KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

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DEPARTMENT OF CHEMISTRY

LEVELS OF ORGANOCHLORINE PESTICIDE RESIDUES IN FRUITS AND SOILS FROM THE MAMPONG MUNICIPALITY

BY

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(BSc. CHEMISTRY)

THIS THESIS IS SUBMITTED TO KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF MPHIL ENVIRONMENTAL CHEMISTRY DEGREE.

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DECLARATION

I hereby declare that this thesis is my own work towards MPhil Environmental Chemistry and that to the best of my knowledge, it neither contains any material previously published by another person nor material which have been accepted for the award of any other degree at any institution, except where due acknowledgement has been made in the text.

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DEDICATION

This project is dedicated to my mum madam Agatha Badu and my brother, Bernard Aning.

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All Glory to the Almighty God, Whose bounteous blessings gave me potential and opportunity to make this humble contribution. I am cordially gratified to my supervisors; Dr. Nathaniel Owusu Boadi and Dr. Lawrence Borquaye of Chemistry Department, Kwame Nkrumah University of Science and Technology and Mr. Samuel Afful of Chemistry Department, Ghana Atomic Energy Commission for their patience, trust, moral support, encouragement and able guidance throughout my study. My special thanks also go to all other individuals who in diverse ways helped to make this project a success.

ABSTRACT

Levels of fifteen organochlorine pesticide (OCP) residues in watermelon, pineapple and banana fruits from the farms and those sold on the market within the Mampong municipality together with the soil found around the fruit in the farms from which the fruits were taken have been analysed. A total of 120 fruits and 60 soil samples were analysed, out of which a total of 100 freshly harvested fruit samples were sampled randomly from farms in Kyerefamso, Woraso, Adidwan, Atonsuagya and Bosomkyekye and 20 from the market. The samples were extracted and analysed for OCP residues using gas chromatography equipped with electron capture detector. The mean residue concentrations ranged from <0.01-3.59±0.14 ng/g and 0.59 ± 0.030.98± 0.03 ng/g respectively in pineapple and banana from Adiwan. The mean OCP levels ranged from 0.20 ± 0.01 - 11.53± 0.10 ng/g, <0.01 - 1.23 ± 0.07 ng/g and <0.01 - 0.39 ± 0.10 ng/g for watermelon, pineapple and banana fruits respectively from the farms in Atonsuagya. The mean levels of OCP residues detected in the fruits from Bosomkyekye ranged from 3.38 ± 0.03-2.16.41±0.05 ng/g, <0.01-3.88 ± 0.08 ng/g and <0.01- 1.18 ± 0.01 ng/g for watermelon, pineapple and banana fruits respectively. The mean residue concentrations in the fruits samples from Kyerefamso also ranged from 0.49 ± 0.41- 48.22 ± 0.85 ng/g, <0.01-2.59 ± 0.08 ng/g and 4.23 ± 0.0 - 12.23 ± 0.32 ng/g for watermelon, pineapple and banana respectively. There were no residues detected in fruits from Woraso. There were no significant variations in the levels of pesticides in the three fruit samples from all the sampling areas ($p>0.05$). Comparison of the results of OCP residues in fruit from the farm and the market showed that higher levels OCPs were recorded in fruits from the farms compared to that from the market. Comparing the residual levels in fruits with that in soil samples taken around the fruit showed that some of the residues detected in the fruit were absent in the soil but, generally, the concentration of the OCP residues in the soils were much higher than that in most of the fruit samples analysed. Highest mean levels of OCPs such as gamma-HCH, aldrin and methoxychlor and beta-HCH and endrin recorded in some watermelon and banana fruits respectively from the farm exceeded the maximum residue limits (MRLs) adopted by the EU but were lower than FAO/MRL. The hazard indices from the health risks assessment showed that all the OCP residues except aldrin did not show any health risk associated. The carcinogenic risk of the OCP in fruits in general were of less concern, since all the OCP except p,p'-DDT, carcinogenic rates in the fruits were below the acceptable risk level.

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LIST OF ABBREVIATIONS

ADI	-	Acceptable Daily Intakes
ATSDR	-	Agency for Toxic Substances and Disease Registry
BW	-	Body Weight
CAC	-	Codex Alimentarius Commission
CBC	-	Cancer Benchmark Concentration
CFCs	-	Chlorofluorocarbons
DDD	-	Dichloro Diphenyl Dichloroethane
DDE	-	Dichloro Diphenyl Dichloroethylene
DDT	-	Dichloro Diphenyl Trichloroethane
ECD	-	Electron Capture Detector
EDI	-	Estimated Daily Intake
EFSA	-	European Food Safety Authority

EPA	-	Environmental Protection Authority
ED	-	Estimated Dose
EU	-	European Union
FAO	-	Food and Agriculture Organization
FDA	-	Food and Drugs Authority
GC	-	Gas Chromatograph
GC-ECD	-	Gas Chromatograph with Electron Capture Detector
GDP	-	Gross Domestic Product
GESAMP	-	Group of Experts on the Scientific Aspects of Marine Environment
GSS	-	Ghana Statistical Service
HCB	-	Hexachlorobenzene
HCH	-	Hexachlorocyclohexane
HI	-	Hazard Index
HR	-	Hazard Ratio
IAEA	-	Nternational Atomic Energy Agency
IARC	-	International Agency for Research on Cancer
IPCS	-	International Programme on Chemical Safety
MOFA	-	Ministry of Food and Agriculture
MRL	-	Maximum Residue Limit
NRCC	-	National Research Council of Canada
NRI	-	Natural Resource Institute
OC	-	Organochlorine
NTP	-	National Toxicology Program
OCP	-	Organochlorine Pesticide
OSF	-	Oral Slope Factor
OSHA	-	Occupational Safety and Health Administration
PAH	-	Polycyclic Aromatic Hydrocarbons

PCBs	-	Poly Chlorinated Biphenyls
PCDs	-	Poly Chlorinated Dibenzodioxins
POPs	-	Persistent Organic Pollutants
R_fD	-	Reference Dose
US EPA	-	United State Environment Protection Agency
WHO	-	World Health Organization

SYMBOLS

K_H	-	Henry's constant
K_{ow}	-	partition coefficient
^oC	-	degree celcius
g	-	gramme
kg	-	kilogramme
mg	-	milligramme
mg/kg	-	milligramme per kilogramme
mg/L	-	milligramme per litre
ng/g	-	nanogramme per gramme
pH	-	degree of acidity/basicity
ppb	-	part per billion
ppm	-	part per million

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the study

The gradual increase in the world population demands more food production, which has resulted in the use of pesticides to protect crops against diseases and damage from pests. Pesticides have been used to stop the activities of pests and have resulted in rise in crop productions. The increasing usage of pesticides to boost agricultural productions has a cost. The pesticides accumulate in the environment and enter the food chain, directly and indirectly through the crops and also domesticated livestock.
(Thundiyil *et al*., 2008).

Over the years, a large number of synthetic chemicals have been produced intentionally to increase agricultural production and many of them have turned to be environmental pollutants (Longanathan and Kannan 1994). Among all the groups of pesticides the major concern was directed to organochlorine pesticides because of their persistence, bioaccumulative and toxic potential they pose to humans and environment. Many organochlorine pesticides have similar characteristics such as their stability against decomposition due to their strong carbon-chloride, hydrophobic and lipophilic. The lipophilic nature and low degradation rates of organochlorine pesticides have resulted in their accumulation in the fatty tissues and subsequent increase in concentrations in organisms progressing up the food chain (Mwevura *et al*., 2002). There are several routes of exposure of organochlorine pesticides to humans but the main route of exposure is through the ingestion of contaminated food

(Nicolopoulou- Stamati and Pitsos, 2001). There is growing apprehension that OCPs have several health effects on organisms including human beings (Brody and Rudel, 2003). Some of the health effects of OCPs reported in humans includes carcinogenicity, neurotoxicity, developmental toxicity, immunotoxicity and disorders of the reproductive system (Skakkebaek *et al*., 2001). The majority of these health effects are due to the ability of the organochlorine compound to modify the amount of enzymes, hormones, neurotransmitters and growth factors (Teilmann *et al*., 2002). The accumulation of OCP in foods and the environment has generated a lot of concern globally and this has resulted in many studies being carried out to determine their levels in numerous ecosystems (Poolpak *et al*., 2008).

