KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

COLLEGE OF SCIENCE

LEVEL OF ORGANOCHLORINE INSECTICIDE RESIDUES IN KEITT VARIETY OF MANGO (*MANGIFERA INDICA*) FRUITS FROM THE DANGME WEST DISTRICT OF GHANA.

BY

ANAFI THERESA ANSAA

OCTOBER, 2012

LEVEL OF ORGANOCHLORINE INSECTICIDE RESIDUES IN KEITT VARIETY OF MANGO (*MANGIFERA INDICA*) FRUITS FROM THE DANGME WEST DISTRICT OF GHANA.

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BY

ANAFI THERESA ANSAA

(BSc NATURAL RESOURCES MANAGEMENT)

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DECLARATION

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

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Anafi Theresa Ansaa Date

(Student)

------------------------------------ ------------------------------------

Rev. Stephen Akyeampong Date

Department of Theoretical and Applied Biology

KNUST, Kumasi

(Supervisor)

------------------------------------ ------------------------------------

Rev. Stephen Akyeampong Date

Department of Theoretical and Applied Biology

KNUST, Kumasi

(Head of Department)

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DEDICATION

This thesis is dedicated to my parents, Mr. Godfried Kwame Anafi and Ms. Rose Effie Assan for their love and support during my education.

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ABSTRACT

Level of organochlorine insecticide residues in mango fruits in Dangme West District of Ghana was studied. Fifty farmers were interviewed on the insecticide use practices. A total of 100 mango fruits were randomly sampled from nine conventional farms, one non-sprayed farm and two markets (in Accra and Tema). These were analyzed by gas chromatography equipped with electron capture detector for organochlorine residues. Residues detected in the mango fruits were within the European Union's recommended Maximum Residual Limits. This indicates that the fruits are safe for consumption. However, the detection of organochlorine residues implies that these chemicals are still present in the environment. Heptachlor was highest in all three locations. The persistent nature of these chemicals is also evident as residues of alpha-HCH, gamma-HCH, delta-HCH, aldrin, heptachlor, trans-chlordane, trans-Nonachlor and o,p-DDT were detected in fruits from unsprayed farm. Residues of alpha – HCH, Endrin, Dieldrin , cis –Heptachlor epoxide, trans –Heptachlor epoxide, Hexachlorobenzene, trans – Nonachlor, o,p-DDE, p,p-DDE and o,p-DDD showed significant differences at all the three sampling locations at $p<0.05$. Farmers are also exposed to health risk as a result of inappropriate use of Personal Protective Equipment. Farmers also have difficulty in disposing off waste water for washing the spraying machine. Disposal of waste water into open canals can contaminate rivers and ground water. There's need for constant monitoring since there could be bioaccumulation of residues in the food chain when fruits are consumed over a long period.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Ghana's agriculture is generally characterized by low yields and productivity as a result of environmental stresses such as drought, pests and diseases which affect plant growth (Horna *et al*., 2012). Pests contribute significantly to food losses and the control of pests is very central to attaining food security. Pesticides are used in agriculture to control pests and increase yield. It is therefore not surprising that pesticide use has increased over time in Ghana and is widely used in the production of high-value cash crops and vegetables (Horna *et al*., 2008).

Pesticides are manufactured under very strict regulatory processes to function with minimal impact on human health and the environment; however, serious concerns have been raised about health risks resulting from pesticide residues in food (Armah, 2011). By their very nature, most pesticides show a high degree of toxicity because they are intended to kill target organisms and therefore pose risk of harm. Its use has raised concerns not only of potential effects on human health but also about impacts on wildlife and sensitive components of the ecosystem (Armah, 2011).

The class of pesticide that is normally used among farmers is organochlorine insecticides because of their cost effectiveness and their broad spectrum activity. However, because of their highly toxic and persistent nature, their residues still appear as pollutants in food as well as in the environment (Bempah *et al.*, 2011). Organochlorine insecticides constitute the major Persistent Organic Pollutants

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(POPs) in the world. They include DDT (dichlorodiphenyltrichloroethane), HCH (hexachlorocyclohexane), chlordane, dieldrins and aldrins (Harrad, 2010).

Surveys conducted by the Environmental Protection Agency (EPA) of Ghana in 2007 showed that around 30 per cent of pesticides on sale were either unlicensed or smuggled. Officials still estimate that at least 10-15 per cent of all imports are illegal, either brought in by unlicensed dealers or involving expired or adulterated goods. Some imports arrive in bulk and are repackaged into small containers, often carrying inadequate or misleading labeling, often only in French (Northern Presbyterian Agricultural Services and Partners (NPASP), 2012). Around seven banned or restricted chemical pesticides – aldrin, dieldrin, endosulfan, lindane, DDT, methylbromide and carbofuran appear to be still being used by some Ghanaian farmers. A recent study carried out for NPAS in Upper East region found four banned were on sale in local agro-dealer shops – DDT, aldrin, lindane and dieldrin (NPASP, 2012)

Even when pesticides are used in accordance with good agricultural practices, their residues in plants may still be totally unavoidable. Research conducted for the past decade in Ghana and internationally indicates the presence of pesticide residues in a number of food items including onions, cucumber, lettuce, cabbage, okra, pepper and tomatoes (Husain *et al*., 2002; El-Nahal, 2004). Insecticide residues do not only pose danger to soil microfauna and microflora. Their toxic effects are observed in humans when bioaccumulation occurs along the food chain after initial plant uptake (Armah, 2011).

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

Insecticide residues in crops are monitored with reference to Maximum Residue Limits (MRL) and are based on analysis of quantity of a given residue remaining on food product samples. The MRL is not a health-based exposure limit and thus exposure to residue in excess of an MRL does not necessarily imply a risk to health (Boobis *et al*., 2008).

1.2 PROBLEM STATEMENT

Organochlorine insecticides are very stable compounds and can persist in the environment for long periods of time after their use. Organochlorines are fat-soluble, meaning that they can accumulate in humans, animals, plants and fatty tissues (Williams *et al.,* 2000). The indiscriminate use of insecticides by farmers to increase yield exposes humans and the environment to organochlorine insecticides. The health of farmers is compromised during application of these toxic chemicals. Organochlorines have been banned in Ghana but residues are still present in food either as a result of persistence, illegal use and a small part from smuggling (NPASP, 2012). Fruits under study are consumed with no preparation. The common practice in Ghana is washing fruits under running water. However, due to limited availability of water, most traders wash fruits in a bowl of water and the water isn't changed

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regularly. Consumption of fruits with insecticide residue could pose serious health risk to consumers as well as reduce nutritional values of these fruits and hence the need for concern.

1.3 OBJECTIVES OF THE STUDY

1.3.1 Main Objective

The study seeks to determine the level of organochlorine insecticide residues in mango (*Mangifera indica*) fruits from the Dangme West District of Ghana.

1.3.2 Specific Objectives

- To assess farmers' knowledge on insecticide use, practices and potential to harm the environment.
- To assess and compare the levels of organochlorine insecticide residues in mango (*Mangifera indica)* fruits produced in the Dangme West district at the farm gate and from the open market.

1.4 JUSTIFICATION FOR THE STUDY

Organochlorine insecticides like DDT, lindane, Chlordane, Aldrin and Endrin were widely used in the past because they are cheap, easy to synthesize and their broad spectrum activities. They have been prohibited from use in Ghana because they are environmentally persistent (Fianko *et al*., 2011). Many groups including Consumer Associations, Non-governmental Organizations and International bodies are against the presence of these persistent pesticides in the environment. They perceive the presence of insecticide residues in the environment as potentially detrimental to

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human health and water quality. The contamination of the environment and exposure of the public to pesticide residues in food could lead to high health risk. There is therefore the need to constantly monitor fresh fruits at farm gates and on markets to ensure safety of the consumers (Fianko *et al.*, 2011).

Mango production in the Dangme West district is on commercial basis for sale in the country and also for export. The fruits for export are expected to match the needs, expectations and requirements of purchasers as well as those of the regulatory authorities in export markets. Those that remain on the local market are not regularly monitored ((Ghana News Agency, 2012: NPASP, 2012). The study therefore seeks to address this concern and provide data on residues in mangoes from the district. Relatively few studies have been done on the relationship between residues in mango fruits from farm gate and those on markets in Ghana. This study will therefore go a long way to add to the growing literature on organochlorine insecticide residues in the environment.

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CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Occurrence of Organochlorine Insecticides in Humans and the Environment

Pesticides have been used for many years to decrease adverse effects of pests on a variety of crops. Pesticides may be classified as major agricultural classes of insecticides, herbicides and fungicides. Additional groupings are rodenticides, nematodicides, molluscicides, attractants (pheromes), defoliants, dessicants, plant growth regulators and repellents. Approximately thousand (1000) chemical compounds, biological agents and physical agents sometimes marketed as various brand names and formulations are utilized in many areas of the world (Krieger, 2001).

The most widely used pesticide among farmers is the organochlorine insecticide because of their cost effectiveness and their broad spectrum activity (Bempah *et al.*, 2011). Organochlorine insecticides use was wide spread 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 the 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 for human ectoparasite disease. Some are still commonly used in developing countries (Williams *et al.*, 2000).

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 applied to soil, a number of things may happen to an agrochemical. It may be taken up by plants or ingested by animals, insects, worms, or microorganisms in the soil. It may move downward in the soil and either adheres 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. Evaporation of water at the ground surface can lead to upward flow of water and insecticide. 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 – their lipophilicity, low vapour pressure and slow rate of degradation 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).

