CONCENTRATIONS OF ORGANOCHLORINE INSECTICIDE RESIDUES IN SELECTED VEGETABLES IN THE SUNYANI WEST DISTRICT OF THE BRONG AHAFO REGION OF GHANA

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BY

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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 has neither in part nor whole been presented for another degree elsewhere.

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ABSTRACT

A major practice in agriculture over the last decade is the use of pesticides to protect crops from insects and other pests that negatively affect crop quality and yield. That notwithstanding, these pesticides are often harmful to more than just their target species. Many of the most widely used pesticides have been classified as Persistent Organic Pollutants (POPs). They are applied directly to the crops and some may still be present as residues in or on vegetables and fruits after their harvest, especially where there is abuse, misuse and overuse of the pesticides. The present study was undertaken to determine the concentrations of organochlorine insecticide residues in selected vegetables (carrots, cabbage and green pepper) from three farming communities in Sunyani, in the Brong Ahafo Region of Ghana. Sixty eight farmers were interviewed on insecticide use practices. The field survey revealed the use of some banned insecticides and approximately 38.2% of the respondents mixed two or more insecticides without considering the health implications on humans, animals and the environment. A total of 120 pieces of all three vegetables were obtained from farmers' fields for analysis. Samples were subjected to extraction, clean-up and analysis by Gas Chromatograph Electronic Capture Detector for organochlorine insecticide residues.

Laboratory analysis confirmed the presence of organochlorine insecticide residues in some of the samples analyzed. Overall, percent insecticide residues in carrot, lettuce and cabbage samples were 38%, 28% and 34%, respectively, levels which were below the limits set by the EU, except for heptachlor and mirex which exceeded the limits in some cases. Therefore, vegetables from these farming communities are considered safe for consumption but there is the need for constant monitoring since there could be bioaccumulation of residues in the food chain when vegetables are consumed over a long period.

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DEDICATION

This work is dedicated to the Almighty God and to my loving father, James Baah.

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LIST OF ABBREVIATONS

ACAT	Acetyl-coenzyme A acetyltransferases
A-HCH	Alpha- Hexachlorocyclohexane
ANOVA	Analysis of Variance
ATSDR	Agency for Toxic Substances and Disease Registry in the United States
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane
EPA	Environmental Protection Agency
EU	European Union
FAO	Food and Agricultural Organization of the United Nations
FASDEP	Food and Agricultural Sector Development Policy
GAEC	Ghana Atomic Energy Commission
GC	Gas Chromatography
GDP	Gross Domestic Product
HCB	Hexachlorocyclobenzene
HCH	Hexachlorocyclohexane
ng/g	Nanogram per gram
mg/kg	Microgram per kilogram
MRL	Maximum Residual Limit
MSLC	Middle School Leaving Certificate
ND	Not Detected
ng	nanogram
nL	nanolitre
OCPs	Organochlorine Pesticides
PCBs	Polychlorinated Biphenols
PPRSD	Plant Protection and Regulatory Services Directorate
sq. km	Square Kilometer
SPSS	Statistical Package for the Social Sciences
USEPA	United States Environmental Protection Agency

WHO	World Health Organization

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CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND

Agricultural production is one of the largest and most important economic activities in the world, particularly in low and middle income countries such as Ghana, where agriculture has a significant impact on GDP growth (Aseno–Okyere *et al.*, 2008). A major factor in agriculture over the last decades is the use of pesticides that protect crops from insects and pests that may be harmful to crop quality and yields. The term "pesticide" describes a category of agrochemicals that are used to protect crops from certain bacteria, insects, and other potentially damaging organisms. Though pesticides have been instrumental in contributing to global agricultural growth, they are often harmful to more than just their target species. According to Longnecker *et al.*, (1997), organophosphates and organochlorine pesticides, for example, can cause damage to nervous systems by harming neurotransmitting enzymes and can be ingested by many different types of creatures. Unfortunately, many chemical pesticides, particularly those containing chlorinated compounds, are often persistent in the environment and can be toxic to humans. These kinds of pesticides are dangerous to many different forms of life, and their impacts can spread far beyond their production and application point to even a global scale. Chemical pesticides can harm agricultural workers who do not wear the proper safety gear and can also be dangerous for nearby communities. Common pathways for human exposure include inhalation when pesticides are applied (particularly when applied through spraying), ingestion of contaminated foods, ingestion of contaminated soil (particularly children, who may not wash hands before eating after playing in dirt), and contamination of surface or groundwater and subsequent ingestion.

Some organochlorine pesticides, including DDT, lindane, endosulfan, and chlordane, are so disruptive and dangerous that many countries have banned their use and have classified them as Highly Hazardous. Despite the risks associated with pesticide use, many forms of these chemicals are still widely used in low and middle income countries in a large variety of agricultural settings and have impacts far beyond the locations where they are sprayed.

Studies have found that over 98% of insecticides used in agricultural processes do not quickly degrade at the point of application and end up entering the larger environment, typically through rain and irrigation runoff, spray carry-over, or residue retention on food (Miller, 2004).

Many of the world's agricultural processes take place in rural and economically disadvantaged areas where regulations are lacking and health standards are not enforced. For these reasons, pesticides are often improperly used and stored, and workers are often not fully aware of, and protected from the dangers that pesticide exposure and contamination can cause. In addition, due to laxity of regulations, low cost, and the effectiveness of certain hazardous pesticides, sustained use of banned pesticides is an ongoing problem in many low-income rural areas (Wesseling *et al.*, 1997). Thus, agricultural workers and their families are more severely affected by dangerous pesticides /chemicals and contamination in these regions than in higherincome countries with tighter regulations. 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, Belgium and Switzerland (Gyau and Spiller, 2007). Unfortunately the yield of vegetables is affected by pests, which necessitates the use of insecticides to control pests. A wide range of pesticides are used for crop protection during cultivation of vegetables due to heavy pest infestation throughout the growing season. A consequence of their use may be the presence of pesticide residues in treated products, fruits, vegetables, grains and other commodities. Studies by Ntow *et al.*, (2006) showed that residues of organochlorine pesticides are present in environmental samples at Akomadan and in human fluids of its inhabitants. These 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.

1.2 PROBLEM STATEMENT

In vegetable and fruit production, insecticides are used to control pests and fungicides to control diseases. They are applied directly to the crops and some may still be present as residues in or on the vegetables and fruits after their harvests, especially where there is abuse, misuse and overuse of the pesticides (Gerkan *et al*., 2001). As a result, consumers of food crops are exposed to pesticides which raise some health concerns. Residues from fruits and vegetables pose a greater threat to public health because they are usually taken raw or partially cooked.

About 87% of farmers who grow vegetables in Ghana use pesticides (Dinham, 2003). Many of the 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. Many of the most widely used pesticides have been classified as Persistent Organic

Pollutants (POPs), meaning that they have long life-spans, do not biodegrade well, and have the ability to bio-accumulate in living tissue. When large amounts of pesticides build up in food sources, they contaminate the food chain of nearby communities.

1.3 JUSTIFICATION

In Ghana, there has been a rapid increase in the quantity of pesticides used in agriculture over the last ten years (Hodgson, 2003). Every pesticide has a withholding period, waiting period, lapse or pre-harvest interval (PHI), which is defined as the number of days required to lapse, between the date of final pesticide application and harvest, for residues to fall below the tolerance level established for that crop or for a similar food type. The PHI differs from pesticide to pesticide and crop to crop. Food products become safe for consumption only after the withholding period has lapsed. By this time, the pesticide residues get dissipated. However the extent and rate of dissipation depends on the nature of the pesticide, crop, cultural practices and various environmental conditions under which the crop is grown or a treated commodity is stored (Handa *et al.*, 1999). Due to lack of education, farmers of Ghana do not follow the prescribed dosages and use pesticides at any stage of the crop without any awareness of the residues and their ill effects on human health. The treated crops are harvested without taking into account the withholding period. Many of the developed countries have established regular monitoring programmes (Reed *et al.*, 1987). Unfortunately, no such regulations have been enforced in Ghana because of the non – availability of sufficient data on the pesticide residue status in agricultural products in the country. 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, immunitoxicity and disruption of the endocrine system (Bassil *et al.*, 2007).

In order to ensure that consumers are not exposed to unacceptable pesticide residue levels and also to preserve the environment, the amounts of residues found in food must be as low as possible. Pesticide residues in food crops can be reduced by following Good

Agricultural Practices (GAP). The maximum residue level (MRL) is the highest level (contamination) of a pesticide residue that is legally tolerated in or on food or feed. This work was therefore aimed at documenting the concentrations of pesticide residues that are likely to be left in some selected vegetables at the time of harvest and compare them with acceptable MRL values.

1.4 OBJECTIVE OF THE STUDY

1.4.1 Main Objective

To determine the concentrations of organochlorine insecticide residues in selected vegetables (carrots, cabbage and green pepper) from three farming communities in Sunyani, in the Brong Ahafo Region of Ghana.

1.4.2 Specific Objectives

The specific objectives of the study were to determine the:

1. Types of pesticides used by the farmers
2. Frequency and mode of application of such pesticides
3. Levels of the pesticide residues in the selected food crops at the time of harvest.

1.5 Hypothesis

1.5.1 Null Hypothesis (H_0)

There are no chemical residues found in vegetables grown and harvested in the three selected communities of the Sunyani West District of the Brong Ahafo Region of Ghana.

1.5.2 Alternative hypothesis (H_1)

There are chemical residues found in vegetables grown and harvested in the three selected communities of the Sunyani West District of the Brong Ahafo Region of

Ghana.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 DEFINITION OF PESTICIDES

The Food and Agriculture Organization (FAO) has defined a 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 or 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 (FAO, 2002).

According to Bateman (2010), the term pesticide can also be defined simply as any substance which is used to control a pest, at any stage in crop production, storage or transport.

From the above definitions, a pesticide can be described as a natural or man-made preparation that may be used to kill or control a pest population, control weeds or diseases in plants and animals including human beings.

They have been widely used throughout the world since the middle of the last century for their various benefits. Pesticides have been applied in agriculture and animal production to eliminate pests. In this way, pesticides are used to increase the output of both animals and crops, improve the quality of products, and decrease the incidence of illnesses propagated by insects (Bempah and Donkor, 2011).

2.2 PESTICIDES AND THE CONTROL OF INSECT PESTS

Pesticides are considered to be indispensable for the production of adequate food supply for an increasing human population and for the control of insect-borne diseases.

There has been a rapid increase in the quantity of pesticides used in Agriculture over the past ten years (Ejobi *et al*., 1996).

According to Gruzdyer *et al* (1983) about 70,000 species of insects and mites attack all parts of agricultural plants in their growth phase or in storage and about 10000 species of them cause substantial economic harm. Stilling (1985) reported that first records of insecticides were made as far back as the year 2500 BC. These were distinguished by their exceptionally broad spectrum of action and cheapness of manufacture (Gruzdyer *et al*., 1983). On the other hand, Miller (2002) reported that humans have utilized pesticides to protect their crops since 2000 BC.

In 1939, Paul Muller discovered that DDT was a very effective insecticide. It quickly became the most widely used pesticide in the world. In the 1940's, manufacturers began to produce large amounts of synthetic pesticides and their use became widespread. Some sources consider the 1940's and 1950's to be the beginning of pesticide era (Murphy, 2005).

Pesticide use has increased fifty fold, since then; 2.3 million tons of industrial pesticides are now being used each year (Miller, 2002). Seventy-five percent (75%) of all pesticides in the world are used in the developed countries but their use in the developing countries is increasing (Miller, 2004). Among farmers, the most widely used pesticide is the organochlorine insecticides because of their cost effectiveness and their broad spectrum activity (Bempah *et al.,* 2011). Organochlorine insecticide usage was widespread in the 1940s in agricultural and malaria control programmes. Sources of organochlorine residues are mostly anthropogenic. Their use has become almost completely discontinued because of their environmental effects. Examples of these commonly used were Heptachlor, aldrin, toxaphene, endosulfan, endrin, chlordane and DDT. One organochlorine compound that is still in use today is Lindane which is used in the medical product, Kwell, against human ectoparasitic infections. Some are still commonly used in developing countries (Williams *et al.*, 2000).

2.3 PESTICIDES AND RESIDUES

Pesticide residues in food items have been a concern to environmental and consumer groups. The gravity of the problem of residues is augmented by untimely, uneconomical and unscrupulous spraying of insecticides. These residues make food commodities hazardous for human consumption and export. They also pollute the environment (FAO, 1989). In Ghana, fruit and vegetable production are on the increase to meet the balanced diet requirements of humans, and for better health. Accordingly, everybody is encouraged to consume more fruits and vegetables as they are essential sources of vitamins, fibre, etc. Research has shown that diets with greater proportions of fruits and vegetables can prevent or delay a number of debilitating and life-threatening diseases. Pesticide residues above the tolerance limits (MRL) in the crop at harvest are a cause of great concern globally and nationally. Currently, organophosphates (OP), carbamates and pyrethroids are mostly used while organochlorine (OC) insecticides have been banned because of their toxicity, persistence and bioaccumulation in the environment (Molto *et al.*, 1991). Carbamates and pyrethroids are of limited persistence as compared to organophosphates. However, knowledge of withholding period becomes important even for less persistent

insecticides, specifically in fruits and vegetables since these crops are harvested shortly after pesticide application (Reed *et al.*, 1987).

