ENSIGN COLLEGE OF PUBLIC HEALTH

KPONG-EASTERN REGION, GHAHA

ASSESSMENT OF ORGANOCHLORINE PESTICIDE RESIDUE LEVELS IN WATERMELON GROWN IN ADA-WEST DISTRICT OF GHANA

BY

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DECLARATION

I hereby declare that except for references to other people's work which has been duly acknowledged, this thesis submitted to the Ensign College of Public Health, Kpong is my own work towards MPH and that this thesis has neither in whole nor in part been submitted to any other Organization or University elsewhere for any form of recognition including award of a degree.

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LIST OF ABBREVIATIONS AND SYMBOLS

ATSDR	Agency for Toxic Substance and Disease Registry
BHC	Benzenehexachloride
CDC	Centre for Disease Control and Prevention
ECD	Electron Capture Detector
EPA	Environmental Protection Agency
EU	European Union
FAO	Food and Agriculture Organization
GAEC	Ghana Atomic Energy Commission
GC	Gas Chromatography
GSA	Ghana Standards Authority
HCB	Hexachlorobenzene
HCH	Hexachlorocyclohexane
IARC	International Agency for Research on Cancer
IJC	International Joint Commission for Great Lakes
LD_{50}	Lethal Dose for fifty percent of population of test animal
LOD	Limit of Detection
LOQ	Limit of Quantification

mg/kg	Milligramme per kilogramme
µg/kg	Microgramme per kilogramme
µl	Micro litre
MoFA	Ministry of Food and Agriculture
MRL	Maximum Residual Limit
MRM	Multi Residue Method
ng/g	Nanogramme per gramme
OCPs	Organochlorine Pesticides
p'p-DDT	para- dichlorodiphenyltrichloroethane
p'p-DDD	para- dichlorodiphenyldichloroethane
p'p- DDE	para- dichlorodiphenyldichloroethene
ppb	Parts per billion
ppm	Parts per million
SPE	Solid- phase extraction
SPSS	Statistical package for social sciences
SRM	Single Residue Method
UNEP	United Nations Environmental Plan
USEPA	United States Environmental Protection Agency

WHO	World Health Organization
α	Alpha
β	Beta
γ	Gamma
%	Percentage
°C	Degree Celsius

ABSTRACT

The study which aimed at assessing the levels of organochlorine pesticide (OCP) residues in watermelon was conducted in two parts; a field survey and laboratory work. The field survey involved the use of semi- structured questionnaires administered to 60 farmers in four selected communities in Ada-West district of Ghana. Laboratory work involved the use of Soxhlet Apparatus and CP-3800 Gas Chromatograph eguipped with a ^{63}Ni electron capture detector to investigate the levels of pesticide residues in samples of watermelon. Data was analysed with SPSS version 23 and Microsoft Excel statistical tools. The survey results showed that 15 pesticides with different trade names were used by farmers, of which 66.67 % were insecticides and 33.33 % were fungicides and these chemicals were used in various cocktail forms. Although the survey results showed that many of the farmers did not observe the correct or any pre-harvest interval as exactly 25 % of the farmers harvested the same day after pesticide application, results from the laboratory analysis revealed that the mean levels of the detected pesticide residues in peel, pulp and seeds of watermelon were below residue limits (MRL) set by WHO/FAO and EU. Most of the OCP residues investigated were below the limit of detection of 0.01ng/g. The highest mean level of 2.10 ng/g of p'p-DDE was recorded in seeds of watermelon from Koluedor. The lowest mean level of 0.20 ng/g of dieldrin and p'p-DDE were recorded in peel of watermelon from Sege. As these toxic chemicals have the potential to bioaccumulate, their presence is therefore undesirable and of great concern. It is recommended that regulatory authorities should ensure compliance and enforcement of the laws on the use of banned and restricted pesticides. A constant and regular monitoring programmes through residue level assessment at the sampling sites is recommended due to the changing trends of insecticide usage.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

Watermelon is a member of the cucurbit family (Cucurbitaceae), which includes cucumbers, melons (*Cucumis species*) and loofahs (*Luffa* species) as well as pumpkins and squashes (*Cucurbita* species) (Laghetti and Hammer, 2007). It is an important source of vitamins, minerals and antioxidants for population around the world as well as for the inhabitants in the study area. Many studies have suggested that consumption of plant foods like watermelon has long been associated with a reduced risk of many lifestyle-related health conditions such as obesity, diabetes, cancers, stroke, hypertension and high blood cholesterol (Matos *et al*., 2000).

In China, watermelon rinds are stir-fried, stewed, or more often pickled. Pickled watermelon rinds are commonly consumed in the Southern US, Russia, Ukraine, Romania and Bulgaria. In Africa, especially in Ghana watermelon is a popular traditional food plant as it is used to improve nutrition, boost food security as well as promote rural development.

The increasing demand or consumption of fruits and vegetables including watermelon has encouraged the use of pesticide in farming for the purposes of preventing, destroying, repelling or mitigating any insect-pest (Taylor *et al*., 2002). It is estimated that about 87 % of farmers in Ghana use pesticides in vegetable cultivation (Dinham, 2003). Although there are benefits to the use of pesticides, there are also drawbacks, such as potential toxicity to humans and the environment (Walter, 2005; US EPA, 2008). There are various types of pesticides and these include insecticides, fungicides, herbicides and antibiotics. Insecticides are mainly organochlorine pesticides (OCPs), organophosphates, carbamates and synthetic pyrethroids. The recent Stockholm convention on persistent organic pollutants (POPs) has banned and restricted the use of OCPs due to their toxicity and persistency in the environment. Even though OCPs are persistent and hazardous, farmers continue to use them due to their cost effectiveness and their broad spectrum of activity (Gerken *et al.*, 2000).

The Environmental Protection Agency (EPA) in Ghana was established by EPA Act, 1994 (Act 490) and has been mandated by law under the Pesticide Act of 1996 (Act 528) to provide for the control, management and regulation of pesticides as well as provide for sanctions for non-compliance. Surprisingly, most of the pesticides use by the fruit crops and vegetable farmers are not registered as they get to the Ghanaian markets through unapproved routes (EPA Ghana, 1999). Hence identifying and determining the level of OCP residues in watermelon is critical to protecting and improving human health.

1.2 PROBLEM STATEMENT

Vegetables and fruits including watermelon form a good accompaniment to various meals, since the vitamins, minerals and fibre they contain constitute vital dietary components for the efficient functioning of the body. Consequently, the cultivation of vegetables and fruits including watermelon on a large scale to meet demands of the world population attracts the use of large amounts of pesticides including OCP in farming. OCP in particular are known to be widely used in the control of insect pests of vegetables and fruits due to their broad spectrum of activity and their cost effectiveness, a situation which may result in the accumulation of pesticide residues in watermelon, a fruit crop mostly consumed raw in Ghana (Clarke *et al.*, 1997; Taylor *et al.*, 2002). OCPs are resistant to environmental degradation through chemical, biological, and photolytic processes and as a result bioaccumulate in living tissues and biomagnify in food chains and with the resultant impacts on human health and the environment (Baird, 1997). These synthetic organic chemicals contribute to many acute and chronic illnesses. They are known or suspected hormone disruptors and have been implicated in a broad range of adverse human health effects including immune system dysfunction, cancers, reproductive failures and birth defects. Recent studies suggest that extremely low levels of exposure to the womb can cause irreversible damage to the reproductive and immune systems of the developing foetus (Lars, 2000; Ritter *et al*., 2007).

Although studies conducted so far in Ghana revealed levels of OCP residues in the environment which are emanating from current and past use of these chemicals, the changing trends of pesticide usage and the paucity of data regarding the pollution status of watermelon in Ghana call for regular and constant monitoring through residue level assessment to protect humans and the environment from the toxic effects of OCPs (Osafo and Frempong, 1998; Ntow *et al.*, 2001, 2005, 2006; Darko and Acquaah, 2008; Darko *et al*., 2008; Agbeve *et al*., 2014). Hence studies of OCP residue levels in watermelon will be useful in determining the quality and safety of watermelon in terms of its pesticide residue contamination.

1.3 JUSTIFICATION

Watermelon is an important source of vitamins, minerals and antioxidants for people around the world as well for the population in Ghana. Many studies have suggested that consumption of plant foods like watermelon has long been associated with a reduced risk of many lifestyle-related health conditions such as obesity, diabetes, cancers, stroke, hypertension, high blood cholesterol just to mention a few (Mabberley, 2008). Unfortunately, the increasing demand of vegetables and fruits including watermelon by local consumers and for export has encouraged the use of pesticides including OCPs in farming for the purposes of controlling and reducing the effect of insect-pests and diseases (Taylor *et al.*, 2002). OCPs are resistant to environmental degradation through chemical, biological, and photolytic processes and as a result bioaccumulate in living tissues and biomagnify in food chains and with the resultant impacts on human health and the environment (Baird, 1997). As a result of toxicity associated with OCPs, there is an international effort under the Stockholm Convention for elimination of OCPs and related compounds from the environment. Ghana being a state party to the convention is obliged to total elimination of OCPs from the environment. Although studies on pesticide residues in certain vegetables and fruits have been previously conducted in Ghana, the changing trends of pesticides usage call for regular and constant monitoring through residue level assessment. The present study therefore becomes relevant in updating data on OCP residue levels in watermelon which is usually consumed raw.

1.4 OBJECTIVES OF THE STUDY

The main objective of the study was to identify and assess the levels of OCP residues in watermelon from selected communities in the Ada-West District of Ghana. To this end, the specific objectives of the study were:

- To determine the levels of OCP residues in the peel, pulp and seed of watermelon from the selected farming communities in the Ada-West District.

- To compare the levels of OCP in the peel, pulp and seed of watermelon from the selected areas with international acceptable levels.

- To conduct field survey to identify pesticides currently in use at the selected sites.

- To establish adherence to pre-harvest interval by collecting samples of watermelon at harvest.

1.5 RESEARCH QUESTIONS

- What are the types and levels of OCPs residues in the watermelon from the study sites?
- What measures can be instituted to reduce the impact of pesticide including OCPs on the people and on the environment?

1.6 HYPOTHESIS

- The OCP residue levels in the peel, pulp and seed of watermelon from the selected areas are above FAO/WHO permissible limits.
- The OCP residue levels in the seed, pulp and peel are not the same for each watermelon sample.

1.7 SIGNIFICANCE OF THE STUDY

The study becomes relevant in updating data on OCP residue levels in watermelon which is usually consumed raw and the possible health effects which might occur from the ingested pesticide residue. The findings of the research will help in scientific assessment of the impact of pesticides on public health and the environment as well as contribute to the development of superior crop production and plant protection practices to curb the pesticide pollution of the environment. Additionally, the research will contribute to knowledge and help inform policy and decision makers on the need for regular and constant monitoring through residue level assessment as a result of the changing trends of pesticides usage. Hence identifying and determining the level of pesticide residues in watermelon from these study locations is critical to protecting and improving human health and the environment.

1.8 SCOPE OF THE STUDY

The research focused on identification and determination of OCP residue levels in watermelon from selected farming communities in the Ada-West district and offer recommendations to ensure quality of watermelon in terms of its pesticide residues contamination. However, the sites were selected based on major crop (watermelon) cultivated, pesticide usage, ease of accessibility and willingness of farmers to participate in the study.

1.9 ORGANISATION OF THE STUDY

The study was organised under six separate chapters as follows:

Chapter one presents the background of the study, statement of the problem, justification of the study, hypothesis, research questions, main objectives, specific objectives, significance, scope and organization of the study.

Chapter two presents the literature review where work done by other researchers similar to the study is brought into focus and for comparison.

Chapter three gives details of the research methodology, ethical consideration and limitations of the study.

Chapter four presents the results of the field survey and laboratory work.

Chapter five discusses the results obtained in chapter four in relation to the research questions, objectives of the study and literature review.

Chapter six draws conclusion and makes appropriate recommendation.

CHAPTER TWO

LITERATURE REVIEW

The term pesticides as defined by the Food and Agricultural Organisation (FAO) includes substances intended for use as a plant growth regulator, defoliant, desiccant or agent for thinning fruit or preventing the premature fall of fruit and substances applied to crops either before or after harvest to protect the commodity from deterioration during storage and transport. A pesticide may be a chemical substance, biological agent (such as a virus, bacterium or antimicrobial), disinfectant or device used against any pest. Pests include insects, plant pathogens, weeds, molluscs, birds, mammals, fish, nematodes (roundworms) and microbes that destroy property, spread disease or are a vector for disease or cause a nuisance (FAO, 2002).

2.1 CLASSIFICATION OF PESTICIDES

Pesticides can be classified by target organisms or by chemical structure. When classified by target pest, pesticides may be broadly defined as being insecticides, fungicides and herbicides depending on whether they are to be used to kill insects, fungi and plants respectively. Pesticides may also be classified as organic or inorganic pesticides according to the chemical structure (Walter, 2005; US EPA, 2008). Inorganic pesticides are made from naturally occurring minerals and have varying modes of action including interfering with conversion of energy within cells and causing death by desiccation. Few examples of common inorganic pesticides include boric acids, silicagel, sodium fluoride and those containing heavy metals such as mercury, arsenic and its compounds (lead and calcium arsenate). Organic pesticides consist of compounds containing carbon in addition to hydrogen. They also contain chlorine, oxygen, sulphur, nitrogen and phosphorus in their molecule. Majority of all modern pesticides are organic pesticides and can be further grouped into synthetic and natural organic pesticides. Synthetic organic pesticides are man-made insecticides. Major classes and few examples include: OCPs (DDT, Metoxychlor, Lindane, Toxaphene and Mirex), Organophosphates (dichlorvos, malathion, parathion, dimethoate and coumaphos), Carbamates (carbofuran, propoxur and aldicarb) and Pyrethroids (fenvalerate, deltamethrin, cyhalothrin and cypermethrin). The natural organics or biopesticides include microbial pesticides, biochemical pesticides, plant-derived pesticides or botanical insecticides. These biological pesticides include pyrethrum extracted from Chrysanthemum species, nicotine from tobacco leaves and rotenone from the roots of Derris species. Others are *Bacillus thuringiensis*, *Bacillus papillae,* viruses, parasitic nematodes, azadirachtin as well as strychnine and scilliroside (Patnaik, 1992; Mukherjee, 2002).