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Effects of pesticides have been reported in milk, vegetables, fruits, meat, fish meal and other foods in Ghana. Analysis of street-vended food samples in Accra, between 1999-2000 revealed disturbing levels of contamination by pesticides, heavy metals, microorganisms and mycotoxins. Vegetables on the Ghanaian market were found to contain detectable levels of lindane, endosulfan and DDT residues in lettuce, cabbage, tomato and onion. The possible reason for pesticides to reach these aquatic environments is through direct runoff, leaching, careless disposal of empty containers, equipment washing. Studies on pesticide residues in exportable quality cocoa beans collected from selected cocoa growing districts in the middle belt of Ghana and the two shipping ports at Tema and Takoradi also showed detectable amount of lindane residues; the average level was about 10% of the maximum residue level of 0.1 µg/g permitted by Codex Alimentarius Commission . 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. 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).

Studies conducted by Bempah *et al*., (2011) in fruits and vegetables from the Kumasi metropolis of Ghana revealed that consumers in the metropolis are exposed to concentrations of pesticide that may cause chronic diseases. An average of concentration 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 done 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 blockage of other soil microorganisms of both organic and inorganic constituents in the soil, hence decreasing the soil fertility. Yield of vegetables notably garden eggs and tomato were suppressed by increased application of lindane. Pesticide application had a higher effect on fungal population. Studies of the solubility of pesticides and its sorption on soil are known to be inversely related, increased solubility implies less sorption. Sunlight induced reactions may contribute to the chemical transformation of organic pollutants.

2.2 Organochlorine Compounds

Organochlorine insecticide is a kind of synthetic chemical which can be divided into two groups: one takes the benzene as the raw material and the other takes the cyclopentadiene. They are both very stable therefore persistence and bioaccumulation is very strong (Rathore, 2012).

2.2.1 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 on fruit, vegetables,

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and forest crops. It is a white solid that may evaporate into the air as a colorless vapor with a slightly musty odor. 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 insecticide use. 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. Technical-grade HCH has not been produced or used in the United States in over 20 years (ATSDR, 2011). Gamma – HCH may be converted to other isomers in the environment and also micro – organism and plants may convert gamma – HCH into alpha, beta or delta schemes. Bioisomerism does not appear to be a significant path way in mammals. In mammals, metabolism of alpha- HCH generally leads to less chlorinated unsaturated metabolites. Gamma HCH undergoes dechlorination in alkalis with DT_{50} values (22^{o}C) of 91 days (pH7) and 11 hours pH9 (Roberts *et al.*, 1999).

Gamma – HCH (lindane) exposure has been associated with recurrent miscarriages. Women with recurrent miscarriages had average lindane concentrations of 6.99 ppb (ng/ml). Lindane also disrupts natural levels of estrogens, androgens and thyroid hormones in rodents (ACAT and Commonweal, 2012).

2.2.2 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 direct foliage. Metabolic processes by which it undergoes transformation are

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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, 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).

2.2.3 Chlordane

Chlordane is viscous, amber to coloured liquid with slight 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. It’s an insecticide used to control termites, ants and other insects. It enters the environment primarily for 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 its initial application.

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2.2.4 Dichlorodiphenyltrichloroethane (DDT)

DDT is a commercial organochlorine insecticide that has been used in agricultural crops as well as vector control. Technical grade DDT is a mixture of fourteen (14) compounds. The active ingredient is p,p- DDT (65% to 80%). The other compounds include o,p- DDT, up to 4% of p,p-DDD and other substances. DDT compounds can be degraded to DDD under anaerobic conditions while it can be degraded to Dichlorodiphenyldichloroethylene. 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, 2012).

2.2.5 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, and binds to soil particles. 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, 2012).

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2.2.6 Endrin

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

Endrin released to soils will persist for up to 14 years or more. It is persistent in treated soils and accumulates in sediments and terrestrial biota but known to be broken down by sunlight. It has a high potential to accumulate in fish and shell fish. The chemical is shown to cause damage to liver, kidney and heart of laboratory animals. In humans, endrin was linked with headache, dizziness, sweating, insomania, nausea and general malaise (Udeh, 2004).

2.3 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 indicates that organochlorines are endocrine

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disrupters. Epidemiological studies suggested an etiological relationship between exposure to organochlorines and Parkinson's disease. Studies indicates a decrease in sperm counts have been associated with exposure to organochlorine insecticides (Kannan *et al.*, 1997).

2.4 Challenges of Alternative Approach to Insecticide Use

Integrated Pest Management (IPM) and organic agricultural strategies produce comparable yields to conventional farming, but adoption of these approaches remains low so far for a variety of reasons (Ntow *et al.*, 2006).

2.4.1 Integrated Pest Management

Integrated pest management is pest management system, that in the context of associated environment and population dynamics the pest species, utilizes all possible techniques and methods in as compatible manner as possible and maintains pest populations at levels below their causing economic injury. It is the integration of all suitable management techniques with the natural regulating and limiting elements of the environment (Koul *et al.*, 2004).

The lack of information on IPM by farmers and extension officers is a major constraint in its implementation. Studies in India reveled three quarters of farmers were not aware of its existence. The mind set of farmers that pesticides are more effective and cost effective also poses a problem for IPM implementation. There also appears to be a conflict between the pesticides industry's need to increase sales and the IPM message (Koul *et al.*, 2004).

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2.4.2 Organic Farming

Organic agriculture is a highly ethical form of agricultural production, with clear concerns for animal and human welfare (Taji and Reganold, 2007). Traditional farming in Ghana can be deemed organic by default simply because it does not use synthetic agriculture inputs or soil-building practices. However, such systems fail to meet food security needs or to protect the fragile environments of the continent largely due to the unsustainable ways of managing the environment and the predominantly subsistence nature of farming. However, where conversion to organic farming has been fully achieved, economic and viable yields are attained. In Africa and for that matter Ghana, organic farming can be classified into two different levels based on certification: certified organic production and non-certified or agro ecological farming (Osei – Asare, 2009).

2.5 Farmer Perceptions and Pesticide Use Practices

Ntow *et al.*, (2006) indicates that the perceptions of farmers regarding, in particular, pesticide risks to human health are important since:

- They may influence decisions regarding pesticide use
- If these perceptions differ from expert opinion, it is useful to know why and whether they lead farmers to take more risks than they realize
- They may influence the methods of protection used against pesticides
- Technical advice given to farmers on pesticide use and crop protection may be inappropriate and irrelevant if it does not tally with their own views of pesticide health effects.

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Studies done by Banjo *et al.,* (2010) in Ogun State of Nigeria revealed that a large number of males compared to females were engaged in farming which is an indication of the South Western culture where the male is the farmer who brings the produce from the farm and females sell them. Farmers were unable to identify smaller pests even though had some education.

Another study by Banjo *et al.,* (2003) in three states of southwestern Nigeria revealed that most of the farmers showed a degree of awareness about the insect pests that are attacking their planted crops. However, in most cases they come across the common insect pest like grasshoppers, termites, larvae of the rhinoceros beetle, palm weevil and aphids. Some farmers claimed that the pests caused only minor damages to their crops, simply because of the types of control measures they applied or adopted. A number of traditional methods were used by the farmers to control pests including the use of wood ashes sprinkled around the base of cocoa and kola trees as well as on the vegetables. Wood ash was also sprinkled on vegetables to keep away caterpillars. Water extracts of the seeds and the leaves of neem tree were used as pest control by the farmers. Some farmers claimed that goat and cow dung has proved useful in plant protection, when sprayed on all green plants of vegetable and fruits. Even in the coconut nursery where termites (*Macrotermes bellicosus*) are major pests, goats and cow dung proved effective as pest control. Cow urine has been effective in the plant protection and adequate facilities for its collection must be provided. Sand, kaolin, husk ash, wood ash and clays constitute a group of materials which are commonly used by small scale farmers in the developing world to protect grains (Banjo *et al.,* 2003).

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The most frequently reported possible pesticide poisoning symptoms among farmers in Ghana are weakness, headache and dizziness. Information on pesticide application rates comes mainly from Agricultural Extension Officers and/or pesticide labels. To a more limited extent, information also comes from other farmers, pesticide dealers or advertisements. To measure pesticides, some farmers used spoons, measuring cylinders, cans and bottles. Mixing of pesticides was encouraged by the farmers' desire to have rapid knockdown of pests. This practice is questionable because farmers combine the different pesticides indiscriminately (Ntow *et al.*, 2006).

Farmers in Ghana use very little personal protection during spraying. This includes rubber boots, an overall with long sleeves, gloves and a piece of cloth to cover the mouth. The majority wear trousers and a long-sleeved shirt. However, some wore a short-sleeved shirt and short trousers, with no gloves, and wore slippers which exposed a greater part of their feet as well as used their bare hands to mix pesticides in a container. As a consequence, their legs, feet and hands came into contact with pesticides. The commonest way of disposing of sprayer wash water and empty pesticide containers among farmers studied was by throwing them on the field. Where farms are close to waterways, the disposal of unwanted pesticide solutions and empty containers in the field presents a problem for aquatic systems which are sources of livelihood for human communities and support varied animal and plant life (Ntow *et al.*, 2006).

2.6 Mango Production in Ghana and Associated Pests

The mango tree originates from the Indian/Burmese monsoon region. The Mango fruit (*Mangifera indica L.*) is the most important tropical fruit after the banana, yet

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due to its sensitivity to bruising, in terms of numbers, it plays only a small role in world trade. Mango has been disseminated for a long time, and is cultivated in all warm countries down to the sub-tropics (Naturland, 2001).

Mango belongs to the family of Anacardiaceous. It is a rapid growing, evergreen tree with a dense, outspread coronet. Its leaves grow alternately, and red-violet or bronze-coloured in the early stages, then of a dark-green, leathery consistency. The blossoms are generally hermaphrodite, and pollination occurs through flies and other insects. Certain types of mango need to be manually pollinated. Mango blossoms up to 3 times a year, depending on climate and fertilization conditions. If the first blossom is not pollinated, a new blossom is induced. Ripe fruits are between yellow, orange-yellow, red or red-green in colour, and contain a flat stone, which is very difficult to separate from the thick fibres of the pulp (Naturland, 2001).