2.4 FATE OF PESTICIDES IN THE ENVIRONMENT

The natural processes that govern the fate and transport of agrochemicals especially pesticides in the environment can be grouped into the broad categories of runoff, leaching, sorption, volatilization, degradation and plant uptake. Once a pesticide is applied to soil, a number of things may happen. It may be taken up by plants or ingested by animals, worms, or microorganisms in the soil. It may move downward in the soil and either adhere to particles or dissolve. The pesticide may vaporize and enter the atmosphere, degrade via solar energy or break down via microbial and chemical pathways into other less toxic compounds. Insecticides may leach out of the root zone or wash off the surface of land by rain or irrigation water, eventually ending in the sediments through the water column. The fate of pesticides applied to soil depends largely on two of its properties; persistence and sorption. Two other pathways of pesticide loss are removal in the harvested plant and volatilization into the atmosphere, which subsequently impact water, sediment, soil, and air quality negatively and creating problems for agricultural workers who could be pesticide intoxicated via inhalation at the treated areas (Fianko *et al.,* 2011).

The physical and chemical properties of organochlorine compounds not only made them effective insecticides but also resulted in their persistence and bioaccumulation in the food chains leading to the discontinuance of their use. Organochlorine insecticides act on the nervous system to produce adverse effects. This class of chemicals is thought to act by the interference with cation exchange across the nerve cell membranes resulting in hyperactivity of the nerves (Williams *et al.*, 2000).

2.5 PERSISTENT ORGANIC POLLUTANTS (POPs)

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 shown that these potent agrochemicals are used in vegetable production (Ntow, *et al.*, 2008). 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.

2.7 ORGANOCHLORINE COMPOUNDS

An organochlorine insecticide is a kind of synthetic chemical which can be divided into two groups: one uses benzene as the raw material and the other uses the cyclopentadiene. They are both very stable, therefore their persistence and bioaccumulation is very strong (Rathore, 2012). These pesticides, characterized by their cyclic structure; number of chlorine atoms and low volatility, can be divided into four groups (Anderson *et al.*, 2000). These four groups are:

1. Dichlorodiphenyle (such as DDT)
2. Cyclodienes (Such as dieldrin, endosulfan and heptachlor)
3. Chlorinated benzenes (Such as hexachlorobenzene) and
4. Cyclohexanes (Such as lindane)

Although these chemicals were widely used until the mid - 1970’s, most of them are now banned from use in the developed countries. They are, however, still being produced in other countries. Furthermore, one of these insecticides, endosulfan is still in widespread use throughout the world despite its known adverse effects on humans as an endocrine disrupting compound (Andersen *et al*., 2000).

2.7.1 Hexachlorocyclohexane (HCH)

Hexachlorocyclohexane (HCH) is a manufactured chemical that exists in eight chemical forms called isomers. One of these forms, gamma-HCH (or γ-HCH, commonly called lindane) is produced and used as an insecticide against fruit, vegetable and forest crop insect pests. It is a white solid that may evaporate into the air as a colourless vapour with a slightly musty odour. It is also available as a prescription (lotion, cream, or shampoo) to treat head and body lice, and scabies. Lindane has not been produced in the United States since 1976, but is imported for use against insects. Technical-grade HCH was used as an insecticide in the United States and typically contained 10-15% gamma-HCH as well as the alpha (α), beta (β), delta (δ), and epsilon

(ε) forms of HCH. Virtually all the insecticidal properties resided in gamma-HCH. In mammals, metabolism of alpha- HCH generally leads to less chlorinated unsaturated metabolites (Roberts *et al.*, 1999).

2.7.2 Heptachlor

Heptachlor is an organochlorine cyclodiene that has been used to control termites, ants and household insects. It is also applied as seed treatment, soil treatment or on direct foliage. Metabolic processes by which it undergoes transformation are epoxidation, hydrolysis and dechlorination. It is not readily dehydrochlorinated but it is most susceptible to epoxidation. It is hydrolysed in water to 1-hydroxychlordene. It is transformed into a variety of products which differ from one another only in steroeochemical features while retaining the carbon skeleton (Roberts *et. al.*, 1999). Heptachlor oxidizes by both photochemical and biological processes to heptachlor epoxide which is extremely persistent in the soil. Plants can draw heptachlor epoxide directly from the soil and the chemical bioaccumulates in humans (Rathore and Nollet, 2012). Heptachlor is shown to cause cancer in laboratory animals investigated and may increase the risk of cancer in humans who are exposed to it for long periods (Udeh, 2004).

2.7.3 Chlordane

Chlordane is a viscous, colourless, or amber-coloured liquid with a chlorine-like odour. It is a mixture of steroeisomers and other chlorinated analogs including heptachlor. It is insoluble in water but miscible with aliphatic and aromatic hydrocarbon solvents including deodorized kerosene. It loses its chlorine content in the presence of alkaline reagents (Udeh, 2004). It's an insecticide used to control termites, ants and other insects. It enters the environment primarily by its application as an insecticide and is not very mobile in soils. Though chlordane adheres to the soil, its presence in ground water indicates its tendency to leach into the groundwater (Udeh, 2004). Rathore and Nollet (2012) indicated that chlordane has been found to be in soils after twenty (20) years of its initial application.

2.7.4 Dichlorodiphenyltrichloroethane (DDT)

DDT is a commercial organochlorine insecticide that has been used in the control of pests of agricultural crops as well as disease vector control. Technical grade DDT is a mixture of fourteen (14) compounds (Rathore and Nollet, 2012). The active ingredient is p,p-DDT (65% to 80%). The other compounds include o,p- DDT, up to 4% of p,pDDD and other substances. DDT compounds can be degraded to DDD under anaerobic conditions while it can be degraded to Dichlorodiphenyldichloroethylene (DDE). These degradation products are more persistent than the parent compound and are bioaccumulative, transported over long ranges and have adverse effects on humans, animals and the environment. In areas where DDT exposure is recent, the DDE/DDT ratio is low whereas in areas where substantial time has passed since its use, DDE/DDT ratio is higher (Rathore and Nollet, 2012).

2.7.5 Dieldrin and Aldrin

Dieldrin and Aldrin are closely related organochlorine insecticides which are extremely persistent in the environment. They have both been used in agriculture and dieldrin for vector control, veterinary purpose and termite control. In both plants and animals, aldrin once present in soil or water is transformed to dieldrin. Dieldrin breaks down very slowly and does not easily evaporate into air, but binds to soil particles (Udeh, 2004). Plants take up aldrin and dieldrin residues directly from the soil. In animals, including humans, it is stored up in the fat and leaves the body very slowly. Because of the low water solubility and tendency to bind up to the soil, both aldrin and dieldrin migrate downward very slowly through the soil or into the surface water or ground water (Rathore and Nollet, 2012).

2.7.6 Endrin

Endrin is an odourless, white crystal. It is slightly soluble in alcohol and insoluble in water. It is an insecticide used on field crops such as maize, cotton, sugar cane, rice, cereals and ornamentals. Endrin has also been used to control grasshoppers on non-crop lands and to control voles and mice in orchids (Udeh, 2004).

When endrin is released into soils, it can persist for up to 14 years or more (Fianco *et al*., 2011). It is persistent in treated soils and accumulates in sediments and terrestrial biota but known to be broken down by sunlight. It has been shown to cause damage to liver, kidney and heart of laboratory animals (Fianco *et al*., 2011). It has a high potential to accumulate in fish and shell fish. In humans, endrin was linked with headache, dizziness, sweating, insomnia, nausea and general malaise (Udeh, 2004).

2.8 HEALTH EFFECTS OF INSECTICIDES ON HUMANS

The presence of environmental chemicals in the human body does not necessarily imply that they are causing adverse health effects. However, environmental chemical exposures can and do affect human health. It is important to note that both the dosage and the timing of exposure have significant effect on any potential health outcome. The health effects of organochlorine pesticide exposure depend on the specific pesticide, the level of exposure, the timing of exposure and the individual. Different insecticides result in a range of health symptoms (ACAT and Commonweal, 2012).

Kannan *et al.,* (1997) reported that studies revealed the association between breast cancer and other neo-plastic diseases in humans and long - term exposure to organochlorines. The report also indicated that organochlorines are endocrine disrupters. Epidemiological studies suggested an etiological relationship between exposure to organochlorines and Parkinson's disease (Udeh, 2004). Studies indicate a decrease in sperm counts have been associated with exposure to organochlorine insecticides (Kannan *et al.*, 1997).

2.9 ENVIRONMENTAL EFFECTS OF PESTICIDES

Pesticides have become widespread pollutants in the environment and now represent a global contamination problem. Pesticide use raises a number of environmental concerns. Over 98% of sprayed insecticides and 95% of herbicides reach a destination other than their target species, including non-target species, air, water and soil (Miller 2004). Pesticide drift occurs when pesticides suspended in the air as particles are carried by wind to other areas, potentially contaminating them. Pesticides are one of the causes of water pollution, and some pesticides are persistent organic pollutants and contribute to soil contamination. Pests can develop a resistance to the pesticide, necessitating a new pesticide. Alternatively, a greater dose of the pesticide can be used to counteract the resistance, although this will cause a worsening of the ambient pollution problem.

2.10 METABOLISM OF PESTICIDES IN PLANTS

Pesticides penetrate into growing plants through the cuticle and stomata of the leaves. The penetration of pesticides through the cuticle is usually determined by the chemical structure of the active ingredient and surface tension of the carrier (Fletchern and Kirkwood, 1982).

The metabolism of pesticides by plants is a key factor in the susceptibility and tolerance of a species to a given pesticide, whereas metabolism by Prokaryotes is often a key determinant in the environmental fate of that pesticide (Hudson and Roberts, 1981). After application, pesticides are degraded by chemical and physical processes in the environment such as sunlight, soil and water (abiotic degradation) or metabolized within living organisms. Breakdown of a pesticide in the environment can be thought of as following a decay curve. This is a function of the chemicals' half-life, which is the time (usually in days) required for half of the applied pesticide to become converted into degradation products which may in turn be biologically active and have substantial half-lives (Bateman, 2009).

The rate of break-down depends on many factors, not least the chemical stability of the pesticide in question, but factors such as temperature and pH are extremely important, so the half-life may be expressed as a range. The most important mode of pesticide degradation is oxidation by activated oxygen (ozone and hydroxyl radicals generated by sunlight, hydrogen peroxide generated in plants) rather than oxygen in the atmosphere (Bateman, 2009). Allowing sufficient time to elapse between application and harvest enables any residue to degrade to acceptable levels (i.e the MRL) and the Pre- Harvest Interval (PHI) has a built-in safety factor. Reducing the dosage reduces the time to which acceptable levels are reached, but pest control may be impaired. Excessive residues occur with short harvest intervals, overdosing, or worst of all both of these (Bateman, 2009).

2.11 SAFETY AND RESIDUES

Pesticide residues is a matter of great concern since members of the general public perceive a risk but feel it is a matter over which they have little control (Bateman, 2009). In response, authorities attempt to regulate by setting standards and monitoring exposure (Hamilton and Crossly, 2004). This is achieved by legislation and enforcement of the legislation. Two important measures are especially prominent in legislation which includes; Acceptable Daily Intake (ADI) and, measures and limits of actual residues based on field studies which includes maximum residue levels (MRLs). It is a practical specification for food producers for a given crop. Testing for residues is carried out following internationally agreed and validated methods and good laboratory practice (GLP) standards applied in some countries (Bateman, 2009).

2.12 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 USEPA 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) (Bateman, 2009).

2.12.1 Maximum Residue Level (MRL)

Maximum residue level (MRL) is the maximum concentration of pesticide residue likely to occur in or on a specific food commodity after the pesticide has been used under Good Agricultural Practice (GAP). MRLs are not necessarily safety limits, but primarily a check that GAP is being followed and are intended to assist international trade in produce, treated with pesticides (GRO- Cocoa, 2006). Limit of Detection (LOD) is the lowest concentration of a pesticide residue that can be measured by routine analysis. Continuing progress in analytical methods means residues can be detected at even smaller concentrations.

Pesticide residues on crops are monitored with reference to minimum residue limits and are based on analysis of quantity of a given Active ingredient remaining on food product samples (GRO- Cocoa, 2006). The minimum residue limit for a given crop or active ingredient is usually determined by measurement, during a number (in order of 10) of field trials, where the crop has been treated according to Good Agricultural Practice and appropriate Pre-harvest interval has elapsed (Bateman, 2009).

2.12.2 Acceptable Daily Intake (ADI)

This is the amount of an active ingredient (Active) that can be consumed daily over a life-time without harm, expressed in mg/Kg body weight of the consumer and based on toxicological evaluations (GRO-Cocoa, 2006).

2.12.3 Acute Reference Dose (ARfD)

This refers to an estimate of amount of an active ingredient, expressed in mg/Kg body weight of the consumer that can be ingested over a short period of time (1 meal or 1 day) without appreciable health risk (GRO-Cocoa, 2006).

A pesticide can only be approved for use if the risk to consumers, based on potential exposure, is acceptable. The limit set for a pesticidal active ingredient (AI), the ADI, is an estimate of the amount that can be consumed daily, for a lifetime, without harm to the person. The term acceptable is considered to involve a 100 fold safety factor from a measure called the No Observed Effect Level (NOEL) obtained in laboratory studies, which is 10 times lower than the Lowest Observable Effect Level (LOEL) (Bateman, 2009)

2.13 DETERMINATION OF PESTICIDE RESIDUES IN CROPS

Methods for determination of pesticide levels in/on crops and various types of foodstuffs consist of three steps. First, the pesticide is extracted from the food with an organic solvent; second, a clean – up is applied to the extract in order to remove coextractive material which may interfere with the analysis, and finally, the quantity of pesticide is determined by different methods such as thin layer chromatography (TLC), gas chromatography (GC), high performance liquid chromatography (HPLC), supercritical fluid chromatography, spectrophotometry, immunoassay and capillary electrophoresis.

