Ga East Municipality of the Greater Accra Region of Ghana.

3.1 Choice of study Area and Sampling sites

Greater Accra Region of Ghana was chosen as case study with specific reference to Musoku, Haatso and Kwabenya in the Ga East area (Figure 3.1). The sampling sites were selected because the area is among the major vegetable production centres in Ghana where vegetables are produced both for local consumption and for export as a result of an irrigation facility in the area. Furthermore, most of the farmers found in the area do not have formal education, and also suffer access to land in the capital city due to unavailability of land and competition from real estate developers. As a result these farmers resort to the use of any means at their disposal in order to prevent pest infestation, obtain higher yield, and avoid post-harvest losses in their farming activities. The study was therefore carried out to assess how application of pesticides impacts on vegetables grown along the Onyasia stream in the Ga East Municipality of the Greater Accra Region of Ghana.

3.1.1 Geographical Location:

Ga East Municipality is located at the northern part of Greater Accra Region. It covers a land area of 166 sq. km and it is known for its vegetable production (Fig. 3.1).

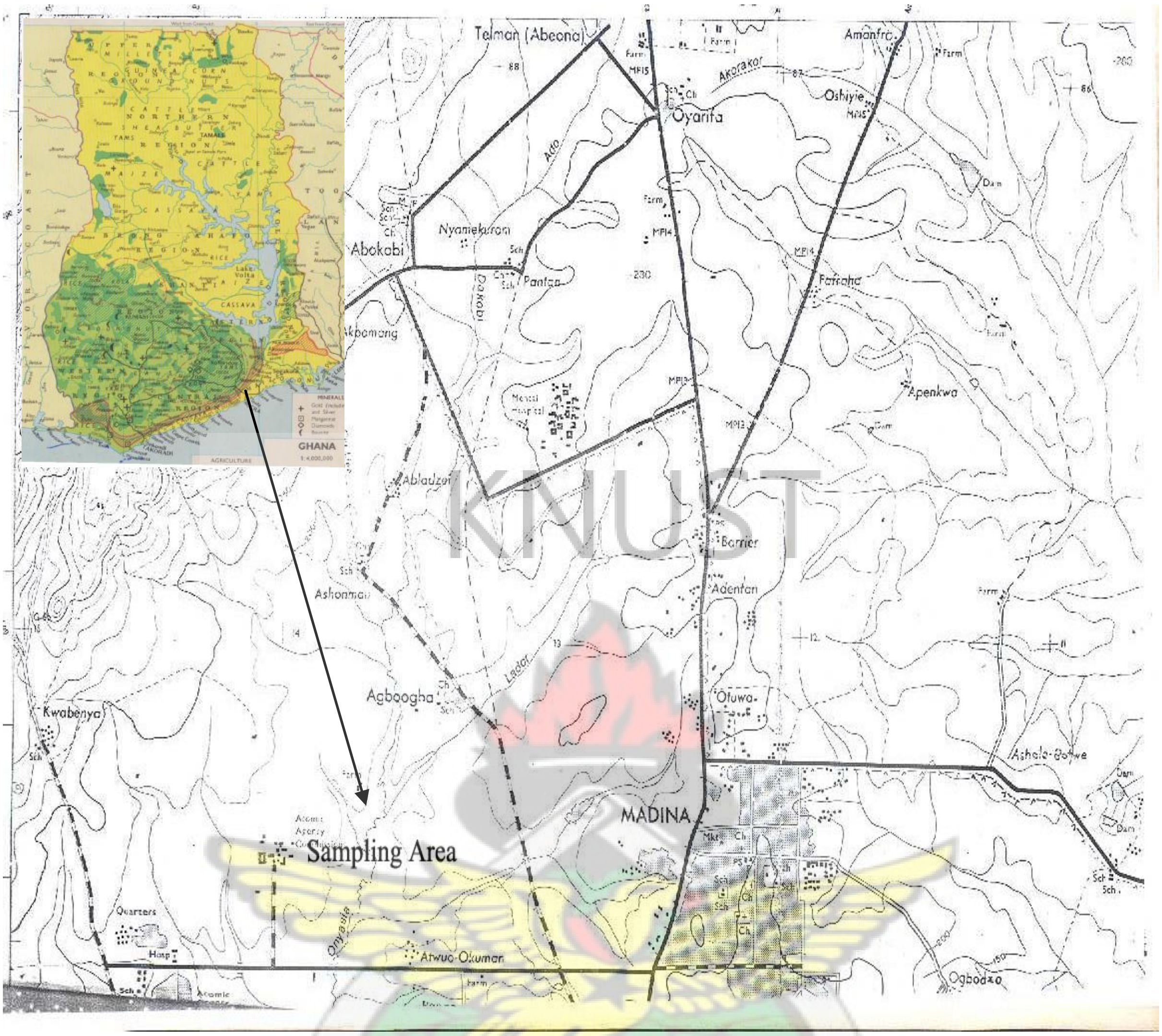


Fig 3.1 Map of the study area

3.1.2 Climate

The area is relatively dry since it falls within the dry coastal equatorial climate zone. The mean annual temperature is around 20 degrees Celsius. Ghana Statistical Services (2002).

The district falls under the climatic zone marked by a double maxima rainfall regime. The mean annual rainfall is 1,140 mm. The rainfall peak is notably in June and October. The first rainfall season between April and July is associated with major cropping season in the region.

3.1.3 Vegetation and Geology

The vegetation is mainly Costal Savannah shrubs. The soil has low organic contents with shallow top soils which limit the capacity for crop production.

3.1.4 Economic Activities:

The main occupation of the indigenes is agriculture. Main crops grown are vegetables, maize and cowpeas.

3.1.5 Sampling Collection

Recognisance survey was conducted in August, 2010. New polypropylene sealable sampling bags were used for collection of vegetables. A total of 120 fresh vegetable samples (40 pieces of carrot, 40 pieces of lettuce and 40 balls of cabbage) were collected due to their commercial importance and potential consumption. These three vegetables were collected each month from January to April, 2011. The samples were taken in accordance with the guidelines of the European Union (EU) (European Commission, 1979); which means that, as far as possible, the samples were taken from Musoku, Haatso and Kwabenya farms at different locations distributed throughout the lot. Fresh vegetables weighing a minimum of 2 kg, collected in reticular bags, sealed labelled with a unique sample identity and placed in an iced chest box. All samples were transported to the Chemistry department of the Ghana Atomic Energy Commission pesticide residues laboratory and were refrigerated (at 5^oC) and analysed within 24 hours.

3.2 Laboratory Analysis

3.2.1 Glass wares and Cleaning Process

Glass wares were rinsed with de-ionized water and immersed in a warm liquid soap bath for two days, then rinsed with de-ionized water in 10 % HNO_3 at room temperature for three days. Glass wares were again rinsed three times with de-ionized water, and then immersed in

50% HNO_3 bath at 90^{o}C for 24 hours. The glass wares were further rinsed with de-ionized water and then filled with de-ionized water containing 1% high purity HCL (Optimal-HCL, obtained from Fisher Co.). They were capped loosely and placed overnight in a clean oven at 60^{o}C. The glass wares were then removed from the oven and allowed to cool down. The acidified water was discarded, and the oven drying step repeated once more (Jos, *et al*., 2007).

3.2.2 Reagents

Pesticide grade ethyl acetate, dichloromethane, n-hexane (HPLC grade) and analytical grade acetone were supplied by Labscan (Dublin, Ireland), sodium hydrogen carbonate and sodium sulphate (purities greater than 98%) were purchased from E. Merck (Germany). Activated charcoal was purchased from Wako Pure Chemical Industries (Japan). Solid-phase florisil cartridges column size (500 mg/8mL) was obtained from Honeywell Burdick & Jackson (Muskegon, USA). Pesticide reference standards (98.0% purity) were obtained from Dr. Ehrenstofer GmbH (Germany), and stored in the freezer at -20^{o}C to minimize degradation.

3.2.3 Apparatus

(a) Homogenizer - FOSS 2096 based on Tecator Technology.

(b) Separator funnel

(c) Weighing balance - Metler Toledo PG 1003-5.

(d) Rotary vacuum evaporator - Büchi RE-200 (Büchi Labortechnic AG, Postfach, Switzerland).

(e) Chromatographic columns - 5 % diphenyl 95 % dimethyl siloxane capillary column (30 m x 0.25 mm x 0.25µm) ZB-5 (USA) was employed.

3.2.4 Preparation of organochlorine mixture standard solution

0.1 mL each of Lindane, Heptachlor and its epoxide, ,Endrin, Dieldrin, *op*- DDE *pp*-DDE, *op* -DDD, *op*-DDT, *pp*-DDT were accurately pipetted into a 50 mL volumetric flask and 48.4 mL of ethyl acetate was added to give organochlorine mixture Standard solution with concentration of 2.0 μg/mL was made for the calibration curve (Armendariz, et al., 2004).

3.2.5 Extraction

The extraction procedure was according to methods described by Bhanti and Taneja (2005). Fifty grams of the sample was cut into pieces with a knife and was mixed with 50 ml ethyl acetate and homogenized in a blender (This was repeated thrice). The resultant mixture was then poured into separator funnel and shaken with 400 ml (4×100 ml) of 3:2 mixtures of n-hexane and dichloromethane for one hour (4×15 min). After shaking, the separator funnel was left in the same position for 30 min to have distinct layers; organic layer was then taken into round bottomed flask and concentrated to dryness by rotary evaporator.

3.2.6 Solid Phase Extraction (SPE) for sample clean-up

The column (60 cm × 22 mm) packed with florisil and activated charcoal (5:1 w/w) in between two layers of anhydrous sodium sulphate was conditioned with 10 mL mixture of ethyl acetate and hexane. A receiving flask was placed under the column to collect the eluate. 5 mL of sample extract (upper layer) was loaded into the column and eluted with 125 ml mixture of ethyl acetate: hexane (3:7 v/v) from above.

The sample extract was concentrated to dryness using the rotary evaporator equipped with water chillier. The residue was dissolved in 2 mL of n-hexane (HPLC grade) by Labscan (Dublin, Ireland) and then transferred quantitatively into 2 mL vial for quantification on to the gas chromatograph.

3.2.7 Preparation of calibration curve

Ethyl acetate (9975 µL) was added to 25 µL of organochlorine mix standard solution (2.0 µg/mL). Serial dilutions of concentrations of 0.20 µg/mL, 0.02 µg/mL, 0.010 µg/mL, and 0.0050 µg/mL were prepared. 1.0 µL of each concentration was injected into the injection port of the GC-ECD and the responses were recorded. A calibration curve was constructed by plotting the concentration against their respective peak areas.

3.2.8 Gas Chromatographic (GC) analysis

A Shimadzu GC-2010 equipped with ^{63}Ni electron capture detector (ECD) and capillary column coated with ZB-5 (30 m x 0.25 mm, 0.25 µm film thickness). The nitrogen gas flow rate was 29 mL/min with the following operating conditions: injector temperature: 225^{o}C: Detector temperature: 300 ^{o}C and column 60^{o}C for 2 min., 180^{o}C /min up to 300^{o}C held for 31.80 minutes.

3.3 Quantification

To determine the quantities of residues in the sample extracts an external standard method was employed. Standard mixture with known quantities of pesticides was run and the response of the detector for each compound was determined. The area of the corresponding peak in the sample was compared with that of the standard which is known.

3.4 Quality control and quality assurance

Quality control and quality assurance were incorporated in the analytical scheme.

3.4.1 Recovery Test

A recovery test was carried out in triplicate and performed by spiked samples with 1.0mL of organochlorine mix standard. The spiked samples as well as blank were subjected to extraction, SPE clean-up, GC-analysis and quantification. Bempah and Donkoh (2010).

The concentration of the pesticides recovered in the extracts was calculated using the formula

$$\text{Recovery test } (\%) = \frac{\text{Pesticide(ppm)recovered from spiked sample}}{\text{Amount of pesticide (ppm)added}} \text{ x } 100$$

3.4.2 Limit of detection (LOD)

The extracts of the spiked samples were serially diluted by a factor of two (2) to give different concentrations. 1.0 μL of each concentration was injected and the least concentration that gave response was noted. Netherlands Analytical Methods (2007)

LOD was calculated by the formula:

$$\text{LOD} = \frac{V_1\,(\mu L)}{V_2\,(\mu L)} \text{ X Concentration spiked}$$

V_1 ─ volume injected

V_2 ─ final volume of spiked extract

3.5 Health Risks Estimation

Health risk estimations were done based on an integration of pesticide analysis data, and exposure assumptions. The following assumptions were made based on the U.S Environmental Protection Agency's guidelines (US EPA, 1996): a) hypothetical body weights of 10-kg for children and 70-kg for adults; and b) maximum absorption rate of 100%

and bioavailability rate of 100%. Food consumption rates were based on the International Food Policy Research Institute data, 2004.