2.6.1 Mango Production in Ghana

In the Southern Belt (Greater Accra, Eastern and Volta Region) of Ghana, large businesses with mostly huge acreages operate as producers and exporters of mangoes at the same time. Small scale farmers are mostly organized in associations since it is mostly difficult to enter business individually (capita – expensive). In the Transition Belt (Brong Ahafo and Ashanti Region), mango farmers are either individual farmers or organized in associations. In the Northern Belt (Northern Region), the Integrated Tamale Fruit Company (ITFC) created an out –grower scheme allowing every participating farmer to grow one acre of mango with input support on a credit basis. Due to the ITFC involvement in the mango sector, small scale farmers are able to grow mangoes in addition to their other farming activities (Wohlmuth *et al.*, 2008)

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Producers of exotic mango varieties can be found close to roads and market centers and are concentrated in areas in the south supported by United States Agency for International Development (USAID). A few companies producing fruit salad, dried mangoes and juice can be found in the Southern Belt (Greater Accra). Only one pulp processing industry is located in the Transitional Belt. They have processed mangoes on trial basis and haven't started exporting yet (Wohlmuth *et al.,* 2008).

2.6.2. Pests Associated with Mango Production

Farmers often get high yield for fruits with no insect damage on the market. Pests are therefore of concern to farmers. Some of the pests of economic importance to mango fruits are fruit flies (*Drosophila melanogaster*), seed weevils (*Sternochetus mangiferae* F.), thrips (*Scitothrips dorsalis* G.) and spider mites (*Tetranychus urticae* K.) (Pena *et al.,* 2002)

The worst pests for mangoes are mealy bugs (Pseudococcus obscurus), cicadas (*Tibicen pruinosa*) and black flies (*Simulium spp*.). These are all sucking insects that live on the leaves, young buds and shoots. They can cause a lot of damage. Yet they all have natural enemies, such as ladybird larvae (*Coccinella septempunctata*) and wasps (*Vespa vulgaris*) (Naturland, 2001).

According to Thistleton and Spencer (2012), pesticides registered or with permits for mango production include the following:

- Methidathion, fenthion and dimethoate (Organophosphates)
- Carbaryl (Carbamates)
- Pyrethrum (Pyrethroid)

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- Mineral and Vegetable Oils

2.7 Regulatory Requirements Regarding Pesticide Use in Ghana

The Environmental Protection Agency of Ghana is the Agency responsible for the enforcement of Act 490 of the Environmental Protection Act, 1994. The second part of the Act 490 deals with pesticides control and management.

The Act requires registration of pesticides (Section 28 - 39). No one is supposed to import, export, manufacture, distribute, advertise, sell or use a pesticide unless the pesticide has been registered by the Agency in accordance with this Act. In determining whether or not to approve the registration of a pesticide and the classification of a registered pesticide, the Board shall consider:

- the characteristics of the pesticide formulation, such as the acute dermal, oral or inhalation toxicity;
- the persistence, mobility and susceptibility to biological concentration of the pesticide;
- the experience gained from the use of the pesticide, such as the likelihood of its misuse and any good safety record which is contrary to available laboratory toxicological information

This Part was enacted as the Pesticides Control and Management Act, 1996 (Act 528). A pesticide registration remains valid for a period not exceeding three years from the date of registration. The Agency publishes annually in the Gazette registered pesticides and their classification, provisionally cleared pesticides, suspended or banned pesticides, and amendments made to the classification of pesticides (EPA Act, 1994).

A license is required to deal in pesticides however the agency may by legislative instrument exempt the requirements of a license. Labeling and packaging should conform to the prescribed EPA standards and records should be kept and made available for inspection on request. The Board may delegate any of its functions to a committee of the board or any other person. The pesticides technical committee of the Board consists of various stakeholders who perform functions assigned to it by the Board (Sections 52 and 53). The Act provides penalties for various offences (EPA Act, 1994).

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CHAPTER THREE

3.0 METHODOLOGY

3.1 DESCRIPTION OF STUDY AREA

The Study area is the Dangme-West District of the Greater Accra Region of Ghana. The area forms 41.5 % of the landmass of Greater Accra Region. It has a population size of 96,809. Agriculture is the dominant occupation. Crop, livestock farming, and fisheries are the major activities in the district, employing 58.6 per cent of the people (Ministry of Food and Agriculture (MOFA), 2011).

Vegetation is mostly coastal savannah and small transitional zone along foothills of Akuapem range. The predominant soil types in the district are the Black clays classified as Akuse series in the large central to eastern parts of the district (MOFA, 2011). The soils are highly elastic when wet but become hard and compact when dry and then crack vertically from the surface. This renders the soil unsuitable for hand cultivation thus mechanized irrigation farming is prevalent (Ministry of Local Government and Rural Development (MLGRD), 2006).

At the gentle foot slopes of the Akwapim Range north of Dodowa, Agomeda and Ayikuma occurs an accumulation of slope wash from the hills above. The slope wash material consists predominantly of the Oyarifa series. These are deep, red, well-drained loamy soils (MLGRD, 2006). Crops production includes maize, cassava, rice, tomatoes, garden eggs, okra, pepper, watermelon, sugarcane, banana, pineapple, pawpaw and exotic vegetables (for export). Tree crops grown are mainly mangoes with a few small- scale cashew plantations in the Ningo area.). Exportable mangoes are under cultivation with varieties like Keitt, Kent, Palmer and Springfield. There is about 20km stretch of the Volta River for irrigation (MOFA, 2011). The soil types, which occur further east of Dodowa, within the Doryumu and Kordiabe areas, are of the Simpa-Doryumu-Agartar-Association. These are brownish grey, slight humus, medium or coarse sand, underlain by a hard porous gristly loam. The soils have low nutritional status and are quick in becoming parched after the end of the rainy season. Rainfall pattern is bimodal (MLGRD, 2006). A map of the study area is shown in Figure 1.

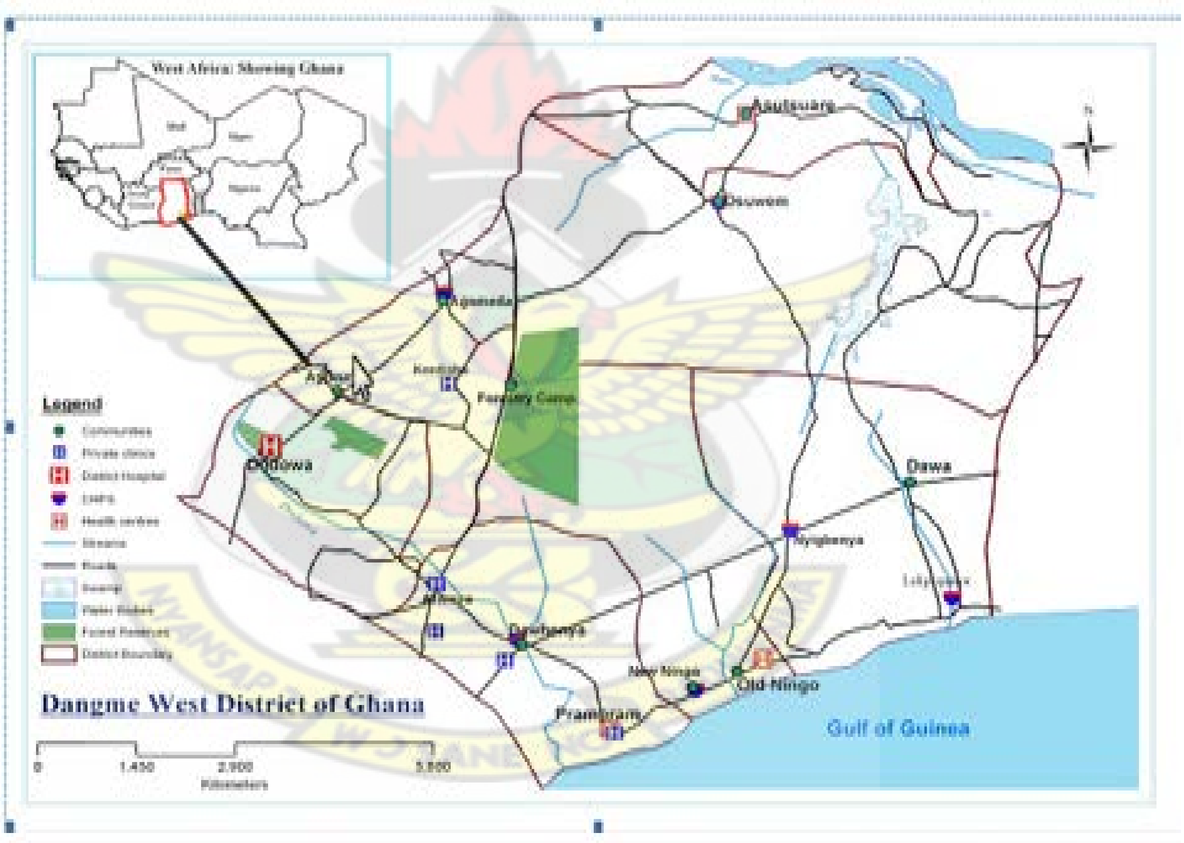

Figure 1. Map showing the Dangme West District of Ghana.
Source: DHRC (2011)

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3.2 QUESTIONNAIRE ADMINISTRATION

Fifty farmers were randomly selected and interviewed using a well structured questionnaire with closed and open ended questions (Appendix one). This was done to ascertain farmers' knowledge on insecticide use and practices and potential to harm the environment as well as identify some health problems faced as a result of insecticide application by the farmers on their farms. The questionnaire was pre – tested before 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. Field observation and spraying practices of five respondent farmers were conducted.