Extraction of pesticide residues with different solvents, cleanup, concentration and their detection and quantification by different analytical techniques are the major steps involved in pesticide residue analysis. The method of extraction and the type of solvent or solvent combination depend on the chemical and physical properties of the pesticide to be extracted, the type of substrate from which it will be quantitatively removed and the final method of analysis.

Different solvents such as n-heaxane, petroleum ether, methylene chloride and acetone or ethyl acetate have been used for extraction of pesticide residues from fruits and vegetables (Balint and Gyorfi, 1978). As more polar pesticides such as organophospates, phenoxyacetic acid and triazine came into use, more polar solvents such as chloroform, acetone, acetonitrile and methanol were found to be good extractants (*Luke et al.*, 1981; Lawrence, 1987; Lee *et al.,* 1990). Many workers used acetonitrile for the extraction of multiresidue of pesticides from fruits instead of methylene chloride, which is hazardous to the environment (Krause and August, 1983; Cook *et al*., 1999). Fermandez-Alba *et al.*, (2000), found that ethyl acetate proved to be a good solvent as compared to other solvents for the extraction of residues of several pesticides from fruits and vegetables because its polarity is high, and it is less volatile and thermally labile.

2.14 PESTICIDE AND OTHER RESIDUE LEVELS IN FRUITS, VEGETABLES AND HUMAN FLUID SAMPLES

Residues of pesticides have been reported in milk, vegetables, fruits, meat, fish meal and other foods in Ghana. Between 1999-2000, Fianko *et al.,* (2011) found disturbing levels of pesticide, heavy metals, microorganisms and mycotoxins contamination in street-vended food samples in Accra. Vegetables on the Ghanaian market such as lettuce, cabbage, tomato and onion, were found to contain detectable levels of lindane, endosulfan and DDT residues (Ntow 1998; Ntow 2001). The possible reason for pesticides to reach these vegetables in the environments where they were sown is through direct runoff, leaching, careless disposal of empty containers, equipment washing, etc. Nonetheless, many other studies conducted so far have revealed the presence of detectable levels of pesticides especially organochlorines in fruits, vegetables, fish and fish products (Botchway, 2000; Yeboah *et al.,* 2004; Essumang *et al.*, 2009). The studies pointed out that majority of the samples contaminated by chlorinated pesticides exceeded the maximum residue limits which could cause pesticide hazard to the consumer (Fianko *et al.*, 2011). This agrees with studies conducted by Okorley and Kwarteng (2002) and confirmed by Johnson (2002) who reported evidence of chloropyrifos in 'Rice and Beans' meal popularly known as

'waakye'.

Studies conducted by Bempah *et al* (2011) on fruits and vegetables from the Kumasi Metropolis of Ghana revealed that consumers in the metropolis are exposed to concentrations of pesticides that may cause chronic diseases. An average concentration of 0.05mg/kg of Gamma – HCH residues was attributed to the extensive use of lindane in the form of Gammalin 20 used by farmers in agriculture for crop protection, suggesting that lindane is extensively used in fruit and vegetable production. The study also revealed that aldrin is converted to dieldrin by epoxidation in biological systems.

Fianko e*t al* (2011) reviewed studies undertaken by Glover-Amengor and Tetteh, (2008) and Nuertey *et al* (2007) on the effect of excessive use of pesticides on biomass and microorganisms in oil palm and vegetable agro-ecosystems in his paper. The findings indicated that the pesticides inhibit bacterial population resulting in inhibited nitrification and deprivation of other soil microorganisms of both organic and inorganic constituents in the soil, hence decreasing the soil fertility.

Several researchers have studied the occurrence of pesticide residues in crops. In the annual report of Pesticide Residue 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% contained no residues tested for; 45% of samples contained residues below the MRL; and 1.2% of them contained residues above the MRL.

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 pyrethroids and carbamates, was done by adopting a multi-residue analytical technique employing Gas Chromatography –Electron Capture Detector and Gas Chromatography –Nitrogen Phosphorus Detector 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 (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 Dieldrin in samples of human breastmilk and serum collected from vegetable farmers in Ghana in the year 2005. The levels of the pesticides in the milk samples were found to correlate positively with the age of the milk sample donors (Ntow, 2008).

In an earlier study (Ntow, 2001) organochlorine pesticide levels in a farming community in Ghana was evaluated. 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 sulphate 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 (mean 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.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 STUDY AREA

The majority of pesticides used in Agriculture in Ghana are employed in the forest zones located in the Ashanti, Brong Ahafo, Western, and Eastern Regions of Ghana. Sunyani West District of the Brong Ahafo Region of Ghana was chosen as a study area because it is a region noted for food production where crops are produced both for local consumption and for export. The District lies between latitude 7º 19´N and 7º 35´N and longitudes 2º 08´ W and 2º 31´ W. It has a total land area of 1,658.7 square kilometres. The climatic zone of Sunyani West District falls within the Wet Semi-Equatorial region and therefore has two rainy seasons in a year. Average annual rainfall is 170cm. The abundance of rainfall offers the District a comparative advantage in agricultural production and forestry (www.mofa.gov.gh., assessed 28-04-2015)

Sunyani West falls within the moist-semi deciduous forest vegetation zones of Ghana. The district is underlined by the Precambrian formation of rock believed to be rich in mineral deposits. Soils in the district fall into the Ochrosols group which is generally fertile and therefore supports the cultivation of agricultural produce. The topography of the District is generally undulating and has heights ranging from 700 feet (213.36 meters) along River Bisi basin to 1100 feet (335.28 meters) above sea level. The drainage is dendritic with several streams and rivers being seasonal. Below (Fig. 1) is a map showing the Sunyani West in the District context.

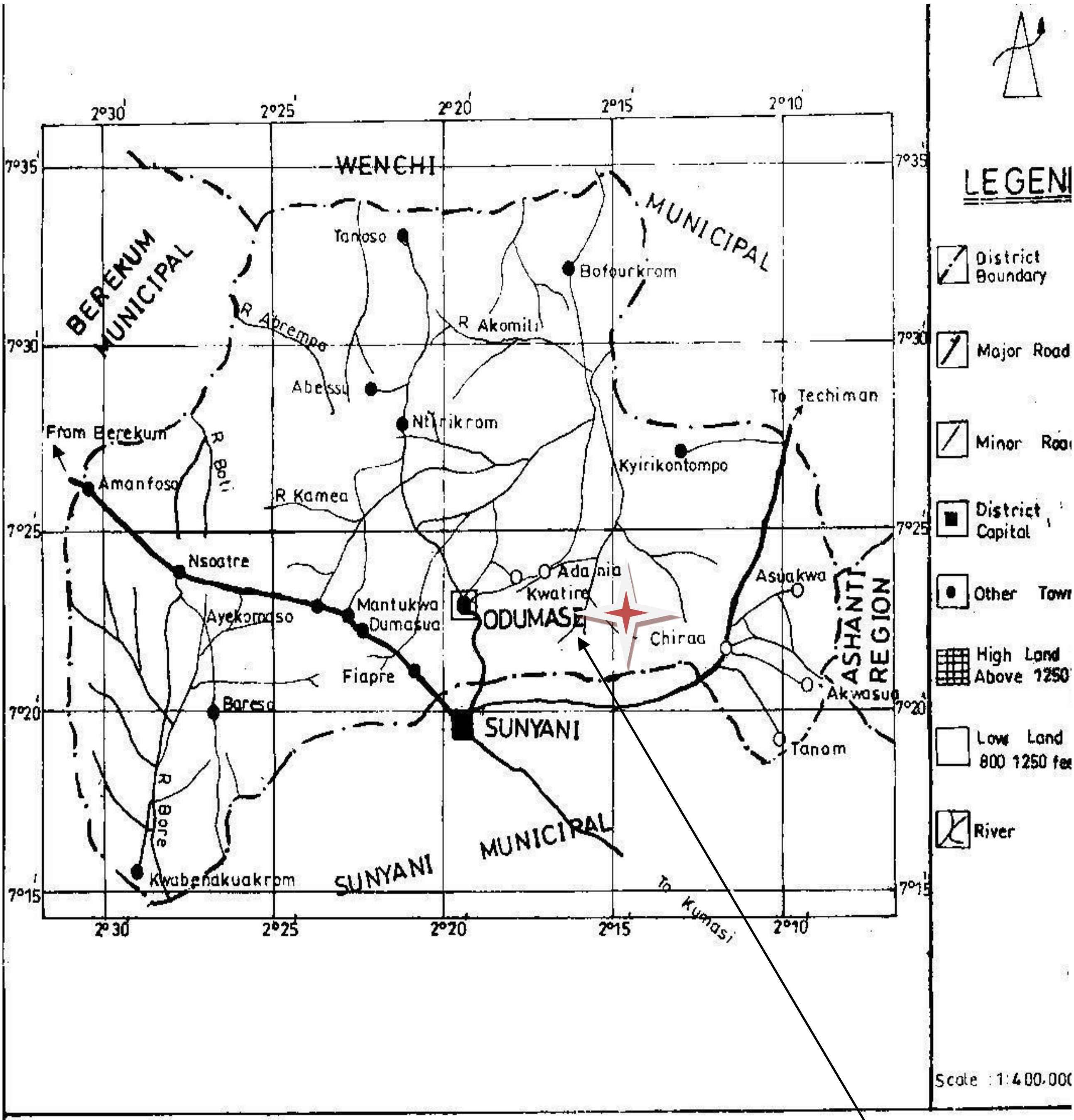

Fig. 1: Map of Sunyani West District

Source: www.mofa.gov.gh (2015)

3.2 STUDY SUBJECTS

A survey was conducted in three communities within the District, regarding the use of pesticides by local farmers. Depending on the locality, types of vegetables grown and pesticide use history, the three communities within the district were selected for questionnaire administration. These Communities were Kwatire, Adantia and Odumase. A total of sixty eight farmers were randomly selected from these communities and were interviewed using a well-structured questionnaire with closed and open ended questions (Appendix 1). This was done to ascertain the types of pesticides most frequently used; the mode of application of such pesticides, their level of knowledge on the use of the pesticide and the frequency of application of the identified pesticides by the farmers on their farms. The questionnaire was pre–tested before being administered. Data were grouped under personal information and work history; and pesticide - use practices and management. The questionnaire was administered at farmers' homes, farms and farmers' association meetings. In all cases, the farmers were notified of the interview through their group leaders or fellow farmers. The study objectives were explained to the selected farmers and their consent to participate in the study was sought. The questions were translated into local and easily understandable languages during the questionnaire administration. Data from the survey were statistically analyzed using the Statistical Package for the Social Scientist (SPSS version 17). The results were presented in charts and tables with the values in percentages.

3.3 SAMPLE COLLECTION

Fresh carrots, cabbages and green pepper were bought from farmers fields in the three farming communities (Odumase, Adantia and Kwatire) during the months of January to April, 2014. These vegetables were bought directly from the farmers during harvest, from each farmer's field in each site. Codex Alimentarius (FAO/WHO, 1984) protocols for sampling and for the portions of commodities to be analysed were followed in the survey. Samples were immediately wrapped in aluminium foil that had already been cleaned with acetone, to prevent contamination. They were then placed in zip-lock bags and appropriately labelled with a unique sampling identity. The labelled samples were then placed in ice chest containing ice and transported to the laboratory. They were then kept in a freezer at a temperature of about -20 ºC prior to analysis. A total of 120 pieces of all three vegetables were obtained from the farmers' fields and subsampled into 30 samples for analysis.

Table 1: Sampling sites of vegetables

Vegetable	Site / Location	Number of Samples
Daucus carota (carrot)	Odumase	3
	Adantia	3
	Kwatire	3
Capsicum annum (green pepper)	Odumase	4
	Kwatire	4
	Adantia	4
Brassica oleracea var capitata (cabbage)	Adantia	3
	Kwatire	3
	Odumase	3
Total number of samples		30

3.4 LABORATORY ANALYSIS

Laboratory analysis was carried out at the Nuclear Chemistry and Environmental Research Laboratory of the Ghana Atomic Energy Commission (GAEC), Kwabenya, Accra.

3.4.1Cleaning of Glassware

Prior to the analysis, glass wares for analysis were cleaned with 'Omo' detergent and rinsed with tap water. They were further rinsed with acetone and dried overnight in an oven at 150^{o}C and stored in dust free cabinets until required.

3.4.2 Reagents

Analytical grade acetone, n-hexane (HPLC grade), sodium sulphate, pesticide grade ethyl acetate, activated charcoal, florisil (mesh size of 60-100 mesh) and sodium hydrogencarbonate were bought from a local chemical shop (Fregeosco Co. Ltd) in Accra who also obtained their supplies from CDH group in India and Germany.

3.4.3 Extraction

In the present study, the method used for the extraction and clean-up procedures was the EPA-method 3540C (US EPA, 1994). Each vegetable sample was chopped with a clean sharp knife on a clean (as described in sec. 3.4.1) chopping board. This was then blended in a Salton elite glass blender to obtain a homogenous representative sample. The knife, chopping board and blender were washed thoroughly with 'Omo' detergent and rinsed under running water to avoid cross contamination. A total of 30 composite samples from the three communities were analyzed. 20g of blended sample was weighed into an extraction jar, 20g of anhydrous sodium sulphate (Na_2SO_4) was added to reduce moisture content of the sample and 5g of sodium hydrogen carbonate ($NaHCO_3$) was added to neutralise the acid in the sample. Furthermore, 40 ml of ethyl acetate ($CH_3COOCH_2CH_3$) was added to the sample using a measuring cylinder. The mixture was sealed and sonicated for 20 minutes and the supernatant (extract) was decanted into a round bottomed flask using a funnel lined with filter paper and activated charcoal. Sonicating and decanting were repeated three times to ensure that enough extract was obtained. The extract was evaporated in a Büchi RE-200 rotary vacuum evaporator at 40 ^{0}C, to evaporate solvents into round bottomed flasks (Plates 1 and 2).