Agriculture is one of the most important economic activities in Ghana, engaging about 50% of the national work force, mainly subsistence farmers on a formal and informal basis and contributes about 19.9% of GDP and total exports (GSS, 2014). In agriculture, fruit production plays a nutritional as well as varied socio-economic role. Fruit production in Ghana has advanced from a largely subsistence activity performed by local farmers to a commercial activity undertaken by most young men and women. One of the main problems faced by fruit growers in Ghana is how to fight against pests. Some fruits usually attract a wide range of pests and diseases, and may require intensive pest management (Dinham, 2003). Pest control practices in Ghana in fruit production include highly toxic pesticide applications that are usually misapplied frequently, leading to pesticide contamination of the products itself and the environment.

In Ghana, the OCP residues have been detected in friut, vegetables, meat, sediment, human blood, breast milk, fish and medicinal plants (Ntow, 2001; and Darko Acquaah, 2007; Afful *et al*, 2010 ; Bempah, *et al*, 2012; Agbeve *et al*, 2014). OCP residues in fruit and vegetables is a threat to public health, as they are usually taken raw so they potentially contain higher levels of pesticide residues compared to other food groups of plant origin. Because of the harmful effects on human health and the environment, concerns about organochlorine pesticide residues in food have been growing. Many countries have put in place regulations to protect consumers against the dangers of these pesticides. Act 1996 pesticide management (Act 528) gives the Environmental Protection Agency (EPA) of Ghana regulator for pesticide use and control. The lack of effective government control mechanisms and the lack of technical capacity on the part of state agencies led to the non-application of these regulations.

1.2 Problem Statement

The detection of organochlorine pesticides (OCP) residues in biological species in the environment from the ingestion of contaminated food is unacceptable, as they have health implications on humans. Organochlorine pesticides are lipophilic and have low biological and chemical degradation leading to their build up in fatty tissues of living organisms and consequent increase in concentrations of organisms moving up along the food chain (Helberg *et al*., 2005). Higher amounts of OCP residues were found in Ghana in food, meat, human blood, breast milk and water (Ntow, 2001; and Darko Acquaah, 2007; Afful *et al*. 2010). Generally, food consumption is the primary route of exposure for humans (Patandin *et al*., 1999). Fruits are a major component of the worldwide food consumption. These fruits are usually taken in their raw state, so they potentially contain higher levels of pesticide residue compared to other food products of plant origin, to act as intermediaries in the transport of residues pesticides from soils to humans (Daou and Dahshur, 2014). Organocholrine pesticide residue levels studies in the fruit have been documented in developed countries. However there is not much information on concentrations of pesticides in fruits that are grown in the Mampong municipality and those sold on the Ghanaian market. This work seeks to analyse certain OCP residues in fruits and soils from selected farms in the Mampong municipality to provide elementary data on the state of pollution of fruits and soils with pesticides.

1.3 Justification.

Agriculture is one of the most important economic sectors of Ghana that employs about 50% of the population and contributes about 19.9% to GDP (GSS, 2014). The population growth necessitated increased food production which has forced the use of chemicals to protect agricultural products from attacks of pests and diseases. Increases in yields of crops due to pesticide usage have substantially resulting in their accumulation in the environment and entry into the human food chain (Thundiyil *et al*., 2008).

Fruits are vital group of food crops and also constitute a key component of human diet. For better crop yields, farmers use large quantities of pesticides during before and throughout the growth of the fruit even at the stage of fruiting. Due to poor handling practices and the use of more toxic pesticides by farmers and the management and regulation of these chemicals in poor developing countries, the emergence of pesticide poisoning in developing countries is much greater than in developed countries (Waichman *et al*., 2007; Bhanti *et al*, 2004) .

OCP is of major concern compared to the other group of pesticides because of their bioaccumulation characteristic, potential health effects to humans and the environment and also persistence in the environment. The indiscriminate uses of these pesticides have resulted in their buildup in agricultural products such as fruits (Sudaryanto *et al*., 2007). The problem of accumulation requires extra consideration in fruits because they are mainly consumed in their raw state, it is assumed to contain higher levels of these pesticides. Prolonged exposure to these pesticides through ingestion of contaminated food is known to induce health effects related to the development of cancer, dysfynction teratogenic, reproductive disorders and endocrine disruption (Monirith *et al*., 2003) and this has led to the inclusion of some them as persistent organic pollutants (POPs) in the Stockholm Convention. This justified the need to study the organochlorine pesticide residue in fruits. In Ghana, although there is sufficient legislation to regulate the manufacture, import and use of chemicals including pesticides, but the lack of government effective control mechanisms and the lack of technical capacity on the part of state agencies has led to the non-application of these regulations (Gerken *et al*, 2001 ; Pesticide Control and Management Act, 1996). The confluence of non-enforcement, lack of market standards and insufficient knowledge on alternatives to pesticide use called for the need to regularly study the pesticide residues in agricultural products.

Fruit productions in the Mampong municipality are on a commercial basis for local consumption and export. The levels of pesticides in fruits for export are usually checked by international regulatory authorities, but those consumed locally are not scrutinized regularly. Since the levels of pesticide residues in food can pose an important health risk to humans, their evaluation and continuous control in food products is of great importance.

1.4 Objective of the study

1.4.1 General objective

The main objective of this study was to determine the levels of organochlorine pesticide residues in fruit and soil samples from selected farms in Mampong municipality and establish the pesticide contamination of the food and soil by these pesticides.

1.4.2 Specific objectives

1. To determine the levels of OCP residues in pineapple, watermelon and banana samples from selected farms in the municipality of Mampong.
2. To determine the levels of OCP in soil from selected farms in Mampong municipality
3. To determine the levels of OCP residues in pineapple, watermelon sold on the Mampong market.
4. To compare the levels of OCP in watermelon, pineapple and banana samples with international acceptable levels.
5. To estimate the potential health risk linked with the daily consumption of fruits from the selected farms.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction to pesticides

Pesticide is defined as any substance or mixture of substances used to control, prevents or destroyed pest damage (FAO, 2004). Pesticides have been widely used around the world since the middle of last century. More than 1000 active ingredients are being made in thousands of different commercial products and are used in our environment, mainly in agriculture (El-Shahawi *et al*., 2010). Between the period of 1980 and 1997, chemical production capacities in developing countries increased by over 300% (Jorgenson, 2001).

Over the years, the use of pesticides has greatly increased the quantity and improves the quality of food for the growing world population. However, with the quantities used, concerns about its adverse effects on living organisms, including human beings has also increased. It has been estimated that less than 0.1% of the pesticide applied to crops actually reaches the target pest; the rest enters the components of the environment, contaminating soil, water and air (Langenbach, 2013). It is estimated that almost 2.5 million tonnes of active ingredient are used annually for the control of pests and diseases worldwide (Carlile, 2006). The widespread use of pesticides not only contaminates the water, soil and air, but also causes them to accumulate in crops (fruits and vegetables).

Pesticides are transported mainly by wind and rain from their application points to neighboring crops and lands, where their presence may have undesirable or harmful effects. The quantities

of pesticides in a given region are determined by a large measure of the intensity of pesticide application and types of crops grown there. The main means by which pesticides are released into the environment are by their use, transportation and storage, neutralization and burial, storage of banned pesticides and expired in landfill and other places for this purpose (Vijgen Egenhofer, 2009;
Holoubek 2011).

2.2 Classification of pesticides

Pesticides can be classified in several ways, for example, by target pest; insecticide for insects, molluscicides for snails and slugs, nematicides for nematodes, piscicide for fish, and vertebrate predators, rodenticides for rodents, fungicides for fungi, avecides for pest birds, herbicides against weeds. They can also be categorized into inorganic and organic compounds based on their structures. Inorganic compounds include arsenic insecticides, fluoride insecticides and inorganic fungicides, while organic include organochlorines, organophosphates and organonitrogen pesticides.