Food consumption rate for vegetables in Ghana is found to be 0.137 kg/person/day. Hence, for each type of exposure, the estimated lifetime exposure dose (mg/kg/day) was obtained by multiplying the residual pesticide concentration (mg/kg) in the food of interest times the food consumption rate (kg/day), and dividing the product by the body weight (kg). The hazard indices to children and adults were estimated as ratios between estimated pesticide exposure doses, and the reference doses which are considered to be safe levels of exposure over the lifetime.

CHAPTER FOUR

RESULTS

4.0 Introduction

The results of the total pesticide residues analysis and health risk estimation are presented in Tables 4.1 - 4.5. The results are compared with the MRLs set in EC directives that have been implemented into UK legislation for vegetables (2006) and concentration falling above the levels are identified and discussed.

4.1 Levels of Pesticide Residues found in Vegetables on farms at Musuko

4.1.1 Pesticide Residues in Carrot at Musuko

The pesticides and their concentrations detected in carrots on farms at Musoku are presented in Table 4.1a.

Table 4.1a Detected pesticide (μgg^{-1}; fresh weight) in carrot (*Daucus carota*) samples from Musuko

Month	Pesticides Tested	Musuko farms			
		A1	A2	A3	Mean ± SD
Jan. 11	Lindane	nd	nd	nd	-
	Heptachlor + its epoxide	0.062*	0.058*	0.041*	0.054*±0.011
	Endrin	nd	nd	nd	-
	Dieldrin	nd	nd	nd	-
	o,p-DDE	0.102*	0.074*	0.032*	0.069*±0.035
	p,p-DDE	nd	nd	nd	-
	o,p-DDD	0.012	0.003	0.106*	0.040±0.035
	o,p-DDT	0.120*	0.013	0.102*	0.078*±0.043
	p,p-DDT	nd	nd	nd	-
Feb.11	Lindane	0.113*	0.002	0.009	0.040*±0.035
	Heptachlor + its epoxide	nd	nd	nd	-

Table 4.1a (Continued.)

Month	Pesticides Tested	Musuko farms			
		A1	A2	A3	Mean ± SD
	Endrin	nd	nd	nd	-
	Dieldrin	nd	nd	nd	-
	o,p-DDE	0.006	0.001	0.018	0.008±0.004
	p,p-DDE	0.019	0.018	0.102*	0.050±0.005
	o,p-DDD	0.012	0.005	0.080*	0.032±0.010
	o,p-DDT	nd	nd	nd	-
	p,p-DDT	0.017	0.092*	0.107*	0.072*±0.019
Mar.11	Lindane	0.012	0.011	0.009	0.011±0.010
	Heptachlor + its epoxide	nd	nd	nd	-
	Endrin	nd	nd	nd	-
	Dieldrin	0.001	0.003	0.001	0.002±0.001
	o,p-DDE	0.012	0.011	0.007	0.015±0.005
	p,p-DDE	nd	nd	nd	-
	o,p-DDD	0.080*	0.101*	0.010	0.064*±0.038
	o,p-DDT	nd	nd	nd	-
	p,p-DDT	0.105*	0.023	0.008	0.045±0.018
April 11	Lindane	nd	nd	nd	-
	Heptachlor + its epoxide	nd	nd	nd	-
	Endrin	nd	nd	nd	-
	Dieldrin	nd	nd	nd	-
	o,p-DDE	0.020	0.002	0.023	0.015±0.010
	p,p-DDE	0.102*	0.109*	0.009	0.073*±0.037
	o,p-DDD	0.008	0.112*	0.011	0.044±0.018
	o,p-DDT	nd	nd	nd	-
	p,p-DDT	nd	nd	nd	-

A1, A2, A3 are samples collected from different farms at Musoku community and each value is an average of three determinations; nd = not detected

* Values designated by asterisks are higher than the Codex-MRLs for the respective pesticide (see MRLs in Table 4.5).

Eight (8) pesticides were detected in carrots from farms at Musuko. Endrin was not detected at Musuko. The highest concentration of pesticide from Musuko in the carrot sample was 0.078 μgg^{-1} of op DDT which was detected in the month of January. The lowest concentration of pesticide was 0.002 μgg^{-1} of Dieldrin which was detected in the month of March.

In all, Heptachlor and its epoxide, op DDE, op DDD and op DDT levels were well above WHO MRL value for the month of January. In February the maximum residue levels (MRL) were recorded in Lindane and pp DDT. Exceedances in March against the WHO limits occurred only for op DDE, whilst in April it occurred in op DDE only.

4.1.2 Pesticide Residues in Lettuce at Musuko

The pesticides detected in lettuce from farms at Musuko are presented in Table 4.1b.

Table 4.1b Detected pesticide (μgg^{-1}; fresh weight) in lettuce (*Lactuca sativa*) samples from Musuko

Month	Pesticides Tested	Musuko farms			
		A1	A2	A3	Mean ± SD
Jan. 11	Lindane	nd	nd	nd	-
	Heptachlor + its epoxide	nd	nd	nd	-
	Endrin	nd	nd	nd	-
	Dieldrin	nd	nd	nd	-
	o,p-DDE	0.214*	0.321*	0.001	0.178*±0.048
	p,p-DDE	0.121*	0.213*	0.010	0.115*±0.089
	o,p-DDD	0.222*	0.105*	0.100*	0.143*±0.017
	o,p-DDT	nd	nd	nd	-
	p,p-DDT	nd	nd	nd	-

Table 4.1b (Continued.)

Month	Pesticides Tested	Musuko farms A1	A2	A3	Mean ± SD
Feb.11	Lindane	nd	nd	nd	-
	Heptachlor + its epoxide	nd	nd	nd	-
	Endrin	nd	nd	nd	-
	Dieldrin	nd	nd	nd	-
	o,p-DDE	0.226*	0.105*	0.113*	0.148*±0.086
	p,p-DDE	nd	nd	nd	-
	o,p-DDD	0.120*	0.205*	0.290*	0.205*±0.267
	o,p-DDT	0.201*	0.311*	0.170*	0.189*±0.193
	p,p-DDT	0.011*	0.120*	0.200*	0.110*±0.009
Mar.11	Lindane	nd	nd	nd	-
	Heptachlor + its epoxide	nd	nd	nd	-
	Endrin	nd	nd	nd	-
	Dieldrin	0.007	0.001	0.012	0.012±0.004
	o,p-DDE	0.101	0.130	0.209	0.147*±0.183
	p,p-DDE	nd	nd	nd	-
	o,p-DDD	nd	nd	nd	-
	o,p-DDT	nd	nd	nd	-
	p,p-DDT	nd	nd	nd	-
April 11	Lindane	0.013	0.112*	0.410*	0.178*±0.194
	Heptachlor + its epoxide	nd	nd	nd	-
	Endrin	nd	nd	nd	-
	Dieldrin	nd	nd	nd	-
	o,p-DDE	0.114*	0.209*	0.091*	0.138*±0.186
	p,p-DDE	0.103*	0.109*	0.114*	0.109*±0.007
	o,p-DDD	nd	nd	nd	-
	o,p-DDT	0.208*	0.110*	0.018	0.112*±0.005
	p,p-DDT	0.310*	0.003	0.210*	0.174*±0.188

A1, A2, A3 are samples collected from different farms at Musuko community and each value is an average of three determinations   nd = not detected

* Values designated by asterisks are higher than the Codex-MRLs for the respective pesticide (see MRLs in Table 4.5).

Seven (7) pesticides were detected in the Lettuce samples analysed in Musuko. Heptachlor and its epoxide and Endrin were not detected in the Lettuce samples. The maximum residue concentration of pesticide was detected for op DDD at a concentration of 0.205 μgg^{-1} in the month of February whilst the minimum concentration of pesticide residue detected was 0.012 μgg^{-1} in the month of March for Dieldrin.

The exceedance observed in the lettuce samples analysed was similar to that of carrot in the same farm.

4.1.3 Pesticide Residues in Cabbage at Musuko

Concentrations of pesticides recorded in cabbage from Musoko farms are presented in Table 4.1c.

Table 4.1c Detected pesticide (μgg^{-1}; fresh weight) in cabbage (*Brassica oleracea)* samples from Musuko

Month	Pesticides Tested	Musuko farms			
		A1	A2	A3	Mean ± SD
Jan. 11	Lindane	nd	nd	nd	-
	Heptachlor + its epoxide	0.101*	0.021*	0.109*	0.077*±0.019
	Endrin	nd	nd	nd	-
	Dieldrin	nd	nd	nd	-
	o,p-DDE	0.101*	0.174*	0.142*	0.139*±0.017
	p,p-DDE	0.024	0.122*	0.012	0.053±0.011
	o,p-DDD	0.102*	0.009	0.016	0.042±0.411
	o,p-DDT	nd	nd	nd	-
	p,p-DDT	nd	nd	nd	-

Table 4.1c (Continued.)

Month	Pesticides Tested	Musuko farms			
		A1	A2	A3	Mean ± SD
Feb.11	Lindane	nd	nd	nd	-
	Heptachlor + its epoxide	nd	nd	nd	-
	Endrin	0.001	0.009	0.012	0.007±0.003
	Dieldrin	nd	nd	nd	-
	o,p-DDE	nd	nd	nd	-
	p,p-DDE	nd	nd	nd	-
	o,p-DDD	0.009	0.105*	0.250*	0.121*±0.084
	o,p-DDT	0.006	0.102*	0.107*	0.072*±0.019
	p,p-DDT	nd	nd	nd	-
Mar.11	Lindane	0.112*	0.300*	0.109*	0.174*±0.044
	Heptachlor + its epoxide	0.009	0.020*	0.024*	0.017*±0.089
	Endrin	nd	nd	nd	-
	Dieldrin	nd	nd	nd	-
	o,p-DDE	0.220*	0.301*	0.106*	0.209*±0.020
	p,p-DDE	0.110*	0.120*	0.009	0.079*±0.018
	o,p-DDD	0.091*	0.301*	0.420*	0.271*±0.081
	o,p-DDT	nd	nd	nd	-
	p,p-DDT	0.195*	0.223*	0.118*	0.179*±0.120
April 11	Lindane	0.211*	0.205*	0.107*	0.174*±0.187
	Heptachlor + its epoxide	nd	nd	nd	-
	Endrin	nd	nd	nd	-
	Dieldrin	nd	nd	nd	-
	o,p-DDE	nd	nd	nd	-
	p,p-DDE	0.119*	0.127*	0.129*	0.125*±0.159
	o,p-DDD	0.120*	0.113*	0.290*	0.174*±0.044
	o,p-DDT	0.201*	0.221*	0.170*	0.197*±0.033
	p,p-DDT	nd	nd	nd	-

A1, A2, A3 are samples collected from different farms at Musuko community and each value is an average of three determinations   nd = not detected

* Values designated by asterisks are higher than the Codex-MRLs for the respective pesticide (see MRLs in Table 4.5).

Eight (8) out of the nine (9) pesticides analysed were detected in Cabbage samples in Musuko. The maximum concentration of pesticide residue was 0.271 µgg^{-1} which was detected in op DDE in the month of March, whilst Endrin had the minimum concentration of 0.007 µgg^{-1} in February. There were two (2) exceedances in January for Heptachlor and its epoxide and op DDE, respectively. Op DDD and op DDE were found in concentrations above the WHO MRL in February.

4.2 Levels of Pesticide Residues found in Vegetables from farms at Kwabenya

4.2.1 Pesticide Residues in Carrot at Kwabenya

Table 4.2a below present results of pesticide concentrations detected in carrots from farms at Kwabenya.

Table 4.2a Detected pesticide (µgg^{-1}; fresh weight) in carrot (*Daucus carota*) samples from Kwabenya

Month	Pesticides Tested	Kwabenya farms			
		A1	A2	A3	Mean ± SD
Jan. 11	Lindane	nd	nd	nd	-
	Heptachlor + its epoxide	nd	nd	nd	-
	Endrin	0.023*	0.017*	0.001	0.014*±0.013
	Dieldrin	0.019	0.008	0.013	0.013*±0.004
	o,p-DDE	nd	nd	nd	-
	p,p-DDE	0.128*	0.015	0.113	0.085*±0.025
	o,p-DDD	0.008	0.102*	0.028	0.046±0.012
	o,p-DDT	nd	nd	nd	-
	p,p-DDT	0.104*	0.201*	0.221*	0.175*±0.048
Feb.11	Lindane	0.013	0.112*	0.009	0.045*±0.063
	Heptachlor + its epoxide	nd	nd	nd	-

Table 4.2a (Continued.)