Plate 1: Sonication of Analytes

Plate 2: Evaporation of analytes with the Rotary Vacuum Evaporator

3.4.4 Clean-up

In order to remove any interfering substances co-extracted with the insecticide residues, the analyte was cleaned up as follows; 1.5 g of activated florisil was packed into a column that had been plugged with glass wool; the column was further packed with 0.5g and 1.0 g of activated charcoal and sodium sulphate (Na_2SO_4) respectively; 10ml of ethyl acetate was used to condition the column prior to the clean- up; analyte was transferred onto the florisil column using a Pasteur pipette and allowed to elute (plate 3); the sample was evaporated to dryness using the Büchi RE-200 rotary vacuum evaporator; the dried residue for each sample was dissolved in 2 ml of ethyl acetate and this was repeated twice to obtain all the extract from the tube. Glass Pasteur pipette was then used to pick samples into 1.5 ml GC valves for analysis by Gas Chromatography (GC).

Plate 3: Cleanup of analytes

3.4.5 Quantification

The determination of the quantities of residues in the sample extracts was done by running a standard mixture of known concentration of insecticide and the response of the detector for each compound was ascertained. The area of the corresponding peak in the sample was compared with that of the standard. All analyses were carried out in triplicate and the mean concentrations computed accordingly.

3.4.6 Gas Chromatographic Analysis of Chlorinated Residues

The residues were analyzed by Shimadzu gas chromatograph, GC-2010 (Shimadzu cooperations, Japan), equipped with 63 Ni, electron capture detector that allows the detection of contaminants even at trace level concentrations. The GC conditions and the detector response were adjusted to match the relative retention time and response. The conditions for analysis were capillary column coated with ZB-5(30m x 0.25 mm, 0.25 μm film thickness). Carrier gas and make-up gas was nitrogen at a flow rate of 1.0 and 29.0 ml/min respectively. The temperature of injector and detector were set at 280^{o} C and 300^{o} C respectively. The oven temperature was programmed to 600^{0}C for 2 minutes and at 1800 ^{o}C/min up to 3000 ^{o}C. The injection volume of the GC was 1.0 nL. The residues detected by the GC analysis were further confirmed by the analysis of the extract on two other columns of different polarities. The first column was coated with ZB-1 (methyl polysiloxane) connected to ECD and the second column was coated with ZB-17 (50% phenyl, methyl polysiloxane) and connected ECD as a detector. The conditions used for these columns were the same.

3.4.7 Quality Control Measures

The efficiency of the method was determined by recoveries of an internal standard. One sample was spiked with a 50μL of 100.0 ng/ml internal standard (isodrin) and extracted under the same conditions as the analytes. To check for interferences, a blank sample containing no detectable compounds was analysed.

3.4.8 Statistical Analysis

Analysis of variance (ANOVA) was used to determine the significance of the differences in the means of the experimental data of organochlorine insecticide residues from the different locations. The analyses were executed by S. P. S. S. (version 17 for windows, 2007). Responses to the questionnaire were analysed using Microsoft Excel and a 90% statistical significance of differences was used.

CHAPTER FOUR

4.0 RESULTS

4.1 FIELD SURVEY

4.1.1 Age group of Respondents

Figure 2 indicates that 53% of the respondents were between the ages of 31-40 years, 23% were between 41- 50 years, 17% were between 21 to 30 years and 7% were 51 to 60 years of age. This implies that all the respondents (farmers) were within the labour force age, that is, 18 to 60 years.

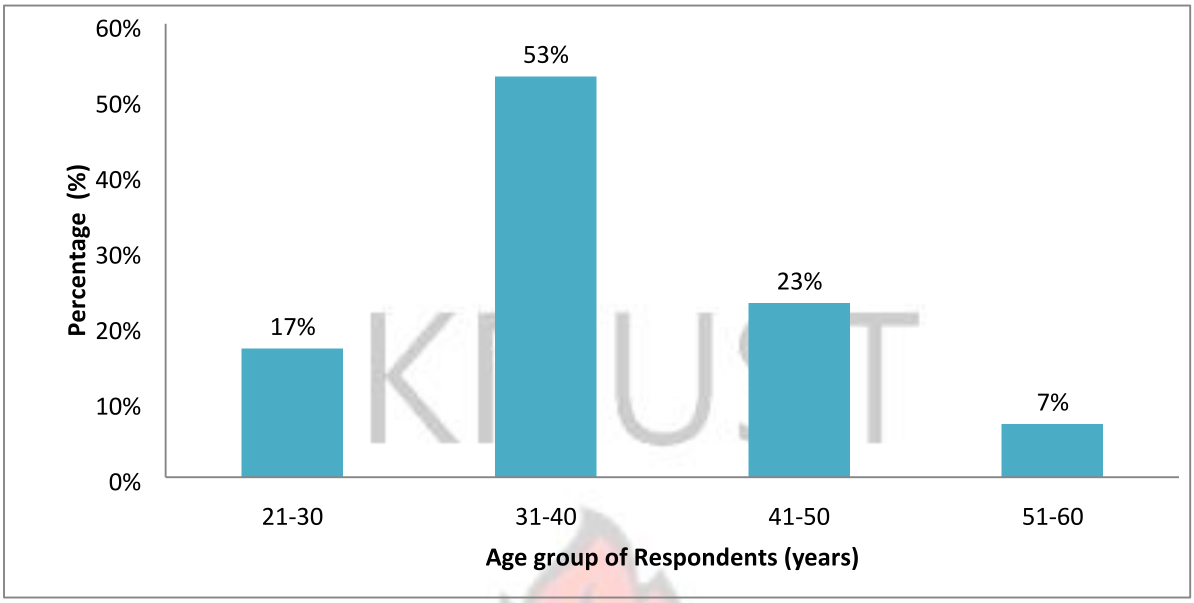

Fig. 2: Age group of Respondents

4.1.2Gender of Respondents

Of the total number of respondents, 60% were males whereas 40% of were females (Fig. 3).

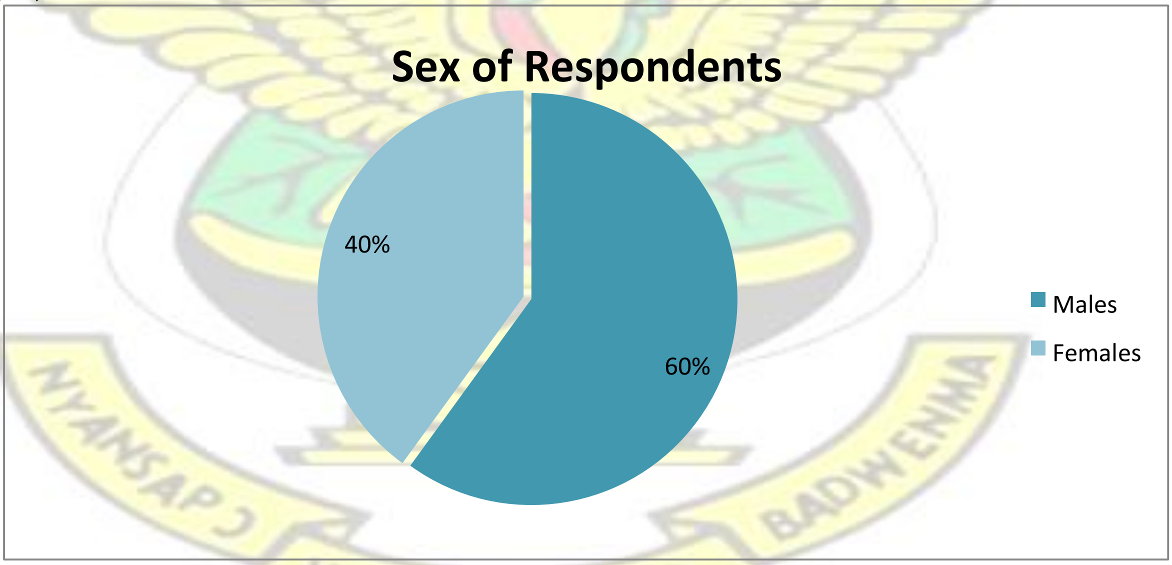

Fig. 3: Gender of Respondents.

4.1.3 Educational Level of Respondents

The educational level of the farmers interviewed is presented in Figure 4. Thirty nine

(39) of the respondents (57.4%) have had basic education, twelve (12) respondents (17.6%) have had secondary education and the remaining twelve (17.6%) and no formal education, Two farmers (2.9%) have had post secondary education, and three (3) farmers representing 4.4% have the Middle School Leaving Certificate (MSLC), now junior high school (JHS).

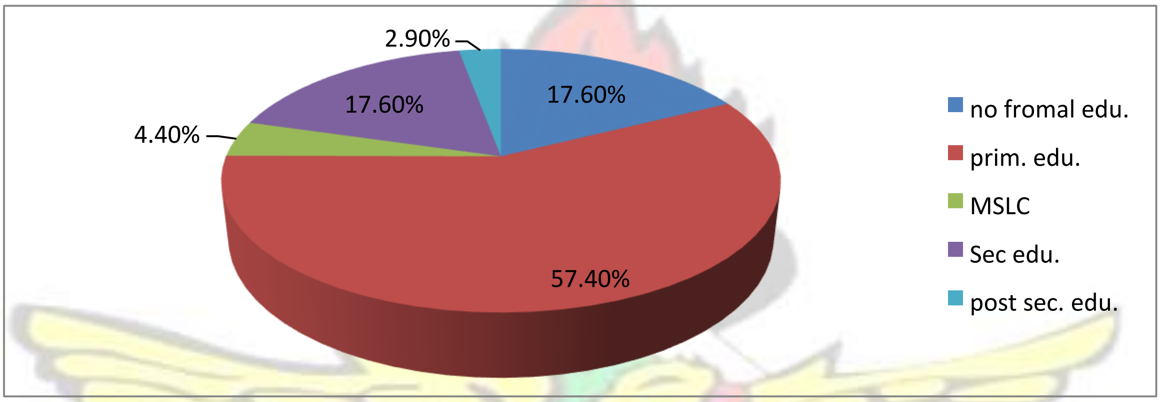

Fig. 4: Educational level of Respondents

4.1.4Insecticides Used by Farmers

Table 2: Types of Insecticides used by Farmers

Trade Name	Active ingredient
1. Karate 5 EC	**Lambda Cyhalothrin**
2. Kombat 2.5 EC	**Lambda Cyhalothrin**
3. K- optimal	**Lambda +acetamipride**
4. Attack	**Emamectin benzoate**
5. Dursban	**Chlopyriphos**
6. PAWA 2.3 EC	**Lambda Cyhalothrin**
7. Confidor 200 sl	**Imidacloprid**
8. Thiodan	**Endosulfan**
9. Carbofuran	**Furaden**
10. Golan S L	**Actemiprid**
11. Poison	
12. Terminix	**Chloropyrifos – ethyl**
13. Multifos 40 EC	**Chlorpyrifos**

14. Polythrine	**Cypermethrin+profenetos**
15. Cymethoate	**Cymethoate**
16. Lambda Super 2.5 EC	**Lambda Cyhalothrin**
17. Conti-halithrin 2.5 EC	**Lambda Cyhalothrin**
18. Bypel 1 (PrG V. Bt)	
19. Sunpyrifos	**Chloropyrifos-ethyl**
20. Warrior	
21. Actellic	**Pyrimiplus methyl**

Table 2 shows the various types of insecticides used by farmers to control insect pest in the production of carrots, green pepper and cabbage in the communities. A total of 21 types of insecticides were used by the farmers. The insecticides were identified by their trade names and their active ingredients.

4.1.5 Combination of Two or More Insecticides

Figure 5 shows that twenty six (26) farmers interviewed (38.2%) mixed two or three insecticides together for controlling insect pests on their farms. The remaining forty two (42) respondents (61.8%) used single insecticides for the control of insect pests. Farmers who do mix two or three pesticides, however, combine the chemicals without considering their effectiveness.

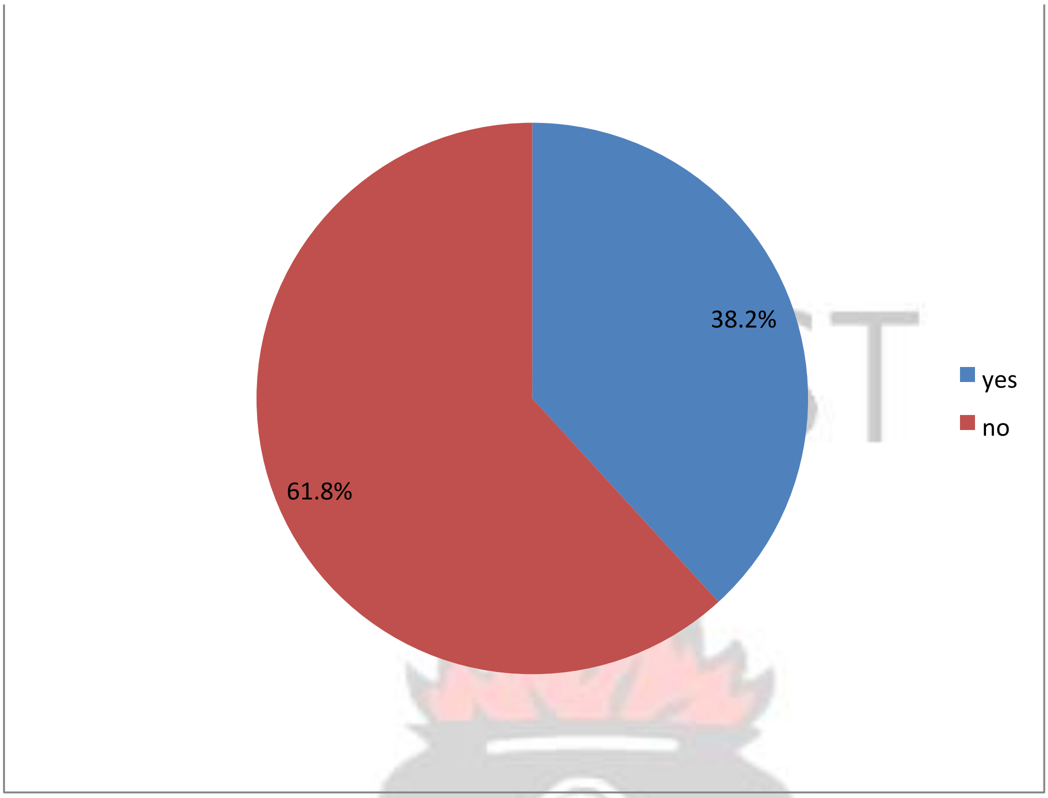

Fig. 5: Combination of two or more insecticides

4.1.6 Frequency of Insecticide Application in a Growing Season

Figure 6 depicts that 40% of the farmers applied chemicals three times in a growing season, 30% applied insecticides twice in a growing season, 20% applied once and 10% applied chemicals more than three times in a growing season.