3.3 FRUIT SAMPLING

A total of 100 mango fruits were sampled from nine conventional farms, one non-sprayed farm and two markets in Accra and Tema for assessment of organochlorine insecticide residues.

One mango fruit was taken from nine different parts of each farm including the center to get a total representation of the farm. Gloves were worn during plucking of the fruit to prevent cross contamination of fruit samples. Due to the large sizes of the fruits, each fruit was sliced on the field wrapped in aluminium foil and then placed in

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a labeled zip lock bag to make it less bulky. Fruits were then transported to the laboratory in an ice chest with ice cubes.

Five fruits each were purchased from the Madina market and Tema Community One market respectively under normal purchase conditions from ten randomly selected sellers who retailed from the Dangme West District of Ghana. Each fruit was sliced at the market and wrapped in aluminium foil and placed in labeled zip lock bags and transported to the laboratory in an ice chest with ice cubes.

3.4 LABORATORY ANALYSIS

Laboratory analysis was carried out at the Nuclear Chemistry and Environmental Research Laboratory of the Ghana Atomic Energy Commission of Ghana.

3.4.1 CLEANING OF GLASSWARE

Prior to the analysis, glass wares for analysis were cleaned with detergent and rinsed with tap water. They were further rinsed with acetone and dried overnight in an oven at 150ºC and stored in dust free cabinets.

3.4.2 REAGENTS

Standards of gamma-HCH, aldrin, dieldrin, endrin, p,p'-DDE, and p,p'-DDT were obtained from Supelco (Bellefonte, PA, USA). Acetone, n-hexane, were Super Purity Solvents from Romil (Cambridge, UK). Ethyl acetate for instrumental analysis was from Pancreac (Barcelona, Spain).

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3.4.3 EXTRACTION AND CLEAN UP

Nine fruits from each farm were peeled and sliced. The pulp was blended using a glass blender into a composite sample. Five fruits from each market were also peeled, sliced and the pulp was blended using a glass blender to form a composite sample. A total of twelve composite samples from the ten farms and two markets were analyzed.

Approximately 20g of each sample was weighed into a conical flask. 5g of sodium bicarbonate was added to neutralise the acid and 20 g of anhydrous sodium sulphate was added to reduce moisture content of the sample. 100 ml of GC grade n-Hexane and 50 ml ethyl acetate were added to the sample using a measuring cylinder and shaken on the mechanical shaker at 300 Revolutions per minute (RPM) for one hour. The samples were then filtered into a round bottom flask using a funnel lined with filter paper and activated charcoal. Samples were then poured into 20 ml test tubes and centrifuged at 4^oC at 3000 RPM for 10 minutes to separate the solids from the liquids if present using a CRi multifunction centrifuge. There was however no solid present after centrifugation. Büchi RE-200 rotary vacuum evaporator was used to evaporate solvents into the round bottom flask by placing the solution in the Büchi Heating bath B-490 at 40 degrees Celsius.

Clean up column was packed with 1g SiO_2, 1.5g sodium sulphate and 1g of activated charcoal powder. The column was conditioned using 5ml of ethyl acetate. Pasteur pipette was used to pick sample that was left after evaporation into the clean up column. 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

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acetate. Glass Pasteur pipette was then used to pick samples into 1.5 ml GC valves for analysis by the Gas Chromatography (GC).

3.4.4 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 triplicates and the mean concentrations computed accordingly.

3.4.5 3.4.5 GAS CHROMATOGRAPHIC ANALYSIS OF CHLORINATED RESIDUES

The residues were analyzed by Shimadzu gas chromatograph, GC-2010 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*0.25mm, 0.25µm film thickness). Carrier gas and make-up gas was nitrogen at a flow rate of 1.0 and 29ml/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 60^{0} C for 2 minutes and at 180^{0} C/min up to 300^{0} 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

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column was coated with ZB-17 (50% phenyl, methyl polysiloxane) and ECD was also used as detector. The conditions used for these columns were the same.

3.4.6 QUALITY CONTROL MEASURES

The efficiency of the method was determined by recoveries of an internal standard. One blended mango sample was spiked with a 50µL of 100ng/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.

3.5 STATISTICAL ANALYSIS

Analysis of variance (ANOVA) was used to analyze 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, year 2007). Responses to the questionnaire were analysed using Microsoft Excel.

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CHAPTER FOUR

4.0 RESULTS

4.1 PERSONAL DETAILS AND WORK HISTORY OF FARMERS

Table 1 shows that majority of the farmers (94%) are males. A greater percentage of the farmers (70%) are farm owners and 36 % of the farmers interviewed had some formal education. A greater number of farmers (60%) had been farming for a period of five (5) to ten (10) years.

Table 1 Personal details and work history of mango farmers interviewed

VARIABLE	FREQUENCY	PERCENTAGE (%)
Sex		
Female	3	6
Male	47	94
Status of Farmer		
Farm Owner	35	70
Labourer	15	30
Educational Background		
Formal Education	17	36
No Formal Education	33	64
Number of years of farming		
0-5	8	16
5-10	30	60
10-15	6	12
15-20	6	12
TOTAL	50	100

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4.2 INSECTICIDE USE AND PRACTICES

4.2.1 Farmers' sources of insecticides and knowledge on application rates

Table 2 shows the sources of insecticides of the farmers in the Dangme West District and how the farmers are able to determine the application rates of these insecticides for production. A greater number of farmers purchase insecticides from the market themselves (80%) whereas the rest (20%) ask the extension officers to help them purchase it. 50% of respondents depend on the shop keepers for the application rates whereas the 30 % seek help from the extension officers. 20 % were however able to read instructions on the label themselves.

Table 2 Sources of Insecticides and knowledge on rate of application by farmers

VARIABLE	FREQUENCY	PERCENTAGE (%)
Source of Insecticide		
Market	40	80
Extension Officers	10	20
Knowledge on rate of application		
Label	10	20
Extension officer	15	30
Shops	25	50
TOTAL	50	100

4.2.2 Knowledge of route of exposure of insecticides

Farmers' knowledge on route of exposure of insecticide to the human body is represented in Figure 2. Most of the respondents were aware that the eye (70%), skin (80%) and swallowing (80%) are the routes by which insecticides enter the human

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body. However, only 30% were aware that inhalation is also a route of exposure to insecticides.

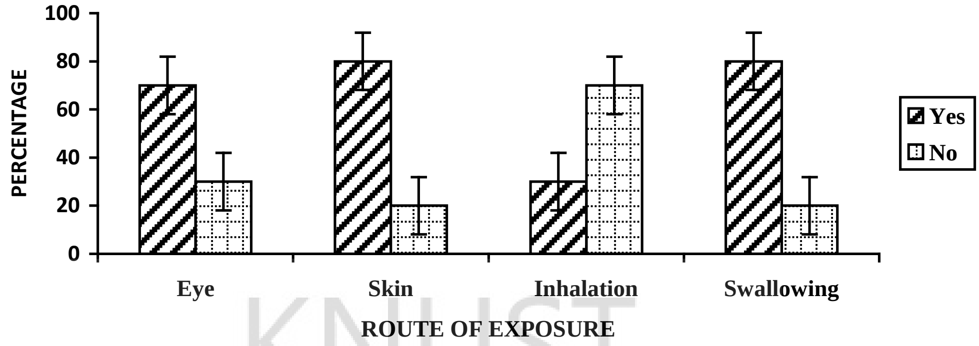

Figure 2 Graph showing farmers' knowledge on route of exposure.

4.2.3 Use of Personal Protective Equipment (PPE) during spraying

Farmers use PPE including goggle, overcoat, gloves, nose masks and boots during spraying. All farmers interviewed use overcoat and boots during spraying representing 100%. 60% of respondents use nose mask whereas 50 % wear gloves during handling of chemicals. Only 10% protect their eyes by wearing goggles. The percentages of farmers who use the various PPE are represented in the figure 3.

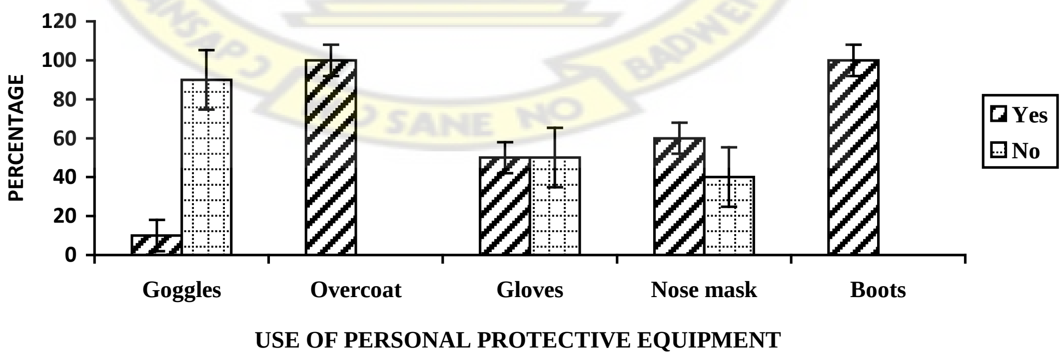

Figure 3 Graph showing use of Personal Protective Equipment by farmers.

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4.2.4 Health Problems experienced by farmers as a result of Insecticide application.

Eighty percent (80%) of farmers experience watery eyes and headache after spraying. Sixty percent (60%) of respondents indicated that they feel dizzy after spraying. Chest pain, nausea and skin irritations are experienced by 40%, 20 % and 30% of respondents respectively. All the farmers indicated that re – entry period into the farm after spraying depended on the type of insecticide and the instructions given as shown in Figure 4.