Pesticides are also classified based on their biological mechanism or mode of action. Broad-spectrum pesticides are those that kill an array of species, while narrow-spectrum or selective pesticides kill a small group of species. A systemic pesticide moves inside a plant following absorption by the plant. With insecticides and most fungicides, this movement is usually upward (through the xylem) and outward. Systemic insecticides, which poison pollen and nectar in flowers may kill bees and other needed pollinators. Antifeedant pesticide for example starve insects while on treated plants to death by inhibiting feeding while a sterilant pesticide makes target organism unable to reproduce (Laws, 2000; Mukherjee, 2002). Pesticides are also classified based on their lethal dose (LD_{50}) value which is the dose that proves to be lethal to 50 % of the population of the test animals. By this, pesticides are put into toxicological classes such as class 1a - Extremely hazardous, demarcated in red; Class1b - Highly hazardous, demarcated in yellow; Class II - Moderately hazardous, demarcated in blue, Class III - Slightly hazardous demarcated green and class U - not likely to be hazardous in normal use. A substance is described as hazardous if it does not easily breakdown, accumulates easily in living organisms, causes harm to human health and produces degradation substances which are themselves harmful and bio accumulate in a living organism (Baird, 1997; Mukherjee, 2002; US EPA, 2008).

2.2 NATURE AND TYPES OF OCPs

The OCPs are synthetic organic insecticides which comprised predominantly of carbon, hydrogen, chlorine and sometimes oxygen. The carbon-chlorine bond or bonds is an essential structural feature of OCPs. The three major types of OCP identified include: **1.** Dichlorodiphenylethanes such as DDT, DDD or TDE, Methoxychlor, Rhothane, Methlochlor, Perthane and Dicofol (Kelthane). **2.** Chlorinated Cyclodienes such as Aldrin, Dieldrin, Endrin, Heptachlor, Chlordane and Endosulfan. **3.** Chlorinated Benzenes or Cyclohexanes such as Lindane, Toxaphene, Mirex, HCB, and Chlordecone (Kepone). OCPs are neurotoxins and believed to disrupt the balance of sodium and potassium ions in nerve cells. Their long-range air transport or trans-boundary dispersion also poses a great threat to human health and the global environment. These banned OCPs have also been designated as the Priority Pollutant of Concern by the International Joint Commission for the Great Lakes (IJC) and listed as a Priority Organic Pollutant by the UNEP (Baird, 1997; Laws, 2000).

2.3 ROUTES OF HUMAN EXPOSURE TO PESTICIDE

Humans are exposed to pesticides in basically three ways. These are dermal exposure (through the skin by absorption), oral exposure (through dietary intake) and inhalation (via the lungs through breathing. (1) **Inhalation** (air and dusts) occurs when gases and vapours of volatile pesticides residues and spray mists are breathed in. It is known that certain activities such as cigarette smoking could lead to inhalation of pesticide molecules. (2) **Ingestion /Oral exposure** (through dietary intake) occurs mainly in the consumption of food crops, vegetables, fruits, fish or drinking water contaminated with the residues of pesticides. Dust or soil particles are also known to be contaminated with pesticide residues when swallowed. (3) **Dermal/Skin contact** with (soil, air and water) is a principal route of exposure in industry. It occurs mainly during production in factories, shipping and packaging in stores and sales rooms, mixing, spraying and when one enters a field shortly after spraying. Usually fat soluble pesticides are absorbed through intact skin while sores and abrasions further enhance the intake of pesticides. **Eye Contact** often leads to pesticide exposure as most products cause irritation of the eye. The route of exposure is important because it affects absorption, distribution and biotransformation as well as determines pesticide toxicity (Stocchi, 1990; Baird, 1997).

2.4 SOME BASIC CHARACTERISTICS OF OCPs

2.4.1 PERSISTENCE

OCPs are known for their persistence in the environment. Persistence is the ability of a chemical to remain unchanged in the environment for a long period of time (long residual action). Persistent compounds are resistant to environmental degradation through chemical, thermal, biochemical and photolytic processes. Most OCP persist in the environment for up to 23 years or more. OCP such as DDT, mirex, endrin and HCH have their half-life range from 10 to 23 years in the soil and in living tissues and they remain active and toxic for these years depending on environmental conditions (Baird, 1997).

2.4.2 TOXICITY

It is simply the degree to which a substance can damage an organism, although the effect is dose dependent. Toxicity of a substance can also be affected by many different factors and some of this include the pathway of administration (whether the toxin is applied to the skin, ingested, inhaled, injected), the time of exposure (a brief encounter or long term), the number of exposures (a single dose or multiple doses over time), the physical form of the toxin (solid, liquid, gas), the genetic make-up of an individual and individual's overall health. The toxicity of OCPs is expressed in terms of acute and chronic toxicity. Acute toxicity is defined as a single exposure to a toxic substance which may result in severe biological harm and are usually characterised as lasting no longer than a day. The lethal dose (LD_{50}) value of a substance is the dose that proves to be lethal to 50 % of the population of test animals. The lesser the value of LD_{50}, the more potent or toxic is the chemical, since less of it is required to affect the animals. Chronic toxicity on the other hand is a long term exposure at relatively low dose of a toxic chemical. It may also be defined as continuous exposure to a toxin over an extended period of time, often measured in months or years (Baird, 1997; US EPA, 2008).

2.4.3 BIOACCUMULATION AND LIPOPHILICITY

One common or remarkable property of OCP is generally high solubility in hydrocarbon like environments, such as fatty material in living matter. The lipophilic tendency leads to bioaccumulation and subsequent biomagnification. Bioaccumulation results in higher concentration of a chemical in an organism than its immediate environment. A chemical whose concentration increases along the food chain is said to be biomagnified. In other words biomagnification results from a sequence of bioaccumulation steps that occur along the food chain (Baird, 1997).

2.5 DESCRIPTION OF SOME SELECTED OCPS

The following OCPs were selected based on their availability as standards. These selected OCPs are elaborated below:

2.5.1 DICHLORODIPHENYLTRICHLOROETHANE (DDT)

One of the most well-known synthetic organic pesticides ever used is DDT. It was discovered in 1939 by a Swiss scientist Paul Muller as a very effective synthetic organic insecticide. Its molecular formula is $C_{14}H_9C_{l5}$ (Miller, 2002). Unfortunately, DDT was widely overused, particularly in agriculture, which consumed 80 % of its production. As a result, its environmental concentration rose rapidly and began to affect the reproductive abilities of certain birds which indirectly incorporated it into their bodies. By 1962, DDT was being called an “elixir of death” by Rachel Carson in her influential book “silent spring” because of its role in decreasing the populations of the bald eagle, whose intake of the chemical was very high. Structurally, DDT is a substituted ethane. Its persistence is due to its low vapour pressure, slow rate of evaporation, low solubility in water and low reactivity with respect to light and to chemicals and microorganisms in the environment. Depending on conditions, its soil half-life can range from 22 days to 30 years. DDD and DDE are degradation products of DDT. DDE is nondegradable biologically and remains in humans for a long period. Its presence in the environment is correlated exactingly to the use of DDT (Baird, 1997; Nollet, 2000).

2.5.2 CHLORDANE

Chlordane is a cyclopentadiene pesticide commonly used on corn and citrus crops as well as for a termite control from 1948 to 1988. The chemical formula of Chlordane is $C_{10}H_6C_{l8}$. Technical grade chlordane consists of isomers such as alpha or cis isomer and gamma or trans isomer while Commercial formulations contain 10 % heptachlor (Nollet, 2000; Metcalf, 2002).

Being hydrophobic, Chlordane adheres strongly to surface soil particles and can stay in the soil for 20 years. Most chlordane leaves the soil by evaporation to the air, where it may be redistributed by air currents, contaminating areas far from their original application site. The US

EPA recommends that children should not drink water with more than 60 ppb for longer than a day. The non-cancer health effects of chlordane compounds include migraines, respiratory infections, diabetes, anxiety, depression and activated immune system (CDC, 2010).

2.5.3 HEXACHLOROCYCLOHEXANE (HCH)

The compound γ-HCH with the molecular formula $C_6H_6Cl_6$ known somewhat misleadingly as benzene hexachloride (BHC) is a mixture of isomers including alpha, beta, gamma, delta and epoxide. Research has shown that only one of the eight isomers the so called gamma isomer, has insecticidal properties and sold separately under the name lindane. Lindane or gamma HCH is the active ingredients in several commercial medical preparations, formulated as a shampoo or lotion used to rid children of lice and scabies. The US EPA and WHO classified lindane as moderately hazardous or acutely toxic. Most of the adverse human health effects reported for lindane have been related to agricultural uses and occupational exposure of seed treatment workers (US EPA, 2004; ATSDR, 2005; UNEP, 2009). Although there was an international ban of lindane, specific exemption allows for its use as second-line treatments for the head lice and scabies for a few more years. In Ghana, lindane was marketed as Gammalin 20 and was used for the control of capsids on cocoa farms and stem borers in maize. Other trade names are gammaxene and gammallin (Baird, 1997; Ntow, 2001; Kuranchie-Mensah, 2009).

2.5.4 METHOXYCHLOR

The molecular formula of Methoxychlor is $C_{16}H_{15}Cl_3O_2$. Methoxychlor is an analog to DDT, thus having the same general size and shape as DDT and therefore possesses the same insecticidal properties. It is reasonably degradable biologically and do not present the problem of bioaccumulation associated with DDT. Methoxychlor is used to protect crops, ornamentals, livestock, and pets against fleas, mosquitoes, cockroaches, and other insects. The major environmental degradation pathways involved dechlorination and demethylation. Human exposure to methoxychlor occurs via air, soil, and water. The US EPA concludes that levels above 40 ppb can cause central nervous depression, diarrhoea, damage to liver, kidney, and heart. The US EPA has also labeled Methoxychlor as Toxicity Class IV which contains agents that are considered practically nontoxic and require no signal word. Trade names for methoxychlor include Chemform, Maralate, Methoxo, Methoxcide, Metox and Moxie (EU, 2009; US EPA, 2004).

2.5.5 ENDRIN

It is an organochlorine pesticide primarily used on cotton plantations and are also used as rodenticide and avicide. As a colourless odourless solid, it is lipophilic and thus tends to bioaccumulate in fatty tissues of living organisms and biomagnified through the food chain. Its half-life in soil is well estimated over 10 years. Although very persistent, it partially decomposes to endrin ketone and endrin aldehyde when exposed to sunlight. In comparison with dieldrin, endrin which is a stereoisomer of dieldrin is less persistent in the environment. Endrin is toxic with an LD_{50} of 17.8 and 7.5 mg / kg (oral, rat). Acute endrin poisoning in humans affects primarily the nervous system (Metcalf, 2002).

2.5.6 ALDRIN AND DIELDRIN

These chemicals were widely applied in agricultural throughout the world to control insects in soil and in public health to control mosquitoes and tsetseflies, the vectors that cause malaria and sleeping sickness. Developed in the 1940s as an alternative to DDT, both aldrin and dieldrin proved to be a highly effective insecticide and were widely used during the 1950s to early 1970s. These two insecticides have similar structure and therefore show similar chemical properties and toxicity. In soil, on plant surfaces, or in the digestive tracts of insects, aldrin oxidises to the epoxide or dieldrin, which is more strongly insecticidal (Nollet, 2000; Metcalf, 2002; EU, 2009).

2.5.7 HEPTACHLOR

Heptachlor is a cyclopentadiene insecticide that was used extensively as a termiticide and on food crops and usually sold as a white or tan powder. Its chemical formula is $C_{10}H_5C_{l7}$. Heptachlor epoxide is the break down product of heptachlor and is more likely to be found in the environment than its parent compound. The epoxide also dissolves more easily in water than its parent compound and is more persistent. Heptachlor and its epoxide adsorb to soil particles and evaporate. The International Agency for Research on Cancer (IARC) and the California EPA have classified the compound as a possible human carcinogen and was designated as a Class 2B. Newborn animals exposed to higher doses of Heptachlor led to decrease in body weight and death. U.S. FDA limit on food crops is 0.01 ppm in milk and on edible sea food is 0.3 ppm USEPA, 2004).

2.5.8 ENDOSULFAN AND ENDOSULFAN SULFATE

Endosulfan is an off-patent organochlorine insecticide and acaricide used in agriculture around the world to control insect pests including whiteflies, aphids, leafhoppers, Colorado potato beetles and cabbage worms. This colourless solid has emerged as a highly controversial agrochemical due to its acute toxicity, potential for bioaccumulation, and role as an endocrine disruptor (Cone, 2010). The molecular formula is $C_9H_6C_{l6}O_3S$. Technical endosulfan is a 7 : 3 mixture of stereoisomers, designated α and β. (Metcalf, 2002). Endosulfan breaks down into endosulfan sulfate and endosulfan diol, both of which are of toxicological concern and have structures similar to the parent compound. The estimated half-lives for the combined toxic residues of endosulfan plus endosulfan sulfate range from roughly 9 months to 6 years (Walter, 2005; US EPA, 2008). The US EPA and WHO classifies it as Category I, Highly Acutely Toxic and Class II, Moderately Hazardous. Endosulfan was registered for use in Ghana in the cotton and coffee industries and for control of ectoparasites on farm animals and pets. Trade names for endosulfan include Benzoepin, Endocel, Parrysulfan, Phaser, Thiodan, Thionex (US EPA, 2008; Ntow *et al*., 2009).