Month	Pesticides Tested	Kwabenya farms			
		A1	**A2**	**A3**	**Mean ± SD**
	Endrin	nd	nd	nd	-
	Dieldrin	nd	nd	nd	-
	o,p-DDE	0.014	0.201*	0.021	0.078*±0.042
	p,p-DDE	nd	nd	nd	-
	o,p-DDD	0.112*	0.013	0.024	0.049±0.024
	o,p-DDT	0108*	0.012	0.110	0.156*±0.014
	p,p-DDT	nd	nd	nd	-
Mar.11	Lindane	nd	nd	nd	-
	Heptachlor + its epoxide	nd	nd	nd	-
	Endrin	0.004	0.010	0.004	0.006±0.002
	Dieldrin	0.012	0.009	0.001	0.007±0.001
	o,p-DDE	0.004	0.001	0.012	0.006±0.003
	p,p-DDE	0.021	0.010	0.011	0.008±0.004
	o,p-DDD	nd	nd	nd	-
	o,p-DDT	nd	nd	nd	-
	p,p-DDT	0.214*	0.020	0.001	0.078*±0.032
April 11	Lindane	0.112*	0.201*	0.007	0.107*±0.043
	Heptachlor + its epoxide	0.009	0.006	0.016	0.010±0.001
	Endrin	nd	nd	nd	-
	Dieldrin	0.012	0.014	0.010	0.012±0.010
	o,p-DDE	nd	nd	nd	-
	p,p-DDE	0.010	0.008	0.019	0.012±0.065
	o,p-DDD	0.030	0.109*	0.010	0.049±0.010
	o,p-DDT	0.070*	0.110*	0.110*	0.009±0.100
	p,p-DDT	nd	nd	nd	-

A1, A2, A3 are samples collected from different farms at Kwabenya community and each value is an average of three determinations   nd = not detected

* Values designated by asterisks are higher than the Codex-MRLs for the respective pesticide (see MRLs in Table 4.5).

At Kwabenya, all the nine (9) pesticides were found in the carrot samples analysed. The maximum pesticide residue concentration of 0.175 μgg^{-1} was detected in pp DDT in the month of January, whilst the minimum concentration of 0.006 μgg^{-1} of op DDE was detected in the month of March. Nine (9) exceedances occurred for all the Carrot samples analysed in Kwabenya.

4.2.2 Pesticide Residues in Lettuce at Kwabenya

Table 4.2b below present results of pesticide concentrations detected in lettuce from farms at Kwabenya.

Table 4.2b Detected pesticide (μgg^{-1}; fresh weight) in lettuce (*Lactuca sativa*) samples from Kwabenya

Month	Pesticides Tested	Kwabenya farms			
		A1	A2	A3	Mean±SD
Jan. 11	Lindane	nd	nd	nd	-
	Heptachlor + its epoxide	nd	nd	nd	-
	Endrin	nd	nd	nd	-
	Dieldrin	nd	nd	nd	-
	o,p-DDE	0.009	0.002	0.207*	0.073*±0.019
	p,p-DDE	nd	nd	nd	-
	o,p-DDD	0.220*	0.110*	0.114*	0.444*±0.411
	o,p-DDT	nd	nd	nd	-
	p,p-DDT	0.110*	0.214*	0.270*	0.198*±0.198
Feb.11	Lindane	0.193*	0.300*	0.201*	0.231*±0.143
	Heptachlor + its epoxide	0.002	0.020*	0.109*	0.044*±0.109
	Endrin	nd	nd	nd	-
	Dieldrin	nd	nd	nd	-
	o,p-DDE	nd	nd	nd	-

Table 4.2b (Continued.)

Month	Pesticides Tested	Kwabenya farms			
		A1	A2	A3	Mean±SD
	p,p-DDE	0.019	0.120*	0.021	0.053±0.027
	o,p-DDD	0.009	0.301*	0.103*	0.138*±0.159
	o,p-DDT	nd	nd	nd	-
	p,p-DDT	nd	nd	nd	-
Mar.11	Lindane	nd	nd	nd	-
	Heptachlor + its epoxide	0.009	0.006	0.001	0.005±0.001
	Endrin	nd	nd	nd	-
	Dieldrin	nd	nd	nd	-
	o,p-DDE	0.119*	0.232*	0.400*	0.250*±0.038
	p,p-DDE	0.110*	0.127*	0.114*	0.117*±0.013
	o,p-DDD	nd	nd	nd	-
	o,p-DDT	0.150*	0.221*	0.021	0.131*±0.031
	p,p-DDT	0.140*	0.205*	0.112*	0.152*±0.086
April 11	Lindane	0.013	0.021*	0.210*	0.081*±0.021
	Heptachlor + its epoxide	0.009	0.021*	0.109*	0.066*±0.012
	Endrin	nd	nd	nd	-
	Dieldrin	nd	nd	nd	-
	o,p-DDE	nd	nd	nd	-
	p,p-DDE	nd	nd	nd	-
	o,p-DDD	0.012	0.009	0.016	0.012±0.077
	o,p-DDT	0.009	0.103*	0.109*	0.074*±0.022
	p,p-DDT	nd	nd	nd	-

A1, A2, A3 are samples collected from different farms at Kwabenya community and each value is an average of three determinations   nd = not detected

* Values designated by asterisks are higher than the Codex-MRLs for the respective pesticide (see MRLs in Table 4.5).

Seven (7) pesticides residue were detected in lettuce in Kwabenya out of the nine (9) organochlorines analysed for (Table 4.2b). Endrin and Dieldrin were not detected in Lettuce at Kwabenya. The highest residue concentration of 0.444 μgg^{-1} was recorded in op DDD in the month of January whilst the minimum residue concentration of 0.005 μgg^{-1} was detected in Heptachlor and its epoxide in the month of March. In all thirteen (13) exceedances were recorded.

4.2.3 Pesticide Residues in Cabbage at Kwabenya

Concentrations of pesticides recorded in cabbage from farms at Kwabenya are presented in Table 4.2c.

Table 4.2c Detected pesticide (μgg^{-1}; fresh weight) in cabbage (*Brassica oleracea*) samples from Kwabenya

Month	Pesticides Tested	Kwabenya farms			
		A1	**A2**	**A3**	**Mean ± SD**
Jan. 11	Lindane	0.213*	0.063*	0.103*	0.126*±0.156
	Heptachlor + its epoxide	0.015*	0.002	0.009	0.009±0.002
	Endrin	0.103*	0.012	0.101*	0.072*±0.035
	Dieldrin	0.009	0.004	0.012	0.008±0.004
	o,p-DDE	nd	nd	nd	-
	p,p-DDE	0.028	0.115*	0.102*	0.082*±0.028
	o,p-DDD	0.108*	0.121*	0.124*	0.118*±0.061
	o,p-DDT	nd	nd	nd	-
	p,p-DDT	0.214*	0.221*	0.311*	0.249*±0.084

Table 4.2c (Continued.)

Month	Pesticides Tested	Kwabenya farms			
		A1	**A2**	**A3**	**Mean ± SD**
eb.11	Lindane	0.013	0.112*	0.009	0.045*±0.018
	Heptachlor + its epoxide	nd	nd	nd	-
	Endrin	0.104*	0.202*	0.401*	0.236*±0.136
	Dieldrin	0.003	0.100*	0.100*	0.068*±0.032
	o,p-DDE	0.114*	0.209*	0.120*	0.148*±0.012
	p,p-DDE	nd	nd	nd	-
	o,p-DDD	nd	nd	nd	-
	o,p-DDT	0.208*	0.110*	0.400*	0.239*±0.180
	p,p-DDT	0.310*	0.003	0.210*	0.174*±0.044
Mar.11	Lindane	nd	nd	nd	-
	Heptachlor + its epoxide	0.103*	0.210*	0.109*	0.141*±0.032
	Endrin	0.009	0.010	0.007	0.009±0.005
	Dieldrin	0.002	0.002	0.003	0.002±0.001
	o,p-DDE	0.214*	0.105*	0.062*	0.127*±0.158
	p,p-DDE	0.121*	0.210*	0.021	0.117*±0.009
	o,p-DDD	nd	nd	nd	-
	o,p-DDT	0.212*	0.311*	0.010	0.178*±0.049
	p,p-DDT	0.204*	0.120*	0.201*	0.175*±0.048
April 11	Lindane	nd	nd	nd	-
	Heptachlor + its epoxide	0.009	0.020*	0.005	0.011±0.010
	Endrin	nd	nd	nd	-
	Dieldrin	0.001	0.004	0.011	0.005±0.001
	o,p-DDE	nd	nd	nd	-
	p,p-DDE	nd	nd	nd	-
	o,p-DDD	0.220*	0.118*	0.420*	0.253*±0.135
	o,p-DDT	0.150*	0.310*	0.113*	0.191*±0.052
	p,p-DDT	0.140*	0.104*	0.211*	0.151*±0.071

A1, A2, A3 are samples collected from different farms at Kwabenya community and each value is an average of three determinations   nd = not detected

* Values designated by asterisks are higher than the Codex-MRLs for the respective pesticide (see MRLs in Table 4.5).

All the nine (9) organochlorines were detected in the Cabbage samples analysed in Kwabenya. The highest residue concentration of 0.353 μgg^{-1} was detected in op DDD in the month of January, whilst the minimum residue concentration of 0.002 μgg^{-1} was recorded for Dieldrin in the month of March. Nineteen (19) Exceedances were recorded in the Cabbage samples in Kwabenya.

4.3 Levels of Pesticide residues found in vegetables from farms at Haatso

Table 4.3a Detected pesticide (μgg^{-1}; fresh weight) in carrot (*Daucus carota*) samples from Haatso

Month	Pesticides Tested	Haatso farms			
		A1	A2	A3	Mean±SD
Jan. 11	Lindane	0.013	0.001	0.010	0.008±0.004
	Heptachlor + its epoxide	0.002	0.100*	0.003	0.035*±0.008
	Endrin	nd	nd	nd	-
	Dieldrin	nd	nd	nd	-
	o,p-DDE	0.008	0.001	0.004	0.004±0.001
	p,p-DDE	0.004	0.003	0.019	0.008±0.004
	o,p-DDD	0.012	0.008	0.003	0.007±0.012
	o,p-DDT	nd	nd	nd	-
	p,p-DDT	nd	nd	nd	-
Feb.11	Lindane	nd	nd	nd	-
	Heptachlor + its epoxide	nd	nd	nd	-
	Endrin	nd	nd	nd	-
	Dieldrin	0.008	0.001	0.006	0.005±0.001
	o,p-DDE	nd	nd	nd	-

Table 4.3a (Continued.)

Month	Pesticides Tested	Haatso farms			
		A1	A2	A3	Mean±SD
	p,p-DDE	0.110*	0.003	0.018	0.044±0.018
	o,p-DDD	0.007	0.004	0.014	0.008±0.002
	o,p-DDT	nd	nd	nd	-
	p,p-DDT	nd	nd	nd	-
Mar.11	Lindane	nd	nd	nd	-
	Heptachlor + its epoxide	0.004	0.010	0.004	0.006±0.002
	Endrin	nd	nd	nd	-
	Dieldrin	nd	nd	nd	-
	o,p-DDE	0.012	0.002	0.001	0.005±0.002
	p,p-DDE	0.004	0.009	0.006	0.006±0.003
	o,p-DDD	0.011	0.113*	0.104*	0.076*±0.016
	o,p-DDT	nd	nd	nd	-
	p,p-DDT	nd	nd	nd	-
April 11	Lindane	0.007	0.018	0.012	0.025*±0.087
	Heptachlor + its epoxide	nd	nd	nd	-
	Endrin	0.006	0.007	0.018	0.010±0.010
	Dieldrin	0.002	0.001	0.008	0.004±0.005
	o,p-DDE	0.030	0.030	0.012	0.024±0.003
	p,p-DDE	nd	nd	nd	-
	o,p-DDD	nd	nd	nd	-
	o,p-DDT	0.019	0.190*	0.013	0.074*±0.019
	p,p-DDT	0.120*	0.110*	0.190*	0.140*±0.004

A1, A2, A3 are samples collected from different farms from Haatso community and each value is an average of three determinations   nd = not detected

* Values designated by asterisks are higher than the Codex-MRLs for the respective pesticide (see MRLs in Table 4.5).

4.3.1 Pesticide Residues in Carrot at Haatso

All the nine (9) pesticides analysed were detected in the Carrot samples in Haatso (Table 4.3a. The highest amount of pesticide residue of 0.140 μgg^{-1} was detected for pp DDT in the month of April in Haatso. And the minimum residue concentration of 0.004 μgg^{-1} detected in op DDE and Dieldrin in the months of January and April, respectively. Exceedances recorded in Haatso were five (5).