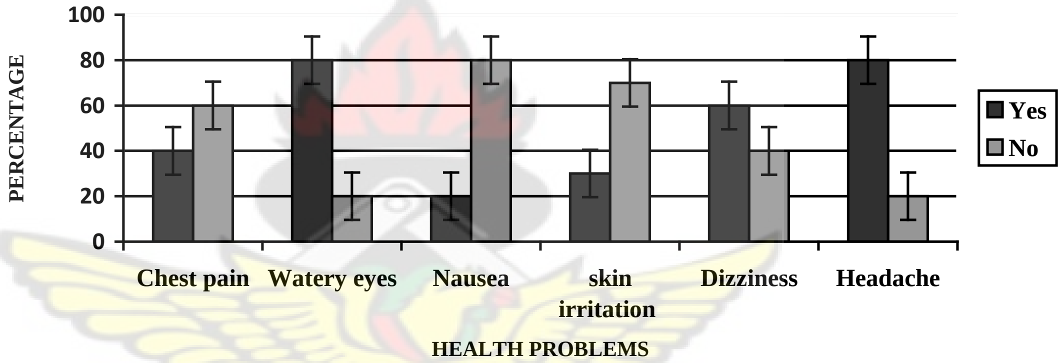

Figure 4 Graph showing health problems experienced by farmers after application of chemicals.

4.2.5 Knowledge of potential for Insecticide to harm the environment

Farmers' knowledge of the potential of the insecticides used as harmful is shown in figure 5. Majority of farmers (80%) were aware that insecticides have the potential to harm living organisms if not used properly whereas 20% indicated that they did not know that. None of the farmers had experienced any accidental spillage of insecticide on their farms.

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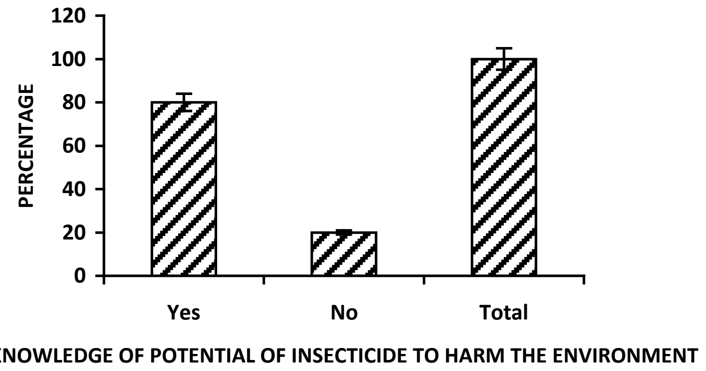

Figure 5 Graph showing farmers' knowledge of potential for insecticide to harm the environment

4.2.6 Disposal of water used for washing spraying machine

Disposal of water used for washing spraying machine after spraying varies and this is represented in figure 6. Seventy percent (70%) of respondents dispose of water used for cleaning the sprayer after spraying on the field. 20% had a designated area for disposing off the water whereas only 10% disposed off the water in a canal.

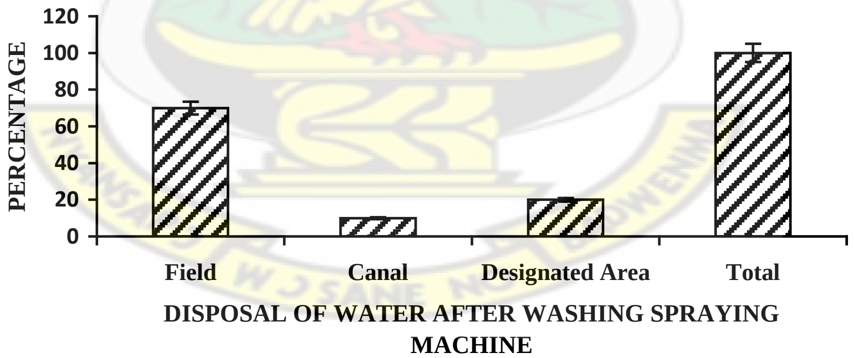

Figure 6 Graph showing disposal of water used for washing of spraying machine after spraying

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4.2.7 Disposal of empty insecticide containers

After mixing of chemicals and spraying the empty containers are either incinerated by 80% of the respondents or packed in sacks for collection and incineration later by 20 % of the respondents. This is represented in figure 7.

Figure 7 Graph showing disposal of empty insecticide containers by farmers

4.3 ORGANOCHLORINE INSECTICIDE RESIDUES IN MANGO FRUITS

4.3.1 Organochlorine Residues in Mango Fruits from Unsprayed Farm in the Dangme West district of Ghana.

Figure 8 shows the percentage of chemical residues present in fruits from the unsprayed farm. Heptachlor was highest with a concentration of 5.71ng/g and accounted for 51%. Gamma – HCH had a concentration of 2.72 ng/g and accounted for 25%. Delta – HCH recorded a concentration of 1.65 ng/g and accounted for 15%. Aldrin recorded a concentration of 0.5 ng/g and represented 15%. O,p-DDT recorded a concentration of 0.07ng/g and represented 5%. Alpha – HCH, trans - Chordane, trans- Nonachlor and o,p –DDT represented 1 % each.

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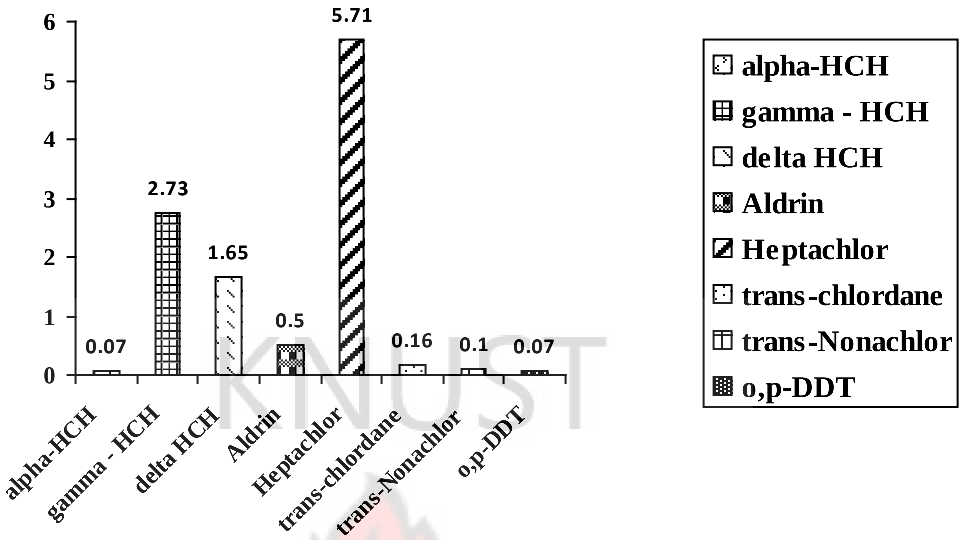
Figure 8 Graph showing percentage of concentration of organochlorine



insecticide residues in mango fruits from unsprayed farm.

4.3.2 Mean Organochlorine Residues in Mango Fruits from Conventional Farms in the Dangme West District of Ghana

Figure 9 shows the mean concentrations of organochlorine insecticide residues in mango fruits sampled from the conventional farms during the survey. There were no residues of cis – chlordane, oxy-chlordane, cis-Nonachlor in samples analyzed. The chemical with highest concentration was Heptachlor and had a mean concentration of 4.6 ng/ g. Gamma – HCH and Delta – HCH had mean concentrations of 3.08 ng/g and 3.55ng/g respectively. Metabolites of DDT were also present. O,p –DDD and p,p – DDD had mean concentrations of 0.34ng/g and 0.18 ng/g respectively. O,p – DDE and p,p-DDE had mean concentrations of 0.33ng/g and 0.03ng/g respectively.

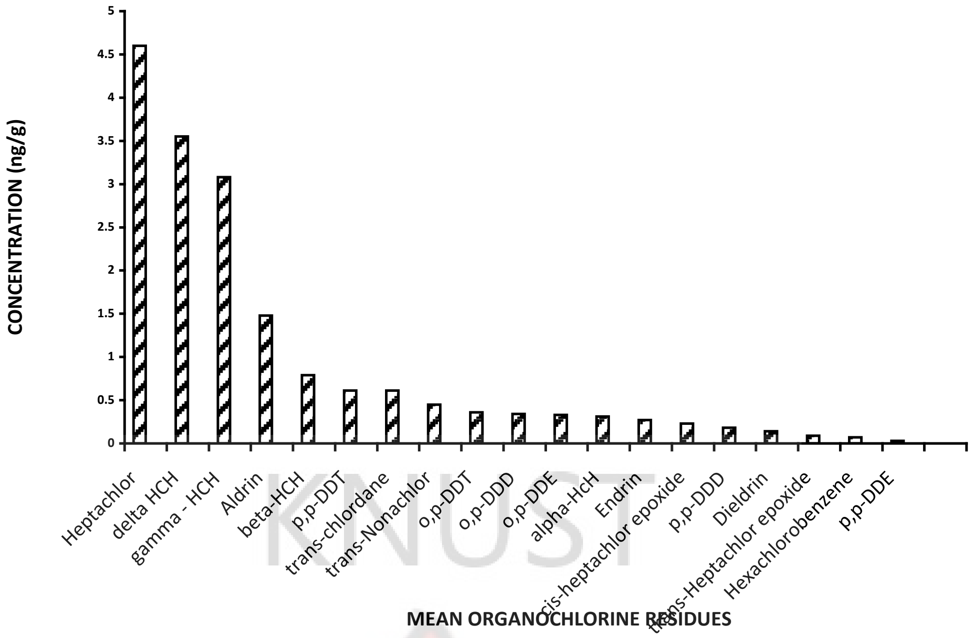


Figure 9 Graph showing mean organochlorine insecticide residues of mango fruits from the conventional farms

4.3.3 Mean Organochlorine Residues in Mango Fruits from Markets in Accra and Tema

The concentrations of organochlorine residues in mangoes from two markets in Accra and Tema are represented in Figure 10. It can be observed that there were no residues of endrin, trans-Heptachlor epoxide, oxychlordane, cis-Nonachlor and p,p-DDD in fruits from both markets. The highest concentration of residue is observed in fruits from the Accra market with an alpha-HCH concentration of 7.43 ng/g. Tema market however recorded a concentration of 1.2 ng/g for the same chemical. The highest concentration of chemical from the Tema market was observed for Heptachlor with a concentration of 3.87 ng/g. The same chemical however recorded a concentration of 5.57 ng/g in Accra market. Cis-heptachor, o,p-DDD, o,p-DDE, p,p-DDEand o,p-DDT residues were not present in fruits from the Tema market but were present in fruits from Accra market. In general, residues in fruits from the market in Accra were higher than those from Tema Market and this is represented in the graph.