2.6 STOCKHOLM CONVENTION ON PERSISTENT ORGANIC POLLUTANTS (POPs)

It is an international environmental convention signed on the 23rd May, 2001 in Stockholm, Sweden after the Governing Council of United Nations Environmental Programme (UNEP) called for global action to be taken on Persistent Organic Pollutants (POPs) in 1995. The convention became effective from 17th May, 2004. The convention is aimed at eliminating or restricting the production and use of persistent organic pollutants (POPs) which the convention defined as "chemical substances that persist in the environment, bio-accumulate through the food web, and pose a risk of causing adverse effects to human health and the environment". These Persistent organic pollutants referred also to as the “dirty dozen” by the Intergovernmental Forum on Chemical Safety (IFCS) and the International Programme on Chemical Safety (IPCS) include the heterogeneous groups of compounds such as OCPs, PCBs and unintentional by-products of chemical manufacturing and combustion processes such as dioxins and furans (UNEP, 2002; Bouwman, 2004; WHO, 2005).

The convention which entered into full force on 17th May, 2004 with ratification by an initial 128 parties and 151 signatories, allows the co-signatories to eliminate or restrict the use of the dirty dozen chemicals, of which nine are organochlorine pesticides namely DDT, chlordane, aldrin, dieldrin, endrin, hexachlorobenzene, heptachlor, mirex and toxaphene. The convention also curtails the inadvertent production of dioxins, furans as well as PCB industrial chemicals and restricts the use of DDT to malaria control. Parties to the convention have also agreed to a process by which persistent toxic compounds can be reviewed and added to the convention, if they meet certain criteria for persistency and transboundary threat. The first sets of new chemicals to be added to the Convention were agreed at a conference in Geneva on 8th May, 2009. Signatory countries are also obliged to take strong measures to control or prevent the release of persistent organic pollutants and to ensure proper and safe disposal of such substances when they become waste. Provisions were also made for information exchange and public awareness creation about the adverse health effects of persistent organic. Ghana signed and adopted the convention on 23rd May, 2003 and was ratified on 30th May, 2003 (Adeola, 2004 Bouwman, 2004).

2.7 BOTANY AND DISTRIBUTION OF WATERMELON

Watermelon (*Citrullus lanatus*) is an annual herbaceous plant in the cucurbit family (Cucurbitaceae) that originated in subtropical Africa, but now cultivated in temperate to sub-tropical regions in Asia and North America for its large juicy fruits. The fruit is found in grassland and bush land, mostly on sandy soils and often along watercourses. It flourishes in dry climates and requires only limited rainfall. Watermelon is a monoecious vine, with branched tendrils and deeply divided hairy leaves. Fruits are globose to oblong, with rinds that are light to dark green, or may be mottled or striped, and range in size from a 15 cm in diameter to 200+ cm in length (for oblong varieties). Fruits of typical varieties weigh from 4 to 14 kg (9 to 30 pounds). Fruits may be harvested 80 to 100 days after planting (Laghetti & Hammer, 2007).

There are over 100 cultivars of watermelon including seedless ones that range in weight from less than one kilogram to more than 90 kilograms (200 lb). They vary widely in taste, texture and colour and the flesh can also be red, orange, yellow or white. The following are also some of the cultivars developed by farmers and horticulturists over the years; Crimson Sweet, Extazy, Golden Midget, Jubilee, Moon and Stars, Cream of Saskatchewan, Florida Giant, Sweet Dragon, Top Harvest, Starlight, Sugar Baby, Sweet Darkota Rose, Tender gold, Thai Baby, Tom Watson, White Sugar Lump, White Wonder, Wilson's Sweet, Black Diamond, (Dane and Liu, 2006; MOFA, 2011).

Figure 2.1: Fresh watermelon and slice

2.7.1 NUTRITIONAL AND HEALTH BENEFIT OF WATERMELON

Watermelon is found to contribute significantly to human health. As with many other fruits, it is a source of vitamins and minerals including vitamins A, C and B6. It is fat-free, high in energy and also a source of the carotenoid, lycopene. Lycopene has been extensively studied for its antioxidant and cancer-preventing properties and these cancers include prostate cancer, breast cancer, endometrial cancer, lung cancer and colorectal cancers. The good amount of potassium and magnesium that is present in watermelon is very beneficial in terms of bringing down blood pressure. Potassium is considered a vasodilator, which releases the tension of blood vessels and arteries, by stimulating increased blood flow and reducing the stress on the cardiovascular system. These carotenoids present in watermelons also prevent hardening of artery walls and veins, thereby helping to reduce blood pressure and the chances of blood clots, strokes, heart attacks and atherosclerosis. Recent published studies also revealed that watermelon consumption increases free arginine, which can help maintain cardiovascular function (Zohary and Maria, 2000; Lynette, 2005; Jian *et al*., 2007).

In China, watermelon rinds are stir-fried, stewed and pickled. Pickled watermelon rinds are commonly consumed in the Southern U.S, Russia, Ukraine, Romania and Bulgaria. In Africa watermelon is a traditional food plant as it is used to improve nutrition, boost food security as well as promote rural development. Global production of watermelon in 2010 was 89.0 million metric tons, harvested from 3.2 million hectares. China is by far the leading producer, responsible for 64 % of the commercial harvest worldwide (Altas *et al*., 2011).

2.8 METHODS FOR THE DETERMINATION OF OCP RESIDUE IN AN ENVIRONMENTAL SAMPLE

Analytical methods employed in residue analysis usually include sampling, pesticide extraction, sample clean up and identification and quantification of pesticide residue using Gas chromatography. The repeated and indiscriminate use of pesticides in crop protection has created the problem of human health hazard due to the toxic residues that persist in food after their application. The level of pesticide residues in the food substance is determined by subjecting the food samples to pesticide residue analysis. The multiple residue method (MRM) and the single residue method (SRM) are the analytical methods used to determine various pesticide residues in a specified matrix. Single residue method determines one pesticide. Where the identity of the pesticide is unknown, a more general method is chosen that allows for the analysis of a wide range of pesticides. Such a method is called multi-residue method. Residues levels were calculated using the equation below (NRI, 1995).

Residue level = Concentration in final extract x dilution factor / Weight of sample analysed.

2.8.1 SAMPLING FOR PESTICIDE RESIDUE ANALYSIS

Sampling precedes all residue analysis. Sampling may be defined as a method adopted to obtain fractions from a body or system for analysis. In otherwise only a tiny fraction of the original material is actually analysed. The first principle of sampling states that the sample taken from a system should have exactly the same chemical composition as the original material. That is sample must be representative of the larger bulk of the material. Basic rules of sampling include the following:

a) Samples are not to be contaminated in any way with the equipment used, the containers, or by the person taking the sample.
b) There should not be any volatilization of chemical compounds as a result of microbial activity, absorption by the walls of the vessels in which the samples are kept or overheating of the samples during transportation and storage.
c) Taking reasonably large samples, provided that there is enough material in the system and this is not subject to the nature conservation laws.
d) Clear and effective sample labeling is essential for correct sample traceability and identification (Bourke *et al.*, 1987).

2.8.2 PESTICIDE EXTRACTION

The process of extraction is to isolate the target contaminants from the sample matrix. An exhaustive extraction and solvent recycle techniques such as soxhlet extraction is mostly preferred since it has proven to have good recovery for environmental matrices including vegetables and fruits (Akerblom and Cox, 1996; Zhang, 2007).

2.8.3 CLEAN UP OF THE SAMPLE EXTRACT

The removal of extraneous co-extractives from the sample extract is known as sample clean up and is meant to remove any interfering compound that may affect the efficiency of the analytical column and that can cause equipment contamination, error in quantification and deterioration of chromatographic resolution. The presence of undesirable components or impurities can also destroy delicate parts of the GC and make it a task to clean the delicate injector port frequently.

The techniques most frequently used for the clean-up are column adsorption chromatography and gel permeation chromatography or liquid-liquid partitioning chromatography. In column adsorption chromatography, the extract is applied to a column packed with a known amount of solid material such as florisil, alumina or silica gel for the components to be adsorbed. The adsorption is followed by elution of components of interest under gravity with solvents or solvent mixtures with increasing polarity (Nollet and Grob, 2005). The use of adsorbent material with relatively close particle size distribution in disposable polypropylene catridges, thus solid phase extraction (SPE) columns also allows for separation to be achieved with greatly reduced solvent volumes (Akerblom and Cox, 1996).

2.8.4 GAS CHROMATOGRAPHY AND DETECTORS USED FOR PESTICIDE RESIDUE ANALYSIS.

Gas chromatography is the most widely used method for pesticide residue analysis due to its simplicity. The instrumentation gives increased sensitivity, high accuracy, high resolution and high speed. A gas chromatograph consists essentially of an injector, capillary column, an oven, a recorder, a carrier gas and a detector (Akerblom and Cox, 1996; Harries, 1999).

A number of detectors are used and these include discharge ionization detector **(**DID), electron capture detector (ECD), flame photometric detector (FPD) , flame ionization detector (FID), helium ionization detector (HID), nitrogen phosphorus detector (NPD), infrared detector (IRD) and mass selective detector (MSD). Electron capture detector (ECD) which uses a radioactive beta particle source to measure the degree of electron capture is a popular detector used in gas chromatography for trace level assessment of chlorinated pesticides because of its sensitivity and selectivity to molecules containing highly electronegative atoms such as the halides. Some gas chromatographs which are connected to a mass spectrometer (GC-MS) are also connected to Nuclear Magnetic Resonance (NMR). The combination is called GC-MS-NMR. (Akerblom and Cox, 1996; Harries, 1999; Nollet and Grob, 2005).

CHAPTER THREE

MATERIALS AND METHODS

3.1 STUDY AREA

The study was undertaken in four main areas in the Ada-West district in the Greater Accra region of Ghana as shown in (figure 3.1). The sites were selected based on major crop cultivated, pesticide usage, ease of accessibility, cooperation from local leaders and willingness of farmers to participate in the study.

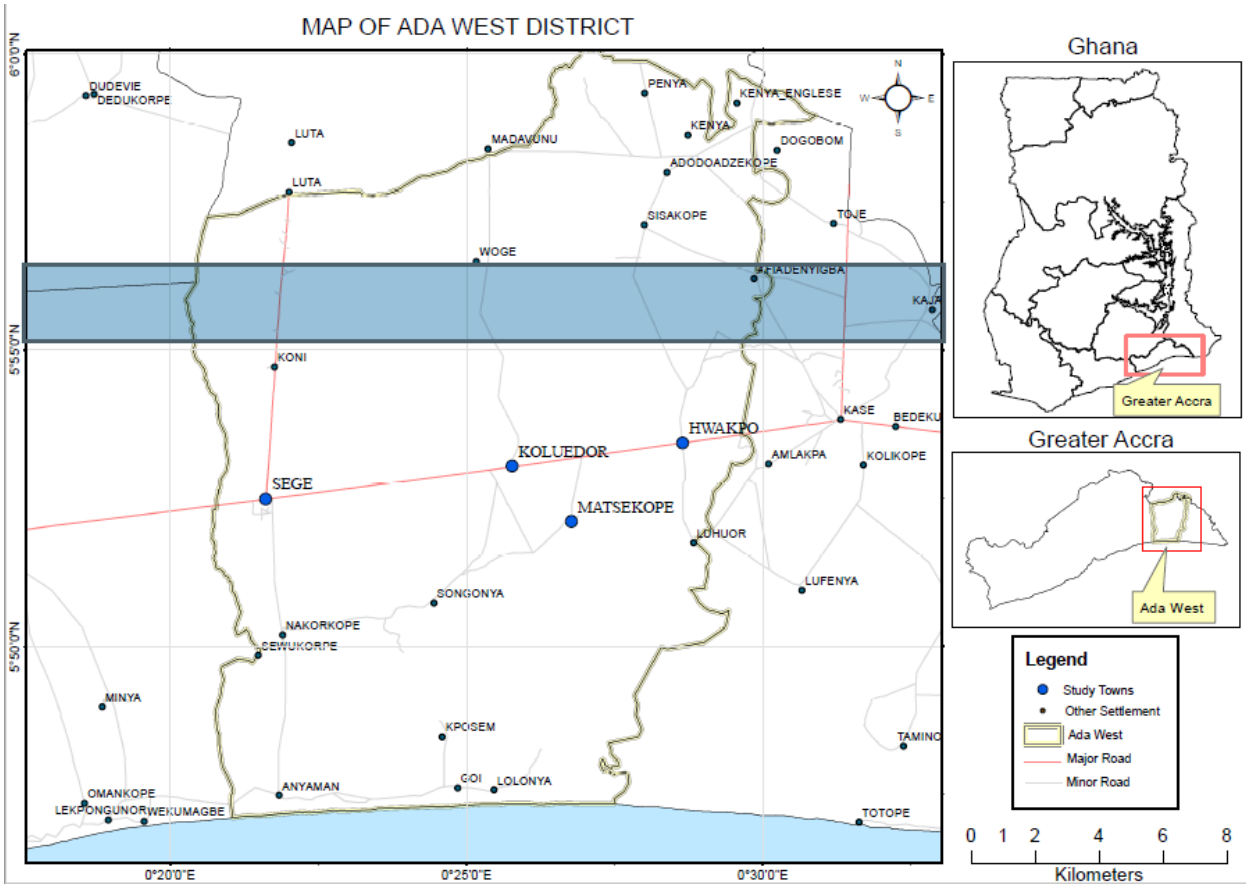

Figure 3.1: Map showing the study area and sampling site

3.1.1 ADA- WEST DISTRICT

The Ada-West District with its capital at Sege was carved out of the former Dangbe East District in the Greater Accra Region in 2012 by Legislative Instrument (LI. 2029). The District shares boundaries with North Tongu District to the North, Ada East District and Ningo Prampram to the East and West respectively. The district which is bounded to the South by the Gulf of Guinea is among sixteen districts in the Greater Accra Region and is approximately 80 Kilometers from Accra, the regional capital. The district lies between latitude 5°45'N and 6°00'N and longitudes 0° 20'E and 0°35'E. The total population of the district is 59,124. Of this figure 48.3 % (28,579) are males and 51.7% (30,545) are females. There are sixteen health facilities including five CHPS compounds spread throughout the district. Currently there are forty five basic schools, (primary and Junior High Schools), few kindergartens and one Senior High Technical School.