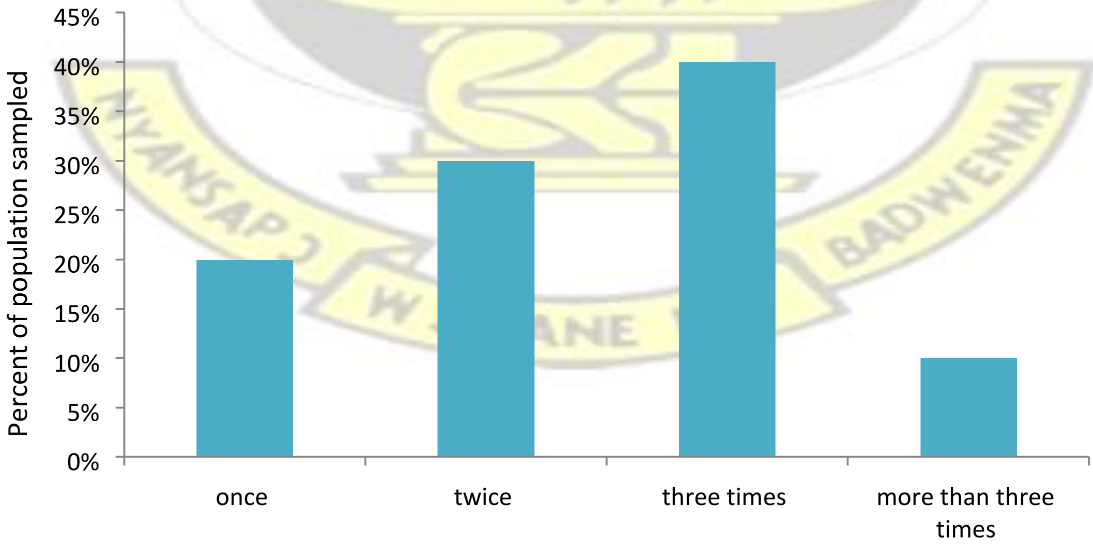

Fig. 6: Frequency of Insecticide Application in a Growing Season

4.1.7 How Farmers Applied Insecticides

Majority of the farmers (93%) applied insecticides by spraying whereas 7% of the farmers applied insecticides by dipping.

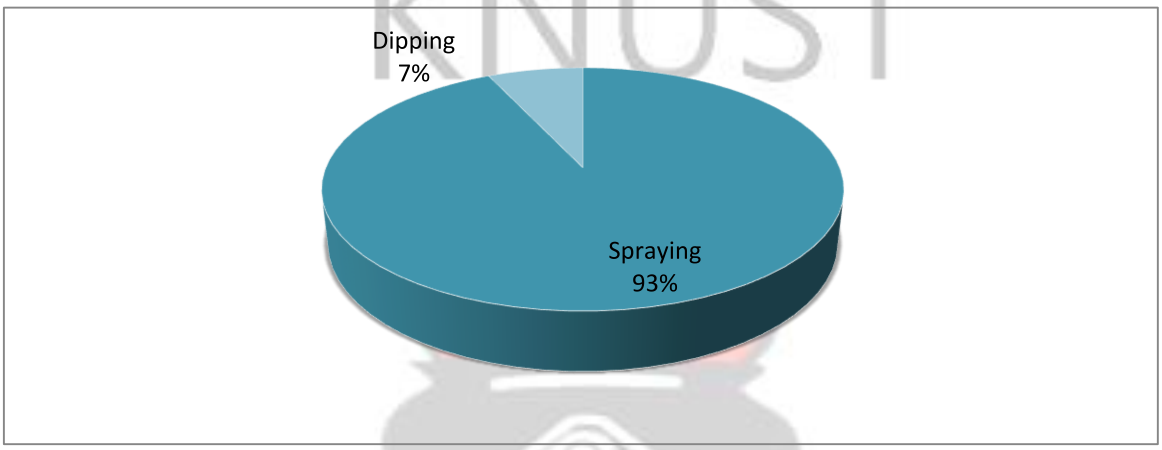

Fig. 7: Mode of insecticide application

4.1.8 Understanding of Instructions on Insecticide Application Procedures Forty two (61.8%) of the farmers do not understand the instructions on insecticide labels on application procedures, even though some could read. They obtain their information from pesticide sellers, colleague farmers and others who depended on their own personal experiences; however, 26 of the farmers (38.2%) are able to read and understand instructions on pesticide application procedures (Fig. 8).

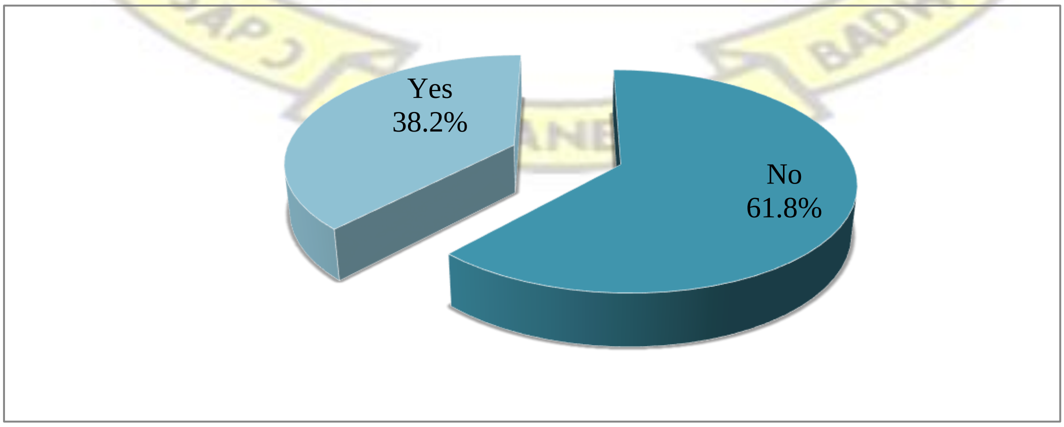

Fig. 8: Ability to Understand Instructions on Insecticide Labels

4.2 ORGANOCHLORINE INSCTICIDE RESIDUE ANALYSIS

The concentrations of the various residues in each sample are calculated in ng/g and presented in Tables 3 – 11.

*Values designated by asterisks are higher than the EU MRLs for the respective pesticide. (see MRLs in Table 12); ND = not detected; SD = standard deviation.

4.2.1 Levels of Pesticide Residues Found in Vegetables From Farms at Odumase

Table 3*:* Detected insecticide residues (ngg^{-1}; fresh weight) in Green Pepper (*Capsicum annum*) samples from Odumase

Insecticides	Odumase Farms				
	A1	**A2**	**A3**	**A4**	**Mean±SD**
alpha-HCH	0.165	ND	0.1255	0.1627	0.151±0.022
hexachlorobenzene (HCB)	ND	ND	ND	ND	-
beta-HCH	ND	ND	ND	ND	-
gamma-HCH (lindane)	ND	ND	ND	ND	-
delta-HCH	ND	ND	ND	0.1952	0.195±0
Heptachlor	ND	ND	ND	0.8489	0.849±0
Aldrin	0.1912	0.1923	0.1867	0.1844	0.189±0.004
Dieldrin	ND	ND	ND	ND	-
Endrin	ND	ND	ND	ND	-

Cis-heptachlor	ND	ND	ND	ND	-
trans-heptachlor	ND	ND	ND	ND	-
cis-Chlordane	ND	ND	ND	ND	-
trans-Chlordane	ND	ND	ND	ND	-
Trans-Nonachlor	ND	ND	ND	ND	-
p,p-DDT	ND	ND	ND	ND	-
o,p-DDT	ND	ND	ND	0.3533	0.353±0
p,p-DDE	ND	ND	ND	ND	-
p,p-DDD	ND	ND	ND	ND	-
o,p-DDD	ND	ND	ND	ND	-
o,p-DDE	ND	ND	ND	ND	-
Mirex	ND	ND	ND	19.768*	19.768*±0

Table 4: Detected Insecticide resiues (ngg^{-1}; fresh weight) in Carrot (*Daucus carota*) Samples from Odumase

Insecticides	Odumase Farms			
	B1	**B2**	**B3**	**Mean±SD**
alpha-HCH	0.1223	ND	1.39	0.756±0.896
hexachlorobenzene (HCB)	ND	ND	ND	
beta-HCH	ND	ND	ND	
gamma-HCH (lindane)	ND	ND	ND	
delta-HCH	0.1474	ND	0.1436	0.146±0.003
Heptachlor	ND	1.993	3.0702	2.532±0.762
Aldrin	0.1856	0.1888	0.201	0.192±0.008

Dieldrin	ND	ND	ND	
Endrin	ND	ND	ND	
Cis-heptachlor	ND	ND	ND	
trans-heptachlor	ND	ND	ND	
cis-Chlordane	ND	ND	ND	
trans-Chlordane	ND	ND	ND	
Trans-Nonachlor	ND	ND	ND	
p,p-DDT	0.01	0.3847	ND	0.197±0.265
o,p-DDT	ND	ND	ND	
p,p-DDE	0.1715	ND	ND	0.175±0
p,p-DDD	ND	ND	ND	
o,p-DDD	ND	ND	ND	
o,p-DDE	ND	ND	ND	
Mirex	ND	19.7368*	ND	19.737*±0

5*: Detected insecticide residues (ngg^{-1}; fresh weight) in Cabbage (Brassica oleracea var capitata*) Samples from Odumase

Insecticides	**Odumase Farms**			
	C1	**C2**	**C3**	**Mean±SD**
alpha-HCH	ND	0.1162	ND	0.116±0
hexachlorobenzene (HCB)	ND	ND	ND	
beta-HCH	ND	ND	ND	
gamma-HCH (lindane)	ND	ND	ND	
delta-HCH	ND	ND	ND	
Heptachlor	ND	ND	ND	
Aldrin	ND	ND	0.2139	0.214±0
Dieldrin	ND	0.1277	ND	0.128±0
Endrin	ND	0.2542	ND	0.254±0
Cis-heptachlor	ND	ND	ND	
trans-heptachlor	ND	ND	ND	
cis-Chlordane	ND	ND	ND	
trans-Chlordane	ND	ND	ND	
Trans-Nonachlor	ND	0.5785	0.2883	0.433±0.205
p,p-DDT	ND	0.5167	0.3925	0.455±0.088
o,p-DDT	ND	ND	ND	
p,p-DDE	ND	0.9438	ND	0.944±0
p,p-DDD	ND	ND	ND	
o,p-DDD	ND	0.1142	ND	0.114±0

Table

o,p-DDE	ND	ND	ND	
Mirex	15.0217*	19.91055*	ND	17.466*±3.457

A1, A2, A3, A4 are samples of green pepper collected from different farms at Odumase. Six (6) insecticide residues were detected in green pepper samples from farms at Odumase. Endrin, dieldrin and heptachlor epoxides were not detected in green pepper samples from Odumase. Mirex recorded the highest concentration of 19.768ngg^{-1} which was above the maximum residue limits set by the EU for vegetables.

Heptachlor recorded a concentration of 0.8489ngg^{-1} on farm 4. All values recorded except for mirex were below the EU MRLs set for green pepper (Table 3).

B1, B2, B3 are samples of carrot collected from different farms at Odumase. Seven (7) insecticide residues were detected in carrot samples from Odumase. Heptachlor was detected on samples from farms 2 and 3 with a maximum value of 3.0702ngg^{-1}. Mirex recorded a value of 19.7368ngg^{-1} which is above the EU MRL value of 10ngg^{-1} (Table 4).

C1, C2, C3 are samples of cabbage collected from different farms at Odumase. Nine (9) insecticide residues were detected in cabbage samples from Odumase farms. Farm 1 recorded a value of 15.0217ngg^{-1} for mirex which is above the EU MRL value for cabbage. Farm 2 recorded a maximum residual concentration of 19.9106ngg^{-1} of mirex and a minimum concentration of 0.1162nng^{-1} of alpha-HCH (Table 5).

4.2.2 Levels of Insecticide Residues Found in Vegetables From Farms at Kwatire

Tables 6, 7 and 8 show different insecticide residues and their concentrations detected in green pepper, carrot and cabbage samples from farms at Kwatire.