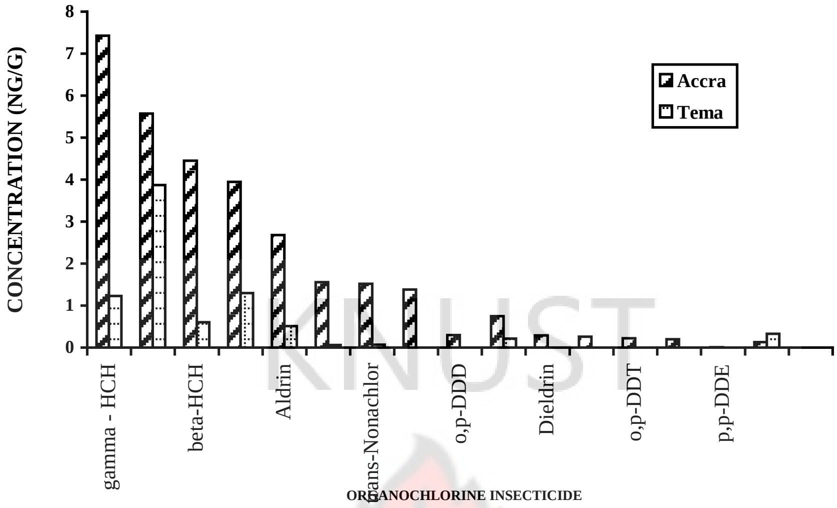


Figure 10 Comparison of concentrations of Organochlorine Residues in mango fruits from Markets in Accra and Tema.

4.3.4 Mean Organochlorine residues in mangoes from all three (3) locations in relation to European Union (EU) Maximum Residual Limits (MRLs)

The organochlorine residues of fruits from the three locations: one unsprayed farm (**1**), nine conventional farms (**2**) and two markets (**3**) is compared to the European Union (EU) Maximum Residual Limits (MRLs) for mangoes. These are presented in Table 3.

Twenty two organochlorine residues were analysed but only nineteen were detected in the mango fruits. Oxychlordane, cis-Chlordane and cis-Nonachlor residues were not detected in any of the samples analysed.

Table 3 Table showing concentration of organochlorine insecticide residues for the three sample locations in relation to EU MRLs

Insecticide	Location	Minimum (ng/g)	Maximum (ng/g)	Mean (ng/g)	MRL (ng/g)
Alpha-HCH	1			0.07	10
	2	0.04	0.09	0.31	10
	3	0.21	0.75	0.48	10
beta – HCH	1			ND	10
	2	0.09	2.97	0.79	10
	3	0.6	4.45	2.58	10
gamma - HCH (Lindane)	1			2.73	10
	2	0.34	7.18	3.08	10
	3	1.23	7.43	4.32	10
delta – HCH	1			1.65	10
	2	0.82	14.98	3.55	10
	3	1.3	3.95	2.62	10
Hexachlorobenzene	1			ND	10
	2	0.29	0.37	0.07	10
	3	0.33	0.13	0.23	10
Aldrin	1			0.5	10
	2	0.44	5.4	1.48	10
	3	0.51	2.7	1.42	10
Dieldrin	1			ND	10
	2	0.02	1	0.14	10
	3	ND	0.18	0.09	10

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Insecticide	Location	Minimum (ng/g)	Maximum (ng/g)	Mean (ng/g)	MRL (ng/g)
Endrin	1			ND	10
	2	0.08	1.82	0.27	10
	3			ND	10
Heptachlor	1			5.71	10
	2	0.17	8.52	4.6	10
	3	3.87	5.57	4.72	10
cis- Heptachlor epoxide	1			ND	10
	2	ND	2.11	0.23	10
	3	ND	1.38	0.69	10
cis - Chlordane	1			ND	10
	2			ND	10
	3			ND	10
Oxychlordane	1			ND	10
	2			ND	10
	3			ND	10
trans- Chlordane	1			0.16	10
	2	0.03	2.4	0.61	10
	3	0.06	1.6	0.81	10
cis- Nonachlor	1			ND	10
	2			ND	10
	3			ND	10
trans-Nonachlor	1			0.1	10
	2	0.02	1.19	0.45	10
	3	0.07	1.6	0.79	10
o.p-DDD	1			ND	50
	2	0.1	1.3	0.34	50
	3	ND	0.3	0.15	50
p,p-DDD	1			ND	50
	2	0.4	1.12	0.18	50
	3			ND	50

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Insecticide	Location	Minimum (ng/g)	Maximum (ng/g)	Mean (ng/g)	MRL (ng/g)
o,p-DDE	1			ND	50
	2	0.9	2.09	0.33	50
	3	ND	0.2	0.1	50
p,p-DDE	1			ND	50
	2	0.04	0.22	0.03	50
	3	ND	0.01	0.01	50
o,p-DDT	1			0.07	50
	2	0.07	1.4	0.4	50
	3	ND	0.23	0.11	50
p,p - DDT	1			ND	50
	2	0.1	2.4	0.61	50
	3	ND	2.6	0.13	50

Location 1: One unsprayed Farm

Location 2: Nine conventional Farms

Location 3: Two Markets

ND - Residues not detected

MRL – Maximum Residual Limits (EU Pesticide Database, 2012)

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CHAPTER FIVE

5.0 DISCUSSION

5.1 Personal Details of Farmers Interviewed

A greater part of the farmers (94%) interviewed were males and predominantly farm owners who had been farming for a period of five to ten years. The large number of males and fewer number of females indicates the south western culture where the male farmer brings produce home and women sell (Banjo *et.al.,* 2010). The females were mostly farm owners and had acquired labourers to work on the farm due to the tedious nature of maintaining the farm and large farm sizes. Only 36% had acquired some form of formal education and could read and write. They didn't however have adequate technical knowledge on pesticide application.

5.2 Farmers' sources of insecticides and knowledge on application rates

Eighty percent (80%) of farmers purchase insecticides from the market themselves whereas the rest (20%) require the help of extension officers in purchasing it. Chemicals were readily available on the open market so farmers could purchase. Some of the farmers however chose to depend on extension officers to purchase for them. Although 34 % had some form of formal education only 20% could read the instructions on the labels themselves and so the rest depend on extension officers and shop attendants. This could be attributed to the fact the instructions are technical and some farmers get confused trying to follow the instructions. Extension officers were readily available to farmers and hence the farmers could approach them for help regarding instructions and application rates of the insecticides.

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5.3 Exposure to Insecticides and Use of Personal Protective Equipment (PPE)

Farmers were aware that exposure of chemicals could result in health problems. Respondents were aware that the eye, skin, swallowing and inhalation could pose some risk. It is common practice for farmers to use overcoats and boots during spraying. However, little attention is paid to protection of eyes as only10% wearing goggles during spraying. These results are similar to the study done in the Ashanti, Greater Accra, Central, Eastern, Northern and Upper East Regions of Ghana (Ntow *et al.*, 2006). Some farmers have their houses close to the farms and this poses health risks as the chemicals can be transported to their homes after spraying. This poses a risk to families and farm hands of farmers who live close to the farms.

5.4 Health Problems experienced by farmers as a result of Insecticide application.

Farmers indicated that they experienced chest pains after spraying. This could be attributed to the heavy spraying machine carried during spraying. Farmers also experience watery eyes, headache, nausea, skin irritation and dizziness. Similar responses were obtained in the Ashanti, Greater Accra, Central, Eastern, Northern and Upper East Regions of Ghana (Ntow *et al.*, 2006). The use of inadequate Personal Protective Equipment during spraying and the chemical composition of insecticides could also account for these symptoms.

All the farmers indicated that re – entry period into the farm after spraying depended on the insecticide used and the instructions given on the label. They therefore post red flags at the entrance to prevent other people from entering the farms after spraying.

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5. 5 Knowledge of potential for Insecticide to harm the environment

Knowledge of potential of chemicals to harm the environment is important. In as much as the health of the farmers is a concern, protection of the environment is equally important. Majority of farmers interviewed were aware of the fact that inappropriate insecticide use could adversely affect the environment. None of the farmers had experienced accidental spillage of chemicals on their farms before. This could be attributed to good handling practices of insecticides by farmers.

5.6 Disposal of waste water and empty cans after spraying

A greater number of respondents (70%) indicated that water used for washing spraying containers is poured back on the field. This is similar to findings from studies done by Ntow *et al.,* (2006). The remaining respondents dispose off the water in a designated area outside the field or in open canals. This could result in contamination of farm soils and surrounding water bodies.

The empty containers are mostly incinerated by farmers in designated area by farmers. This should not be encouraged since the incineration of empty chemical containers is done in the open and releases noxious combustion products including acids (HCl), Polyaromatic Hydrocarbons and metals. Farmers who did not have designated areas for incineration pack the empty containers in sacks for collection and incineration by authorized persons.