The total land size of the district is about 323.721 square kilometers. The vegetation is basically the coastal savannah type, characterised by short savannah grass and interspersed with shrubs and short trees. A few strands of mangrove can also be found around the Songhor Lagoon and the tributaries of the Volta River where the soil is waterlogged and salty.

The district experiences double rainfall pattern namely the major and minor rainfall seasons. The annual rainfall ranges from 750 to 1000 millimeters and with temperatures also ranging between 23°C and 28°C. A maximum temperature of 33°C is experienced in the district. The relatively high temperatures help in the quick crystallization of salt for the salt industry. About 42.5 % of the population is engaged in agriculture out of which 48.1 % is into food crop farming. The climate in the district favours the cultivation of food crops such as watermelon, tomatoes, pepper, okro and cassava (www.ghanadistricts.com and personal communication with the Ada-West District Environmental Officer, 2016).

Currently the district is becoming one of the large watermelon growing areas in Ghana. The crop is gaining ground in the district as the most widely cultivated crop due to the increasing demand and the presence of existing market. Watermelon is planted two times in a year, between January and March and also from September to November. The flat plains of the district couple with low precipitation seem to be an ideal condition for watermelon cultivation. Some suitable varieties include Sugar Baby, Florida Giant, Black Diamond and Charleston Gray. But Sugar Baby, Top Harvest, Sweet Dragon and Crimson Sweet are cultivated on a large scale in the district (personal communication with the Ada-West District Environmental Officer, 2016). Agriculture therefore constitutes the main source of income for the people of Ada-West.

3.2 THE STUDY DESIGN AND DATA COLLECTION

The study design employed for the research was a cross-sectional and tools for data collection were administration of questionnaires.

3.2.1 QUESTIONNAIRE DESIGN

The questionnaire was adapted from a work done by Dey (2012) with modifications as well as from the experiences of the researcher to suit the objectives of the study. The questionnaire design was also based on published literature on the subject and best practice methodology. The semi-structured questionnaires were used to obtain relevant information from selected respondents in the Ada-West District. Issues covered included bio-data, farming experience, types of pesticide use, source of pesticide supply, pre-harvest interval and reasons for and against the use of pesticide combination. To ensure respondents understand what they answer, simple words that conveyed exact meaning were used in designing the questionnaires. Questionnaires were also translated into local languages such as Ga-dangbe, Ewe and Twi as appropriate for those who could not read or understand the English language. Copies of the questionnaires were attached in the appendix.

3.2.2 QUESTIONNAIRE ADMINISTRATION

The farming communities selected for the study were Hwakpo, Matsekope, Koluedor and Sege in the Ada-West District. The semi-structured questionnaires were administered to a total of 60 watermelon farmers. The objective of the study was briefly explained to the respondents highlighting the need and importance. The questionnaires were also pre-tested on a small sample of respondents in two selected communities namely Kpotame and Tojeh in the North Tongu and Ada-East Districts of Ghana for content validity as specified by Rogers (1995).

3.2.3 SAMPLING TECHNIQUE AND SAMPLE SIZE

Purposive sampling technique which is a non-probability sampling method was used. This technique enabled the researcher to choose persons that were relevant to the research and were easily available to the researcher. The semi-structured questionnaires were administered to a total of 60 watermelon farmers comprising 15 farmers each from the four selected communities.

3.2.4 ELIGIBILITY CRITERIA

Only farmers actively involved in watermelon cultivation for at least a year; serving as an active member of watermelon association, being more than eighteen years of age and have started harvesting or near harvesting to ensure that all farm operations would have already been carried out and agreeing to comply with the study protocol were selected and administered questionnaire for reliability and validity as suggested by Quansah *et al*., (2016).

3.2.5 ETHICAL CONSIDERATION

To acquire good quality data and maximise the rate of response to questions, the following strategies by Frazer and Lawley (2000) were adapted to. These included; providing reward and a message of appreciation of the respondents cooperation. Confidentiality was also promised by explaining on questionnaire that information provided would be treated as confidential and used only for the purpose of the research. Right and dignity of the individual were highly considered and respected. Purpose and objective of the study were explained and verbal consent taken from each respondent. Scientific review of the study was obtained from the Ethical Review Board (ERB) of the Ensign College of Public Health, Kpong. Permission was also sought from the district assembly and community's leaders before research started.

3.3 LIMITATIONS OF THE STUDY

The research focused on OCP residue levels in watermelon from selected district in Ghana. The findings may not give a general picture of the OCP residue contamination status of watermelon from other districts in Ghana. Additionally, only watermelon was selected among the other food crops grown in the district for the study and for that matter results may not reflect the general contamination status of food crops in the district. An alternative would have been to include other food crops grown in the district such as tomatoes and okra. However, this would required more resources.

3.4 LABORATORY EXPERIMENT

3.4.1 EXPERIMENTAL SITE

Laboratory work was carried out at the Ghana Atomic Energy Commission (GAEC) and Ghana Standards Authority (GSA) in Accra, Ghana.

3.4.2 CHEMICALS AND STANDARDS

Solvents and reagents used in the study included n-hexane (99% + purity, Sigma-Aldrich), acetone (99.9% +, BDH England), ethyl acetate (99.8% +, Sigma-Aldrich), florisil 60-100 mesh (Hopkin and William Ltd England), anhydrous sodium sulfate (Aldrich-Chemie, Germany) and de-ionised water. The pesticide standards used for the identification and quantification of OCP residues were obtained from Dr. Ehrenstorfer Gmbh (Augsburg, Germany). The internal standards (isodrin) used for the recovery experiment were obtained from United Nations Environmental Programme (UNEP) in sealed ampules.

3.4.3 EQUIPMENT AND TOOLS

The following equipment and materials were used. These included Pasteur pipettes, Soxhlet extraction chambers and condensers, Round bottom flasks, Aluminum foil, Desiccators, Measuring cylinders, Rotary evaporator, Glass wool, vials, Sartorius analytical balance, Beakers, filter papers, test-tubes, heating mantles, Glass columns, spatula, Gas Chromatograph-Varian CP-3800 (Varian Association Inc. USA) equipped with 63Ni electron capture detector (ECD), blender, Note book, polyethylene bags, Mortar and pestle.

3.4.4 SAMPLE COLLECTION

To establish the adherence to pre-harvest interval, a total of 96 samples of watermelon comprising 24 watermelons from each of the communities were randomly collected at harvest. The collection of 96 watermelons was based on similar work conducted by Lozowicka *et al.*, (2015) where a total of 82 samples of cucumbers and tomatoes were collected from top agro-based market and greenhouses in the Almaty Region of Kazakhstan and analysed using a gas chromatography–micro electron capture detector/nitrogen–phosphorous detector (GC-μECD/NPD). The watermelon samples collected were wrapped in aluminum foil and sealed in polyethylene bags, well labelled with unique identity and transported to the Ghana Atomic Energy Commission (GAEC) laboratory for analysis and storage.

3.4.5 SAMPLE PREPARATION

Sample extraction, clean up, and GC analysis of the pesticides were carried out according to the procedure described by the (Afful *et al*., 2010; Bempah *et al*., 2012) with modifications.

3.4.5.1 SAMPLE EXTRACTION

Thoroughly washed watermelon samples were separated into three representative parts (peel, pulp and seeds) and shredded while seeds crushed with mortar and pestle. Approximately 10 g of these parts were mixed together with anhydrous sodium sulphate and sodium hydrogen carbonate to remove moisture. These homogenised samples were soxhlet extracted with 3:1 hexane: acetone mixture for 8 hours. The extracts were concentrated using a rotary evaporator fitted to a vacuum pump. A virgin cellulose extraction thimble was extracted in the same manner as the samples to obtain the blank. Each concentrated extract as well as the blank was later dissolved with a known volume of n-hexane on to the clean-up column. Each sample in a batch was spiked with 5μl of internal standard for the recovery analysis.

3.4.5.2 CLEAN UP OF SAMPLE

The florisil packed column with 2.0 g of anhydrous sodium sulphate at the top was conditioned with 10 ml of n-hexane prior to cleanup. The extracts of samples and blanks were eluted three times each with 10 ml portions of n-hexane and eluate collected into a flask with a ground-glass stopper and concentrated to dryness on the rotary evaporator fitted to a vacuum pump and later recovered with a known volume of ethyl acetate. About 2 ml of the extracts were transferred quantitatively into 2 ml glass vials using Pasteur pipette for Gas Chromatography (GC) analysis.

3.4.5.3 GAS CHROMATOGRAPHIC ANALYSIS

A Varian CP-3800 Gas Chromatograph (Varian Associates Inc. USA) equipped with ^{63}Ni Electron Capture Detector was used for the analysis. A volume of 1 µl of the extracts as well as the blank were injected and the separation performed on a fused silica gel capillary column coated with VF- 5 ms, 40 m long with internal diameter and film thickness of 0.25 mm and 0.25 µm respectively. The carrier gas and make up gas were nitrogen at a flow rate of 1.0 and 29 ml / min respectively. The injector and detector temperatures were 270 °C and 300 °C respectively. The column oven temperature was programmed as follows: 80 °C for 1min to 180 °C at 25 °C / min and up to 300 °C at 5 °C / min held for 1 min. Sample peaks were identified by their retention times compared to the corresponding retention times of the pesticide standards.

3.5 ANALYTICAL QUALITY ASSURANCE

Quality of pesticide residues were established through analysis of solvent blanks, spikes and triplicate samples. Solvent blanks were used to eliminate any interference in the system, while the spike samples were used for recovery analysis. Triplicate samples were used to confirm precision or reproducibility of the method. The spiked samples and blank were subjected to the same extraction and clean up procedure. It was also ensured that there was enough cleaning solvent in the GC cleaning vials to rinse the injection needle between injections.

Recovery was determined using the relationship: % Recovery = Pesticide recovered from fortified sample / amount of pesticide added.

3.6 DATA ANALYSIS

Statistical analysis incorporated in the work included mean of samples, analysis of variance (ANOVA) and standard deviations. All test were regarded as statistically significant when p <

0.05. All these calculations were performed using statistical software, SPSS version 23 and Microsoft Excel 2007.

CHAPTER FOUR

RESULTS

This chapter deals with the results and findings obtained from the field survey and laboratory analysis carried out in the four selected communities namely Hwakpo, Matsekope, Koluedor and Sege in the Ada-West District of Ghana.

4.1 WATERMELON FARMERS

All the 60 respondents purposively selected for the questionnaire survey responded to it, thus constituting 100 % response level.

4.1.1 BIO-DATA OF FARMERS

Table 4.1 shows proportion of males 56 (93.33 %) and females 4 (6.67 %) which indicates clearly that watermelon cultivation was dominated by males in the Ada-West district.

Table 4.1: Showing proportion of male and female farmers

Sex	Frequency	Percent
Male	56	93.33
Female	4	6.67
Total	60	100.0

Most of the farmers 28 (46.7 %) were aged between 40-49 years, 16 (26.7 %) were aged between 30-39 years, 7 (11.7%) of farmers were aged within 20-29 and 50-59 years and 2 (3.3 %) were aged 60 years and above as shown in table 4.2.

Table 4.2: Distribution of age of respondents

Age	Frequency	Percent
20-29	7	11.7
30-39	16	26.7
40-49	28	46.7
50-59	7	11.7
60 and above	2	3.3
Total	60	100.0

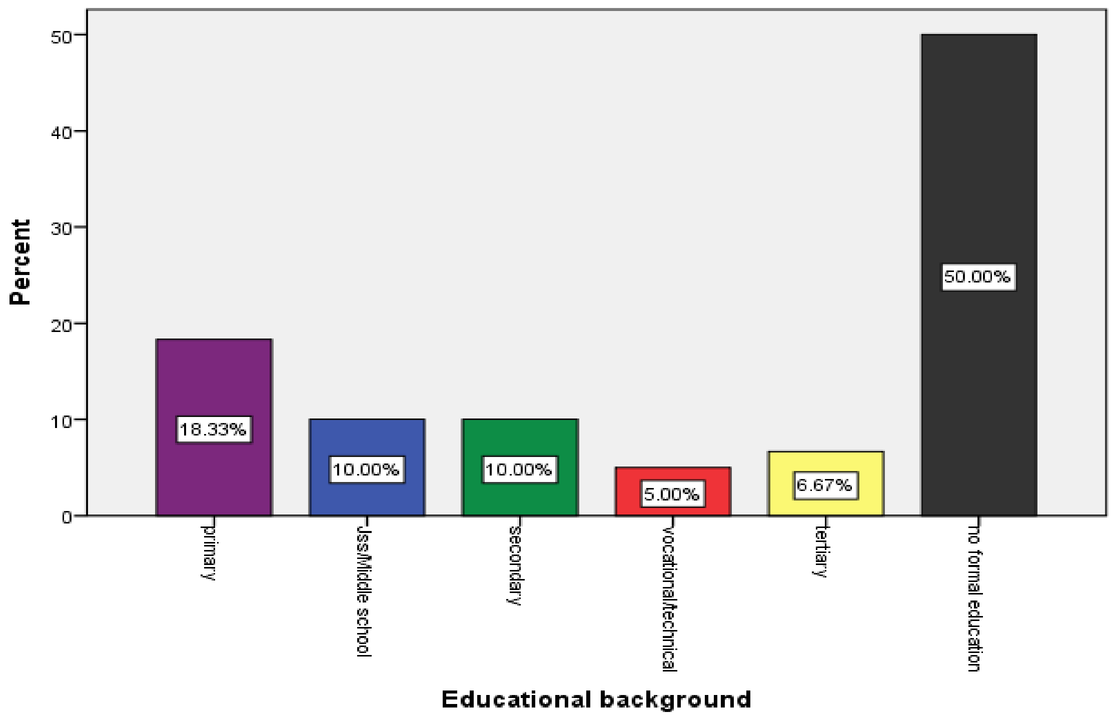

Figure 4.1: Showing the level of educational background

On educational background, figure 4.1 depicts that half (50 %) of the farmers had no formal education. 18.3 % were educated up to the primary level, 10 % had both JSS/Middle school and secondary qualification while 6.67 % and 5 % had tertiary and vocational/technical qualification respectively.