4.3.2 Pesticide Residues in Lettuce at Haatso

Seven (7) organochlorines were detected in the Lettuce samples in Haatso (Table 4.3b). pp DDT and Lindine were not detected in Haatso. The highest concentration of pesticide residue of 0.209 μgg^{-1} was detected in op DDE in the month of January. The minimum residue concentration of 0.006 μgg^{-1} of Dieldrin was detected in the month of March. Exceedances recorded were eleven (11).

Table 4.3b Detected pesticide (μgg^{-1}; fresh weight) in lettuce (*Lactuca sativa*) samples from Haatso

Month	Pesticides Tested	Haatso farms			
		A1	**A2**	**A3**	**Mean±SD**
Jan. 11	Lindane	nd	nd	nd	-
	Heptachlor + its epoxide	0.009	0.004	0.024*	0.012±0.014
	Endrin	nd	nd	nd	-
	Dieldrin	nd	nd	nd	-
	o,p-DDE	0.220*	0.301*	0.106*	0.209*±0.263
	p,p-DDE	0.110*	0.103*	0.009	0.071*±0.037
	o,p-DDD	nd	nd	nd	-
	o,p-DDT	nd	nd	nd	-
	p,p-DDT	nd	nd	nd	-

Table 4.3b (Continued.)

Month	Pesticides Tested	Haatso farms			
		A1	A2	A3	Mean±SD
Feb.11	Lindane	nd	nd	nd	-
	Heptachlor + its epoxide	0.006	0.020*	0.005	0.011*±0.010
	Endrin	nd	nd	nd	-
	Dieldrin	0.007	0.004	0.011	0.007±0.003
	o,p-DDE	0.113*	0.207*	0.200*	0.173*±0.193
	p,p-DDE	nd	nd	nd	-
	o,p-DDD	nd	nd	nd	-
	o,p-DDT	0.004	0.310*	0.113*	0.142*±0.048
	p,p-DDT	nd	nd	nd	-
Mar.11	Lindane	nd	nd	nd	-
	Heptachlor + its epoxide	0.009	0.002	0.007	0.009±0.003
	Endrin	0.011	0.012	0.012	0.012*±0.011
	Dieldrin	0.008	0.004	0.006	0.006±0.002
	o,p-DDE	nd	nd	nd	-
	p,p-DDE	0.001	0.115*	0.210*	0.011±0.010
	o,p-DDD	0.200*	0.121*	0.250*	0.190*±0.051
	o,p-DDT	0.040	0.203*	0.107*	0.117*±0.011
	p,p-DDT	nd	nd	nd	-
April 11	Lindane	nd	nd	nd	-
	Heptachlor + its epoxide	nd	nd	nd	-
	Endrin	nd	nd	nd	-
	Dieldrin	0.009	0.001	0.100*	0.036*±0.013
	o,p-DDE	0.010	0.101*	0.120*	0.077*±0.023
	p,p-DDE	0.028	0.103*	0.110*	0.080*±0.024
	o,p-DDD	nd	nd	nd	-
	o,p-DDT	nd	nd	nd	-
	p,p-DDT	nd	nd	nd	-

A1, A2, A3 are samples collected from different farms from Haatso community and each value is an average of three determinations   nd = not detected

* Values designated by asterisks are higher than the Codex-MRLs for the respective pesticide (see MRLs in Table 4.5).

Table 4.3c Detected pesticide (μgg^{-1}; fresh weight) in cabbage (*Brassica oleracea*) samples from Haatso

Month	Pesticides Tested	Haatso farms			
		A1	A2	A3	Mean±SD
Jan. 11	Lindane	0.013	0.201*	0.410*	0.208*±0.018
	Heptachlor + its epoxide	nd	nd	nd	-
	Endrin	nd	nd	nd	-
	Dieldrin	nd	nd	nd	-
	o,p-DDE	0.218*	0.101*	0.091*	0.137*±0.159
	p,p-DDE	0.204*	0.103*	0.114*	0.140*±0.017
	o,p-DDD	nd	nd	nd	-
	o,p-DDT	0.009	0.012	0.018	0.013±0.008
	p,p-DDT	0.202*	0.104*	0.210*	0.172*±0.048
Feb.11	Lindane	0.001	0.020*	0.006	0.009±0.005
	Heptachlor + its epoxide	nd	nd	nd	-
	Endrin	nd	nd	nd	-
	Dieldrin	nd	nd	nd	-
	o,p-DDE	0.113*	0.301*	0.400*	0.271*±0.133
	p,p-DDE	0.100*	0.103*	0.114*	0.106*±0.023
	o,p-DDD	0.007	0.004	0.014	0.008±0.004
	o,p-DDT	0.004	0.211*	0.021	0.079*±0.018
	p,p-DDT	nd	nd	nd	-

Table 4.3c (Continued.)

Month	Pesticides Tested	Haatso farms			
		A1	A2	A3	Mean±SD
Mar.11	Lindane	nd	nd	nd	-
	Heptachlor + its epoxide	nd	nd	nd	-
	Endrin	nd	nd	nd	-
	Dieldrin	nd	nd	nd	-
	o,p-DDE	0.012*	0.002	0.001	0.005±0.003
	p,p-DDE	0.001	0.003	0.010	0.004±0.004
	o,p-DDD	0.200*	0.110*	0.100*	0.107*±0.007
	o,p-DDT	0.040	0.103*	0.100*	0.081*±0.021
	p,p-DDT	0.243*	0.214*	0.102*	0.186*±0.193
April 11	Lindane	0.114*	0.318*	0.304*	0.245*±0.128
	Heptachlor + its epoxide	nd	nd	nd	-
	Endrin	nd	nd	nd	-
	Dieldrin	nd	nd	nd	-
	o,p-DDE	0.009	0.130*	0.207*	0.115*±0.015
	p,p-DDE	0.110*	0.105*	0.103*	0.106*±0.021
	o,p-DDD	nd	nd	nd	-
	o,p-DDT	nd	nd	nd	-
	p,p-DDT	nd	nd	nd	-

A1, A2, A3 are samples collected from different farms from Haatso community and each value is an average of three determinations   nd = not detected

* Values designated by asterisks are higher than the Codex-MRLs for the respective pesticide (see MRLs in Table 4.5).

4.3.3 Pesticide Residues in Cabbage at Haatso

Six (6) organochlorines pesticides residue were detected in the Cabbage samples in Haatso (Table 4.3c). Endrin and Dieldrin were not detected in Haatso. The highest concentration of pesticide residue of 0.271 μgg^{-1} of op DDE was recorded in the month of February. The minimum residue concentration of 0.004 μgg^{-1} of pp DDE was detected in the month of March. Exceedances recorded were thirteen (13).

Figures 4.1 – 4.3 compare the frequency of occurrence of the various chemicals in the vegetables studied on the three farms.

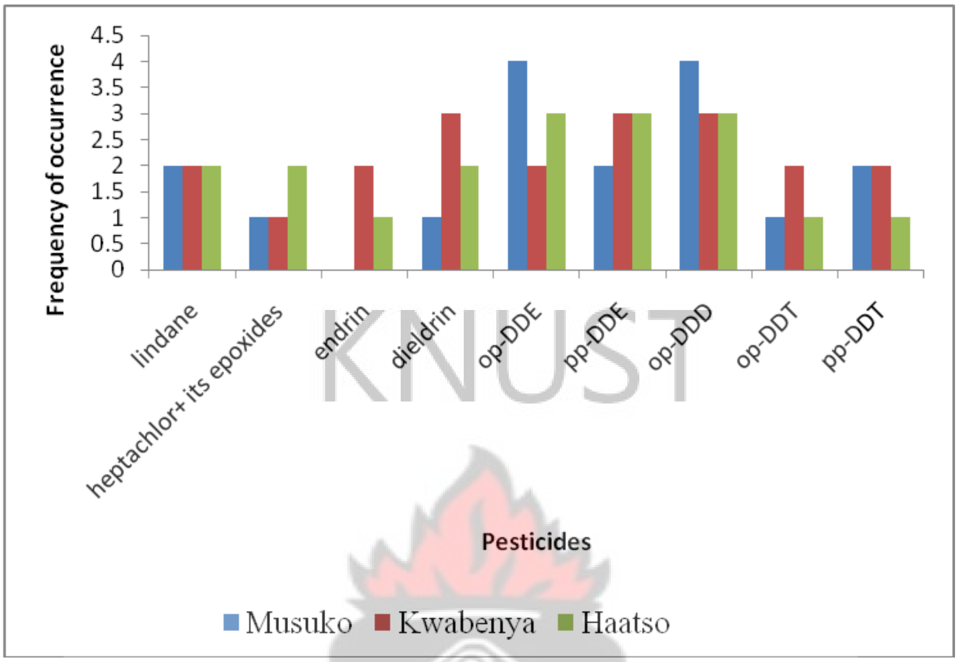


Figure 4.1 Frequency of occurrence of pesticide residues in carrot samples found in various farms.

The frequency of occurrence of pesticide residue in carrot sample was highest in Musuko farms.

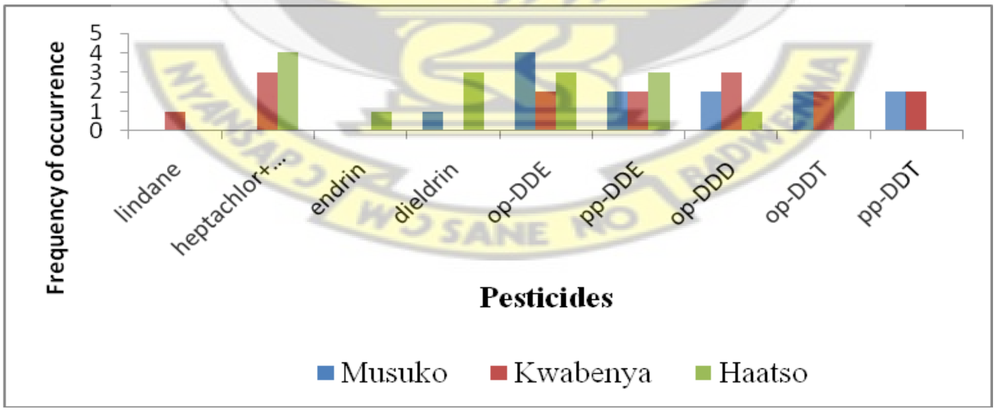


Figure 4.2 Frequency of occurrence of pesticide residues in lettuce samples found in various farms.

The Frequency of occurrence of heptachlor+ its epoxide and op-DDE in lettuce samples were highest in Musuko and Haatso farms

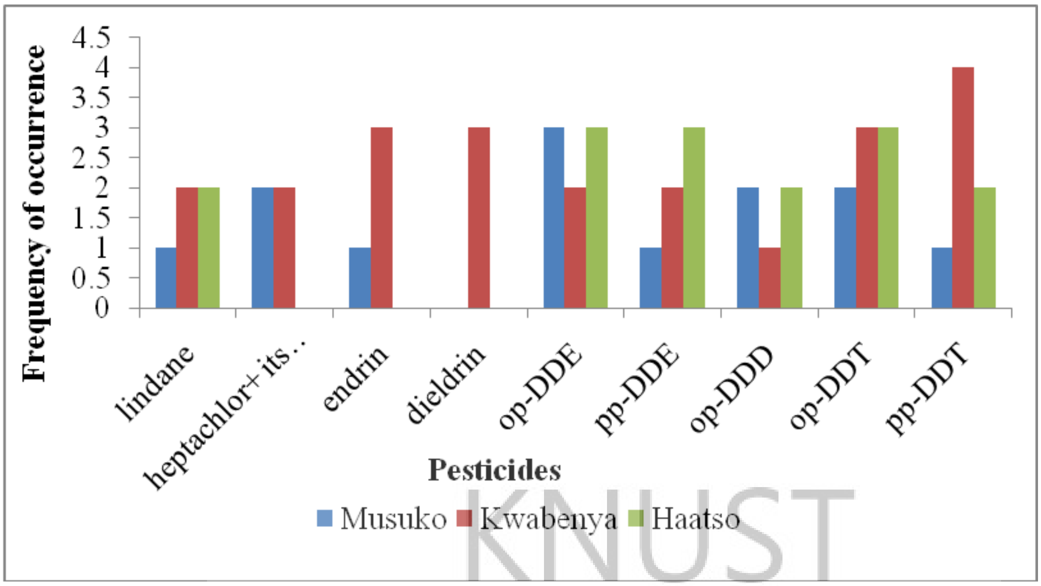


Figure 4.3 Frequency of occurrence of pesticide residues in cabbage samples found in various farms. The Frequency of occurrence of pp-DDT in the cabbage samples was highest in Kwabenya farms.