2.3 Organochlorine pesticide compounds

2.3. 1 Aldrin

Aldrin was synthesized in 1948, but was formulated commercially as a pesticide in 1950 (Smith, 1991). Aldrin is the common name for the pesticide that contains about 95% of HHDN(1, 2, 3, 4, 10, 10-Hexachloro-1, 4, 4a, 5, 8, 8a-Hexahydro-exo-1, 4endo-5, 8- Dimethanonaphthalene) as the main active ingredient .Technical grade contains about 85.5% of the main ingredient (HHDN), 4.5% of associated compounds and 10% of other compounds (Smith, 1991). Aldrin can readily decompose to dieldrin within plants and animals and as a result, lower levels of aldrin residues are mostly detected in foods and in animals (WHO, 1999). Aldrin toughly binds to soil particles and is very resilient to leakage into groundwater. Volatilization is a significant means in which aldrin is lost from the soil. Aldrin is produced through the Diels-Alder reaction of hexachlorocyclopentadiene against surplus bicycloheptadiene at a temperature of l00 ° C (WHO, 1999). Aldrin can be used to control pests such as termites, rootworm, larvae, rice weevil, and grasshoppers (WHO, 1999). Figure 2.1 below shows the chemical structure of Aldrin.

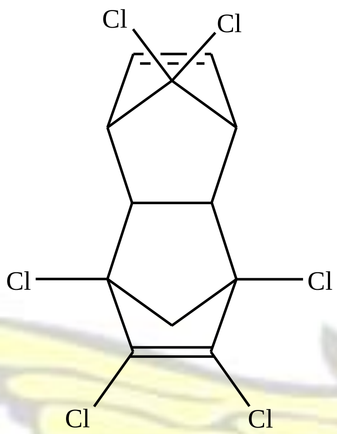


Figure 2.1: The chemical structure of aldrin

2.3.2 Dieldrin

Dieldrin was first synthesized in 1948 and commercially manufactured in 1950. Dieldrin is the generic name for the insecticide that contains HEOD (1,2,3,4,10,10-6,7-epoxy hexachloro- l, 4,4a, 5,6,7,8,8a endn-octahydro-1,4-exo-5,8 dimethanonapthalene) as the main active ingredient. Technical grade dieldrin contains about 80.75% HEOD, insecticidally correlated chemicals of about 14.25% and then about 5% of supplementary compounds (Smith, 1991). Dieldrin does not easily leach into groundwater due its persistency in soil. One major mechanism in which dieldrin can be lost from the soil is volatilization. The persistent nature and hydrophobicity has led to the bioconcentration of dieldrin (WHO, 1999). Dieldrin can be synthesized via the epoxidation of aldrin using a peracid such as peracetic acid (WHO, 1999). Dieldrin was widely used in the agriculture sector to control soil insects but its usage has been banned in various countries due to their toxic effects on humans and the environment (Smith, 1991).

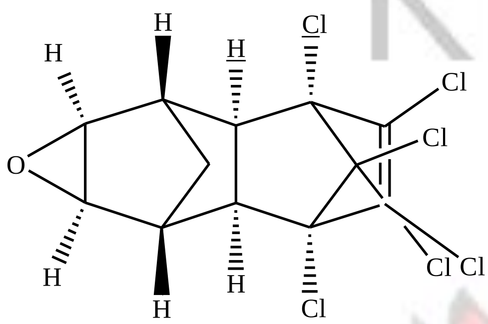


Figure 2.2: The chemical structure of dieldrin

2.3.3 Heptachlor

Heptachlor was synthesized by isolation from technical grade chlordane and formulated as a commercial insecticide in the USA in 1952 (WHO, 1994). Technical grade contains about 72% of pure heptachlor and 28% of associated compounds which includes about 20% of chlordane (IARC, 1991). The solubility of heptachlor is very low in water but high in most organic solvents. Heptachlor is very volatile and usually partitions into the atmosphere as a result. Within animals heptachlor is transformed into heptachlor epoxide, which has similar toxicity as that of heptachlor and also accumulates in the fatty tissues of animals. The production of heptachlor is similar to that of chlordane. Firstly, hexachlorocyclopentadiene reacts with cyclopentadiene to produce chlordane. Then heptachlor is synthesized through the radical chlorination of chlordane (IARC, 1991). Heptachlor is an insecticide produced for non-systemic stomach and contact. They were extensively used to control insects and termites in the soil (WHO, 1994). It was also used to kill cotton insects, grasshoppers, and some crop pests (Smith, 1991).

Heptachlor was also employed in the past to control the spread of malaria (IARC, 1991). The half-life of heptachlor in mild soil is up to about two years (WHO, 1994). The chemical structure of heptachlor is presented in Figure 2.3.

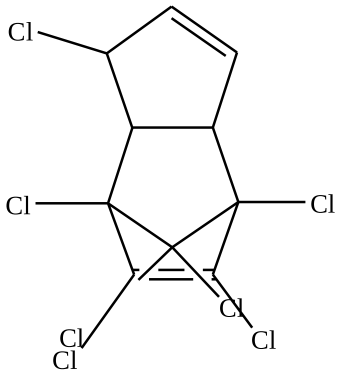


Figure 2.3: The chemical structure of heptachlor

2.3.4 Chlordane

Chlordane consists of mixture of chlorinated hydrocarbons such as chlordane, heptachlor, nonachlor and other related compounds. Technical grade of chlordane mostly contains about 64-67% chlorine (NRC, 1992). Chordane like all the organochlorine compounds is very soluble in organic solvents but insoluble in water. Chlordane is partially volatile and probable can partition into the atmosphere. Chlordane has a high partition constant (log K_{OW} = 6.00) and so it quickly binds to aquatic sediments and bioconcentrate in the fatty tissues of living organisms (Smith, 1991). Chlordane was first announced as an insecticide in 1945. It is manufactured through the reaction of hexachlorocyclopentadiene with cyclopentadiene to form chlordene first. The chlordene is then further chlorinated to produce chlordane (IARC, 1991). Chlordane is a wide-ranging spectrum insecticide that was used massively on agricultural crops, such as vegetables, corn, oilseeds, potatoes, sugar cane, sugar beets, fruits, nuts, cotton and jute (Smith, 1991). Chlordane has been detected in arctic air, water and organisms, due to its chemical properties it can travels over a wide range (Lockhart *et al*., 1992). Figure 2.4 below shows the chemical structure of chlordane.

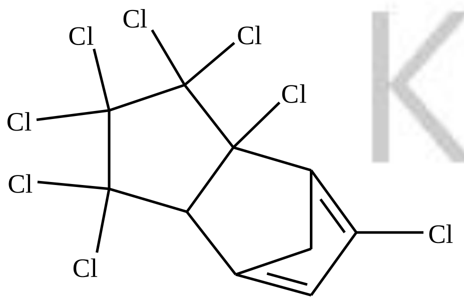
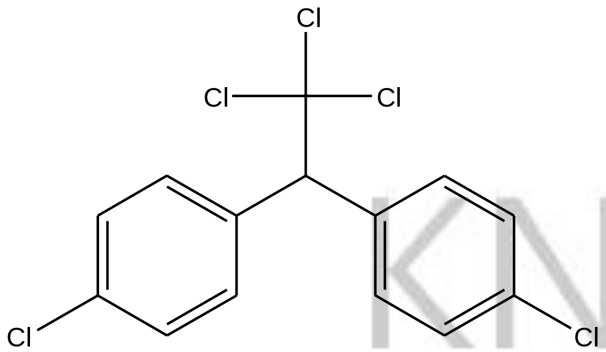