4.2 FARM CHARACTERISTICS

4.2.1 FARMING EXPERIENCE

Table 4.3: Distribution of farming experience of respondents

Years	Frequency	Percent
1-5	12	20.0
6-10	28	46.7
11-20	15	25.0
21+	5	8.3
Total	60	100.0

Table 4.3 indicates the farming experience of the watermelon farmers. From the study, most of the respondents 28 (46.75 %) had been in the farming business between 6-10years, 15 (25 %) of the respondents had also been in the business between 11-20 years, 12 (20 %) of the farmers had between 1-5 years, and 5 (8.3 %) of the respondents had farming experiences above 20years.

4.2.2 FARM SIZE OF FARMERS

Table 4.4: Distribution of farm size of respondents

Acres	Frequency	Percent
less than 1acre	2	3.3
1-5 acres	26	43.3
6-10 acres	21	35.0
above 10 acres	11	18.3
Total	60	100.0

Table 4.4 shows clearly the farm sizes of respondents. From the survey conducted, 26 (43.3 %) of the respondents administered questionnaires indicated that their farm sizes ranged between 1-5 acres, 21 (35 %) had farm sizes ranging between 6-10 acres while 11 (18.3 %) of the farmers had farm sizes above 10 acres. However, 2 farmers that accounts for 3.3 % of total respondents had farm sizes less than 1 acre.

4.2.3 VARIETIES OF WATERMELON GROWN BY FARMERS

Table 4.5 shows the varieties of watermelon grown by farmers in the Ada- West District. The outcomes of the survey indicates that most of the respondents 41 (68.3 %) cultivated Sweet Dragon, 10 (16.7 %) cultivated Sugar Baby, 4 (6.7 %) cultivated Top Harvest and 3 (5.0 %) cultivated Crimson Sweet. However, a small percentage 3.3 % of the farmers cultivated Black Diamond.

Table 4.5: Distribution of varieties of watermelon grown

Varieties	Frequency	Percent
Sugar Baby	10	16.7
Top Harvest	4	6.7
Sweet Dragon	41	68.3
Crimson Sweet	3	5.0
Black Diamond	2	3.3
Total	60	100.0

4.2.4 SOURCES OF PESTICIDE USED BY FARMERS

Table 4.6: Source of pesticides supply

Sources	Frequency	Percent
From other farmers	8	13.3
From market on table tops	8	13.3
From vehicles that come on market days	12	20.0
From dealers shop	32	53.4
Total	60	100.0

Table 4.6 shows where the farmers obtained their pesticides supplies. From the survey, most of the farmers 32 (53.4 %) obtained their pesticide from dealers shop, 12 (20.0 %) of the respondents bought their pesticides from vehicles that come on market days and the remaining two representing 13.3 % (8) of each of the respondents bought their pesticides from other farmers and on market days on table tops.

4.2.5 CHOICE OF PESTICIDE USED BY FARMERS

Table 4.7: Reasons for choosing a particular pesticide

Reasons	Frequency	Percent
Price is moderate	18	30.0
Effective control	32	53.3
Easily available	6	10.0
Improve fruit colour	3	5.0
Keeps fruits firm	1	1.7
Total	60	100.0

Reasons given by farmers for their choice of pesticide for controlling pests and diseases in the cultivation of watermelon are presented in table 4.7 above. From the survey conducted, more than half of the respondents 32 (53.3 %) of the farmers select their pesticide based on its effectiveness in pests and diseases control, 18 (30 %) select pesticides for their watermelon cultivation based on the price affordability, while 6 (10 %) and 3 (5 %) select pesticides based on easy accessibility and on the fact that they will improve the fruit (watermelon) colour. However only 1 respondent which accounts for 1.7 % of the total farmers selects pesticides based on the ability of keeping the watermelon fruits firm.

4.2.6 PESTICIDE USED FOR WATERMELON PRODUCTION

Table 4.8 indicates the different kinds of pesticides used at different stages in the production of watermelon in the Ada-West District. From the survey, it was observed that at the nursery stage of production 5 different kinds of insecticides and 5 fungicides were used in pests and diseases management and control. At the growth stages, 9 different insecticides and 5 fungicides were used. At the flowering stages, 8 different insecticides and 5 fungicides were used. At fruiting period 4 different insecticides and 4 fungicides were also applied. It was also observed that 4 different insecticides and 3 fungicides were applied at harvesting stage as shown in table 4.8

Table 4.8: Pesticide used during watermelon production

STAGES OF PRODUCTION	PESTICIDE	TRADE NAME
Nursery	Insecticide	Pawa, Kilsect, Polythrin, Striker, Golan
	Fungicide	Topsin, Topcop, Sulpher-80, Kocide, Funguran-OH
Growth	Insecticide	Pawa, Karate, Polythrin, K-optimal, Golan, Acetastar, Kilsect, Dursban, Striker
	Fungicide	Topsin, Kocide, Topcop, Sulpher-80, Funguran-OH
Flowering	Insecticide	Pawa, Polythrin, K-optimal, Golan, Acetastar, Kilsect, Cyperdem, Striker
	Fungicide	Topsin, Kocide, Topcop, Sulpher-80, Funguran-OH
Fruiting	Insecticide	Pawa, Polythrin, Striker, K-optimal
	Fungicide	Topsin, Topcop, Sulpher-80, Funguran-OH
Harvesting	Insecticide	Pawa, Polythrin, Striker, K-optimal
	Fungicide	Topsin, Sulpher-80, Funguran-OH

4.2.7 PESTICIDES COMBINATION USED BY FARMERS

Table 4.9: Use of pesticides combination in watermelon production

Response	Frequency	Percent
Yes	41	68.3
No	19	31.7
Total	60	100.0

Table 4.9 indicates responses of farmers in using pesticides combinations or cocktail in controlling pests and diseases in their watermelon production. Majority of the respondents that is 68.3 % of the farmers indicated that they mix different pesticides when spraying their watermelon in the field while 31.7 % said they do not mix pesticides when spraying their crop as shown in table 4.9.

4.2.8 NUMBER OF PESTICIDES COMBINATION USED

Table 4.10: Distribution of the number of pesticides that are mixed at a time

Number	Frequency	Percent
Two	18	43.9
Three	17	41.5
Four	6	14.6
Total	41	100.0

Table 4.10 shows clearly the number of the pesticides used in cocktail preparation by the farmers in the watermelon cultivation. Out of the number 41(68.3 %) that responded ‘yes’ to the question of whether they used a combination of pesticides at a time in controlling pest and diseases in watermelon production, it was revealed that 18 (43.9 %) of the respondents used two different kinds of pesticides at a time in cocktail preparation, 17 (41.5 %) used three types of pesticides while 6 (14.6 %) also used four different kinds of pesticides in controlling pests and diseases at a time in the watermelon cultivation.

4.2.9 REASONS WHY FARMERS MIXED DIFFERENT PESTICIDES

Table 4.11: Distribution of the reasons for the cocktail mix

Reasons	Frequency	Percent
Increase potency of pesticide	34	82.9
Produce healthy and disease free crop	7	17.1
Total	41	100.0

Out of the total number of respondents indicating that they used cocktail mixture in watermelon production as shown in table 4.9, 34 of them (82.9 %) indicated that they did so in order to increase the potency of pesticides, while the remaining 7 (17.1 %) did that to produce healthy and disease free crops as shown in table 4.11.

However, of the remaining 19 (31.7%) who responded 'no' to the question of whether they used a combination of pesticides at a time in controlling pest and diseases in watermelon production from table 4.9, 40 % indicated that it is not safe to mix or use a combination of pesticides, 30 % also said pesticides are already formulated for effective pest control and remaining 30 % indicated that individual pesticides are effective in controlling pests and diseases as shown in figure 4.2

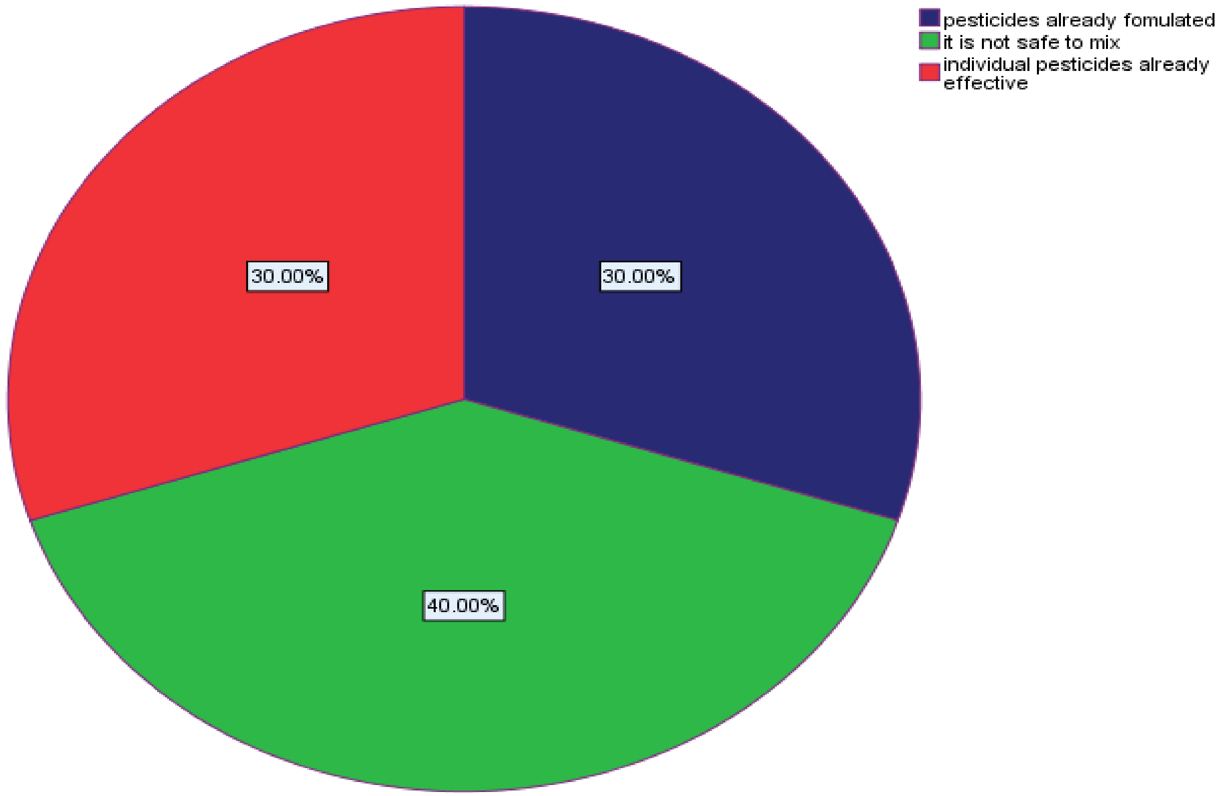

Figure 4.2: Reasons why some respondents do not use a cocktail of pesticides

4.2.10 APPLICATION OF PESTICIDES DURING HARVESTING

Table 4.12: Distribution of pesticides application during harvesting

Response	Frequency	Percent
Yes	16	26.7
No	44	73.3
Total	60	100.0

When the farmers were asked whether they sprayed their crops during harvesting, 16 (26.7 %) of the respondents indicated that they spray their crop during the harvesting period while the majority of the farmers 44 (73.3 %) indicated they do not spray their crops during the harvesting period as shown in table 4.12.

4.2.11 REASONS FOR AND AGAINST THE USE OF PESTICIDES DURING HARVESTING

Table 4.13: Distribution of why some farmers apply pesticide during harvest

Reasons	Frequency	Percent
Enhance fruit firmness	1	6.3
Better protection	12	75.0
Improve fruit colour	3	18.8
Total	16	100.0

Out of the respondents, 16 (26.7 %) that indicated they applied pesticides during harvesting, exactly three-quarters of these respondents 12 (75 %) said they applied pesticides during harvesting mainly for better fruit protection, 3 (18.8 %) of the respondents said it was done to improve colour of the watermelon while only 1 (6.3 %) indicated that it was done to enhance the firmness of the fruits as presented in table 4.13 above. However, out of the total number of the farmers who did not apply pesticides during harvesting representing 44 (73.3 %), more than half of them (59.09 %) indicated that pesticide is not safe for human consumption, 25 % of them also revealed that pesticides take time to break down and the rest 15.91 % also said it was against the directives of the agriculture extension officers as shown in figure 4.3

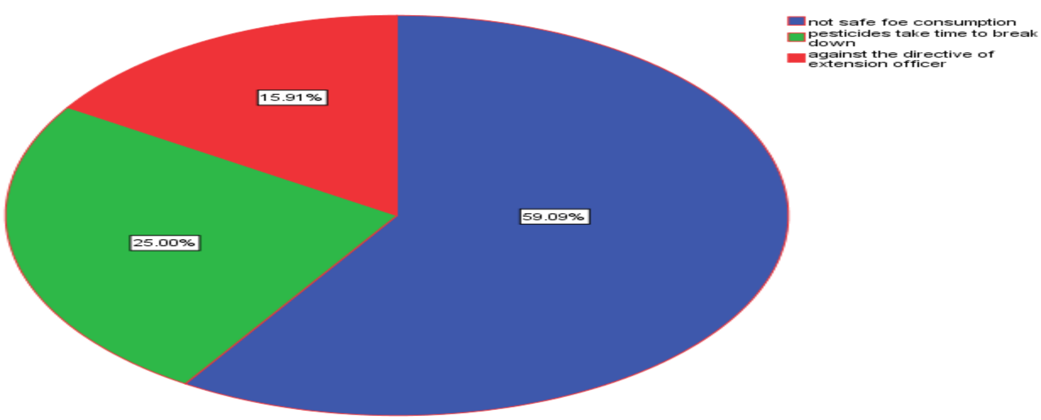

Figure 4.3: Showing why some farmers do not apply pesticides during harvesting.