Table 4.4: Overall per cent total pesticide residues in vegetables from Ga East Municipality.

Scientific Name	English Name	No. of Sample	% with one or more residues
Daucus carota	Carrot	40	32
Lactuca sativa .	Lettuce	40	43
Brassica oleracea	Cabbage	40	56

Incidence of pesticide residues in the vegetable samples analysed are presented in Table 4.4 In all, 120 samples of vegetables (Table 4.4) were collected within the months of January through April of 2011 for pesticides analysis. Overall per cent total pesticide residues found in carrot, lettuce and cabbage samples were 32%, 43% and 56%, respectively.

Table 4.5: Number and percentages of contaminated and violated samples of different types of vegetables collected from the study area

Pesticides45	Contaminated samples with each pesticide						MRL (µg/g)[b]	Samples that violated MRLvalues of EC					
	Carrot n	%	Cabbage n	%	Lettuce n	%		Carrot n	%	Cabbage n	%	Lettuce n	%
Lindane	18	45.0	24	60.0	9	22.5	0.01	4	10	16	44.4	7	17.5
Heptachlor + its epoxide	12	30.0	15	37.5	18	45.0	0.01	4	10	10	25.0	6	15.0
Endrin	9	22.5	12	30.0	3	7.5	0.01	2	5.0	5	12.5	0	0.0
Dieldrin	18	45.0	12	30.0	12	30.0	0.01	0	0.0	2	5.0	1	2.5
o,p-DDE	27	17.0	24	60.0	27	67.0	0.05	4	10	21	52.5	20	50.0
p,p-DDE	24	60.0	27	67.0	21	52.5	0.05	5	12.5	19	47.5	15	37.5
o,p-DDD	30	75.0	24	60.0	18	45.0	0.05	10	25.0	18	45	14	35.0
o,p-DDT	12	30.0	24	60.0	18	45.0	0.05	7	17.5	16	40.0	13	32.5
p,p-DDT	15	37.5	21	52.5	12	30.0	0.05	10	25.0	20	50.0	11	27.5

n = number of samples contaminated

Samples [a] = total number of analysed samples for each type of vegetable (carrot, cabbage lettuce = 40 each).

4.4 Tolerance Limits

The concentration of organochlorine pesticides in various vegetable samples in Ga East Municipality farms were compared with maximum residue limits (MRLs) set forth by the EC directives (Table 4.5). Pesticide residues were detected in measurable concentrations. Percentage contaminated samples differed among the three vegetables (carrot, cabbage and lettuce).

Lindane contamination accounted for 22.5% in lettuce, 45.0% in carrot and reached 60% in cabbage samples (Table 4.5). The residue levels of Lindane that was above the MRL accounted for 10% in carrot, 17.5% in lettuce and 44.4% in cabbage, when compared with MRLs established by EC Directives (2006). This may indicate illegal use of this compound.

The highest residue level occurred with the op-DDE recorded 17%, 60% and 67% of the samples analysed from carrot, cabbage, and lettuce, respectively, with 11.1% of carrot, 58.3% cabbage and 55.6% lettuce levels above the MRLs (Table 4.5).

Percent contamination levels of heptachlor plus its epoxide found in carrot, cabbage and lettuce were 30%, 37.5% and 45%, respectively. Carrot (10%), cabbage (25%) and lettuce (15%) were above the M R L s. (Table 4.5).

Contamination with endrin accounted to 22.5% in carrot, 30% in cabbage and 7.5% in lettuce. 5% carrot samples and 12.5% cabbage exceeded the MRL. There was 45.0% contamination with dieldrin in carrot, 30% in cabbage and lettuce. However, cabbage and lettuce exceeded the M R Ls set by E C.

60% pp-DDE in carrot samples were found to be contaminated, likewise 67.0% in cabbage and 52.5% in lettuce. 12% carrot, 47.5% cabbage and 37.5% lettuce violated MRL levels set forth by EC Directives. Carrot recorded 60% contamination of p,p-DDE whiles cabbage recorded 67% with lettuce recording a low value of 52.5%. Considering the residue concentration above M R Ls samples with pp- DDE, 12.5% was observed in carrot, 47.5% in cabbage and 37.5% in lettuce.

Percent contamination of op-DDT was reported in 30%, 60% and 45.0% in carrot, cabbage and lettuce respectively whiles samples were in the order of carrot (17.5%)< lettuce (32.5%) < cabbage (40%). Lastly, pp-DDT contamination levels accounted for 37.5% carrot, 52.5%

cabbage and 30% lettuce samples. Pp-DDT accounted for 25% carrot, 50% cabbage and 27.5% lettuce. These were all above the M R Ls set by EC.

CHAPTER FIVE

DISCUSSION

5.0 Introduction

The concentration levels of pesticide residue in the vegetable samples for the three farms are discussed in this chapter.

5.1 Concentration level of pesticide residues in carrot (*Daucus carota*)

The residue levels of organochlorine (OC) pesticides in carrot (*Daucus carota*) collected from the three farms in Ga East Municipality in Ghana are shown in Table 4.1a, 4.2a, 4.3a. In general, nine (9) pesticides were detected in carrot, from all the three farms except endrin which is absent at Mussuko farm. Comparing farms with regard to total mean pesticides on carrot, samples from Haatso had the highest pesticides level than any of the two farms. This farm indeed is one of the popular supplying sites where most sellers purchase their produce, suggesting most farmers who cultivate these vegetables use a lot of pesticides to boost yields.

DDT is banned in Ghana because it bioaccumulates and its persistence in the environment, whiles lindane and endosulfan are restricted for the control of pests on cocoa and coffee. However, the data indicate that these dangerous pesticides are used irrespective of whether they are approved for vegetable production or not.

The high level of DDD and DDE are as a result of DDT which is known to biodegrade to DDE under aerobic and to DDD in anaerobic conditions (Bumbus and Aust 1987). The ratio of (DDD + DDE) / DDTs < 1, hence the predominance and high levels of op-DDD, op-DDE and pp-DDE in carrot samples show that either the DDT compounds were not from the historical source or that the biotransformation of DDT in the carrot samples is not efficacious.

The least pesticide found in carrot samples is endrin. This is in contrast to its persistence, and may be due to its susceptibility to volatilization and photo degradation by heat (Bempah and Donkor, 2010).

The higher levels of DDT metabolites (Table 4.3a) indicate considerable exposure to DDTs in Haatso farm land. High concentrations of OC pesticides in that location may be because of the combination of their intensive usage in both agricultural activities and malaria control program. This is similar to work carried out by Chowdhury et al, (2011). It also agrees with research done by Ntow (2001) which confirmed that residues of some pesticides are present in areas of highly intensive agricultural production.

5.2 Concentration level of pesticide residues in lettuce (*Lactuca sativa*)

In the case of lettuce sampled from all the three farms from Ga East Municipality, all the nine OCs were detected in all the lettuce samples. However, not all the nine were detected in all the farms (Table 4.1b, 42b, 4.3b). Haatso farms recorded the highest level of pesticide residues followed by Kwabenya farms and then Musuko farms in that order.

Ratios of (DDD + DDE) / DDTs > 0.5 shows DDTs have been subjected to long term weathering (Doong et al., 2007). In the present study, 53.33% of the carrot samples from all the three farms in the Ga East municipality had the ratio (DDD + DDE) / DDTs > 0.5, showing that both weathered and fresh DDT could be contaminating lettuce samples in the areas.

High concentration of DDTs recorded in lettuce samples from all the farms indicates considerable use of this compound in these areas. Moreover, due to its low vapour pressure, low water solubility and high particle affinity, this chemical is less transportable via air and water, and thus still found higher levels in areas close to point sources. The work agrees with research carried out by Amoah *et al*. (2006) whose work determined and compared the level of exposure of the Ghanaian urban population to hazardous pesticides found in vegetables sold in Ghanaian urban markets.

5.3 Concentration level of pesticide residues in Cabbage (*Brassica oleracea*)

The residue levels of the OC pesticides in cabbage samples are given in Table 4.1c, 4.2c and 4.3c. Cabbage contained the highest level of pesticide residues with DDT as the most predominant, followed by Lindane, heptachlor, endrin and dieldrin in that order.

The high level of DDT metabolites suggests either efficient biotransformation of the parent materials in the plant systems or old sources of DDT contamination. The least pesticide found in cabbage samples were endrin and dieldrin. In contrast to its persistence, endrin decreased perhaps due to its susceptibility to volatilization and photo degradation by heat to dieldrin (Bempah and Donkor, 2010), and this research agrees with work done by Zhang *et al.* (2007) which evaluated the multi-residual dynamics of the pesticides (chlorpyrifos, dimethoate, cyhalothrin, cypermethrin, fenvalerate, deltamethrin and chlorothalonil) in spring cabbage in China.

Generally, the data showed that most of the vegetable samples analyzed contain residues of the monitored pesticide above the accepted maximum residue limit (MRL) as adopted by the EC Directives, although some pesticides were not detected in all the vegetable samples. The results obtained showed that 54.2% of the vegetables samples were above the MRL, and 45.8% were below.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSIONS

Over the nine-month study period, it can be concluded that pesticide residues were found in most of the vegetables (lettuce, carrot and cabbage) that were sampled for organochlorines from farms at Musuko, Kwabenya and Haatso in the Ga East Municipality of the Greater Accra Region of Ghana. In all, cabbage contained the highest levels of residues, followed by lettuce and then carrot (Table 4.4) . 54.2% of the vegetables contained residues above the EC MRL levels while 45.8% were below the level. These levels of vegetable contamination present a potential health risk to vegetable consumers in the Ga East Municipality and even beyond.

The results also give an indication that vegetable growers in the study area use some of the restricted / banned pesticides to control pests on their vegetable farms. Basic reasons for the use of the restricted pesticides could be attributed to their wide spectrum of activity and ready availability at low cost.

6.2 RECOMMENDATIONS

The recommendation captures issues that need to be addressed further for improvement.This, in my view will assist in ensuring that vegetables sold on the Ghanaian market conforms to international standards. These include Laws/Legislation, education, consumer safety needs ,Standard Control Board, Monitoring Task force, Integrated Pest Management Approach and Adequate Policy.

6.2.1 Laws / Legislation

There should be tougher laws to regulate imports of pesticide into the country. These laws should specify which given pesticide is needed for a given vegetable or commodity. This will certainly avoid misapplication of the pesticide, e.g. the use of karate for vegetables and not food crops like plantain, cassava etc.

6.2.2 Education

There should be an intensive education of the usage application by experts in the field to prevent its avoidable implication on the unsuspecting consumer. The quantities, periodic intervals needed for the application should be noted by the user and applied appropriately to avoid any side effect.

6.2.3 Consumer Safety Needs

There should be some strong consumer association/watch dog committees. This association should be empowered by law to verify, agitate and protect consumers on the usage of pesticide of all kinds.

6.2.4 Standard Control Board

The Standard Control Board should be strengthened to make inroad investigations on the effects of all pesticide applied to Ghanaian vegetables and crops. There should be periodic reports and this will help consumers to avoid some pesticide which might be harmful.

6.2.5 Monitoring Task Force

This should be a force to undertake regular field monitoring to make sure users conform to all prescriptions so far as usage and application of chemical pesticide are concerned.

The monitoring Program will gather adequate data to guide policy making on vegetables grown in Ghana.

6.2.6 Integrated Pest Management Approach

This approach should be encouraged and practiced in order to reduce the use of pesticide to the barest minimum. This method avoids the application of the pesticide.

6.2.7 Policy

Policy should be formulated to ensure that vegetables sold at the market conform to the MRL values set by EC.

REFERENCE

Adetola, E., J.K. Ataki, E. Atidepe, D.K. Osei and A.B. Akosa (1999). Pesticide Poisoning–A Nine Year Study (1989 – 1997). Department of Pathology, University of Ghana Medical School and Ghana Standards Board. Accra.

American Chemical Society (1997). *Advances in Pesticide population Technology.ACS Symposium Series 254.* Washington, D.C.

Amoah, P., Drechsel, P., Abaidoo. R.C., Ntow, W.J., (2006), Pesticide and Pathogen Contamination of Vegetables in Ghana's Urban Market Archives on Environmental Contamination and Toxicology 50,1-6 Spinger Science Business media Inc.

Armendariz, C., Perez de Ciriza, J. A. and Farre, R. (2004). Gas chromatographic determination of organochlorine pesticides in cow milk. International Journal of Food Sciences and Nutrition, 55(3): 215-221.

Bassil, K.L., Vakil C., Sanborn, M., Cole, D.C., Kaur, J.S. and Kerr K.J. (2007). Cancer health effects of pesticides: systematic review. *Cancer Family Physician* 53(10): 1704–11. PMID 17934034.