Figure 2.4: The chemical structure of chlordane

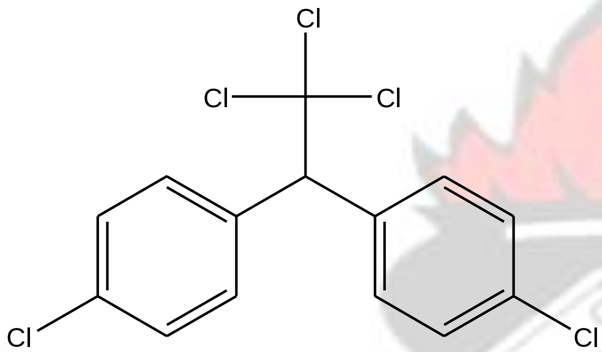
2.3.5 DDT

DDT was first synthesized by Othmar Zeidler in Germany in 1874. The insecticidal properties were discovered in 1939 by Swiss chemist Paul Muller. During the Second World War DDT was expansively used to control the spread of malaria, typhus and other vector-borne diseases to humans and crops (Smith, 1991). DDT was the widely used to control pests on various agricultural crops and also used to control disease vectors. The growing apprehension about the toxic effects that DDT had on the environments and animals, such as birds led to austere limitations and sanctions of its usages in several countries in the 1970s (Gips, 1990). DDT is very insoluble in water but soluble in most organic solvents. Their lipophilic nature has resulted in their accumulation in the fatty tissues of organisms leading to its bioconcentration and biomagnification. The metabolites of DDT (DDD and DDE) are more persistent in the environment than the parent compound. DDT and other correlated compounds are very persistent in soil so much that about 50% can remain in the soil 10-15 years post application (Keller, 1990). The chemical structures of p, p-DDT, p, p'-DDD and p, p-DDE are presented in figures 2.5a-2.5c



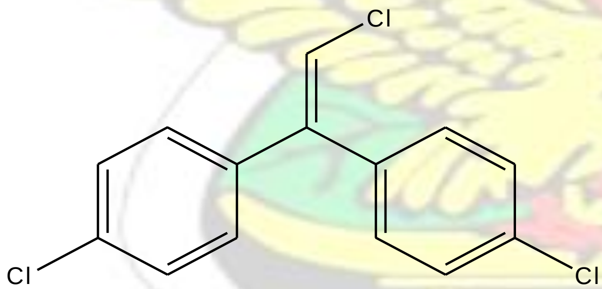
p,p' Dichloro Diphenyl Trichloroethane

Figure 2.5a: the chemical structure of p, p'-DD



p,p' Dichloro Diphenyl Trichloroethane

Figure 2.5b: The chemical structure of p, p'-DDD



p,p' Dichloro Diphenyl Dichloroethylene

Figure 2.5c: The chemical structure of p, p' DDE

2.3.6 Endrin

The usage of endrin as a pesticide was first sanctioned for use in 1952 in America (Smith, 1991). The purity of technical grade endrin is about 92% (WHO, 1992). When endrin gets into the body of animals, it breaks down quickly and so the accumulation of endrin in the fatty tissues of animals is not much as compared to the other organochlorine pesticides compoumds having the same chemical structure. Endrin readily enters the atmosphere through volatilization and can also pollute the surface water through runoff from soil (WHO, 1992). The production of endrin involves the vinyl chloride condensation using hexachlorocyclopentadiene dehydrochlorination of the adduct and consequent reaction with cyclopentadiene to produce isodrin, which is epoxidized by reacting with peracetic or perbenzoic acid (WHO, 1992). Endrin being foliar insecticide, it is usually applied to field crops such as cotton and grains and can also was also use to control rodents such as mouse (Smith, 1991). The levels of endrin detected in the environment are as a result of the extensive usage for agricultutral purposes, which has resulted in their accumulation in soil (ATSDR, 1996; IPCS, 1992). The chemical properties of endrin such as lower solubility in water, high stability in the environment, and semi-volatility also increases its wide range transport and have resulted in their accumulation in the arctic freshwater (Lockhart *et al*., 1992). The chemical structure of endrin is presented in Figure 2.6.

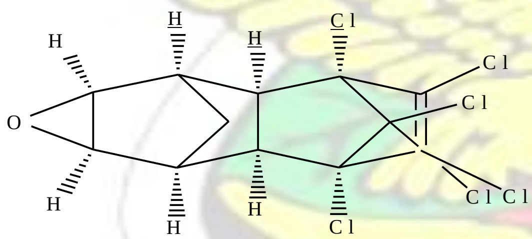
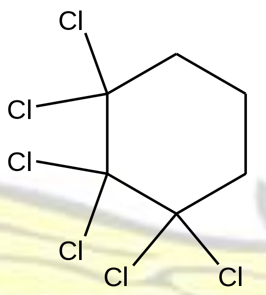


Figure 2.6: The chemical structure of endrin

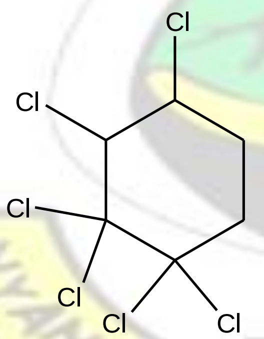
2.3.7 Hexachlorocyclohexane (HCH)

Hexachlorocyclohexane (HCH) formulations include the various isomers such as alpha, beta, gamma and delta. The gamma isomer which is normally referred to as lindane, have been used extensively in the past as a pesticide to control soil insects. The other isomers are mostly produced during the production of lindane, and were also used mostly as fungicides to control fungi. The technical grade HCH is a mixture that consists of about 64% alpha and 10% to 15% gamma isomer. HCH isomers, particularly the alpha and gamma are the HCH isomers that have been extensively found to be present in air, soil, water and sediment due to their massive productions and usage in the past. The half-life of gamma HCH commonly kwon as lindane in soil and water is about two weeks. The bioaccumulation of HCH in plants is not substantial compared to animals, because HCH isomers are lipophilic so they can accumulate in the fatty tissue of animals. The major route of exposure of the general public to HCH is through the ingestion of food containing the residues of HCH (ATSDR, 2005). The chemical structures of beta-HCH and delta HCH are presented in figures 2.7a - 2.7b below.



beta-Hexachlorocyclohexane

Figure 2.7a: The chemical structure of the beta-HCH

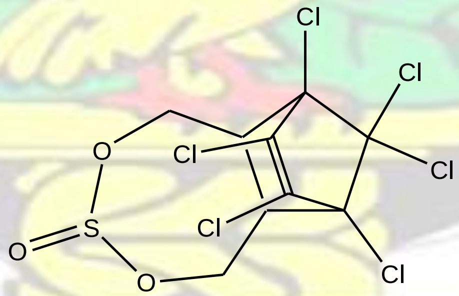


delta-Hexachlorocyclohexane

Figure 2.7b: The chemical structure of the delta-HCH

2.3.8 Endosulfan

Endosulfan belongs to chlorinated hydrocarbon insecticide subgroup of cyclodiene. The chemical name for the main active ingredient in endosulfan is 6,7,8,9,10,10hexachloro-1,5,5a,6,9,9a-hexahydro-6,9-methano-2,4,3 benzodioxathiepin- 3 oxide. Endosulfan is a wide-ranging spectrum organochlorine insecticide and acaricide which were extensively used on food and non-food crops. It can also be used to preserve wood. The formulation of endosulfan is mostly in wettable powder and emulsifiable concentrated liquid which mostly look like cream to brown-coloured crystals (ATSDR, 2001). Pests such as aphids, colorado potato beetle, cabbageworms and leafhoppers can be controlled by using endosulfan. Endosulfan is used in some countries to control tsetsefly in the cultivation of cotton and coffee. Technical grade endosulfan contains two isomers of endosulfan: alpha-endosulfan and betaendosulfan. There are several routes of exposure of endosulfan to humans but the major route of exposure is through the ingestion of endosulfan contaminated food and water. Endosulfan is amongst the most detected pesticides residues in foods (ATSDR, 2001). Figure 2.8 below shows the chemical structure of endosulfan.