4.2.12 PRE-HARVEST INTERVAL OBSERVED BY FARMERS

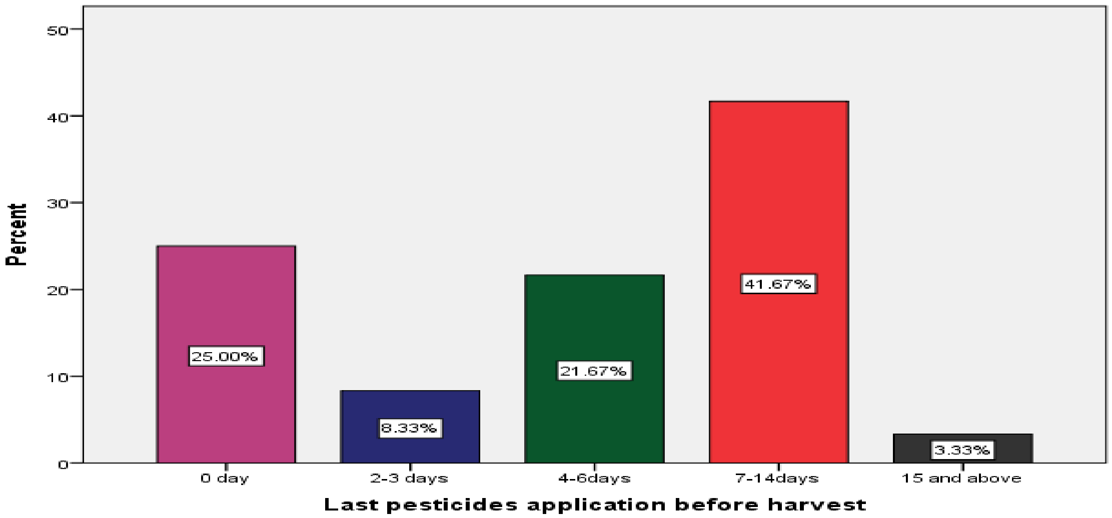

Figure 4.4: Showing pre-harvest interval observed by farmers.

From figure 4.4 above, 41.67 % of the farmers waited between 7-14 days after application before harvesting is done, 25 % harvest the same day after spraying, 21.67 % of the farmers harvest between 4- 6 days after application of pesticides. 8.33 % of the farmers also harvest between 2-3 days after pesticides application while the remaining 3.33 % of the farmers harvest after a fortnight of the pesticide application.

4.2.13 INSTRUCTION ADHERENCE ON PESTICIDES LABELS

Table 4.14: Farmers adherence to instructions on label before pesticides application

Response	Frequency	Percent
Yes	13	21.7
No	47	78.3
Total	60	100.0

The survey revealed that majority (78.3 %) of the respondents did not follow all instructions on label before pesticides application. 21.7 % of the respondents actually followed all instructions on label before application of pesticides as shown in table 4.14.

4.3 RESULTS OF PESTICIDE RESIDUE LEVELS IN PARTS OF WATERMELON FROM ADA-WEST DISTRICT

Chemical analysis revealed the presence of fifteen OCP residues and ten other pesticides comprising two organophosphates and eight synthetic pyrethroids residues in watermelon samples from Ada-West District as shown in the appendix. Spiked samples were also determined with good recoveries.

4.3.1 OCP RESIDUE LEVELS IN THE PEEL, PULP AND SEED OF WATERMELON AND COMPARISON WITH STANDARD LIMITS

Table 4.15 to 4.18 shows the results of the OCP residue levels in parts of watermelon samples obtained from the selected sampling sites and their comparison with standard limits set forth by WHO/FAO Codex Alimentarius Commission and EU guidelines.

Table 4.15: Levels (ng/g) of OCP residues in watermelon parts from Hwakpo

	HWAKPO				
	WATERMELON				
PESTICIDE	PEEL Mean±SD	PULP Mean±SD	SEED Mean±SD	EU/MRL (ng/g)	FAO/WHO MRL (ng/g)
Gamma - HCH	<0.01	<0.01	<0.01	10	NA
Beta - HCH	<0.01	<0.01	<0.01	10	NA
Heptachlor	<0.01	<0.01	<0.01	10	10
Delta - HCH	<0.01	<0.01	<0.01	10	NA
Endrin	<0.01	<0.01	<0.01	10	50
Gamma- chlordane	<0.01	<0.01	<0.01	10	20
A - endosulfan	<0.01	<0.01	<0.01	50	500
p,p' - DDE	<0.01	<0.01	<0.01	50	200
Dieldrin	<0.01	<0.01	<0.01	10	50
Aldrin	<0.01	<0.01	<0.01	10	50
p,p' - DDT	<0.01	<0.01	<0.01	50	200
B - endosulfan	<0.01	<0.01	<0.01	50	500
p,p' - DDD	<0.01	<0.01	<0.01	50	200
Endosulfan-S	<0.01	<0.01	<0.01	50	500
Methoxychlor	<0.01	<0.01	<0.01	10	NA

Limit of detection of pesticide residues = 0.01 ng/g, SD = Standard Deviation, NA = Not available, EU = European Union, MRL = Maximum Residue Limit

Table 4.16: Levels (ng/g) of OCP residues in watermelon parts from Matsekope

	MATSEKOPE				
	WATERMELON				
PESTICIDE	PEEL Mean±SD	PULP Mean±SD	SEED Mean±SD	EU/MRL (ng/g)	FAO/WHO MRL (ng/g)
Gamma - HCH	<0.01	<0.01	<0.01	10	NA
Beta - HCH	<0.01	<0.01	<0.01	10	NA
Heptachlor	<0.01	<0.01	<0.01	10	10
Delta - HCH	<0.01	<0.01	<0.01	10	NA
Endrin	<0.01	<0.01	<0.01	10	50
Gamma- chlordane	<0.01	<0.01	<0.01	10	20
A - endosulfan	<0.01	<0.01	<0.01	50	500
p,p' - DDE	<0.01	<0.01	<0.01	50	200
Dieldrin	<0.01	<0.01	<0.01	10	50
Aldrin	<0.01	<0.01	<0.01	10	50
p,p' - DDT	<0.01	<0.01	<0.01	50	200
B - endosulfan	<0.01	<0.01	<0.01	50	500
p,p' - DDD	<0.01	<0.01	<0.01	50	200
Endosulfan-S	<0.01	<0.01	<0.01	50	500
Methoxychlor	<0.01	<0.01	<0.01	10	NA

Limit of detection of pesticide residues = 0.01 ng/g, SD = Standard Deviation, NA = Not available, EU = European Union, MRL = Maximum Residue Limit

Table 4.17: Levels (ng/g) of OCP residues in watermelon parts from Koluedor

	KOLUEDOR				
	WATERMELON				
PESTICIDE	PEEL Mean±SD	PULP Mean±SD	SEED Mean±SD	EU/MRL (ng/g)	FAO/WHO MRL (ng/g)
Gamma - HCH	<0.01	<0.01	<0.01	10	NA
Beta - HCH	<0.01	<0.01	<0.01	10	NA
Heptachlor	<0.01	<0.01	<0.01	10	10
Delta - HCH	<0.01	<0.01	<0.01	10	NA
Endrin	<0.01	<0.01	<0.01	10	50
Gamma- chlordane	<0.01	<0.01	<0.01	10	20
A - endosulfan	<0.01	<0.01	<0.01	50	500
p,p' - DDE	0.70 ± 0.14	0.40 ± 0.00	2.10 ± 0.14	50	200
Dieldrin	0.50 ± 0.14	0.35 ± 0.07	1.10 ± 0.14	10	50
Aldrin	<0.01	<0.01	<0.01	10	50
p,p' - DDT	<0.01	<0.01	<0.01	50	200
B - endosulfan	<0.01	<0.01	<0.01	50	500
p,p' - DDD	<0.01	<0.01	<0.01	50	200
Endosulfan-S	<0.01	<0.01	<0.01	50	500
Methoxychlor	<0.01	<0.01	<0.01	10	NA

Limit of detection of pesticide residues = 0.01 ng/g, SD = Standard Deviation, NA = Not available, EU = European Union, MRL = Maximum Residue Limit

Table 4.18: Levels (ng/g) of OCP residues in watermelon parts from Sege

	SEGE				
	WATERMELON				
	PEEL	PULP	SEED	EU/MRL	FAO/WHO
PESTICIDE	Mean±SD	Mean±SD	Mean±SD	(ng/g)	MRL (ng/g)
Gamma - HCH	<0.01	<0.01	<0.01	10	NA
Beta - HCH	<0.01	<0.01	<0.01	10	NA
Heptachlor	<0.01	<0.01	<0.01	10	10
Delta - HCH	<0.01	<0.01	<0.01	10	NA
Endrin	<0.01	<0.01	<0.01	10	50
Gamma- chlordane	<0.01	<0.01	<0.01	10	20
A - endosulfan	<0.01	<0.01	<0.01	50	500
p,p' - DDE	0.20 ± 0.00	0.40 ± 0.00	1.10 ± 0.14	50	200
Dieldrin	0.20 ± 0.00	0.35 ± 0.07	1.15 ± 0.07	10	50
Aldrin	<0.01	<0.01	<0.01	10	50
p,p' - DDT	<0.01	<0.01	<0.01	50	200
B - endosulfan	<0.01	<0.01	<0.01	50	500
p,p' - DDD	<0.01	<0.01	<0.01	50	200
Endosulfan-S	<0.01	<0.01	<0.01	50	500
Methoxychlor	<0.01	<0.01	<0.01	10	NA

Limit of detection of pesticide residues = 0.01 ng/g, SD = Standard Deviation, NA = Not available, EU = European Union, MRL = Maximum Residue Limit

CHAPTER FIVE

DISCUSSION

5.1 BIO-DATA OF FARMERS

The survey revealed that watermelon cultivation was dominated by male farmers. Some of the possible reasons for this trend of low female participation in watermelon cultivation may be due to the fact that watermelon cultivation is labour intensive and certain farm tasks such as pesticide application for pests control and management, weeding, watery, raising of bed or mound and mulching is usually male dominated while the female would have to invest a lot of money in labour thus making it an expensive task for them (Dey, 2012). A similar trend was reported in studies conducted in Accra, Kumasi and Tamale where less than 10 % of the respondents were women (Nkpe, 2006). The survey showed that the active age group of farmers fell within the age group of 40-49 years. This gives an indication that watermelon cultivation was dominated by the middle aged class rather than the youth. The study also revealed that half of the farmers had no formal education and only small proportion of respondents had tertiary and technical/vocational education. This means that majority of the farmers could not read and write thereby supporting the findings by Abdul-Rahaman (2015) that farmers who apply pesticides to crops are often illiterate and lack the necessary safety information. This is of critical concern for the growth of fruit and vegetable production industry, since abuse of pesticides in agriculture has been partly attributed to the high illiteracy levels of farmers (Asante and Ntow, 2009).

5.2 FARM CHARACTERISTICS

5.2.1 AVERAGE SIZE OF FARM

The size of farms of the majority of the respondents ranged from 1 to 5 acres followed by 6 to 10 acres and is in conformity with the observation that the majority of respondents in the study area are smallholder farmers. It is also reported that agriculture is predominantly on a smallholder basis in Ghana (Agric in Ghana, 2011).

5.2.2 TYPE OF PESTICIDES APPLIED IN WATERMELON PRODUCTION

A total of 15 of pesticides were found in use for pest and disease management in the selected communities in the Ada-West district. The pesticides consisted of 10 insecticides (66.67 %) and 5 (33.33 %) fungicides. Insecticides were found to be the pesticides mostly used by the farmers for the insect-pest and disease management followed by fungicides. In a similar work conducted by Ntow *et al*., (2006), herbicide was rather found to be the most commonly used pesticide followed by insecticide and fungicide. In another study carried out in Zimbabwe by Sibanda *et al*., (2000), it was reported that farmers mainly focused on the use of synthetic pesticides to control pests. Possibly farmers use insecticides as the only means to effectively control pest and diseases on their vegetable and food crop farms.

5.2.3 SOURCES OF PESTICIDE USED BY FARMERS

From the survey conducted, majority of the farmers obtained their pesticide from dealers or agrochemical shops. This is not surprising as the majority of the respondents are unable to distinguish between different pests and disease pathogens and control measures such as insecticides and fungicides application and rely on information and advice given by local agrochemical dealers. However, others bought pesticides from unapproved sources such as from moving vehicles and peddlers who sell on table tops in the market days and also from other farmers probably due to cheaper prices. Pesticide usage by farmers seems to be highly influenced by peddlers and dealers through promotional sales in some farming communities with the sole aim of achieving high pesticide sales without considering the farmers health. Epstein and Bassein (2003) revealed that in many developing countries, the choice of pesticide usage by most farmers is usually influenced by the pesticide distributors. The situation calls market surveys to be conducted in order to inspect the insecticides and other pesticides being sold to farmers especially by retail shops and street hawkers. There should also be farmer education on the risks involved in buying pesticides from unapproved sources.

5. 2.4 CHOICE OF PESTICIDE USED BY FARMERS

Majority of farmers in the study area selected their pesticide based on their effectiveness in pests and disease control while others selected pesticides based on their affordability, availability, enhancement of fruit colour and to keep fruit firm. This practice has therefore led to the use of many different pesticides in fruit and vegetable cultivation thereby posing a danger to human health and the environment. It is estimated that 87 % of farmers in Ghana used pesticides to control pest and disease on their vegetables (Dinham, 2003). The world health organization (WHO) also reports that 20 % of pesticide use in the world is concentrated in developing countries posing a danger to human health and environment (Hurtig *et al*., 2003).

5.2.5 VARIETIES OF WATERMELON GROWN BY FARMERS

The result of the study also showed that five different watermelon varieties were grown but the majority of the farmers cultivated Sweet Dragon as a result of the demand and ready market for this variety in the country. Sugar Baby and Top Harvest varieties were also preferred by consumers and are cultivated while Crimson Sweet and Black Diamond which are gradually gaining ground are also cultivated by few respondents in the study area.