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5.7 Organochlorine residues in mangoes from conventional farms and the unsprayed farm

Organochlorine residues were generally not detected in fruits from unsprayed farms. Even though no insecticide had been applied to the unsprayed farm in the last four years, there were residues of eight chemicals. The 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 is evident in the presence of 0.07 ng/g residue of o,p-DDT in fruits from the unsprayed farm.

Heptachlor and its epoxide can persist in the environment for a long time (Rathore, 2012). This is evident in the presence of Heptachlor from both locations. Fruits from sprayed and conventional farms recorded concentrations of 4.6 ng/g and 5.71. ng/g respectively. Gamma-HCH (lindane) which has been banned in Ghana (Rathore 2012) recorded a mean concentration of 3.08 ng/g in the fruits from the conventional farms.

5.8 Organochlorine residues in mangoes from the markets.

In Accra, the chemical with the highest mean concentration was alpha – HCH with a concentration of 7.43 ng/g. Heptachlor had the highest mean concentration in fruits from Tema with a concentration of of 3.87 ng/g. Metabolites of DDT (o,p-DDD, o,p-DDE, p,p- DDE, o,p-DDT, p,p-DDT) and cis - Heptachlor was detected in fruits from market in Accra but were not present in those from Tema. Gamma-HCH (lindane) was also present in samples from both markets. Generally, residues were higher in samples from Accra than those from Tema. This could be attributed to the differences in handling and storage practices in these markets.

5.9 Organochlorine residues in mango fruits from unsprayed farm, conventional farm and markets.

The concentrations of alpha - HCH, beta HCH, gamma HCH, Hexachlorobenzene (HCB), cis -Heptachlor epoxide, trans-Chlordane and trans-Nonachlor residues were higher in samples from markets than those from the farms. The concentration of these chemicals on the fruits from the markets could be attributed to the chemical treatment of the fruits on the market.

Concentrations of o,p-DDD, o,p-DDE, p,p-DDE, o,p-DDT, p,p-DDT , Aldrin and Dieldrin residues were lower on fruits from the market. However, Endrin, trans-Heptachlor epoxide and p,p-DDD were not detected in fruits from the market even though they were detected in fruits at the farm gate. Heptachlor was the highest insecticide residue in the fruits from all the three sampling locations. Heptachlor is 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 results of this study can be compared to a study done by Bempah *et al*., (2011) on mango fruits from markets in Kumasi. However, the results in this study are lower than residues detected in tomatoes from the study done by Bempah *et al*.,

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(2011). The lower concentrations of organochlorine residues in this study indicate that there is minimal misuse of chemicals in the study area as a result of the ban of organochlorine insecticide residues for agricultural purposes in Ghana. Soils in the study area were not tested prior to the study. This however could also be a source of the residues as organochlorines are known to persist in the environment for a long time because of the physical and chemical properties of organochlorine compounds (Williams *et al.*, 2000).

Residues of alpha – HCH, Endrin, Dieldrin , cis –Heptachlor epoxide, trans – Heptachlor epoxide, Hexachlorobenzene, trans – Nonachlor, o,p-DDE, p,p-DDE and o,p-DDD showed significant differences at all the three sampling locations at $p<0.05$ (Appendix Two).

5.10 Concentration of organochlorine residues in mangoes in relation to EU MRLs

The residues detected in mango fruits from the Dangme West District were all below the recommended EU MRLs. This indicates that the mangoes are safe for human consumption. There is need for concern even though concentrations were below the MRLs because exposure from other sources will tend to result in cumulative effect of these insecticides in humans.

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CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

The study revealed that organochlorine residues in the mango fruits from the Dangme West District of Ghana were below the EU recommended MRLs. This indicates that the fruits are safe for consumption. However, the detection of organochlorine residues indicates that organochlorine residues are still present in the environment. There's therefore the need for constant monitoring since it could be bio-accumulated in consumers when consumed for a long period.

The persistent nature of these chemicals is also evident as residues of alpha-HCH, gamma-HCH, delta-HCH, aldrin, heptachlor, trans-chlordane, trans-Nonachlor and o,p-DDT were present in fruits from unsprayed farm. Heptachlor had not been oxidized to Heptachlor-epoxide. This was evident as there were no residues of heptachlor epoxide in fruits from the unsprayed farm. The concentrations of some residues (alpha-HCH, beta-HCH, gamma-HCH, HCB, cis-Heptachlor epoxide, trans-Chlordane and trans-Nonachlor) were higher in fruits from the markets than those from the farm gate. This is a source of concern since fruits are eaten without any form of processing. Residues of alpha – HCH, Endrin, Dieldrin , cis –Heptachlor epoxide, trans –Heptachlor epoxide, Hexachlorobenzene, trans – Nonachlor, o,p-DDE, p,p-DDE and o,p-DDD showed significant differences at all the three sampling locations at $p<0.05$.

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Farmers are also exposed to health risk as a result of inappropriate Personal Protective Equipment. Farmers also have difficulty in disposing off waste water for washing the spraying machine. Disposal of waste water into open canals can contaminate rivers and ground water.

6.2 RECOMMENDATIONS

The following recommendations are therefore suggested:

- Similar research should be conducted to determine organochlorine residues in soils from the district to determine if there is a relationship between the residues in fruits from farms and that from the soils.

- Continuous sensitization on the harmful effects of organochlorine insecticide and continuous monitoring of organochlorine residues in fruits from the area is essential.

- Farmers should be encouraged to use Personal Protective Equipment to avoid health problems.

- Regulatory authorities should ensure strict enforcement of laws banning the use of organochlorines to avoid illegal smuggling and use of organochlorine insecticides.

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APPENDICES

APPENDIX ONE

QUESTIONNAIRE FOR SURVEY ON FARMERS' KNOWLEDGE ON PESTICIDE USE AND PRACTICES

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

DEPARTMENT OF THEORETICAL AND APPLIED BIOLOGY (MSc ENVIRONMENTAL SCIENCE)

QUESTIONNAIRE ON FARMERS KNOWLEDGE AND PERCEPTION OF PESTICIDE USE AND APPLICATION

NB: Information obtained from this survey is strictly for academic purpose. Thank you for cooperating

A. PERSONAL

1. Sex: Male (   )   Female   (   )   2. Age: ………………

3. Educational Background: Formal Education (   )   No Formal Education (   )

B. FARM DETAILS AND WORK HISTORY

4. Status of farmer: Farm owner (   )   Labourer (   )

5. Number of years of farming: ………………   6. Size of farm (Acres) ………

C. PESTICIDE USE AND MANAGEMENT

7. Prevalent pests: …………………………………………………………………..

8. Chemicals used: ………………………………………………………

……………………………………………………………………………

9. Source of chemical: Market (   )   Other farmers (   )   Extension Agents (   )

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10.Knowledge on application rates: Label (   ) Extension officer (   ) Fellow farmer (   ) Shops (   )

11. Knowledge of ways pesticide enter the body: Eye (   ) Skin (   ) Inhalation (   ) Swallowing (   )

12. During spraying: Protective clothing (   ) Nose mask (   ) Handkerchiefs (   ) Gloves (   )

13. Have you experienced any health problems after spraying? Yes (   ) No (   )

Chest pain ( ) Watery eyes ( ) Nausea ( ) dizziness ( ) Fever ( ) Skin Irritation ( ) Itchy eyes ( ) Other …….

14. Do you know if pesticides have potential to harm the Environment? Yes (   )

No (   )

15. Has there been any accidental spillage of pesticide: Yes (   ) No (   )

16. How is spraying done/ number of times before harvesting: ……………………

17.Re –entry period after spraying the farm: less than 48hrs (   ) 48 -72 hrs ( ) after 72hrs (   )

18. How is water disposed off after washing sprayer: Field (   ) Irrigation Canal (   ) Nearby stream (   )

19. How is empty pesticide container disposed off? ………………………………

*20. Will you opt for organic farming (Give Reasons)? ……………………

APPENDIX TWO: Raw Data and Statistical Analyses of Organochlorine Residues in Mangoes

A: Concentrations of (ng/g) of Organochlorine Insecticide Residues in Mangoes

	Unsprayed Farm	Sprayed Farms									Markets	
Name of Insecticide	007/AK1	012/AY	010/AG2	009/LE	008/AG1	006/AY1	005/AK2	003/AK3	002/A0	001/S0	004/TM	011/MD
alpha-HCH	0.0704	0.33715	0.04315	0.90015	0.12355	0.7642	0.20885	0.25705	0.03825	0.10705	0.2055	0.75495
beta-HCH	nd	0.97845	nd	2.6091	nd	2.97415	0.08705	0.4354	nd	nd	0.6019	4.4548
gamma-HCH (lindane)	2.72815	4.12845	0.39905	2.2551	2.34775	7.1815	2.67915	2.8347	2.3311	3.5553	1.2296	7.42795
delta-HCH	1.653	1.437	0.9339	2.244	0.81875	7.23865	0.98435	1.709	14.9866	1.5686	1.29625	3.9462
Heptachlor	5.7136	8.5254	0.16735	4.15645	8.05	2.76575	3.1289	5.98215	4.337	4.26725	3.86845	5.5683
Aldrin	0.499	0.8414	0.7704	2.3	0.3992	5.3965	0.6377	1.8818	0.6126	0.44325	0.50775	2.6812
cis-Heptachlor epoxide	nd	nd	nd	nd	nd	2.1058	nd	nd	nd	nd	nd	1.383
oxychlordane	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
trans-Heptachlor epoxide	nd	0.0586	0.17085	0.56425	nd	nd	nd	0.06665	nd	nd	nd	nd
trans-Chlordane	0.16015	0.76155	0.0389	0.6181	0.3039	2.38075	0.22495	0.4583	0.2992	0.3665	0.06095	1.5587
o,p-DDE	nd	nd	nd	2.0881	nd	0.90135	nd	nd	nd	nd	nd	0.19915
cis-Chlordane	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
trans-Nonachlor	0.1014	1.1888	0.19795	0.77855	0.2577	0.94175	nd	0.01685	0.4702	0.2117	0.06665	1.52
p,p-DDE	nd	nd	0.04065	0	nd	nd	nd	nd	0.21555	0.03685	nd	0.0122
Dieldrin	nd	0.0338	nd	0.99965	nd	0.19625	nd	nd	0.0221	0.01955	nd	0.18465
o,p-DDD	nd	0.28755	0.133	1.23715	nd	0.3086	nnd	nd	nd	1.05385	nd	0.29425
Endrin	nd	0.08055	nd	0.5599	nd	nd	nd	nd	nd	1.81915	nd	nd
p,p-DDD	nd	0.4367	nd	1.18005	nd	nd	nd	nd	nd	nd	nd	nd
o,p-DDT	0.07345	nd	nd	1.3786	nd	0.47715	nd	nd	0.4041	0.9777	nd	0.2294
cis-Nonachlor	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
p,p-DDT	nd	0.31275	0.1314	2.3849	nd	2.0438	nd	nd	0.39325	0.181	nd	0.26295