6,7,8,9,10,10-Hexachloro-1,5,5a,6,9,9a-hexahydro- 6,9-methano-2,4,3-benzodioxathiepine-3-oxide

Figure 2.8: The chemical structure of endosulfan

2.4 Presence of organochlorine pesticides in the environment

The long term uses of pesticides for both agriculture and non- agriculture purposes can affect human health via the ingestion of foods that contains the residues of these pesticides. Each year there is about 25 million peoples reported from the southern hemisphere who are exposed to pesticides, out of which about 220,000 die (Adeyeye and Osibanjo, 1999). To protect the health of consumers, most developing countries depend on international permissible levels that have been established by the joint committee of Food and Agriculture Organization and the World Health Organization through the Codex Alimentarius Commission (FAO, 2004).

A study by Kumari *et al*., (2002) in India reported that 100% of all the analysed vegetables contain residues of pesticides. Out of total 60 samples analysed 92% were found to contain organochorine compounds, 80% with organophosphorus with pyrethroids and carbamates also recording 41% and 30% respectively. Nearly 23% of the recorded levels of organophosphorus residues were above respective MRL values. Endosulfan, wich is the most commonly used insecticide on cotton, in 1999-2000 caused food poisoning death of about 70 citizens in Benin (Vodouhe, 2001).

In Ghana, some studies have also been undertaken over the years to estimate the levels of OCP residues in the environment.

Abegve *et al*., (2014) reported organochlorine pesticide residues in the roots of *Cryptolepis sanguinolenta*, anti-malarial herbal plant. Out of total 14 OCPs monitored, beta-HCH, delta-HCH, gamma-HCH, heptachlor, aldrin, gammachlordane, alpha-endosulfan, p, p-DDE, dieldrin, endrin, p, p '-DDD p, p'-DDT and methoxychlor were the ones detected in the samples. The studies were conducted in Abetifi Pepease in the Kwahu East and Worawora and Apesokobi in the Biakoye districts of Ghana. The average levels of the OCP residues detected in the *Cryptolepis* samples from Biakoye and Kwahu East districts during the dry season were relatively higher than that detected in samples collected during the wet season. The average levels ranged from 0.006-0.061

mgkg $^{-1}$ for dry season samples, but the concentrations for the rainy season samples ranged from 0.001-0.011 mgkg^{-1}. The average levels of OCP residues detected in the samples were mostly lower than the MRL values established by joint committee of FAO/WHO.

Azanu *et al*., (2014) also reported OCP levels in some natural spices sold in Kumasi. A total of twenty samples including ten different spices were purchased from suppliers from at Asafo and central markets in Kumasi, Ghana, and analysed. Lindane concentration (ug / kg) for all spices ranged from 10 to 180, HCB ranged from below the detectable limit (1 ppb) to 166 ppb. Most of the organochlorine pesticide residues detected were below the maximum residue limits established by the Codex Alimentarius Commission (CAC).

A study by Bempah *et al*., (2012) also determined levels of particular OCP and OP residues in fruits and vegetables purchased from some markets in Ghana. A total of 309 fruit and vegetable samples were bought from some key metropolitan markets and supermarkets in Greater Accra. The results found from the study indicated the presence of methoxychlor in most of the samples analysed. The levels of methoxychlor detected in pineapples, lettuce, cabbage, cucumber and onion were higher than EU / MRL. The levels of lindane in papaya, pineapple, cabbage and onion and dieldrin also in papaya, banana, pineapple and cabbage exceeded the EU/MRL values. The levels of residues of endrin in lettuce and carrots were higher than the EU/MRL, as was the chlorpyrifos in pineapple.

Similar study was carried out by Bempah *et al*., (2011) on the levels of organochlorine pesticides (OCP) residues in vegetables. Total of 240 vegetable samples were purchased from selected markets within Greater Accra region of Ghana. The OCP targeted were lindane, heptachlor and its epoxide, endrin, dieldrin, o, p DDE, p, p -DDE, o, p-DDD, o, p-DDT and p, p'-DDT. The results from their study revealed the presence of OCP residues detected in almost all the vegetables. OCP residues were detected in about 71.9% of all the vegetable samples analysed, out of which the levels detected in 31.48% of the samples were higher than MRL values. DDT and its metabolites (o, p'-DDE, p, p'-DDE and o, p'-DDD) were the most detected pesticides followed by lindane. The levels of OCP residues detected in vegetables from the supermarket were relatively higher than that in vegetables from the roadside grocery stores and open markets.

Osei-Tutu *et al*., (2011) analysed the levels and kinds of OCP residues present in the breast milk obtained from 21 first-time mothers in La, an area within Accra. Fourteen OCP residues specifically p, p-DDT, p, p-DDE, gamma-HCH, delta-HCH, heptachlor, aldrin, endrin, endrin-aldehyde, endrin-ketone, alpha-endosulfan, endosulfan-sulfate, gamma-chlordane, dieldrin, and methoxychlor were detected in the breast milk samples. P, p'-DDE were detected in all the samples. p, p-DDT, delta-HCH, gammaHCH and endosulfan sulfate were also detected in about 76.79, 95.25, 80.95 and 85.71%, respectively in the total samples. The levels of OCP residues in the samples ranged from 1.839- 99.05 g / kg of fat. The levels of endosulfan sulfate (99.052 g / kg) was higher than the Australian MRL values of 20 g/kg for milk, whiles the mean levels of the rest OCP residues were below their respective permissible limits.

Ntow, (2001) determine the levels of OCP residues in a total of 208 samples of water, sediment, tomato and breast milk of mothers taken from Akomadan. Endosulfan sulfate was the frequent OCP residues detected in water with a mean concentration of 30.8 ng/L. Lindane was detected in 76% of the 38 samples analysed. Sediment samples recorded the greatest number of OCP residues. Their study revealed the presence of OCP residues in the environmental samples at Akomadan and also in the body fluids of its inhabitants.

2.5 Pesticides in soil

A significant percentage of pesticides that are used for agriculture and other purposes accumulate in the soil. The indiscriminate and frequent use of pesticides also exacerbates the problem of soil accumulation. Many factors such as soil properties and soil microflora determines the fate of pesticides applied to the soil, because of which it undergoes a series of degradation processes, transport and adsorption / desorption (Laabs *et al*., 2007 ; Hussain *et al.*, 2009). Pesticides reach the ground by the application, disposal, discharge, surface runoff from the plant or by incorporation of pesticide applied crop residues in the soil (Brown and Hock, 1990). Soil performs as a filter, buffer and have potential for degradation of pollutants mainly due to the organic matter content of the soil (and Burauel Bassmann, 2005). These pesticides can either be absorbed by the components of soil, travel away from intrusion area or go via microbial, chemical and photo-degradation (Brown and Hock (1990). In addition, pesticide degradation is very slow in the soil and can lead entering the human food chain due to runoff and subsurface drainage, hypodermic and leaching, and translocation in plants and animals (Tariq *et al*., 2007). The chemical discharges from domestic and industrial sources, chemical applications in the form of fertilizers and pesticides in agriculture and soil erosion due to deforestation have been described as sources of soil contaminants (Bhattacharya *et al*., 2003).

2.5.1 The degradation of pesticides in soil

Degradation is the process by which the pesticides decompose after application. Pesticides can be decomposed by microbes, chemical reactions and light or photo-degradation. Microbial degradation is the degradation of pesticides by microorganisms such as fungi, bacteria and other micro-organisms in the soil. The texture of soil, organic matter content and characteristics of the area such as temperature, aeration, humidity, and pH can all affect the microbial degradation (Kerle *et al*., 2007). Chemical degradation occurs through a reaction between pesticide with oxygen, water, or other chemicals in the soil. The chemical degradation is the distribution of pesticides by chemical reactions within the soil. The rate and type of chemical reactions that occur are affected by the binding of pesticides in soil, soil temperature and pH levels (Kerle *et al*., 2007). Photodegradation is the breakdown of pesticides by sunlight. All pesticides are susceptible to photodegradation to some extent. The intensity of the sunlight, the exposure time and the properties of the pesticide may affect the photodegradation rate. Pesticides can break faster in plastic covered greenhouses than inside the glass greenhouses, because the glass filter a large part of the ultraviolet light that degrades pesticides (Kerle *et al*., 2007).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Materials

3.1.1 Reagents

Pesticide grades ethyl acetate, hexane, diether and acetone were obtained from BDH Laboratory Supplies, England. Analytical grades of sodium sulphate and sodium hydrogen carbonate were purchased also from BDH Laboratory Supplies, England. Florisil and silica adsorbents were purchased from Hopkins and William Limited, England. Pesticide reference standards were purchased from Dr. Ehrenstorfer Laboratories (GmbH Germany) and kept in the freezer to reduce degradation.