Battu, R.S., Singh, B., Kang, B. K., and Joia B. S., (2005) Risk Assessment through dietary intake of total diet contaminated with pesticides residue in Punjab, India, 1999-2002. Ecotoxicology and Environmental Safety, 62 (1): 132-139.

Bempah, K.C., Donkor, K.A., (2010). Pesticide residue in Fruits at the Market level in Accra Metropolis, Ghana, a preliminary study. *Environmental Monitoring Assessment* 175:551- 561

Bhanti, M. and Taneja, A. (2005). Contamination of vegetables of different seasons with organophosphorus pesticides and related health risk assessment in northern India. Chemosphere, 69: 63-68.

Bumbus, J. A., and Aust, S.B., (1987) Biodegradation of DDT [(1, 1, 1-Trichloro-2, 2-Dis (4-Chlorophenyl) ethane] by the white Rot fungus Phanerochaete chrysosporium Applied and Environmental Microbiology 53(9):2001-2008.

Casida, J. E., and Quistad, G. B., (1998). Golden Age of Insecticide Research: Past, Present, or Future? *Annual Review of Entomology*, 43: 1-16.

Chowdhury, M.T.I., Razzaquema, M.A., Khanmsi. S. I., (2011). Chlorinate pesticide residue status in tomato, potato and carrot. *Journal of experimental sciences*, 2(1):1-5

Clarke, E.E.K., (1995). Knowledge, attitudes and practices to pesticide related to health. Birmingham. Oxfordjournals.org

Clarke, E.E.K., Levy, L.S., Spurgeon, A., and Calvert, I.A., (1997). The Problems Associated with Pesticide Use by Irrigation Workers in Ghana. In: Occupational Medicine. 47(5): 301-308.

Council on Scientific Affairs, American Medical Association (1997). Educational and Informational Strategies to Reduce Pesticide Risks. *Preventive Medicine*, 26(2): 191-200.

Dewailly, E., Mulvad, G., Pedersen, H. S., Ayotte, P., Demers, A., Weber, J. P., and Hansen, J. C. (1999). Concentration of organochlorines in human brain, liver, and adipose tissue autopsy samples from Greenland. *Environmental Health Perspectives*, 107(10): 823–828.

Dinham, B., (2003). Growing vegetables in developing countries for local urban population and export market: Problem Confronting small scale producers. Pesticides Management Science, 59: 591 – 596.

Doegheim S.M; Gad-Alla S.A; El-Marseing (1996) Organochrorine & Organophosporus Pesticides Residue in Food from Egyptian local market. J. AOAC. 78 949-952.

Doong, R.A., Sun, Y. C., Liao, P. L., Peng, C. K., and Wu, S.C., (2007) Distribution and Fate of Organochlorine Pesticide Residues in Sediments from the selected rivers in Taiwan, Chemosphere 48(2): 237-248.

Eillion J., Suane, F. and Selwyn, J. (2000), Multiresidue method for the determination of residues of 251 pesticides in fruits and vegetables by gas liquid chromatography/ mass spectrometry and liquid chromatography/ mass spectrometry and liquid chromatography with fluorescence detector, JAOAC, lnternational, 83: 698-713.

Ellen, M., and Marc J., (2001). Environmental Change and Security Project Report. Retrieved on 5th July, 2010 from: http.//ecsp.siedu/PDC/ECS97- Features article 1. Pdf. 6/7/02.

EPA (1994). National Profile to Assess the Chemicals Management Infrastructure in Ghana. Environmental Protection Agency: Accra.

EPA (1997). National Profile to Assess the Chemicals Management Infrastructure in Ghana. Environmental Protection Agency: Accra.

EPA (2007). National Profile to Assess the Chemicals Management Infrastructure in Ghana. Environmental Protection Agency: Accra.

FAO/WHO (1996). Codex Alimentarius codex Committee on Pesticide Residue in Food- Maximum Residue Limits, (2nd Ed). Rome, Italy: FAO.

FAO of the UN (2002). International Code of Conduct on the Distribution and Use of Pesticides. Italy, Rome: FAO.

FAO of the UN Programmes (2007): International Code of Conduct on the Distribution and Use of Pesticides.UN Non-Governmental Liaison Service. Italy, Rome: FAO.

Food and agriculture organization of the United Nations (1986). *International code of conduct on the distribution and use of pesticide*. Rome, FAO.

Ghana Statistical Services (2002). *2000 Population and Housing Census: Summary Report of Final Results*, Accra, Ghana, 62 pages.

Gunnell, D., **Eddleston**, **M., Michael, R., Phillips and Konradsen, F., (2007).** The global distribution of fatal pesticide self-poisoning: Systematic review**.** BMC Public Health, 7:357.

Gyau, A. and Spiller, A. (2007). The role of organizational culture in modelling buyer seller relationships in the fresh fruit and vegetable trade between Ghana and Europe, *African Journal of Business Management*, 1(8):218-229.

Horna D., Timpo S., Alhassan R.M., (2007). vegetable production and pesticide use in Ghana; World G.M. varieties have an impact at the farm level? AAAE Conference proceedings (2007), 473 – 477.

Johnson P.N.T., (2002) Overview of a recent DFID/NRI/FRI project on street-vended food in Accra. In: SADAOC (2002) Street food in Ghana: Types, environment patronage, laws and regulations. Proceedings of a roundtable conference on 6-9-01. ISSER. University of Ghana, Legon, Accra, pp.41-51.

Jos, F., Pilar, H., Carmen, M., Pilar, F., (2007). Pesticide Residue Analysis of Vegetables by Gas Chromatography with Electron-Capture Detection. Journal of AOAC International, 90(1): 263-270.

Jurewicz, J., and Hanke W., (2008) Explosive to Pesticide and Childhood Career risk: Has there been any progress in epidemiological studies? International Journal of Occupational Medicine and Environmental Health 19(3): 152-169.

Kotey, D. A., Winfred, S. K., Gbewonyo and Afreh-Nuamah, K. (2008, June). High chlorpyrifos levels of vegetables in Ghana. Pesticide News, 80: 1-6.

Kumari, B., Madan, V.K., Kumar R. and Kathpal, T.S. (2001). Monitoring of Seasonal vegetables for Pesticides Residues. Environmental Monitoring and Assessment, 74: 263 – 270.

Longnecker, M. P., Rogan, W. J. and Lucier, G. (1997). The human health effects of DDT (dichlorodiphenyltrichloroethane) and PCBs (polychlorinated biphenyls) and an overview of organochlorines in public health. *Annual Review of Public Health*, 18: 211-244.

Mackenzie, D. (1995, December). Ozone's future in up in the air. New scientist, 14-15.

Miller, G. T. (2004), *sustaining the Earth*, 6th edition. Thompson Learning, Inc. Pacific Grove, California, 9: 211-216.

Ministry of Public Health, Welfare and Sports (2007). Netherlands Analytical methods of pesticide residues and foodstuffs. Ministry of Public Health, Welfare and Sports**:** Netherlands.

MoFA (1998): Handbook of Decentralisation. Accra: Ministry of Food and Agriculture.

Mukherjee, I., Gopal M., (1996). Insecticide Residue in Bay food, animal feed and vegetables. Bulletin on Environmental contamination toxicology 56: 381 – 388.

Ntow, W.J., (2001) Organochlorine pesticides in water, sediment, crops, and human fluids in a farming community in Ghana. Archives of environmental contamination and toxicology, 40:557-563.

Ntow, W.J., Tagoe, L.M., Drechesel, P., Kalderman, P., Gizen, H. J. and Nyarko, E. (2008). Accumulation of persistent organochlorine contaminant in milk and serum of farmers from Ghana. Environmental research, 106(1): 17-26.

Ntow, W.J., Gijzen, H. J., Kalderman, P. and Drechesel, P. (2006). Farmer perceptions and pesticides use practices in vegetable production in Ghana. Pesticide management science, 62: 356-365.

Nyanteng, V.K. (Ed. 1997). Policies and Options for Ghanaian Economic Development. Accra: ISSER Legon.

Okorley, E.L and Kwarteng, J.A. (2002). Current status of the use of pesticides in urban and peri-urban vegetable production in the central region of Ghana. Paper presented at a workshop on the Sustainable Food Production Project on January 30, 2002: Accra, Ghana.

Pesticide Residue Committee (PRC) (2008). Annual Report PRE Secretariat Chemicals Regulation. United Kingdom: Chemical regulation directorate (RD) of Health.

Peter, J.V. and Cherian, A. M. (2000). Organic insecticides. Anaesthesia and Intensive Care, 28(1):11-21.

Sabon, I., Gilles de, Revel, Kotseridis, Y. and Bertrand, A. (2007). Determination of volatile compounds in Grenache Wines in relation with different Terroires in the Rhone Valley *Journal of Agriculture and Food Chemistry*. 50 (22): 6341 – 6345.

Sadlo, S. Szpyrka, E. Jazwa A, Zawislak A. (2007). Pesticide Residues in Fruit and Vegetables from South Eastern Poland, Polish Journal of Environmental Studies, 16(2): 313-319.

Toft, G, Hagmar, L. Giwercman, A. and Bonde, J. P. (2004). Epidemiological evidence on reproductive effects of persistent organochlorines in humans. *Reproductive Toxicology*,19(1): 5-26.

U.S. Environmental Protection Agency (2007). Pesticides: Health and Safety. National Assessment of the Worker Protection Workshop #3. Washington DC, USA: U.S. Environmental Protection Agency.

Whatmuth, M. S.; (2002), Applying bio solids to acid soils in New South Wales: Are guidelines soil metal limit from other countries appropriate?, Australia Journal of soil Residue, 40: 1041 – 1056.

Zhang, Z, Xian-Jin, L., Xiang-Yang, Y., Cun-Zheng, Z. and Xiao-Yue, H. (2007). Pesticide residues in the spring cabbage (*Brassica oleracea* L. var. *capitata*) grown in open field. *Food Control*, (18): 723-730.

APPENDICES

Appendix 1: Detected pesticide (μgg^{-1}; fresh weight) in carrot (*Daucus carota*) samples from Musuko, Kwabenya and Haatso farms

Month	Pesticides Tested	Musuko farms				Kwabenya farms				Haatso farms			
		A1	A2	A3	Mean ± SD	A1	A2	A3	Mean ± SD	A1	A2	A3	Mean ± SD
Jan. 11	Lindane	nd	nd	nd	-	nd	nd	nd	-	0.013	0.001	0.010	0.008±0.004
	Heptachlor + its epoxide	0.062*	0.058*	0.041*	0.054*±0.011	nd	nd	nd	-	0.002	0.100*	0.003	0.035*±0.008
	Endrin	nd	nd	nd	-	0.023*	0.017*	0.001	0.014*±0.013	nd	nd	nd	-
	Dieldrin	nd	nd	nd	-	0.019	0.008	0.013	0.013*±0.004	nd	nd	nd	-
	o,p-DDE	0.102*	0.074*	0.032*	0.069*±0.035	nd	nd	nd	-	0.008	0.001	0.004	0.004±0.001
	p,p-DDE	nd	nd	nd	-	0.128*	0.015	0.113	0.085*±0.025	0.004	0.003	0.019	0.008±0.004
	o,p-DDD	0.012	0.003	0.106*	0.040±0.035	0.008	0.102*	0.028	0.046±0.012	0.012	0.008	0.003	0.007±0.012
	o,p-DDT	0.120*	0.013	0.102*	0.078*±0.043	nd	nd	nd	-	nd	nd	nd	-
	p,p-DDT	nd	nd	nd	-	0.104*	0.201*	0.221*	0.175*±0.048	nd	nd	nd	-
Feb.11	Lindane	0.113*	0.002	0.009	0.040*±0.035	0.013	0.112*	0.009	0.045*±0.063	nd	nd	nd	-
	Heptachlor + its epoxide	nd	nd	nd	-	nd	nd	nd	-	nd	nd	nd	-
	Endrin	nd	nd	nd	-	nd	nd	nd	-	nd	nd	nd	-
	Dieldrin	nd	nd	nd	-	nd	nd	nd	-	0.008	0.001	0.006	0.005±0.001
	o,p-DDE	0.006	0.001	0.018	0.008±0.004	0.014	0.201*	0.021	0.078*±0.042	nd	nd	nd	-
	p,p-DDE	0.019	0.018	0.102*	0.050±0.005	nd	nd	nd	-	0.110*	0.003	0.018	0.044±0.018
	o,p-DDD	0.012	0.005	0.080*	0.032±0.010	0.112*	0.013	0.024	0.049±0.024	0.007	0.004	0.014	0.008±0.002
	o,p-DDT	nd	nd	nd	-	0108*	0.012	0.110	0.156*±0.014	nd	nd	nd	-
	p,p-DDT	0.017	0.092*	0.107*	0.072*±0.019	nd	nd	nd	-	nd	nd	nd	-