5.2.6 APPLICATION OF PESTICIDES DURING HARVESTING

The application of pesticide during harvesting periods was observed and respondents assigned various reasons as to why they did not apply or applied pesticides during the harvesting period. For those who applied pesticides, majority indicated that the application ensured better protection of fruit and others said it improved fruit colour and enhanced fruit firmness to satisfy consumers demand. For the majority of farmers who did not apply pesticides during harvesting, they indicated that the pesticides were not safe for human consumption, that pesticides takes time to break down and that it was against the directive of agricultural extension officers of the Ministry of Food and Agriculture (MoFA). The result indicated that some farmers applied fungicides and insecticides up to the point of harvest and during harvest with the assumption that pesticides residues left on the fruits after harvest will continuously increase the shelf life of the fruits. Farmers desire to satisfy consumers taste and to produce high yield crops could account for the high proportions of fungicides and insecticides used (Thomas, 2003). Majority of the farmers also never consulted the agricultural extension officers or agents. This lack of know how in good plant protection practices, couple with the low extension-farmer ratio in the study area may have contributed to the misuse of plant protection chemicals.

5.2.7 PESTICIDES COMBINATION (COCKTAILS) USED BY FARMERS

The result from the studies indicated that majority of the respondents (68.3 %) mixed different pesticides when spraying their watermelon crop and 31.7 % did not use pesticide combination. The number of pesticides used in cocktails obtained from the results indicated majority of the farmers mixed two different pesticides when controlling pests and diseases on their watermelon crops followed closely by those who mixed three different pesticides. Some respondents also mixed four different pesticides. As reported by Amoako *et al*., (2012), most farmers mix two or more pesticides together without considering their compatibility or active ingredients but rather rely on perceived efficacy based on trade names. Mixing of pesticides was encouraged by farmers desire to have rapid knock down of pests or economics of managing both insect-pests and diseases at a single application. This idea was however, queried by Medina (1987) at least as a practiced, because the combinations used could be indiscriminate and incompatible resulting in ineffectiveness of pesticides to manage pest and disease. The findings are also consistent with that of Biney (2001) who attributed the increased in incidences of insect-pest infestation of vegetable produced in Ghana to the practice of using indiscriminate combinations of pesticides, particularly of insecticides. In a study conducted by Ngowi (2003), it was revealed that farmers were not given agricultural extension services and so have attempted various means in pest and disease control especially in pesticide application.

5.2.8 REASONS WHY FARMERS MIXED OR DID NOT MIX PESTICIDES

The result from the survey revealed the various reasons why farmers mixed or did not mixed different pesticides in the field. Majority of the farmers said they mixed pesticides in order to increase the potency of pesticides while the rest of the respondents also said they mixed to ensure the production of healthy and disease free crop. However, those respondents who did not mix pesticides felt that it was not safe to mix the pesticides since they did not know their chemical composition. Others indicated that the individual pesticides were already effective in controlling pests and diseases therefore there was no need to mix while the rest also said that they did not mix different pesticides because pesticides had been already formulated for effective pest control.

5.2.9 PRE-HARVEST INTERVAL OBSERVED BY FARMERS

The survey revealed that the pre-harvest intervals were not correctly observed by respondents as exactly 25.0 % of the respondents harvested within the same day after pesticide application, 21.67 % of farmers harvested within four to six days and 8.33 % of the farmers also harvested within two to three days after pesticides application. Meanwhile majority (41.67 %) of the respondents harvested within seven to fourteen days after pesticides application. It was observed that only few respondents (3.33 %) harvested more than two weeks after application of pesticides. Amoako *et al*.,(2012) reported that majority of cabbage farmers in the Ejisu-Juaben Municipality of the Ashanti Region of Ghana continue spraying pesticides during harvesting, hence no waiting period is observed thereby exposing consumers to high pesticide residue levels.

Every insecticide has a withholding period, waiting period, lapse period or pre-harvest interval which is defined as the number of days required to lapse between the date of final insecticide application and harvest, for residues to fall below the tolerance level established for that crop or for a similar food type. The pre-harvest period differs from insecticide to insecticide and from crop to crop. Food products become safe for consumption only after withholding period has lapsed (Handa *et al*., 1999). Yeboah (1998) observed that most insecticides approved for use in Ghana have pre-harvest intervals ranging from 7 to 21 days and it is known that failure to wait sufficiently after pesticide application before harvesting poses toxicological risks to consumers (WHO, 1990).

Reading and understanding product label plays a critical role in the cultivation of fruits and vegetables including watermelon in Ghana (Abdul-Rahaman, 2015). The survey revealed that majority (78.3 %) of the respondents did not follow all instructions on label before pesticides application. The product label contains important information including product features, risks relating to product use, correct measures to take in the case of an emergency, dose rates, frequency of use and pre harvest interval. This situation also calls for farmers' education and training by the extension officers to ensure that farmers follow all instructions on labels before pesticides application in the study area.

5.3 OCCURRENCE AND DISTRIBUTION OF OCP RESIDUES IN THE PEEL, PULP AND SEED OF WATERMELON

The results in table 4.15 to table 4.18 indicated the mean and standard deviation values obtained from the laboratory work. The detectable OCP residues were dieldrin and p'p DDE in watermelon samples from Koluedor and Sege. None of the OCP residues were detected in watermelon samples from Hwakpo and Matsekope. The mean levels of dieldrin detected in the peel, pulp and seeds of watermelon from Sege were 0.20 ng/g, 0.35 ng/g and 1.15 ng/g while that of p'p DDE recorded mean levels of 0.20 ng/g, 0.40 ng/g and 1.10 ng/g in the peel, pulp and seeds of watermelon respectively. In Koluedor, dieldrin recorded a detectable mean level of 0.50 ng/g, 0.35 ng/g and 1.10 ng/g in the peel, pulp and seeds of watermelon and that of p'p DDE recorded mean levels 0.70 ng/g, 0.40 ng/g and 2.10 ng/g in the peel, pulp and seeds respectively. Statistically the differences were significant ($p < 0.05$) as shown in the appendix. The highest mean level of 2.10 ng/g of p'p DDE was recorded in seeds of watermelon from Koluedor followed by a mean concentration of 1.15 ng/g of dieldrin detected in seeds of watermelon from Sege. The lowest mean concentration of 0.20 ng/g of dieldrin and p'p DDE were recorded in the peel of watermelon from Sege. Most of the OCP residues analysed were also below the limit of detection of 0.01ng/g. The high detectable mean level of p'p DDE may due to metabolic conversion and dehydrochlorination of p'p DDT and possible isomerisation of p'p DDT by solar radiation to p'p DDE (Barriada-Pereira *et al*., 2005). The ratio of DDE to DDT levels are often used as a criterion for the identification of new DDT sources. The high DDE/DDT levels suggest that the current exposure levels originate from previous contamination and environmental persistency. DDE is generally more persistent in the environment than DDT as a result when the input levels of DDT in the environment ceases, the levels of its metabolite DDE will be higher than the parent compound DDT (Ntow, 2005). Comparing this study with the similar one conducted in Accra by Bempah and Donkor (2010) where the mean concentration of 0.05 μg/g of p'p DDE was detected in samples of pawpaw from markets in Accra metropolis with mean concentration of 2.10 ng/g of p'p DDE detected in seed of watermelon from Koluedor, then the pawpaw in Accra seem highly contaminated. Additionally, the high detectable mean level of dieldrin may indicate the metabolism of the parent aldrin into dieldrin. That is sunlight and bacteria may have altered aldrin into dieldrin. The use of aldrin in Ghana was marketed under the trade name Aldrex 40 (Nollet, 2000). Comparing also the mean level of 1.15 ng/g of dieldrin detected in seed of watermelon from Sege to a mean level of 8.59 ng/g of dieldrin detected in watermelon from selected farms in Asante Mampong Municipality in a similar study conducted by Forkuo (2015) then the watermelon in Mampong Municipality seem to be highly contaminated. The level of OCP residues in the peel, pulp and seed of the watermelon were also compared with maximum residue limits (MRL) set forth by European Union (EU) and FAO/WHO Codex Alimentarius Commission. The results indicated that all the OCP residue levels were below MRL of EU and FAO/WHO as shown in table 4.15 to table 4.18 (EU, 2013; FAO/WHO, 2013). The low levels of OCP residues in the fruit may be attributed to low lipid contents of the fruit (Bempah and Donkor, 2010). The great level of significant difference ($p < 0.05$) that existed in the OCP residues detected as shown in the appendix, suggests that the difference is real and not by chance. That is, the respective mean effect on the peel, pulp and seeds were not the same for each watermelon sample at 5 % level of significance.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

The study was in two parts, the field survey and a laboratory work. It is clear from the survey that watermelon cultivation was dominated by men of the active age group (40 – 49) years with about majority (50 %) having no formal education. The study revealed that insecticides were the pesticides mostly used by the farmers for the insect-pest and disease management followed by fungicides and with majority obtaining their pesticides from agrochemical shops. Majority of the respondents (68.3 %) mixed different pesticides when spraying their watermelon crop with the hope of increasing potency of pesticide. The survey revealed that pre-harvest interval or waiting period on labels were neither observed nor correctly followed as some farmers harvested within the same day after pesticide application, presuming that pesticides residues on fruits after harvest will continuously increase the shelf life of fruits.

Laboratory work revealed the presence of fifteen OCPs residues in the peel, pulp and seeds of watermelon from the selected communities in the Ada-West district. Detectable OCP residues were dieldrin and p,p'–DDE. The seeds of watermelon from Koluedor recorded the highest level of 2.10 ng/g of p’p-DDE while the lowest level of 0.20 ng/g of dieldrin and p’p-DDE were recorded in the peel of watermelon from Sege. The detectable OCP residues are also among the banned pesticides of the EPA of Ghana (Afful *et al.*, 2010). Most of the OCP residues investigated were below the limit of detection of 0.01ng/g. The detectable OCP residues were below maximum residue level (MRL) set forth by EU guidelines and FAO/WHO Codex Alimentarius Commission. But as these toxic chemicals have the potential to bioaccumulate, their presence in the watermelon is of great concern and undesirable since increased accumulation in living tissues could pose serious health hazards to the general population. The study therefore provided important information (baseline information) on current pesticide contamination status of watermelon that will help in scientific assessment of the impact of pesticides on public health and the environment in general.

6.2 RECOMMENDATION

1. It is recommended that the regulatory agencies and authorities including the Environmental Protection Agency, the Ministry of Food and Agriculture, the Food and Drug Authority and Ghana Standards Authority should ensure compliance and enforcement of the laws on the use of banned and restricted pesticides.
2. Continuous sensitisation on the risks involved in buying pesticides from unapproved source**s** and farmer education on safe pesticide use and pre- harvest interval should be intensified in order to control and prevent pesticides residues from reaching dangerous levels particularly in the food supply.
3. A constant and regular monitoring programmes through residue level assessment is recommended due to the changing trends of pesticide usage in order to acquire adequate information on pesticide residues at the sampling sites.
4. Future monitoring studies are also recommended in order to assess the levels of other toxic chemicals such as heavy metals in food crops grown in the district.

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APPENDICES

APPENDIX I

WHO classification of pesticides used and their registration status in Ghana

TRADE NAME	ACTIVE INGREDIENT	PRE-HARVEST INTERVAL	WHO CLASS	USAGE OF PESTICIDE	REGISTRATION STATUS IN GHANA
KILSECT	LAMBDA CYHALOTHRIN 2.5 EC	2 - 3 DAYS	II	INSECTICIDE-SP	FRE
POLYTHRINE	CYPERMETHRIN	4 DAYS	II	INSECTICIDE-SP	PLC
STRIKER	LAMBDA CYHALOTHRIN 2.5 EC	2 - 3 DAYS	II	INSECTICIDE-SP	FRE
GOLAN	ACETAMIPRID	10 - 14 DAYS	II	INSECTICIDE	PCL
TOPSIN	THIOPHANATE-METHYL	7 - 14 DAYS	III	FUNGICIDE-OP	PCL
TOPCOP	SULPHUR	2 - 14 DAYS	III	FUNGICIDE	PCL
SULPHER 80	SULPHUR	2 - 14 DAYS	III	FUNGICIDE	PCL
KOCIDE	COPPER HYDROXIDE	7 - 14 DAYS		FUNGICIDE	FRE
FUNGURAN-OH	COPPER HYDROXIDE	7 - 14 DAYS		FUNGICIDE	FRE
K-OPTIMAL	LAMBDA CYHALOTHRIN 2.5 EC	2 - 3 DAYS	II	INSECTICIDE-SP	FRE
ACETASTAR	ACETAMIPRID	10 - 14 DAYS	II	INSECTICIDE	FRE
CYPERDEM	CYPERMETHRIN	7 - 14 DAYS	II	INSECTICIDE-SP	FRE
DURSBAN	CHLORPYRIFOS	4 DAYS	II	INSECTICIDE -OP	FRE
KARATE	LAMBDA CYHALOTHRIN 2.5 EC	2 - 3 DAYS	II	INSECTICIDE-SP	FRE
PAWA	LAMBDA CYHALOTHRIN 2.5 EC	2 - 3 DAYS	II	INSECTICIDE-SP	FRE

FRE = Fully registered for use in Ghana (valid for a maximum of three years) **OP** = Organophosphate

PCL = Provisional Clearance in Ghana (valid for a maximum of one year) **SP** = Synthetic pyrethroid

II = Moderately hazardous, **III** = Slightly hazardous, **WHO** = World health organization toxicity classes

(Agric in Ghana, 2011).