3.1.2 Cleaning of glassware

Glassware was soaked in soapy water for two days after which they were thoroughly washed with detergent. After washing, the glassware was rinsed six times with tap water followed by deionized water and then dried in an oven at 100 ^{o}C for about one hour.

3.1.3 Equipment

The following are key equipment used in this work for laboratory analysis:

i. A Varian CP-3800 Gas Chromatograph (Varian Associates Inc. USA) equipped with 63Ni electron capture detector, fused silica gel capillary column coated with VF-5ms, 40m long with internal diameter and film thickness of 0.25 mm and 0.25 µm respectively. **ii.** Weighing balance-Metler Toledo PG 1003-5.

iii. Rotary vacuum evaporator-Buchi RE-200 (Buchi Labortechnic AG, Postfach, Switzerland).

iv. Ultrasonic bath (Branson 220, Branson Ultrasonic Cleaner, USA)

v. Macerator (Ultra-turax macerator Type T 25 generator from IKKA®) **vi.** Centrifuge (CRi multifunction) was obtained from Thermo Electron Industries SAS, France).

3.2 Method

3.2.1 Description of Study Area

The study was conducted at Adidwan, Woraso, Bosomkyekye, Atonsuagya and kyerefamso all in the Mampong municipality (Figure 3.1). Mampong municipality is located in the northeast of Kumasi, the Ashanti regional capital. It is bounded to the north by Atebubu district in the Brong Ahafo region, east by Sekyere Central, south to Sekyere South and Ejura-Sekyedumasi to the West. It is located between 0.05 West longitude and 1.30 West and latitudes 6.55 North and 7.30 Northeast, covering a total area of 449 km^2 and has approximately 79 localities with approximately 61 percent being rural areas. Rural areas are mainly in the northern part of the municipality where the communities of less than fifty (50) people are dispersed. The total population of the municipality is projected at 88,051 (GSS, 2010) with a projected 1.6% rate of growth of the population. The municipality is partly situated on the Mampong escarpment that goes east. The highest point of the municipality is 2400 m above the sea level, while the lowest is about 135 m. Thus, the Municipality is generally low altitude and gradually increases through hills stretching south to Mampong. The municipality is part of the transition zone of savannah of Ghana, with the vegetation being savannah woodland, with high elephant grass stains north and patches of mixed dry forest and grassland in south, 80% of the area land is used for small scale agriculture (MOFA, 2003). Average annual rainfall is between 800 and 1500 mm and is bimodal and equitably distributed. The municipality is remarkable for the production of cash crops such as fruit adidwan, Kyirefamso, Woraso, Ninting and Bosomkyekye (MOFA, 2003).

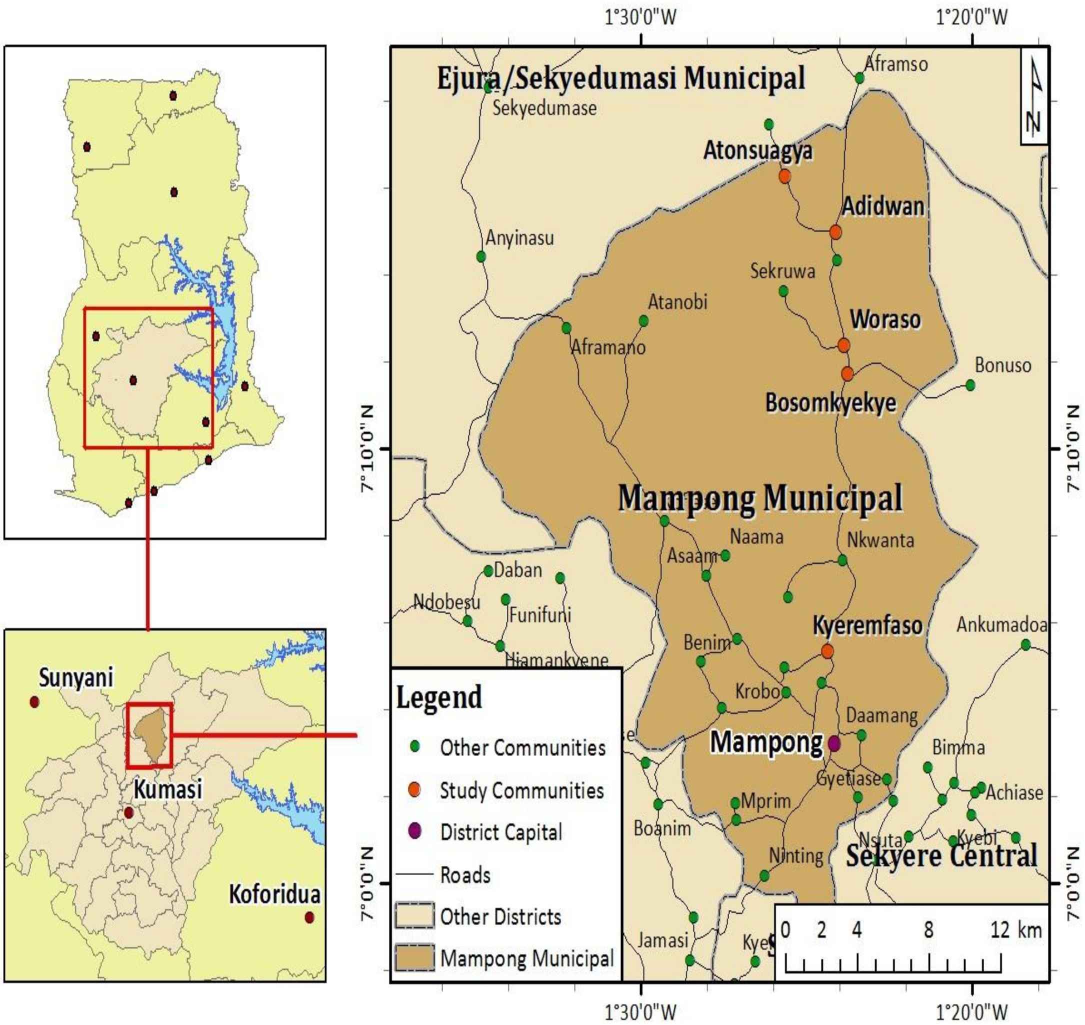


Figure 3.1: Map showing study areas

3.2.2 Sampling

3.2.2.1 Sampling of fruits

A total of 120 fruit samples were analysed, out of which total of 100 samples of freshly harvested fruit samples were sampled randomly from farms in Kyerefamso, Woraso, Adidwan, Atonsuagya and Bosomkyekye and a total of 20 samples were also purchased from the market all located in the Mampong municipality. All farms selected for the studies were based on the fact that farmers were active users of pesticides and farmer selection was done randomly. The samples were taken from different segments of the farm and also in the market; fresh samples were purchased from different vendors in order to have a true representation. The samples were then wrapped in aluminum foil and sealed in polyethylene bags, labeled and transferred to the laboratory and stored in a refrigerator for further analysis.

3.2.2.2 Sampling of soil

A total of 60 different soil samples were collected from a depth of 0-30 cm in the same place in the farms where fruit samples were taken. Soil samples were collected in paper bags covered with aluminum foil. It was then appropriately labeled and transferred to the laboratory for subsequent analysis.