6: Detected Insecticide residues (ngg-1; fresh weight) in Green Pepper *(Capsicum annum*) Samples from Kwatire

Insecticides	**Kwatire Farms**				
	D1	**D2**	**D3**	**D4**	**Mean±SD**
alpha-HCH	0.1242	0.1389	0.1325	0.1191	0.129±0.009
hexachlorobenzene (HCB)	ND	ND	ND	ND	
beta-HCH	ND	ND	ND	ND	
gamma-HCH (lindane)	0.0112	ND	0.01	ND	0.011±0.0008
delta-HCH	0.2515	0.2091	0.1477	0.1548	0.191±0.049
Heptachlor	14.8236*	1.0511	0.4312	ND	5.435±8.136
Aldrin	0.2478	0.1891	0.1836	0.1916	0.203±0.030
Dieldrin	ND	ND	ND	ND	
Endrin	ND	ND	ND	ND	
Cis-heptachlor	ND	ND	ND	ND	
trans-heptachlor	ND	ND	ND	ND	
cis-Chlordane	ND	ND	ND	ND	
trans-Chlordane	ND	ND	ND	ND	
Trans-Nonachlor	0.277	ND	ND	ND	0.277±0
p,p-DDT	ND	ND	ND	ND	
o,p-DDT	ND	ND	ND	ND	

Table

p,p-DDE	ND	ND	ND	ND	
p,p-DDD	ND	ND	ND	ND	
o,p-DDD	ND	ND	ND	ND	
o,p-DDE	ND	ND	ND	ND	
Mirex	19.8779*	ND	ND	ND	*19.878±0

Table 7*: Detected Insecticide residues (ngg^{-1}; fresh weight) in Carrot (*Daucus carota*) Samples from Kwatire*

	Kwatire Farms			
Insecticides	**E1**	**E2**	**E3**	**Mean±SD**
alpha-HCH	0.1197	0.139	0.1213	0.127±0.011
hexachlorobenzene (HCB)	ND	ND	ND	
beta-HCH	ND	ND	ND	
gamma-HCH (lindane)	ND	ND	ND	
delta-HCH	ND	0.151	0.1794	0.165±0.020
Heptachlor	ND	2.4737	ND	2.474±0
Aldrin	0.1877	0.1847	0.1951	0.189±0.005
Dieldrin	ND	ND	ND	
Endrin	ND	ND	ND	
Cis-heptachlor	ND	ND	ND	
trans-heptachlor	ND	ND	ND	
cis-Chlordane	ND	ND	ND	
trans-Chlordane	ND	ND	ND	

Trans-Nonachlor	ND	ND	ND	
p,p-DDT	0.4175	ND	ND	0.418±0
o,p-DDT	ND	ND	ND	
p,p-DDE	ND	ND	ND	
p,p-DDD	ND	ND	ND	
o,p-DDD	ND	ND	ND	
o,p-DDE	ND	ND	ND	
Mirex	19.8227*	ND	ND	19.823*±0

8*:* Detected Insecticide residues (ngg^{-1}; fresh weight) in Cabbage (*Brassica oleracea var capitata*) samples from Kwatire

Insecticides	Kwatire Farms			
	F1	F2	F3	Mean±SD
alpha-HCH	0.133	ND	0.136	0.135±0.002
hexachlorobenzene (HCB)	ND	ND	ND	
beta-HCH	ND	ND	ND	
gamma-HCH (lindane)	ND	ND	ND	
delta-HCH	0.1463	ND	0.14	0.143±0.004
Heptachlor	ND	ND	ND	
Aldrin	0.1983	0.193	ND	0.196±0.004
Dieldrin	ND	0.2476	ND	0.248±0
Endrin	ND	0.4782	ND	0.478±0
Cis-heptachlor	ND	ND	ND	

Table

trans-heptachlor	ND	ND	ND	
cis-Chlordane	ND	ND	ND	
trans-Chlordane	ND	ND	ND	
Trans-Nonachlor	0.4012	1.0196	0.2812	0.567±0.396
p,p-DDT	ND	0.4219	ND	0.422±0
o,p-DDT	ND	ND	ND	
p,p-DDE	0.2921	0.6568	0.1884	0.379±0.246
p,p-DDD	ND	0.0125	ND	0.013±0
o,p-DDD	ND	0.2818	ND	0.282±0
o,p-DDE	ND	ND	ND	
Mirex	ND	ND	20.0491	20.049±0

D1, D2, D3 and D4 were samples of green pepper collected from different farms at Kwatire. Seven (7) insecticide residues were detected in green pepper samples from farms at Kwatire. Heptachlor recorded a value of 14.8236ngg^{-1} which was above the EU MRLs. Alpha-HCH was detected in samples from all four farms at a minimum concentration of 0.1191ngg^{-1} and a maximum concentration of 0.1389ngg^{-1}. DDT was not detected in the samples analyzed. A concentration of 19.8779ngg^{-1} of mirex was recorded which is above the EU MRLs (Table 6).

Table 7 shows the results for samples of carrots from farms at Kwatire. E1, E2, E3 were samples of carrot collected from different farms at Kwatire. Alpha- HCH and aldrin were detected in carrot samples from all three (3) farms in Kwatire but at concentrations below the EU MRLs (Table 12). . The maximum concentration of mirex residue in the carrot samples from Kwatire was 19.8227ngg^{-1}. Heptachlor recorded a value of 2.4737ngg^{-1}

which was below the maximum residue limit for carrots. A total of six pesticide residues were detected in the carrot samples from Kwatire.

Eleven (11) pesticide residues were detected in the cabbage samples analyzed from Kwatire. Samples were represented with F1, F2 and F3. Concentrations exceeding the EU MRL values occurred only for mirex (20.0491ngg^{-1}). Heptachlor and its epoxides were not detected in the cabbage samples. However, Aldrin, dieldrin, endrin, p,p-DDE, p,p-DDD and o,p-DDD were detected in the cabbage samples (Table 8).

4.2.3 Levels of Insecticide Residues Found In Vegetables From Farms at Adantia

Table 9, 10 and 11 represents results of pesticide concentrations detected in the vegetable samples from Adantia farms.

Table Detected insec
9: ticide residues (ngg^{-1}; fresh weight) in Green Pepper samples (*Capsicum annum*) from Adantia

Insecticides	Adantia Farms				
	G1	G2	G3	G4	Mean±SD
alpha-HCH	ND	0.1346	0.1139	0.116	0.122±0.011
hexachlorobenzene (HCB)	ND	ND	ND	ND	
beta-HCH	ND	ND	ND	ND	
gamma-HCH (lindane)	ND	0.1284	ND	ND	0.128±0
delta-HCH	0.1487	0.567	ND	ND	0.358±0.296
Heptachlor	ND	80.9474*	ND	ND	80.947±0
Aldrin	ND	0.4982	ND	ND	0.498±0
Dieldrin	ND	ND	ND	0.0342	0.034±0
Endrin	ND	ND	ND	ND	
Cis-heptachlor	ND	ND	ND	0.0235	0.024±0
trans-heptachlor	ND	0.2562	ND	ND	0.256±0
cis-Chlordane	ND	ND	ND	ND	
trans-Chlordane	ND	0.224	ND	ND	0.244±0
Trans-Nonachlor	ND	ND	ND	0.1095	0.110±0
p,p-DDT	ND	ND	ND	ND	
o,p-DDT	ND	ND	ND	ND	
p,p-DDE	ND	ND	ND	ND	
p,p-DDD	ND	ND	ND	ND	
o,p-DDD	ND	ND	ND	ND	

Table Detected insec

o,p-DDE	ND	ND	ND	ND	
Mirex	ND	ND	20.0531*	18.0901*	19.072±1.388

10: ticide residues (ngg^{-1}; fresh weight) in Carrot (*Daucus carota*) samples from Adantia

Insecticides	Adantia Farms			
	F1	**F2**	**F3**	**Mean±SD**
Alpha - HCH	ND	ND	0.142	0.142±0
hexachlorobenzene (HCB)	ND	ND	ND	
Beta - HCH	ND	ND	ND	
Gamma - HCH (lindane)	ND	ND	ND	
Delta - HCH	ND	ND	0.0115	0.012±0
Heptachlor	0.7626	ND	1.0342	0.898±0.192
Aldrin	0.2198	ND	0.0463	0.133±0.123
Dieldrin	ND	ND	ND	
Endrin	0.1662	ND	ND	0.166±0
Cis - heptachlor	ND	ND	ND	
Trans - heptachlor	ND	ND	ND	
Cis - Chlordane	ND	ND	ND	
Trans - Chlordane	ND	ND	ND	
Trans - Nonachlor	0.3649	ND	ND	0.365±0
p,p - DDT	0.5344	0.3814	0.2981	0.405±0.120
o,p - DDT	ND	ND	ND	

Table Detected insec

p,p - DDE	ND	ND	ND	
p,p - DDD	ND	ND	ND	
o,p - DDD	ND	ND	ND	
o,p - DDE	ND	ND	ND	
Mirex	19.9765*	ND	12.0731*	16.025*±5.589

11: ticide residues (ngg^{-1}; fresh weight) in Cabbage (*Brassica oleracea var capitata*) samples from Adantia

Insecticides	Adantia Farms			
	J1	**J2**	**J3**	**Mean±SD**
Alpha - HCH	0.127	0.1162	ND	0.122±0.008
hexachlorobenzene (HCB)	ND	ND	ND	
Beta - HCH	ND	ND	ND	
Gamma - HCH (lindane)	ND	ND	ND	
Delta - HCH	0.0276	0.038	ND	0.033±0.007
Heptachlor	ND	ND	ND	
Aldrin	ND	ND	0.0314	0.031±0
Dieldrin	ND	0.1576	ND	0.158±0
Endrin	ND	0.0436	ND	0.044±0
Cis - heptachlor	ND	ND	ND	
Trans - heptachlor	ND	ND	ND	
Cis - Chlordane	ND	ND	ND	
Trans - Chlordane	ND	ND	ND	
Trans - Nonachlor	ND	0.6985	0.1467	0.423±0.390
p,p - DDT	ND	0.029	0.045	0.037±0.011
o,p - DDT	ND	ND	ND	
p,p - DDE	ND	0.9438	ND	0.944±0

Table Detected insec

p,p - DDD	ND	ND	ND	
o,p - DDD	ND	0.113	ND	0.113±0
o,p - DDE	ND	ND	ND	
Mirex	5.735	ND	ND	5.735±0

G1, G2, G3 and G4 were samples of green pepper collected from different farms at Adantia. Eleven (11) insecticide residues were detected in the green pepper samples analyzed. Mirex recorded the maximum pesticide residue concentration of 20.0531ngg^{1} whereas a minimum value 0.1139ngg^{-1} was recorded for alpha - HCH. Three insecticide residues exceeded the MRL values set by the EU for green pepper (Table 9). H1, H2, H3 were samples of carrot collected from different farms at Adantia and each value is an average of three determinations. Eight (8) insecticide residues were detected in carrot samples from farms at Adantia, out of twenty one (21) organochlorine residues anlysed. Heptachlor recorded a minimum concentration of 0.7626ngg^{-1} and a maximum concentration of 1.034ngg^{-1}. Two insecticide residues exceeded the EU MRLs that were set for mirex in the carrot samples (Table 10).

J1, J2, J3 were samples collected from different farms at Adantia. Ten (10) insecticide residues were detected in cabbage samples from Adantia but all were below the EU MRLs. Mirex recorded a maximum concentration of 5.735 ngg^{-} and a minimum concentration of 0.0436ngg^{-1}of endrin (Table 11).

4.2.4 Insecticide Residues in Green Pepper, Carrot and Cabbage in the Study Area

Figs. 9, 10 and 11 indicate that eleven (11) organochlorine insecticide residues were detected in the Green pepper samples, nine (9) organochlorine pesticide residues were detected in the Carrot samples and eleven (11) organochlorine insecticide residues were detected in the Cabbage samples respectively.

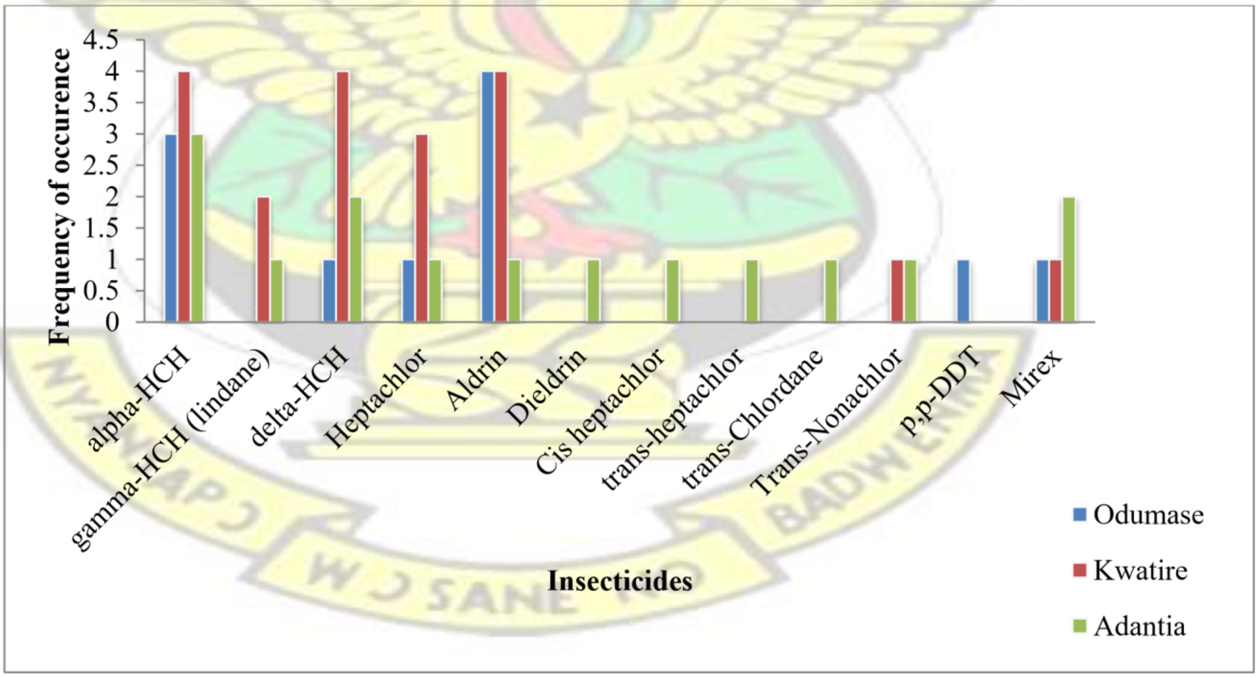

Fig. 9: Comparison of the frequency of occurrence of various insecticide residues in Green Pepper *(Capsicum annum)* in the three study locations

Adantia recorded eleven (11) different pesticide residues in the green pepper samples but at lower frequencies. The frequency of occurrences of heptachlor, delta-HCH, lindane and alpha-HCH were high among samples collected from Kwatire (Fig. 9).