APPEN DIX II

Summary of analysis of variance results for pesticide residue in peel, pulp and seed of watermelon from Hwakpo

PESTICIDES	HWAKPO				
	PEEL	PULP	SEED	F-VALUE	P-VALUE
	MEAN±SD	MEAN±SD	MEAN±SD		
Beta-HCH	<0.01	<0.01	<0.01	-	-
Delta-HCH	<0.01	<0.01	<0.01	-	-
Gamma-HCH	<0.01	<0.01	<0.01	-	-
Heptachlor	<0.01	<0.01	<0.01	-	-
Aldrin	<0.01	<0.01	<0.01	-	-
Dieldrin	<0.01	<0.01	<0.01	-	-
Endrin	<0.01	<0.01	<0.01	-	-
Alpha-endosulfan	<0.01	<0.01	<0.01	-	-
Endosulfan-S	<0.01	<0.01	<0.01	-	-
P'P-DDT	<0.01	<0.01	<0.01	-	-
P'P-DDE	<0.01	<0.01	<0.01	-	-
P'P-DDD	<0.01	<0.01	<0.01	-	-
Methoxychlor	<0.01	<0.01	<0.01	-	-
Bifenthrin	<0.01	<0.01	<0.01	-	-
Lambda-Cyhal	3.3±0.14	1.1±0.14	0.21 ± 0.014	377.62	0.000
Beta-endosulfan	<0.01	<0.01	<0.01	-	-
Permethrin	1.7±0.14	0.7±0.14	<0.01	86.075	0.002
Cyfluthrin	0.5±0.14	0.2 ± 0.00	<0.01	9	0.095
Cypermethrin	5.7±0.42	3.8 ± 0.28	0.21 ± 0.01	179.24	0.001
Fenvalerate	2.5±0.14	2.1 ± 0.14	0.21 ± 0.01	223.29	0.001
Deltamethrin	3.8±0.28	2.5 ± 0.14	0.2 ± 0.00	199.4	0.001
Allethrin	<0.01	<0.01	<0.01	-	-
Dimethoate	<0.01	<0.01	<0.01	-	-
Chlorpyrifos	<0.01	<0.01	<0.01	-	-
Gamma-chlord	<0.01	<0.01	<0.01	-	-

F = Test of significance, p = probability

APPENDIX III

Summary of analysis of variance results for pesticide residue in Peel, pulp and seed of watermelon from Koluedor

PESTICIDES	KOLUEDOR				
	PEEL	PULP	SEED	F-VALUE	P-VALUE
	MEAN±SD	MEAN±SD	MEAN±SD		
Beta-HCH	<0.01	<0.01	<0.01	-	-
Delta-HCH	<0.01	<0.01	<0.01	-	-
Gamma-HCH	<0.01	<0.01	<0.01	-	-
Heptachlor	<0.01	<0.01	<0.01	-	-
Aldrin	<0.01	<0.01	<0.01	-	-
Dieldrin	0.5 ± 0.14	0.35 ± 0.07	1.1 ± 0.14	21	0.017
Endrin	<0.01	<0.01	<0.01	-	-
Alpha-endosulfan	<0.01	<0.01	<0.01	-	-
Endosulfan-S	<0.01	<0.01	<0.01	-	-
P'P-DDT	<0.01	<0.01	<0.01	-	-
P'P-DDE	0.7 ± 0.14	0.4 ± 0.00	2.1 ± 0.14	123.5	0.001
P'P-DDD	<0.01	<0.01	<0.01	-	-
Methoxychlor	<0.01	<0.01	<0.01	-	-
Bifenthrin	<0.01	<0.01	<0.01	-	-
Lambda-Cyhal	1.9 ± 0.14	0.8 ± 0.00	<0.01	121	0.008
Beta-endosulfan	<0.01	<0.01	<0.01	-	-
Permethrin	1.3 ± 0.14	0.8 ± 0.00	<0.01	-	-
Cyfluthrin	<0.01	<0.01	<0.01	-	-
Cypermethrin	1.9 ± 0.14	0.9 ± 0.14	<0.01	50	0.019
Fenvalerate	0.7 ± 0.14	0.38 ± 0.03	<0.01	9.846	0.088
Deltamethrin	<0.01	<0.01	<0.01	-	-
Allethrin	<0.01	<0.01	<0.01	-	-
Dimethoate	<0.01	<0.01	<0.01	-	-
Chlorpyrifos	<0.01	<0.01	<0.01	-	-
Gamma-chlord	<0.01	<0.01	<0.01	-	-

F = Test of significance, p = probability

APPENDIX IV

Summary of analysis of variance results for pesticide residue in peel, pulp and seed of watermelon from Matsekope.

MATSEKOPE					
PESTICIDES	PEEL	PULP	SEED	F-VALUE	P-VALUE
	MEAN±SD	MEAN±SD	MEAN±SD		
Beta-HCH	<0.01	<0.01	<0.01	-	-
Delta-HCH	<0.01	<0.01	<0.01	-	-
Gamma-HCH	<0.01	<0.01	<0.01	-	-
Heptachlor	<0.01	<0.01	<0.01	-	-
Aldrin	<0.01	<0.01	<0.01	-	-
Dieldrin	<0.01	<0.01	<0.01	-	-
Endrin	<0.01	<0.01	<0.01	-	-
Alpha-endosulfan	<0.01	<0.01	<0.01	-	-
Endosulfan-S	<0.01	<0.01	<0.01	-	-
P'P-DDT	<0.01	<0.01	<0.01	-	-
P'P-DDE	<0.01	<0.01	<0.01	-	-
P'P-DDD	<0.01	<0.01	<0.01	-	-
Methoxychlor	<0.01	<0.01	<0.01	-	-
Bifenthrin	<0.01	<0.01	<0.01	-	-
Lambda-Cyhal	3.3 ± 0.14	2.1 ± 0.14	<0.01	72	0.014
Beta-endosulfan	<0.01	<0.01	<0.01	-	-
Permethrin	4.5 ± 0.14	1.7 ± 0.14	<0.01	392	0.003
Cyfluthrin	1.05 ± 0.07	0.2 ± 0.00	<0.01	289	0.003
Cypermethrin	20.1 ± 0.14	17.5 ± 0.71	0.2 ± 0.00	1350.11	0.00
Fenvalerate	3.5 ± 0.14	1.9 ± 0.14	<0.01	128	0.008
Deltamethrin	3.9 ± 0.14	2.5 ± 0.14	<0.01	98	0.01
Allethrin	<0.01	<0.01	<0.01	-	-
Dimethoate	<0.01	<0.01	<0.01	-	-
Chlorpyrifos	7.1 ± 0.14	0.35 ± 0.07	<0.01	3645	0.000
Gamma-chlord	<0.01	<0.01	<0.01	-	-

F = Test of significance, p = probability

APPENDIX V

Summary of analysis of variance results for the pesticide residues in Peel, pulp and seed of watermelon from Sege

SEGE					
PESTICIDES	PEEL	PULP	SEED	F-VALUE	P-VALUE
	MEAN±SD	MEAN±SD	MEAN±SD		
Gamma-HCH	<0.01	<0.01	<0.01	-	-
Delta-HCH	<0.01	<0.01	<0.01	-	-
Beta-HCH	<0.01	<0.01	<0.01	-	-
Heptachlor	<0.01	<0.01	<0.01	-	-
Aldrin	<0.01	<0.01	<0.01	-	-
Dieldrin	0.2±0.00	0.35±0.07	1.15±0.07	156.5	0.001
Endrin	<0.01	<0.01	<0.01	-	-
Alpha-endosulfan	<0.01	<0.01	<0.01	-	-
Endosulfan-S	<0.01	<0.01	<0.01	-	-
P'P-DDT	<0.01	<0.01	<0.01	-	-
P'P-DDE	0.2±0.00	0.4±0.00	1.1±0.14	67	0.003
P'P-DDD	<0.01	<0.01	<0.01	-	-
Methoxychlor	<0.01	<0.01	<0.01	-	-
Bifenthrin	<0.01	<0.01	<0.01	-	-
Lambda-Cyhal	15.6±0.57	0.5±0.14	<0.01	1341.235	0.001
Beta-endosulfan	<0.01	<0.01	<0.01	-	-
Permethrin	<0.01	<0.01	<0.01	-	-
Cyfluthrin	<0.01	<0.01	<0.01	-	-
Cypermethrin	1.7±0.14	0.5±0.14	<0.01	72	0.014
Fenvalerate	0.9±0.14	0.2±0.00	<0.01	49	0.02
Deltamethrin	1.3±0.14	0.4±0.00	<0.01	81	0.012
Allethrin	<0.01	<0.01	<0.01	-	-
Dimethoate	<0.01	<0.01	<0.01	-	-
Chlorpyrifos	<0.01	<0.01	<0.01	-	-
Gamma-Chlord	<0.01	<0.01	<0.01	-	-

F = Test of significance, p = probability

APPENDIX VI

QUESTIONNAIRE SURVEY

This questionnaire is aimed at assessing the types of pesticides used by watermelon farmers in the Ada-West District in the Greater Accra Region of Ghana. This is part of the requirement for the award of a Master of Public Health Degree from Ensign College of Public Health, Kpong in the Eastern Region. The information provided will be treated as confidential and used only for the purpose of the research. No individual will be identifiable in any published work.

Thank you for your cooperation.

Questionnaire Number   Name of Enumerator

Date   Name of District

Tick as appropriate or complete by filling in the blank spaces where necessary. Multiple responses to a question may be provided, where applicable.

A. Respondents Characteristics

1. Name of Respondent

2. Age of Respondent

3. Sex of Respondent 1. Male [ ] 2. Female [ ]

4. Marital Status 1. [Married] 2. [Single] 3. [Divorced] 4. [Widowed] 5. [Others specify]

5. Major Occupation 1. [Farmer] 2. [Trader] 3. [Government employed] 4. [Others specify]

6. Educational background 1. [Primary] 2. [JSS/Middle School] 3.[Secondary] 4. [Vocational /Technical] 5. [Tertiary] 6. [No. Formal Education]

7. What ethnic group do you belong to? 1. [Akan] 2. [Ga-Adangbe] 3. [Ewe] 4. [Others specify]

8. What is your religious affiliation? 1. [Christianity] 2. [Islamic] 3. [Traditional religion] 4. [Others specify]

9. What is the name of your Community?

B. Farm Characteristics

10. Farming Experience

11. What is /are the average size of your farm (s)?

12. Name the type of watermelon varieties grown 1. [Sugar Baby] 2. [Top Harvest] 3. [Sweet Dragon] 4. [Crimson Sweet] 5. [Black Diamond] 6. [Florida Giant] 7. [Others specify]

13. Do you apply any pesticide in the cultivation of watermelon? 1. [Yes] 2.[No]

14. Who recommended the pesticide (s)? 1. [Extension officer] 2. [Agro-chemical retailer] 3. [Agent of agro-chemical distributor] 4. [Through advertisement] 5. [From friends] 6. [Others specify]

15. List all the types of pesticide used in watermelon cultivation

16. Do you use combination of pesticides at times to control insect pests and diseases on your watermelon? 1. [Yes] 2. [No]

17. What are the reasons for the cocktail mixture? 1. [To Increase the potency of pesticide] 2. [To produce healthy and disease free crop] 3. [Others specify]

18. How many types of pesticides do you mix at a time? 1. [One] 2. [Two] 3. [Three] 4. [Four] 5. [Others Specify]

19. What are the reasons for not using combination of pesticides? 1. [Pesticides already formulated] 2. [It is not safe to mix] 3. [Individual pesticides already effective] 4. [Others specify]

20. Name the pesticides use during the nursery stage 1.[Insecticide and Fungicide] [Insecticide] 2. [Fungicide] 3. [Others specify]

21. Name the pesticides use during the growth stage of the watermelon 1. [Insecticide and Fungicide] 2. [Insecticide] 3. [Fungicide] 4. [Others specify]

22. Name the pesticides use during the flowering stage 1.[Insecticide and Fungicide] [Insecticide] 2. [Fungicide] 3. [Others specify]

23. Name the pesticides you use during fruiting stage 1.[Insecticide and Fungicide] 2. [Insecticide] 3. [Fungicide] 4. [Others specify]

24. Do you apply pesticide to your crop during harvesting period? 1.[Yes] 2. [No]

25. Why do you apply pesticides during harvest? 1. [To enhance fruit firmness] 2. [To give better fruit protection] 3. [To improve fruit colour] 4. [Others specify]

26. What are the reasons for not applying pesticide during harvest? 1. [Pesticide not safe for consumption] 2. [Pesticide takes time to break down] 3. [Against the directive of agric extension officers] 4. [Others specify]

27. How long do you wait after the last pesticide application before harvesting? 1. [0 day] 2. [2-3days] 3. [4-6 days] 4. [7-14 days] 5. [Others specify]

28. What are some of the reasons for choosing a particular pesticide? 1.[Price is moderate] 2.[Effective control] 3. [Easily Available] 4. [Improve fruit colour] 5. [Keeps fruit firm] 6 .[Others specify]

29. Do you follow all instructions on labels for the correct use of pesticide? 1. [Yes] 2. [No]

30. Name the type of sprayers you use in spraying your crops? 1. [Motorized/ motor blow]

2. [Knapsack sprayer] 3. [Others specify]

31. What do you use to measure the quantity of pesticides you pour in to the spraying machine or container? 1.[Tea spoon] 2. [Table spoon] 3. [Small tomato tin] 4. [Pesticide lid] 5. [Milk tin] 6. [Calibrated measuring cylinder] 7. [Others specify]

32. Where do you obtain your pesticide supplies? 1. [From other farmers] 2. [From the markets on table tops] 3. [From vehicles that comes on market days] 4. [From dealers shop] 5. [Cooperative association] 6. [Others specify]

33. Do you wear protective clothing or use any PPE when spraying? 1. [Yes] 2. [No] if yes list them

34. What time of the day do you spray? And why?

35. What are some of the effects experience after spraying? 1. [General weakness] 2. [Itching and rashes] 3. [Abdominal pain] 4. [Sneezing] 5. [Dizziness and headache] 6. [Vomiting] 7. [Others specify]

36. How do you sell your watermelon? 1. [On the farm] 2. [In the market] 3. [Sold to wholesalers] 4. [Retailers] 5.[Others specify]

37. Do you receive any complaint from the buyers with regards to the watermelon they buy from you? 1. [Yes] 2. [No] if yes what are some of the complains receive

38. Do you eat the watermelon from your farm 1. [Yes] 2. [No] if no why

APPENDIX VII

SAMPLE COLLECTION FORM

OCP RESIDUE ASSESSMENT IN WATERMELON

Date of Collection……………………………..

Time of Collection……………………………

Sample ID………………………………………

Number Collected………………………………

Sampling Site…………………………………..

Farmers ID……………………………………..