3.2.3.1 Extraction of soil samples

Soil samples were dried with hot air at 40 °C for 72 hours and crushed in a mortar and filtered with a 1 mm sieve. Samples were homogeneously mixed for extraction. OCP residues in soil samples were extracted through sonication of 2.5 g of the sample using ultrasonic bath for 1 hour at 40 ° C with 50 mL of 3: 1 hexane / acetone mixture (Afful *et al.*, 2013). The extracts were filtered with filter paper. The extract was then dried over anhydrous sodium sulfate and concentrated to about 5 mL using a rotary evaporator.

3.2.3.2 Extraction of fruit samples

The method adopted by Bempah *et al.*, (2012) was used for the extraction of fruit samples. Samples of fresh fruits were carefully torn and homogenized using a blender.

About 20.0 g of the samples was macerated with 40 mL of ethyl acetate. About 5.0 g Sodium bicarbonate and 20.0 g anhydrous sodium sulphate was added to dry the extract and further macerated for 3 minutes. Then the samples were centrifuged for 5 minutes at 3000 rpm to obtain the two phases. The supernatant was transferred to a clean graduated cylinder (25 mL) to measure its volume.

3.2.4 Combined silica-florisil clean up

The cleanup procedure was performed according to the method of Mensah-Kuranchie, *et al.* (2011). A combined florisil- silica solid phase extraction columns were prepared by packing 1.5 g and 0.5 g of pre-activated florisil and silica respectively with 1.0 g of sodium sulphate placed above the adsorbents in a glass column. The columns were then conditioned with 10 mL of hexane before clean up after which the extract was passed through the column and the eluate collected in 50 mL conical flask. The columns were first eluted with 15 mL of hexane, then 5 mL of 2: 1 hexane / diether mixture. The eluate was concentrated almost to dryness on a rotary evaporator and taken up in 1.5 mL of ethyl acetate. The extract was finally transferred into 2 mL glass vial using a Pasteur pipette for GC - ECD analysis.

3.2.5 Preparation of the standard solution of pesticides

About 0.1 mL each of p, p 'DDD, p, p' DDE, endrin, p, p 'DDT, heptachlor, chlordane, alpha endosulfan, beta endosulfan, endosulfan sulphate, methoxychlor , HCH (beta, delta and gamma), dieldrin and aldrin were pippeted into a 50 ml volumetric flask and 48.4 mL of ethyl acetate was added to give organochlorine mixture. Standard solution with a concentration of 2.0 ug / mL was prepared for the calibration.

3.2.6 Gas chromatographic analysis

A Varian CP-3800 gas chromatograph (Varian Associates Inc. USA) with 63Ni electron capture detector was used for analysis. A volume of about 1 uL of the extract was injected and separation was performed on a capillary column of fused silica gel coated with VF-5ms, 40 m long with an internal diameter and a film thickness of 0.25 mm and 0.25 um respectively. The carrier gas and make-up gas was nitrogen at a rate of 1.0 to 29 ml / min respectively. The temperatures of the injector and detector were 270 ° C and 300 ° C respectively. The column oven temperature was programmed as follows: 80 °C for 1 min at 18 ^{o}C to 25 ^{o}C / min and up to 300 ^{o}C to 5 ° C / min maintained for 1 min. GC equipped with an electron capture detector was used for analysis and a volume of 1 uL of the extract of the sample aliquots was injected. Levels of organochlorine pesticides were recognized based on the comparison of retention times with known standards and quantitated by the method of external standard.

3.2.7 Analytical Quality Assurance

Quality assurance and quality control were included in the analytical scheme. Quality of pesticide residue analysis were established through solvent blanks analysis, spikes and triplicate samples. Solvent blanks were used to eliminate the interference of the reactants, while the spike samples were used for determination of recovery. Triplicate samples were used to confirm accuracy of the method. The spiked samples and blank were subjected to the same extraction and clean up performed on each sample, then GC-analysis and quantification. Recoveries ranged from 76.93 to 112% of

organochlorine pesticide residues.

3.2.8 Analysis of data

The integrated statistical analysis in the work included means and standard deviations equivalents. Data were also analysed using ANOVA (SPSS Version 18) to establish for the differences in pesticide residues between samples, as well as the different sampling sites. All tests were considered statistically significant when $p < 0.05$.

3.2.9 Exposure Assessment

3.2.9.1 Estimation of daily dose (ED)

To evaluate the potential health risk associated with each OCP residues, certain assumptions based on guidelines from the Environmental Protection Agency (USEPA, 2005) were taken in to considerations. The first assumption that was made is that, a theoretical weight of 10 kg for children and 60 kg for adults, and the second is that there are 100% absorption and bioavailability rates. Fruit consumption rate in Ghana is estimated at 64 g / day (Bempah, *et al*., 2012). The estimated daily intake (ng/g) of the individual organochlorine pesticide was calculated by multiplying the average pesticide concentrations (ng /g) in the fruit of the interest by the fruit consumption rate (g / day) dividing the product by the body weight (g).

$$ED = \frac{Cp \times FCR}{BW}$$

ED is indicates estimated dose, Cp is the pesticide concentration (ng / g), FCR is the food consumption rate (g / day) and BW is the average weight (g) of children and adults in Ghana.

3.2.9.2 Risk Characterization

Risk of organochlorine pesticides to children and adults through daily fruit consumption was classified on the basis of the guidelines proposed by the US EPA

(2005). For non-cancer effects, hazard indices (HI) for adults and children were calculated as the ratio of estimated dose (ED) to reference dose of the pesticides.

$$HI = \frac{ED}{R_fD}$$

where ED is the estimated dose, Cp is the concentration of the pesticide (n/g), FCR is the food consumption rate (g / day) and BW is the average body weight (g) of Ghanaian children and adults.

3.2.9.3 Combined risk of multiple OCP pollutants

The exposure to multiple pesticides may result in commutative effects (Reffstrup *et al*, 2010; Akoto *et al.*, 2015). The method of risk index established by the EPA was used to assess risks to health of humans by a group of pesticides that are similar toxicologically (US EPA 2000; Reffstrup *et al*., 2010). The cumulative risk index (HI) was evaluated using the equation suggested by Reffstrup *et al*., (2010)

$$HI = \frac{ED_1}{R_fD_1} + \frac{ED_2}{R_fD_2} + \cdots + \frac{ED_n}{R_fD_n} = \sum_{i=1}^{n} \frac{ED_i}{R_fD_1}$$

where ED_1, ED_2, ED_n and ED_i are the estimated dose of eac h individual pesticide. R_fD_1, R_fD_2, R_fD_n and R_fD_i are the reference dose for each pesticide (US EPA 2000).

3.2.9.4 Carcinogenic effect

Carcinogenic risks related to the exposure to OCP residues in fruits were evaluated. The benchmark concentration of carcinogenic effect was estimated using US EPA oral slope factor (EPA, 2014). Risk assessments were analyzed on the basis of OCP residue levels in fruit. Risk ratios (HR) were determined by dividing the estimated dose (ED) by the reference concentrations (CBC) (Dougherty *et al*., 2000). When the hazard ratio is greater than one (1), it denotes that the estimated daily intake of the pesticide through the fruit consumption exceeds the reference concentration (Dougherty *et al*., 2000).

$$\text{Hazard Ratio (HR)} = \frac{\text{Estimated Dose ED}}{\text{Benchmark Concentration CBC}}$$

$$\text{Benchmark Concentration (BC)} = \frac{\text{Risk} \times \text{Body weight}}{\text{Fruit Consumption Rate} \times \text{Slope Facto}}$$

where the risk is the probability of getting cancer throughout lifetime due to the exposure to pesticides (1×10^{-6}). (Han *et al.*, 1998), and slope factor is cancer slope factor from EPA Integrated Risk Information (IRIS) (US EPA, 2014)

CHAPTER FOUR

4.0 RESULTS AND DICUSSIONS

Table 4.1: Concentrations (ng/g) of OCP residues in fruit samples from Adidwan

Pesticide	Watermelon Mean±SD	Pineapple Mean±SD	Banana Mean±SD	EU/MRL (ng/g)	FAO/WHO MRL (ng/g)
Gamma - HCH	<0.01	<0.01	0.59±0.03	10	NA
Beta - HCH	<0.01	3.59±0.14	<0.01	10	NA
Heptachlor	<0.01	<0.01	<0.01	10	10
Delta - HCH	<0.01	<0.01	<0.01	10	NA
Aldrin	<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
Endrin	<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	0.98±0.03	10	NA