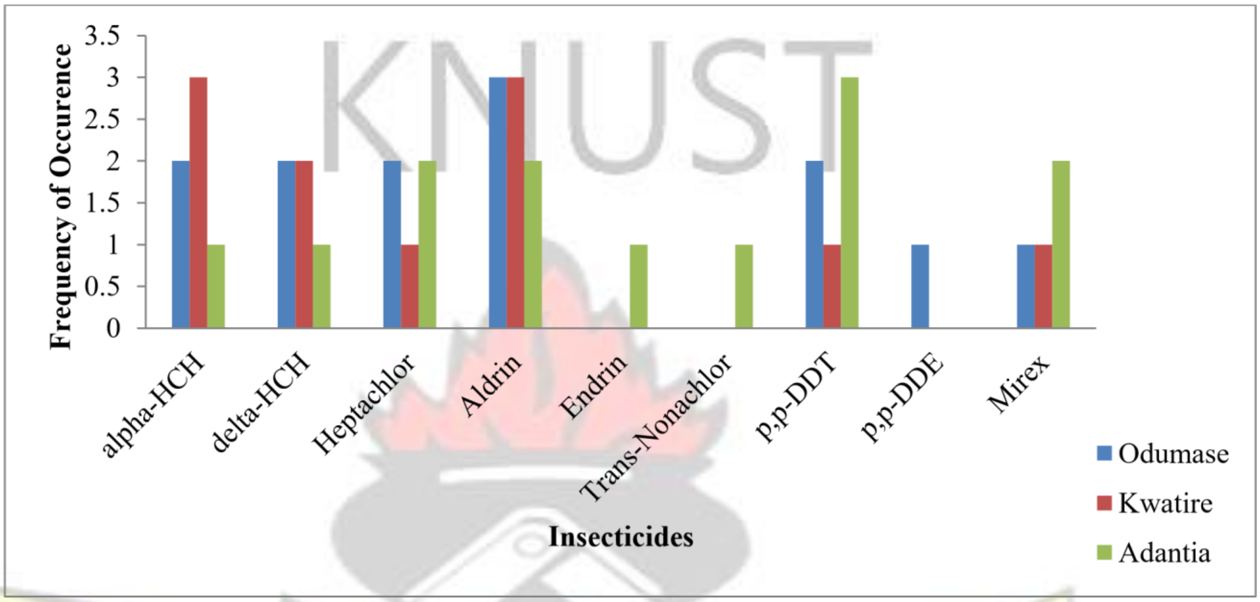

Fig. 10: Comparison of the frequency of occurrence of various insecticide residues in Carrot (*Daucus carota*) samples in the three study locations

Samples of carrot obtained from Odumase recorded higher frequencies in the occurrence of insecticide residues. Aldrin and alpha-HCH occurred at higher frequencies in samples obtained from both Odumase and Kwatire. A total of nine (9) different insecticide residues were detected in all carrot samples analyzed (Fig. 10).

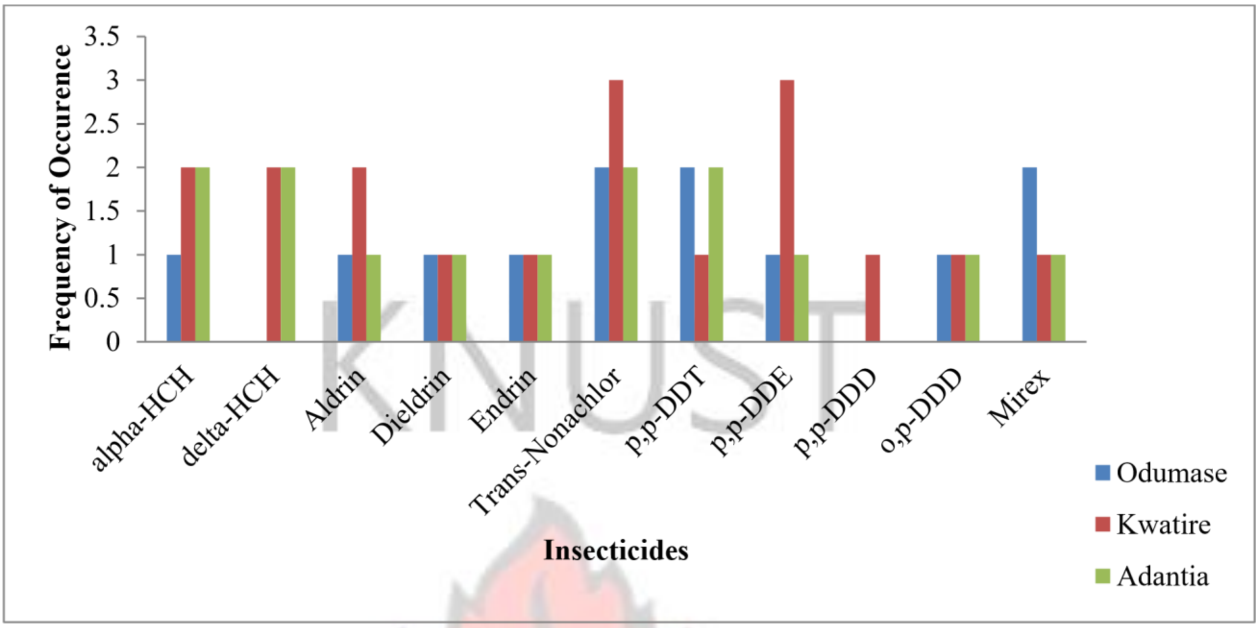

Fig. 11: Comparison of the frequency of occurrence of various insecticide residues in Cabbage (*Brassica oleracea var capitata)* samples in the three study locations

Samples of cabbage (*Brassica oleracea var capitata*) from Kwatire recorded higher frequency of occurrences of pesticide residues. Trans-nonachlor and p.p-DDE were detected in samples from all three different farms in Kwatire. In all, eleven (11) different insecticide residues were detected in the cabbage samples obtained from Kwatire. Nine (9) different insecticide residues were however detected in cabbage sample obtained from Odumase, but at comparatively lower frequency of occurrences (Fig 10).

Table 12*:* Number and percentage of insecticide residues in vegetable samples with exceeding MRL values in all three locations

Insecticides	**Contaminated samples with each insecticide**	**MRL (ng/g)**	**Samples that violated MRL values of EU**

	carrot n %		cabbage n	%	Green pepper n	%		Carrots n	%	Cabbage n	%	Green pepper n	%
Alpha-HCH	6	54	5	45	9	75	10	0	0	0	0	0	0
Delta–HCH	5	45	4	36	7	58.3	10	0	0	0	0	0	0
Aldrin	8	72	4	36	9	75	10	0	0	0	0	0	0
Endrin	1	9	3	27	0	0	10	0	0	0	0	0	0
Dieldrin	0	0.0	3	27	1	8.3	10	0	0	0	0	0	0
Lindane	0	0.0	0	0	3	25	10	0	0	0	0	0	0
Heptachlor	5	45	0	0	5	41.7	10	0	0	0	0	2	16
Trans-heptachlor	0	0.0	0	0	2	16.7	10	0	0	0	0	0	0
Cis- heptachlor	0	0.0	0	0	1	8.3	10	0	0	0	0	0	0
Trans- nonachlor	1	9	7	63	2	16.7	10	0	0	0	0	0	0
Trans- chlordane	0	0.0	0	0	1	8.3	10	0	0	0	0	0	0
p,p-DDT	6	54	5	45	0	0.0	50	0	0	0	0	0	0
p,p-DDE	1	9	5	45	0	0.0	50	0	0	0	0	0	0
p,p-DDD	0	0.0	1	9	0	0.0	50	0	0	0	0	0	0
o,p-DDD	0	0.0	3	27	0	0.0	50	0	0	0	0	0	0
o,p-DDT		0.0		0	1	8.3	50	0	0	0	0	0	0
Mirex	4	36	4	36	4	33.3	10	4	44	3	33	4	33

n = number of samples contaminated

Table 13*: Overall percent total insecticide residues in Vegetable samples from Sunyani West District*

Scientific Name	English Name	No. of Samples	% with one or more residues
Daucus carota	Carrot	10	38
Capsicm annum	Green Pepper	10	28

Brassica oleracea var capitata	Cabbage	10	34

Incidence of insecticide residues in the vegetable samples analyzed are presented in Table 13. In all, 30 samples of vegetables were collected for insecticide analysis. Overall per cent total insecticide residues found in carrot, lettuce and cabbage samples were 38%, 28% and 34%, respectively.

CHAPTER FIVE

5.0 DISCUSSION

5.1 SEX AND AGE OF RESPONDENTS

Vegetable production in the three communities in the district was dominated by males between the ages of twenty – one (21) and sixty (60) years. This was so because vegetable production is laborious and needs more care with frequent spraying of insecticides to control insect pests.

5.2 EDUCATIONAL BACKGROUND OF RESPONDENTS

The study revealed 57.4% of the farmers have had some basic education with the remaining (42.6%) either having secondary education (17.6%), Post secondary education (2.9%) or a Middle School Leaving Certificate (4.4%). This means that majority of the farmers could read the instructions and warnings on pesticide containers, but may not fully understand these instructions very well. The farmers might apply these chemicals at concentrations which may be hazardous to both plants and animals. Poor interactions between farmers and the agricultural extension officers might have contributed to this situation. In the absence of such effective interactions, the farmers mostly rely on information from the agro- chemical sellers, colleague farmers and relatives for instructions in the choice and application of the pesticides. The knowledge from this source may not be any better than that of the receiving farmer. This accounted for insecticide abuse as indicated by the farmers, resulting from ignorance or their lack of knowledge. The field survey however, revealed that both illiterate and literate farmers do take precautionary measures during spraying.

5.3 TYPES OF PESTICIDES USED BY FARMERS

The study showed that the choice of specific pesticides by farmers mostly depended on their availability on the market and not their efficacy or safety. Some of the pesticides used by the farmers were WHO/EPA category II insecticides banned for use in the production of crops by the European Union (EU) and Japan (Bateman, 2010). These chemicals are persistent in the environment and can bio-accumulate in the tissues of both plants and animals. Some of the pesticides used by the farmers are not recommended for the control of pests on vegetables. These findings agree with an earlier study by Menlah (2008) that although the organochlorines are banned from importation, sales and use in

Ghana, there was evidence of their continued usage and presence in the ecosystem. In a study to analyze pesticides and pathogen contamination of vegetables in Ghana's urban markets, Amoah *et al.*,(2006) documented that chlorpyrifos (Dursban) was detected on 78% of lettuce, Lindane on 31%, endosulfan on 36%, Lambda cyhalothrin (Karate) on 11% and DDT on 36%. Similar work already done in some farming communities in the Ashanti Region of Ghana and some other countries indicated the presence of organochlorine insecticide residues in fish (Osafo and Frempong, 1998), vegetables, water, sediments, mother's milk, and blood samples (Menlah, 2008).

5.4 COMBINATION OF TWO OR MORE CHEMICALS

Over thirty – eight percent (38.2%) of the respondents mixed two or more chemicals to control pests on their farms. 'Poison' which was later discovered as DDT was normally mixed with other insecticides to ensure very effective control of insect pests on their farms. This was done without regard to the health implications on humans and animals. Majority of the respondents (61.8%), however did not mix the insecticides but applied them as they were on their crops. Some of the farmers sometimes violated the instructions on the insecticide labels by applying more or less depending on the severity of the pests, or the soil or vegetation type.

5.5 MODE AND FREQUENCY OF APPLICATION OF PESTICIDES

Farmers mostly applied chemicals by spraying with the knapsack sprayer, which was considered one of the most effective modes of chemical application. The frequency of spraying however depended on the type of chemical, severity of insect infestation and the dosage of pesticide used. Forty percent of the respondents applied the pesticides twice in a growing season which may last for a period of three to four months. Only ten percent (10%) of the farmers applied the pesticides more than three times in a growing season and this was due to severe insect infestation.