Month	Pesticides Tested	Musuko farms				Kwabenya farms				Haatso farms			
		A1	A2	A3	Mean ± SD	A1	A2	A3	Mean ± SD	A1	A2	A3	Mean ± SD
Mar.11	Lindane	0.012	0.011	0.009	0.011±0.010	nd	nd	nd	-	nd	nd	nd	-
	Heptachlor + its epoxide	nd	nd	nd	-	nd	nd	nd	-	0.004	0.010	0.004	0.006±0.002
	Endrin	nd	nd	nd	-	0.004	0.010	0.004	0.006±0.002	nd	nd	nd	-
	Dieldrin	0.001	0.003	0.001	0.002±0.001	0.012	0.009	0.001	0.007±0.001	nd	nd	nd	-
	o,p-DDE	0.012	0.011	0.007	0.015±0.005	0.004	0.001	0.012	0.006±0.003	0.012	0.002	0.001	0.005±0.002
	p,p-DDE	nd	nd	nd	-	0.021	0.010	0.011	0.008±0.004	0.004	0.009	0.006	0.006±0.003
	o,p-DDD	0.080*	0.101*	0.010	0.064*±0.038	nd	nd	nd	-	0.011	0.113*	0.104*	0.076*±0.016
	o,p-DDT	nd	nd	nd	-	nd	nd	nd	-	nd	nd	nd	-
	p,p-DDT	0.105*	0.023	0.008	0.045±0.018	0.214*	0.020	0.001	0.078*±0.032	nd	nd	nd	-
April 11	Lindane	nd	nd	Nd	-	0.112*	0.201*	0.007	0.107*±0.043	0.007	0.018	0.012	0.025*±0.087
	Heptachlor + its epoxide	nd	nd	nd	-	0.009	0.006	0.016	0.010±0.001	nd	nd	nd	-
	Endrin	nd	nd	nd	-	nd	nd	nd	-	0.006	0.007	0.018	0.010±0.010
	Dieldrin	nd	nd	nd	-	0.012	0.014	0.010	0.012±0.010	0.002	0.001	0.008	0.004±0.005
	o,p-DDE	0.020	0.002	0.023	0.015±0.010	nd	nd	nd	-	0.030	0.030	0.012	0.024±0.003
	p,p-DDE	0.102*	0.109*	0.009	0.073*±0.037	0.010	0.008	0.019	0.012±0.065	nd	nd	nd	-
	o,p-DDD	0.008	0.112*	0.011	0.044±0.018	0.030	0.109*	0.010	0.049±0.010	nd	nd	nd	-
	o,p-DDT	nd	nd	nd	-	0.070*	0.110*	0.110*	0.009±0.100	0.019	0.190*	0.013	0.074*±0.019
	p,p-DDT	nd	nd	nd	-	nd	nd	nd	-	0.120*	0.110*	0.190*	0.140*±0.004

A1, A2, A3 are samples collected from different farms and each value is an average of three determinations

nd = not detected

* Values designated by asterisks are higher than the Codex-MRLs for the respective pesticide (see MRLs in Table 4.5).

Appendix 2: Detected pesticide (μgg^{-1}; fresh weight) in lettuce (*Lactuca sativa*) samples from Musuko, Kwabenya and Haatso farms

Month	Pesticides Tested	Musuko farms				Kwabenya farms				Haatso farms			
		A1	A2	A3	Mean ± SD	A1	A2	A3	Mean ± SD	A1	A2	A3	Mean ± SD
Jan. 11	Lindane	nd	nd	nd	-	nd	nd	nd	-	nd	nd	nd	-
	Heptachlor + its epoxide	nd	nd	nd	-	nd	nd	nd	-	0.009	0.004	0.024*	0.012±0.014
	Endrin	nd	nd	nd	-	nd	nd	nd	-	nd	nd	nd	-
	Dieldrin	nd	nd	nd	-	nd	nd	nd	-	nd	nd	nd	-
	o,p-DDE	0.214*	0.321*	0.001	0.178*±0.048	0.009	0.002	0.207*	0.073*±0.019	0.220*	0.301*	0.106*	0.209*±0.263
	p,p-DDE	0.121*	0.213*	0.010	0.115*±0.089	nd	nd	nd	-	0.110*	0.103*	0.009	0.071*±0.037
	o,p-DDD	0.222*	0.105*	0.100*	0.143*±0.017	0.220*	0.110*	0.114*	0.444*±0.411	nd	nd	nd	-
	o,p-DDT	nd	nd	nd	-	nd	nd	nd	-	nd	nd	nd	-
	p,p-DDT	nd	nd	nd	-	0.110*	0.214*	0.270*	0.198*±0.198	nd	nd	nd	-
Feb.11	Lindane	nd	nd	nd	-	0.193*	0.300*	0.201*	0.231*±0.143	nd	nd	nd	-
	Heptachlor + its epoxide	nd	nd	nd	-	0.002	0.020*	0.109*	0.044*±0.109	0.006	0.020*	0.005	0.011*±0.010
	Endrin	nd	nd	nd	-	nd	nd	nd	-	nd	nd	nd	-
	Dieldrin	nd	nd	nd	-	nd	nd	nd	-	0.007	0.004	0.011	0.007±0.003
	o,p-DDE	0.226*	0.105*	0.113*	0.148*±0.086	nd	nd	nd	-	0.113*	0.207*	0.200*	0.173*±0.193
	p,p-DDE	nd	nd	nd	-	0.019	0.120*	0.021	0.053±0.027	nd	nd	nd	-
	o,p-DDD	0.120*	0.205*	0.290*	0.205*±0.267	0.009	0.301*	0.103*	0.138*±0.159	nd	nd	nd	-
	o,p-DDT	0.201*	0.311*	0.170*	0.189*±0.193	nd	nd	nd	-	0.004	0.310*	0.113*	0.142*±0.048
	p,p-DDT	0.011*	0.120*	0.200*	0.110*±0.009	nd	nd	nd		nd	nd	nd	-

Month	Pesticides Tested	Musuko farms				Kwabenya farms				Haatso farms			
		A1	A2	A3	Mean ± SD	A1	A2	A3	Mean ± SD	A1	A2	A3	Mean ± SD
Mar.11	Lindane	nd	nd	nd	-	nd	nd	nd	-	nd	nd	nd	-
	Heptachlor + its epoxide	nd	nd	nd	-	0.009	0.006	0.001	0.005±0.001	0.009	0.002	0.007	0.009±0.003
	Endrin	nd	nd	nd	-	nd	nd	nd	-	0.011	0.012	0.012	0.012*±0.011
	Dieldrin	0.007	0.001	0.012	0.012±0.004	nd	nd	nd	-	0.008	0.004	0.006	0.006±0.002
	o,p-DDE	0.101	0.130	0.209	0.147*±0.183	0.119*	0.232*	0.400*	0.250*±0.038	nd	nd	nd	-
	p,p-DDE	nd	nd	nd	-	0.110*	0.127*	0.114*	0.117*±0.013	0.001	0.115*	0.210*	0.011±0.010
	o,p-DDD	nd	nd	nd	-	nd	nd	nd	-	0.200*	0.121*	0.250*	0.190*±0.051
	o,p-DDT	nd	nd	nd	-	0.150*	0.221*	0.021	0.131*±0.031	0.040	0.203*	0.107*	0.117*±0.011
	p,p-DDT	nd	nd	nd	-	0.140*	0.205*	0.112*	0.152*±0.086	nd	nd	nd	-
April 11	Lindane	nd	nd	nd	-	0.013	0.021*	0.210*	0.081*±0.021	nd	nd	nd	-
	Heptachlor + its epoxide	nd	nd	nd	-	0.009	0.021*	0.109*	0.066*±0.012	nd	nd	nd	-
	Endrin	nd	nd	nd	-	nd	nd	nd	-	nd	nd	nd	-
	Dieldrin	nd	nd	nd	-	nd	nd	nd	-	0.009	0.001	0.100*	0.036*±0.013
	o,p-DDE	0.114*	0.209*	0.091*	0.138*±0.186	nd	nd	nd	-	0.010	0.101*	0.120*	0.077*±0.023
	p,p-DDE	0.103*	0.109*	0.114*	0.109*±0.007	nd	nd	nd	-	0.028	0.103*	0.110*	0.080*±0.024
	o,p-DDD	nd	nd	nd	-	0.012	0.009	0.016	0.012±0.077	nd	nd	nd	-
	o,p-DDT	0.208*	0.110*	0.018	0.112*±0.005	0.009	0.103*	0.109*	0.074*±0.022	nd	nd	nd	-
	p,p-DDT	0.310*	0.003	0.210*	0.174*±0.188	nd	nd	nd	-	nd	nd	nd	-

A1, A2, A3 are samples collected from different farms and each value is an average of three determinations

nd = not detected.

* Values designated by asterisks are higher than the Codex-MRLs for the respective pesticide (see MRLs in Table 4.5)

Appendix 3 Detected pesticide (μgg^{-1}; fresh weight) in cabbage (*Brassica oleracea*) samples from Musuko, Kwabenya and Haatso farms

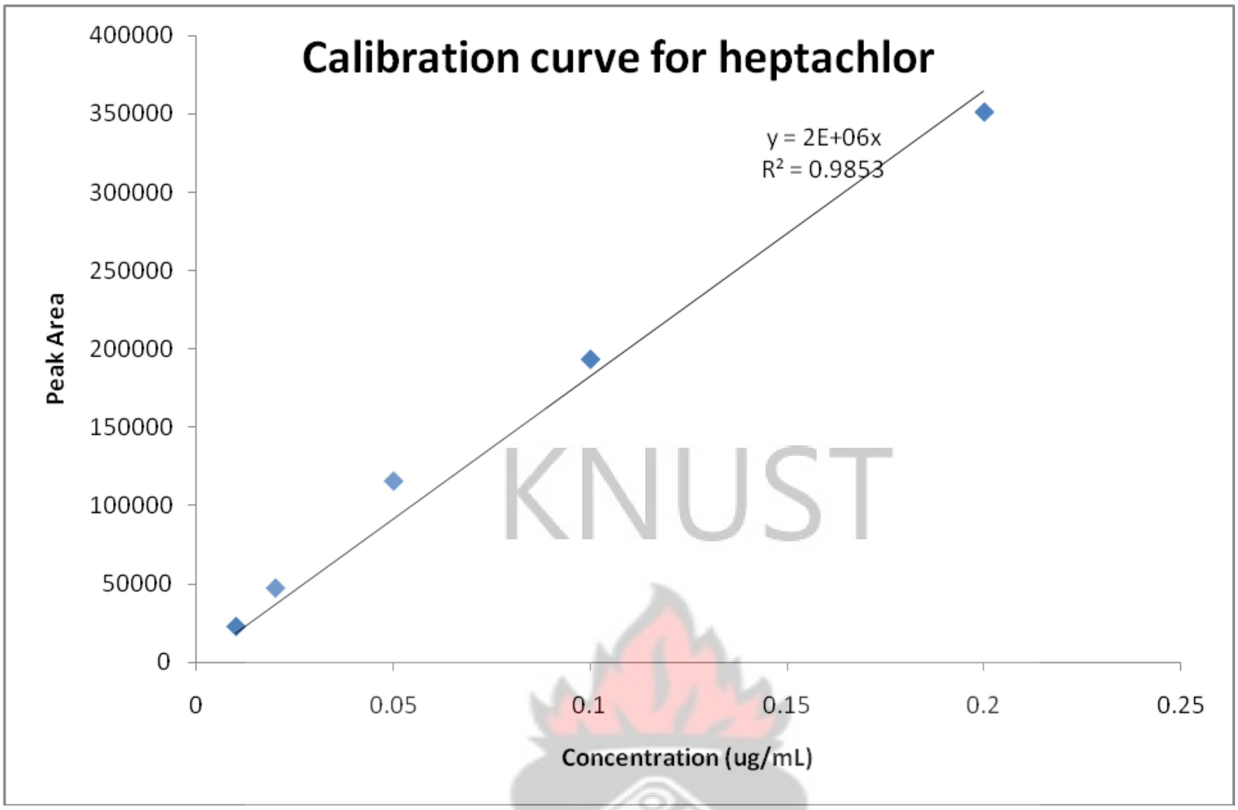
Month	Pesticides Tested	Musuko farms				Kwabenya farms				Haatso farms			
		A1	A2	A3	Mean ± SD	A1	A2	A3	Mean ± SD	A1	A2	A3	Mean ± SD
Jan. 11	Lindane	nd	nd	nd	-	0.213*	0.063*	0.103*	0.126*±0.156	0.013	0.201*	0.410*	0.208*±0.018
	Heptachlor+ its epoxide	0.101*	0.021*	0.109*	0.077*±0.019	0.015*	0.002	0.009	0.009±0.002	nd	nd	nd	-
	Endrin	nd	nd	nd	-	0.103*	0.012	0.101*	0.072*±0.035	nd	nd	nd	-
	Dieldrin	nd	nd	nd	-	0.009	0.004	0.012	0.008±0.004	nd	nd	nd	-
	o,p-DDE	0.101*	0.174*	0.142*	0.139*±0.017	nd	nd	nd	-	0.218*	0.101*	0.091*	0.137*±0.159
	p,p-DDE	0.024	0.122*	0.012	0.053±0.011	0.028	0.115*	0.102*	0.082*±0.028	0.204*	0.103*	0.114*	0.140*±0.017
	o,p-DDD	0.102*	0.009	0.016	0.042±0.411	0.108*	0.121*	0.124*	0.118*±0.061	nd	nd	nd	-
	o,p-DDT	nd	nd	nd	-	nd	nd	nd	-	0.009	0.012	0.018	0.013±0.008
	p,p-DDT	nd	nd	nd	-	0.214*	0.221*	0.311*	0.249*±0.084	0.202*	0.104*	0.210*	0.172*±0.048
Feb.11	Lindane	nd	nd	nd	-	0.013	0.112*	0.009	0.045*±0.018	0.001	0.020*	0.006	0.009±0.005
	Heptachlor+ its epoxide	nd	nd	nd	-	nd	nd	nd	-	nd	nd	nd	-
	Endrin	0.001	0.009	0.012	0.007±0.003	0.104*	0.202*	0.401*	0.236*±0.136	nd	nd	nd	-
	Dieldrin	nd	nd	nd	-	0.003	0.100*	0.100*	0.068*±0.032	nd	nd	nd	-
	o,p-DDE	nd	nd	nd	-	0.114*	0.209*	0.120*	0.148*±0.012	0.113*	0.301*	0.400*	0.271*±0.133
	p,p-DDE	nd	nd	nd	-	nd	nd	nd	-	0.100*	0.103*	0.114*	0.106*±0.023
	o,p-DDD	0.009	0.105*	0.250*	0.121*±0.084	nd	nd	nd	-	0.007	0.004	0.014	0.008±0.004
	o,p-DDT	0.006	0.102*	0.107*	0.072*±0.019	0.208*	0.110*	0.400*	0.239*±0.180	0.004	0.211*	0.021	0.079*±0.018
	p,p-DDT	nd	nd	nd	-	0.310*	0.003	0.210*	0.174*±0.044	nd	nd	nd	-