`

B: Mean of Organochlorine Insecticide Residues (ng/g) from Conventional and Unsprayed farms

Name of Insecticide	CONVENTIONAL FARM	UNSPRAYED FARM
alpha-HCH	0.31	0.07
hexachlorobenzene (HCB)	0.07	ND
beta-HCH	0.79	ND
gamma-HCH (lindane)	3.08	2.73
delta-HCH	3.55	1.65
Heptachlor	4.6	5.71
Aldrin	1.48	0.5
cis-Heptachlor epoxide	0.23	ND
oxychlordane	ND	ND
trans-Heptachlor epoxide	0.09	ND
trans-Chlordane	0.61	0.16
o.p-DDE	0.33	ND
cis-Chlordane	ND	ND
trans-Nonachlor	0.45	0.1
p.p-DDE	0.03	ND
Dieldrin	0.14	ND
o.p-DDD	0.18	ND
Endrin	0.27	ND
p.p-DDD	0.18	ND
o.p-DDT	0.36	0.07
cis-Nonachlor	ND	ND
p.p-DDT	0.61	ND

`

C: Mean of Organochlorine Insecticide Residues (ng/g) in Samples from Markets in Accra and Tema

Name of Insecticide	Accra	Tema
alpha-HCH	0.75	0.21
hexachlorobenzene (HCB)	0.13	0.33
beta-HCH	4.45	0.6
gamma-HCH (lindane)	7.43	1.23
delta-HCH	3.95	1.3
Heptachlor	5.57	3.87
Aldrin	2.68	0.51
cis-Heptachlor epoxide	1.38	0
oxychlordane	0	0
trans-Heptachlor epoxide	0	0
trans-Chlordane	1.56	0.06
o.p-DDE	0.2	0
cis-Chlordane	0	0
trans-Nonachlor	1.52	0.07
p.p-DDE	0.01	0
Dieldrin	0.18	0
o.p-DDD	0.29	0
Endrin	0	0
p.p-DDD	0	0
o.p-DDT	0.23	0
cis-Nonachlor	0	0
p.p-DDT	0.26	0

`

D: Descriptive Statistics of Sprayed Farms

descriptive statistics	farm1	farm2	farm 3	farm 4	farm 5	farm 6	farm 7	farm 8	farm 9
Mean	0.924	0.138	1.206	0.586	1.638	0.361	0.62	1.096	0.664
Median	0.288	0.019	0.95	0	0.621	0	0	0.011	0.072
Mode	0	0	0	0	0	0	0	0	0
Standard Deviation	1.975	0.253	1.11	1.79	2.264	0.861	1.419	3.262	1.183
Kurtosis	11.813	5.352	0.606	16.969	1.822	6.66	9.912	17.439	4.383
Skewness	3.328	2.408	0.917	4.028	1.636	2.722	3.02	4.07	2.205
Minimum	0	0	0	0	0	0	0	0	0
Maximum	8.525	0.934	4.156	8.05	7.239	3.129	5.982	14.987	4.267

E: Descriptive Statistics of Unsprayed Farm, Sprayed Farms and Markets

Descriptive statistics	unsprayed farm	sprayed farms	markets
Mean	0.5	0.8	1.58
Median	0	0	0
Mode	0	0	0
Standard Deviation	1.338	0.149	1.413
Sample Variance	1.791	0.022	1.996
Kurtosis	11.661	11.661	11.661
Skewness	3.328	3.328	3.328
Minimum	0	0	0

ANOVA

`

Anova: Single Factor						
SUMMARY						
Groups	Count	Sum	Average	Variance		
Unsprayed farm	22	10.9992	0.49996	1.79127		
Sprayed farms	22	1.22213	0.05555	0.02211		
Market	22	11.6102	0.52774	1.99582		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	3.089	2	1.545	1.216	0.303	3.143
Within Groups	79.993	63	1.27			

Multiple Comparisons				
			LSD	Omega
Treatment	Treatment	Difference	Alpha = 0.05	Alpha = 0
Unsprayed farm	sprayed farms	0.444	0.679	0.807
Unsprayed farm	Market	-0.028	0.679	0.807
Sprayed farms	Market	-0.472	0.679	0.807

`

F: ANOVA for Mean Concentration of Alpha –HCH in all Three Locations

Location	Mean	Degree of Freedom	Significance
sprayed	13.1	2	-2.308
unsprayed	0.89	20	
Market	0.858		

G: ANOVA for Mean Concentration of beta –HCH in all Three Locations

Location	Mean	Degree of Freedom	Significance
sprayed	7.084	2	0.304
unsprayed	000	20	
Market	4.756		

`

H: ANOVA for Mean Concentration of Gamma –HCH (Lindane) in all Three Locations

Location	Mean	Degree of Freedom	Significance
sprayed	24.552	2	0.679
unsprayed	2.728	20	
Market	8.043		

I: ANOVA for Mean Concentration of Delta –HCH in all Three Locations

Location	Mean	Degree of Freedom	Significance
sprayed	30.526	2	0.745
unsprayed	1.653	20	
Market	4.594		

`

J: ANOVA for Mean Concentration of Hexachlorobenzene (HCB) in all Three Locations

Location	Mean	Degree of Freedom	Significance
sprayed	0.652	2	-25.489
unsprayed	0.000	20	
Market	0.291		

K: ANOVA for Mean Concentration of Aldrin in all Three Locations

Location	Mean	Degree of Freedom	Significance
sprayed	12.889	2	0.388
unsprayed	4.499	20	
Market	2.935		

`

L: ANOVA for Mean Concentration of Endrin in all Three Locations

Location	Mean	Degree of Freedom	Significance
sprayed	0.843	2	-26.587
unsprayed	0.000	20	
Market	0.000		

M: ANOVA for Mean Concentration of Dieldrin in all Three Locations

Location	Mean	Degree of Freedom	Significance
sprayed	1.254	2	-7.598
unsprayed	0.000	20	
Market	0.185		

`

N: ANOVA for Mean Concentration of Heptachlor in all Three Locations

Location	Mean	Degree of Freedom	Significance
sprayed	37.587	2	0.792
unsprayed	5.714	20	
Market	7.503		

0: ANOVA for Mean Concentration of cis- Heptachlor epoxide in all Three Locations

Location	Mean	Degree of Freedom	Significance
sprayed	2.106	2	-2.124
unsprayed	0.000	20	
Market	1.383		

`

P: ANOVA for Mean Concentration of trans – Heptachlor epoxide in all Three Locations

Location	Mean	Degree of Freedom	Significance
sprayed	0.860	2	-14.373
unsprayed	0.000	20	
Market	0.000		

Q: ANOVA for Mean Concentration of trans-Chlordane in all Three Locations

Location	Mean	Degree of Freedom	Significance
sprayed	5.126	2	0.617
unsprayed	0.160	20	
Market	1.589		

`

R: ANOVA for Mean Concentration of trans – Nonachlor in all Three Locations

Location	Mean	Degree of Freedom	Significance
sprayed	3.875	2	-1.18922
unsprayed	0.101	20	
Market	1.553		

S: ANOVA for Mean Concentration of o,p-DDE in all Three Locations

Location	Mean	Degree of Freedom	Significance
sprayed	2.989	2	-1.908
unsprayed	0.000	20	
Market	0.199		

`

T: ANOVA for Mean Concentration of p,p-DDE in all Three Locations

Location	Mean	Degree of Freedom	Significance
sprayed	0.260	2	-347.535
unsprayed	0.000	20	
Market	0.012		

U: ANOVA for Mean Concentration of o,p-DDD in all Three Locations

Location	Mean	Degree of Freedom	Significance
sprayed	2.083	2	-3.764
unsprayed	0.000	20	
Market	0.294		

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V: ANOVA for Mean Concentration of p,p-DDD in all Three Locations

Location	Mean	Degree of Freedom	Significance
Sprayed	1.617	2	-5.802
Unsprayed	0.000	20	
Market	0.000		

W: ANOVA for Mean Concentration of o,p-DDT in all Three Locations

Location	Mean	Degree of Freedom	Significance
sprayed	2.368	2	-3.027
unsprayed	0.073	20	
Market	0.229		

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X: ANOVA for Mean Concentration of p,p-DDT in all Three Locations

Location	Mean	Degree of Freedom	Significance
sprayed	5.286	2	-0.558
unsprayed	0.000	20	
Market	0.263		