5.6 ORGANOCHLORINE INSECTICIDE RESIDUES IN VEGETABLE SAMPLES

The results obtained indicated that insecticide residues were indeed present in some of the vegetable samples analysed from all three communities studied. Analysis of twenty one (21) organochlorine insecticide residue levels in the vegetable samples indicated that Heptachlor and Mirex, had residue levels, which were higher than the FAO/WHO (1995) Guideline value of 10ng/g. The results further showed that other organochlorine insecticides such as Alpha HCH, Gamma BHC (Lindane), Delta HCH, DDT, DDE, Endrin and Dieldrin, were present, but all were below the FAO/WHO (1995) Guideline value of 10ng/g. Organochlorine insecticides are banned for vegetable production in Ghana, therefore, detection of these organochlorine pesticide residues in some of the vegetable samples indicated misuse of agrochemicals among the farmers in the study area. Work already done in some farming communities in the Ashanti Region of Ghana and some other countries indicated the presence of organochlorine pesticide residue in fish (Osafo and Frimpong, 1998), vegetables, water sediments, mother's milk and blood samples (Ntow, 2001).

Since these chemicals are toxic to living organisms, increased accumulation in the food chain may pose serious health hazards to the general populace. Previous work done by Gerken, *et al.* (2001) suggested that organochlorine pesticides are widely used by farmers because of their effectiveness and their broad spectrum activity. Lindane (Gamma BHC) is widely used in Ghana in cocoa plantations, on vegetable farms and for the control of stem borers in maize. Endosulfan, marketed as Thiodan, is widely used in cotton growing areas on vegetable farms and on coffee plantations. Its presence could be from the soil as a result of past activities on the land as well as water used for irrigation as these were not tested.

Organochlorines are known to persist longer in the environment (D'Mello, 2003). This was evident in the presence of residue concentrations in seventeen out of twenty one organochlorine insecticide residues analyzed for. Heptachlor tends to stay in the soil for long periods of time. One study found heptachlor epoxide in crops that were grown in heptachlor-treated soil 15 years earlier. One can be exposed to heptachlor and its epoxides by eating these crops (ATSDR, 1993). Heptachlor has been shown to cause cancer in laboratory animals when exposed at high levels over their lifetimes. This may increase the risk of cancer in humans who are exposed for a long time (Udeh, 2004).

The concentrations detected in this work were lower compared to those of similar works done elsewhere in Ghana. For example, Essumang *et al*. (2008) reported that the concentrations of insecticides in tomatoes from Ghana ranged between 0.03 to 10.76 mg/kg (or 30 to 10760 μg/kg). The low levels of the organochlorines in this work could be due to minimal misuse of these pesticides in the study area as a result of their ban from agricultural use. Although the levels were generally lower than those of similar works, the results showed that organochlorine insecticides are still found in the environment, despite the fact that they have been banned from use in Ghana (EPA, 2008).

The presence of these pesticides in the environment years after their ban could be due to their ability to persist in the environment. Persistency is defined as a half-life greater than two months in water or six months in soil and sediment. These chemicals are difficult to degrade into less hazardous substances in the environment. They are lipophilic compounds that tend to bioaccumulate in fatty tissues through the food chain. These pesticides are water insoluble and semi-volatile, enabling their entry into the atmosphere and transported over long distances globally, mainly by air mass movements. They can reach polar or high mountainous regions and are effectively deposited in cold regions by snow through the phenomenon of cold condensation and global distillation (Wania and Mackay, 1995).

Their detection also indicates that some Ghanaian farmers still use these agrochemicals illegally. Farmers prefer the organochlorine pesticides because they are relatively cheap and very effective (Essumang *et al*., 2008). This study, therefore, suggests the possibility of sporadic use of these insecticides for agriculture or mainly due to the past extensive use of these insecticides for agriculture in Ghana as it has been banned for over a decade ago. These findings corroborate the findings of Nakata *et al*. (2002) who found elevated levels of organochlorine pesticide residues in fruits and vegetables collected from Shanghai and Yixing, China. Similarly, in an investigation carried out by Hura (1999), by monitoring organochlorine residues in fruits and vegetables in

Eastern Romania, it was concluded that organochlorine pesticides were found in all analyzed samples. A similar research conducted by Mukherjee *et al*. (2011) in West Bengal, India, to access the level of organochlorine pesticide residues in vegetables revealed that, the concentration of OCPs was ranged between, <0.01– 65.07 μg/kg with average of 9.67±2.34 μg/kg (wet wt.).

Table 12 shows that with the exception of Heptachlor in green pepper samples from Adantia and Kwatire, and Mirex which was detected in almost all the samples, all the seventeen organochlorine insecticides detected were below the UK/EC MRLs. This means that carrots, cabbage and green pepper from these three communities in the Sunyani West District of the Brong Ahafo Region of Ghana posed minimal health risk to consumers and, therefore, are safe for consumption. It is important to note that, the effect of an insecticide on human health does not depend only on the quantity of the insecticide accumulated. It also depends on the duration and frequency of exposure and the health of the person at the time of the exposure (Karalliedde *et al.*, 2003). Therefore, even though the levels were lower than the UK/EC MRLs, there is still a cause for concern. This is because consumers who frequently consume these vegetables may have these organochlorines accumulating in their bodies. Besides, consumers who already have other sources of exposure such as drinking water and meat will suffer the cumulative effect of these ubiquitous insecticides.

The results of the present study are comparable to those of other studies. For example, Darko and Acquaah and Darko (2007) found that the levels of organochlorines in meat from the Kumasi and Buoho abattoirs were lower than the maximum limits set by FAO/WHO. Adeyeye and Osibanjo (1999) found that residue levels of organochlorine pesticides in raw fruits, vegetables and tubers from markets in Nigeria were generally low and none were above the FAO's maximum residue limits. In a similar study, Usman *et al.* (2009) found that all the marketed fruits and vegetables sampled from Lahore, Parksitan had residue levels below the maximum residue limit (MRL) set by WHO.

The insecticide residue levels detected in the present study were lower than those found in vegetables from three major markets in Ghana *(*Amoah *et al., 2006)* which exceeded the MRLs for consumption. In a similar study by Odhiambo *et al*. (2007), the organochlorine residues detected in vegetables exceeded the Chinese Extraneous Maximum Residue Limit of 50ng/g (50µg/kg) for DDTs in vegetables.

The detection of the breakdown products of DDT (DDE and DDD) was an indication of photochemical degradation of the DDT (Wandiga, 1995). The low level of technical

DDT might be due to De-hydrochlorination and/or photo-degradation to form the metabolite form of DDE (Bempah and Donkor, 2011). The results corroborate the findings of Abou-Arab and Abou Donia (2001) who detected levels of DDT and its derivatives at levels ranging from 0.009 to 0.116 mg/kg and mean value of 0.05 mg/kg in the West African city farms (Manirakiza *et al*., 2003). The low level of endrin may likely be due to its susceptibility to volatilization, photo-degradation, and heat to form metabolites of endrin (Fan and Alexeeff, 1999).

In all the three communities the average concentration of heptachlor was higher than that of heptachlor epoxide. For example, the average concentration of heptachlor in green pepper from Kwatire was 14.8236ng/g while trans-heptachlor epoxide and cisheptachlor epoxide were not detected at all. Heptachlor undergoes both biological and chemical transformation to heptachlor epoxide and other degradation products in the environment. Heptachlor epoxide degrades more slowly and, as a result, is more persistent than heptachlor (ATSDR 2005a). Therefore, the higher concentrations of heptachlor than heptachlor epoxide indicate that this insecticide has been used recently. The detection of the Mirex, Heptachlor, HCHs and DDTs at appreciable levels is worrisome, since they are among the organochlorines listed by the Stockholm

Convention as persistent organic pollutants. The International Agency for Research on Cancer (IARC) has classified HCH (all isomers) as possible human carcinogens. Longterm exposure to α-HCH, β-HCH, γ-HCH, or technical-grade HCH has been reported to result in liver cancer. It can also result in blood disorders, dizziness, headache and possible changes in the levels of sex hormones in the blood (IARC, 2001; ATSDR, 2005b).

Statistical analysis showed no significant difference in the mean concentrations of all the organochlorine residues among the varieties ($p > 0.01$) as shown in appendices 6 – 9. This could be because the cuticle of fruits limits the loss of substances from the fruits internal tissues, protects the fruits against physical, chemical, and biological attacks and protects the fruits against the external environment while the fruit is on the plant as well as after harvest (Antonio *et al*., 2005). Appendices 6 – 9, with reference to all Tables comparing organochlorines by location shows that statistically, there were no significant differences in the mean concentrations of all the organochlorine residues among the sampling locations.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

The study was carried out in two phases; a field survey and laboratory analysis. The result of the field survey showed that twenty one (21) different insecticides were used by the vegetable farmers sampled to control insect pests on vegetable crops in the Sunyani West District of the Brong Ahafo region of Ghana. The field survey also indicated that there was misuse and improper combinations of insecticides to control insect pests, since majority of the farmers interviewed have up to basic education only.

The second phase was a laboratory analysis of the vegetable samples from the sampled farms. The laboratory analysis revealed the presence of banned organochlorine pesticides in vegetable samples analyzed. The average levels of organochlorine residues in the vegetables sampled in this study were, however, generally below the EU MRLs, with the exception of mirex and heptachlor of which concentrations were quite high (20.0531 ng/g and 14.8236 ng/g respectively), posing a potential health risk to vegetable consumers in the Sunyani West District. However, because of their lipid solubility and resistance to metabolism, they can bioaccumulate in human tissues of consumers. So, chronic exposure could pose health problems. The results of the study also revealed the misuse of insecticides. Although the concentrations are generally low, the study showed that the organochlorine insecticides are still being used despite the fact that they have been banned from use in Ghana. 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

Based on the results from the study, the following recommendations are made;

1. Educative and informative programmes should be organised by stakeholders such as the Ministry of Food and Agriculture, EPA, etc, for the farmers and the general public at large to sensitize them against the illegal use of banned chemicals, their impacts on human health as well as the environment.
2. Extension officers must render their services readily to the farmers and chemical sellers to avoid misappropriate use of pesticides.
3. Stakeholders such as the Ministry of Food and Agriculture, EPA and Ghana Association of Agro Input dealers should be resourced and motivated to combat the importation and smuggling of banned pesticides into the country.
4. EPA must ensure the enforcement of the laws banning the use of

organochlorine insecticides.

5. Constant monitoring and further research should be conducted to determine organochlorine insecticide residues in the study area and beyond.

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APPENDICES

Appendix 1: Research Questionaire

Name of farmer……………………………………………………………………….

1. Age………………………………..Sex………………………….……………

2. Level of education

   a. degree [ ] b. HND [ ] c. Cert A [ ] d. Secondary education [ ]
   e. middle school/ JSS [ ] f. Primary [ ] g. Illetrate [ ]

3. What vegetable crops do you grow a. carrots [ ] b. sweet pepper [ ]
   c. cabbage [ ]

4. What type of chemicals do you use on your farm?

Agrochemical	Tick	Agrochemical	Tick	Agrochemical	Tick
Thiodan /endosulfan		*Methylthiophanate*		*Kocide*	
Dursban/ Lorsban/ Chlorpyrifos		*Metalaxyll*		*Mancozeb*	
Carbofuran (furaden)		*Karate*		*Dimethoate*	
Lambda		*Warrior*		*Demand*	
DDT		*Other*			

Other, specify ………………………………………………………….…………………………

5. How many growing seasons do you have in a year?

…………………….……………………………………………………………..

6. How many times do you apply the chemicals in a growing season?

a. once [ ] b. twice [ ] c. thrice [ ] d. more than thrice [ ]

7. How long after application do you harvest your crops?

a. one week [ ] b. less than a week [ ] c. two weeks [ ]

d. more than 2 weeks [ ] e. other specify …………………………………

8.

9. How do you apply the chemicals a. spraying [ ] b. dipping [ ]

c. fumigation [ ] d. other …………………………………………………..

10. What concentration of the pesticide do you apply?...

11. Are you able to read and understand instructions on pesticide application procedures? a. YES [ ] b. NO [ ]

12. If no, who provides you with the information . a. other farmers [ ] b. chemical sellers [ ] c. extension officers [ ] d. friends and relatives [ ]

e. other……………………………………………

13. Do you normally mix two or more pesticides to enhance their effectiveness? YES [ ] NO [ ]

14. If YES which chemicals do you normally mix?…………………………………

15. Which of the following protective apparatus do you use during application?

a. goggles [ ] b. gloves [ ] c. coat [ ] d. nose mask [ ]

e. boot [ ] f. combination…………………………………………..

16. Do you experience any health problems with regards to chemical application

a. YES [ ] b. NO [ ]

17. If YES specify ……………………………………………………………

THANK YOU VERY MUCH

Appendix 2: Analysis Of Variance (Anova) For An Experiment Repeated Over Different Locations

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F-ratio	P-value
Blocks (within Places)	2	60.248	30.124	87.825	0.000**
Places	2	58.083	29.042	84.671	0.000**
Treatments	2	27.667	13.833	40.329	0.000**
Treatment x Places	4	47.454	11.864	34.589	0.000**
Error	33	11.333	0.343		
Total	43	598.083			

***significant at 0.01**

Appendix 3: Anova Table for green pepper (*Capsicum annum*)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between	27.83333	11	2.530303	2.455882	0.075837	2.81793
Within	0.666667	1	0.666667	0.647059	0.438206	4.844336
Error	11.33333	11	1.030303			
Total	39.83333	23				

*not significant

Appendix 4: Anova Table for carrot (*Daucus carota*)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between	11	8	1.375	1.622951	0.254398	3.438101
Within	0.222222	1	0.222222	0.262295	0.622383	5.317655
Error	6.777778	8	0.847222			
Total	18	17				

*not significant

Appendix 5: Anova Table for cabbage (*Brassica oleracea var capitata*)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	7.454545	10	0.745455	2.277778	0.105159	2.978237
Columns	0.727273	1	0.727273	2.222222	0.16689	4.964603
Error	3.272727	10	0.327273			
Total	11.45455	21				

*not significant