Month	Pesticides Tested	Musuko farms				Kwabenya farms				Haatso farms			
		A1	A2	A3	Mean ± SD	A1	A2	A3	Mean ± SD	A1	A2	A3	Mean ± SD
Mar.11	Lindane	0.112*	0.300*	0.109*	0.174*±0.044	nd	nd	nd	-	nd	nd	nd	-
	Heptachlor+ its epoxide	0.009	0.020*	0.024*	0.017*±0.089	0.103*	0.210*	0.109*	0.141*±0.032	nd	nd	nd	-
	Endrin	nd	nd	nd	-	0.009	0.010	0.007	0.009±0.005	nd	nd	nd	-
	Dieldrin	nd	nd	nd	0.209*±0.020	0.002	0.002	0.003	0.002±0.001	nd	nd	nd	-
	o,p-DDE	0.220*	0.301*	0.106*	0.079*±0.018	0.214*	0.105*	0.062*	0.127*±0.158	0.012*	0.002	0.001	0.005±0.003
	p,p-DDE	0.110*	0.120*	0.009	0.271*±0.081	0.121*	0.210*	0.021	0.117*±0.009	0.001	0.003	0.010	0.004±0.004
	o,p-DDD	0.091*	0.301*	0.420*	-	nd	nd	nd	-	0.200*	0.110*	0.100*	0.107*±0.007
	o,p-DDT	nd	nd	nd	0.179*±0.120	0.212*	0.311*	0.010	0.178*±0.049	0.040	0.103*	0.100*	0.081*±0.021
	p,p-DDT	0.195*	0.223*	0.118*		0.204*	0.120*	0.201*	0.175*±0.048	0.243*	0.214*	0.102*	0.186*±0.193
April 11	Lindane	0.211*	0.205*	0.107*	0.174*±0.187	nd	nd	nd	-	0.114*	0.318*	0.304*	0.245*±0.128
	Heptachlor+ its epoxide	nd	nd	nd	-	0.009	0.020*	0.005	0.011±0.010	nd	nd	nd	-
	Endrin	nd	nd	nd	-	nd	nd	nd	-	nd	nd	nd	-
	Dieldrin	nd	nd	nd	-	0.001	0.004	0.011	0.005±0.001	nd	nd	nd	-
	o,p-DDE	nd	nd	nd	-	nd	nd	nd	-	0.009	0.130*	0.207*	0.115*±0.015
	p,p-DDE	0.119*	0.127*	0.129*	0.125*±0.159	nd	nd	nd	-	0.110*	0.105*	0.103*	0.106*±0.021
	o,p-DDD	0.120*	0.113*	0.290*	0.174*±0.044	0.220*	0.118*	0.420*	0.253*±0.135	nd	nd	nd	-
	o,p-DDT	0.201*	0.221*	0.170*	0.197*±0.033	0.150*	0.310*	0.113*	0.191*±0.052	nd	nd	nd	-
	p,p-DDT	nd	nd	nd	-	0.140*	0.104*	0.211*	0.151*±0.071	nd	nd	nd	-

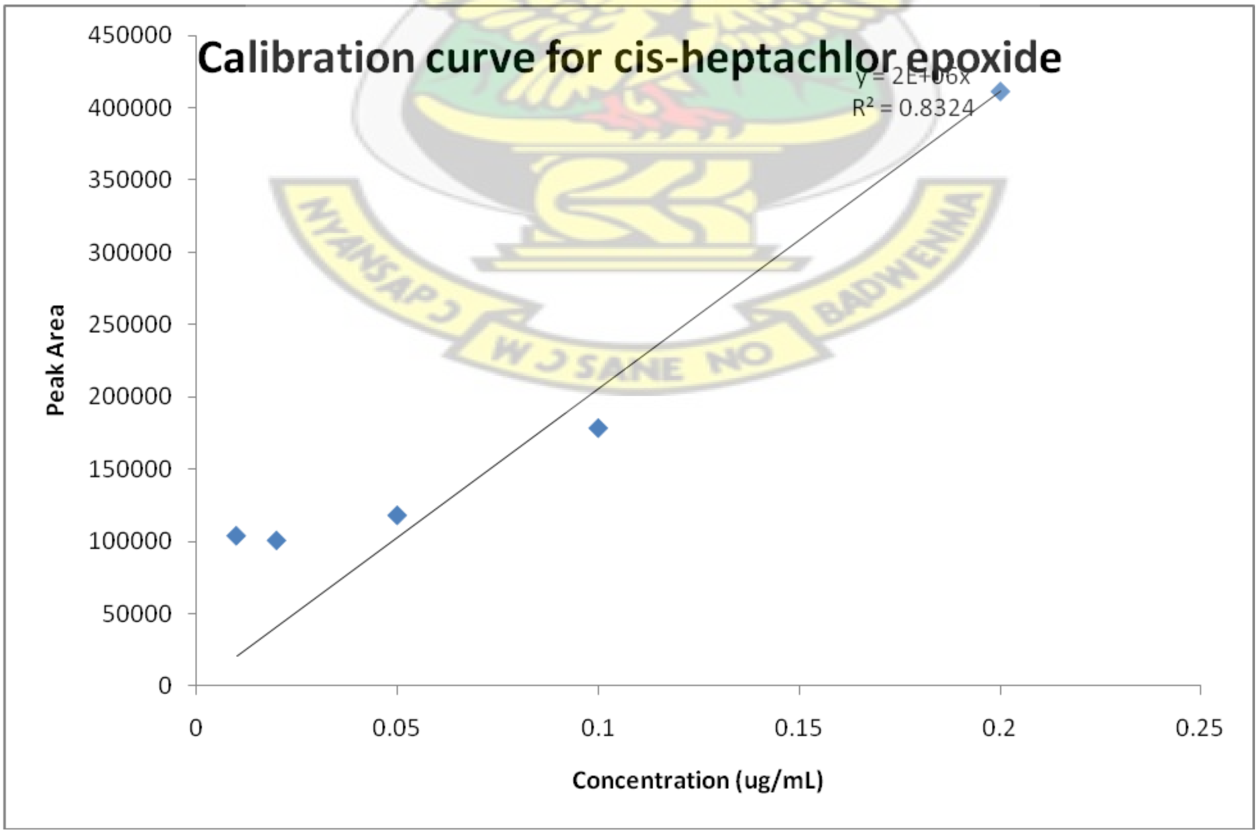
A1, A2, A3 are samples collected from different farms and each value is an average of three determinations
nd = not detected

* Values designated by asterisks are higher than the Codex-MRLs for the respective pesticide (see MRLs in Table 4.5)

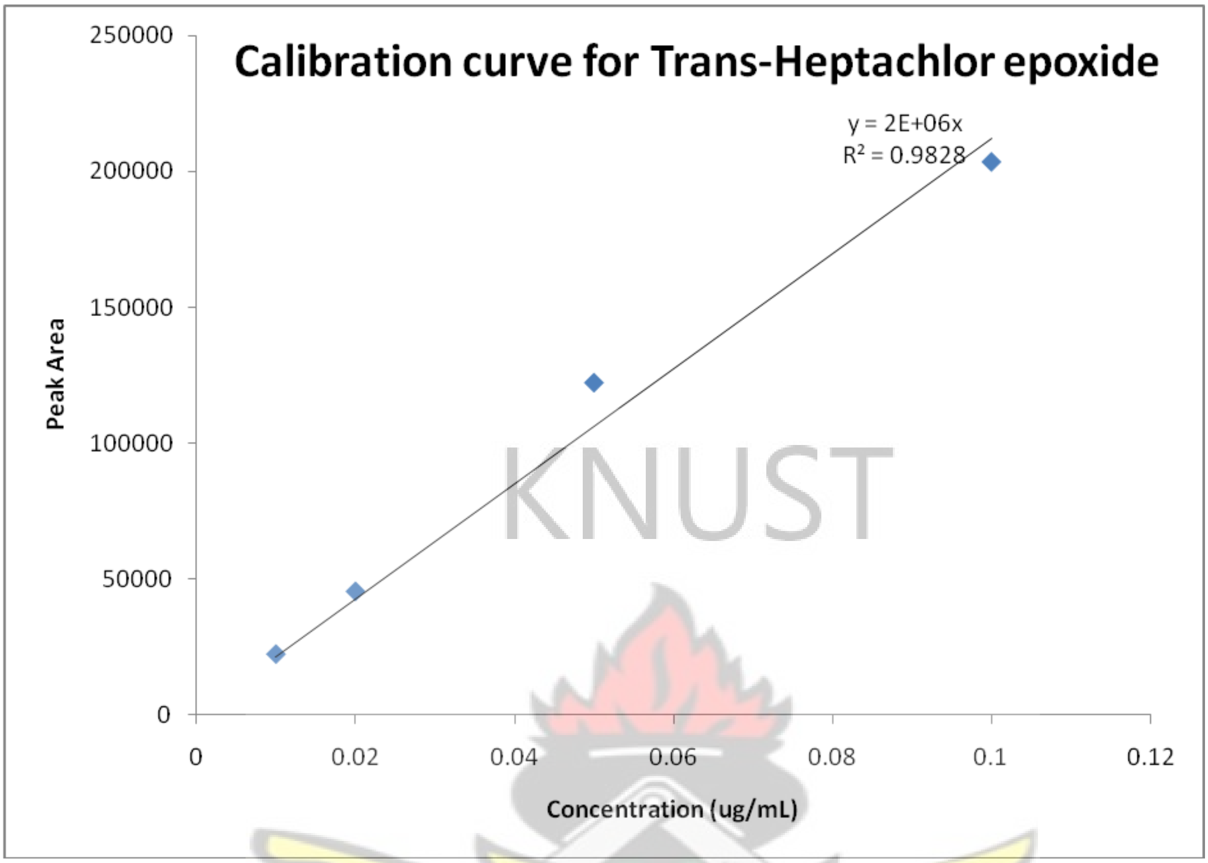
Appendix 4: Calibration curve for heptachlor



Appendix 5: Calibration curve for cis-heptachlor



Appendix 6: Calibration curve for trans-heptachlor epoxide



Appendix 7: **Calibration curve for pp-DDE**