Limit of detection for all pesticides = 0.01 ng/g, SD = Standard Deviation NA = Not available

4.1. Occurrence and distribution of organochlorine in fruit samples from Adidwan

The results in table 4.1 indicate the mean and standard deviation values obtained from the analysis done on all the fruit samples from Adidwan. A total of three organochlorine pesticides were detected in the fruit samples analysed. Pineapple and banana recorded one and two OCP resideues respectively. None of the OCP was detected in watermelon. The three organochlorune pesticides detected were Gamma– HCH, beta–HCH and methoxychlor. Most of the organochlorine pesticides were below the limit of detection of 0.01ng/g. The levels of OCP residues detected in all the fruits ranged between 0.59±0.03-3.59±0.14 ng/g. The highest mean concentration of 3.59±0.14 ng/g of beta-HCH was recorded in pineapple followed by a concentration of 0.98±0.03 ng/g for methoxychlor in banana and then concentration of 0.59±0.14 ng/g for gamma-HCH also in banana. The concentration of

organochlorine pesticide residues in the various fruit samples from the selected farms in Adidwan when compared with maximum residue limits set forth by European Union (EU 2013) and FAO/WHO indicated that, all the residual levels were below their MRL guidelines.

Table 4.2: Concentrations (ng/g) of OCP residues in fruit samples from Atonsuagya

Pesticide	Watermelon Mean±SD	Pineapple Mean±SD	Banana Mean±SD	EU/MRL (ng/g)	FAO/WHO MRL (ng/g)
Gamma - HCH	7.55±0.21	<0.01	<0.01	10	NA
Beta - HCH	0.20±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
Aldrin	<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
Endrin	<0.01	<0.01	<0.01	10	50
p,p' - DDT	5.16±0.08	<0.01	0.39±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	11.53±0.10	1.23±0.07	<0.01	1 0	NA

Limit of detection for all pesticides = 0.01 ng/g, SD = Standard Deviation NA = Not available

4.2 Occurrence and distribution of OCP residues in fruit samples from Atonsuagya

Table 4.2 presented the various mean concentrations of organochlorine pesticide residues detected in fruit samples from Atonsuagya. In all, a total of four organochlorine pesticides were detected and they included gamma–HCH, beta–HCH, p,p' – DDT and methoxychlor. In Atonsuagya, the fruit sample which recorded greater number of organochlorine pesticide residues were watermelon followed by banana and

pineapple recording fewer organochlorine pesticide residues. All the four OCPs detected were present in watermelon but only one was recoreded in banana and pineapple. The mean concentration of OCP residues recorded in all the fruit samples from this site ranged between 0.20±0.01-11.53±0.10 ng/g. The highest mean concentration of 11.53±0.10 ng/g and lowest mean concentration of 1.23±0.07 ng/g for methoxychlor were detected in watermelon and pineapple respectively but was absent in banana. Gamma-HCH was aslso detected in watermelon at a level of 7.55±21 ng/g but was below the detection limit in both pineapple and banana samples. p,p'–DDT was detected in watermelon and banana with highest mean concentration of 5.16±0.08 ng/g and lowest mean concentration of 0.39±0.01 ng/g in watermelon and banana respectively. Heptachlor, delta–HCH, aldrin, gamma- chlordane, alpha – endosulfan, p,p' – DDE , dieldrin and endrin were below the limit of detection in all the samples. The mean concentration of methoxychlor (11.53 ng/g) recoreded in watermelon was higher than their respective EU/MRL (10 ng/g). All the other OCP levels recorded were below EU/MRL. The levels of all OCP residues detected in fruis from this site were lower than their respective MRL values set forth by
FAO/WHO.

Table 4.3: Concentrations (ng/g) of OCP residues in fruit samples from Bosomkyekye

Pesticide	**Watermelon Mean±SD**	**Pineapple Mean±SD**	**Banana Mean±SD**	**EU/MRL (ng/g)**	**FAO/WHO MRL (ng/g)**
Gamma - HCH	3.38±0.03	<0.01	<0.01	10	NA
Beta - HCH	<0.01	3.88±0.08	<0.01	10	NA
Heptachlor	<0.01	<0.01	<0.01	10	10
Delta - HCH	<0.01	<0.01	<0.01	10	NA
Aldrin	<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
Endrin	<0.01	<0.01	<0.01	10	50
p,p' - DDT	2.16±0.04	<0.01	1.18±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 for all pesticides = 0.01 ng/g, SD = Standard Deviation NA = Not available

4.3 Occurrence and distribution of OCP residues in fruit samples from Bosomkyekye

Table 4.3 illustrates the results for the fruit samples collected from Bosomkyekye that were analysed. In the analyses, a total of three different organochlorine pesticide residues were detected in the samples. Gamma- HCH, beta-HCH and p,p' – DDT were the OCP detected. Most of the organochlorine pesticides were below the limit of detection. Watermelon recorded the highest number of OCP residues. The mean concentrations of OCP residues detected in all the fruit samples ranged between 1.18±0.01-3.88±0.08 ng/g. The highest mean concentration of OCP detected was 3.88±0.08 ng/g for beta-HCH in pineapple followed by 3.38±0.03 ng/g for gammaHCH in watermelon. p,p' – DDT recorded the highest mean concentration of 2.16±0.04 ng/g in watermelon. The metabolites of p,p'–DDT were all below the limit of detection. The difference in concentration of OCPs in the watermelon, pineapple and banana samples from this town was not significant ($p>0.05$). Comparing the levels of OCP residues in the fruit with maximum residue limit (MRL) set forth by EU and FAO/WHO revealed that none of the levels of OCP residues detected in the fruits were above their MRL values.

Table 4.4: Concentrations (ng/g) of OCPs residues in fruits samples from Kyerefamso

Pesticide	Watermelon Mean±SD	Pineapple Mean±SD	Banana Mean±SD	EU/MRL (ng/g)	FAO/WHO MRL (ng/g)
Gamma - HCH	19.03±0.07	<0.01	<0.01	10	NA
Beta - HCH	8.20±0.14	ND	11.27±0.13	10	NA
Heptachlor	4.10±0.41	<0.01	<0.01	10	10
Delta - HCH	0.49±0.04	<0.01	<0.01	10	NA
Aldrin	22.84±0.83	<0.01	4.23	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	8.59±0.65	<0.01	<0.01	10	50
Endrin	<0.01	<0.01	12.23±0.32	10	50
p,p' - DDT	48.22±0.85	2.59±0.08	<0.01	50	200
B - endosulfan	<0.01	<0.01	<0.01	50	500
p,p' - DDD	0.78±0.06	<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 for all pesticides = 0.01 ng/g, SD = Standard Deviation NA = Not available

4.4 Occurrence of organochlorine pesticide residues in fruit samples from Kyerefamso

Table 4.4 illustrated the results for fruit samples collected from kyerefamso that were analysed. Nine out of the fifteen OCPs analysed were detected in the samples. The levels of p, p'–DDT metabolites, p,p'–DDD and p,p'–DDE, endosulfan-s, chlordane and A-endosulfan, were all below the limit of detection. The levels of OCP residues recorded in fruit samples from kyerefamso ranged between 0.49±0.04-48.22±0.85 ng/g. The highest mean concentration of OCPs recorded were p,p'–DDT with a mean concentration of 48.22±0.85 ng/g in watermelon followed by aldrin and gamma-HCH with mean concentrations of 22.84±0.83 and 19.03±0.07 ng/g respectively in watermelon. Endrin was also detected at a high mean concentration of 12.23±0.32 ng /g in banana. Highest mean concentration of beta-HCH recorded was 11.27±0.13 ng/g in banana. Heptachlor was detected only in watermelon samples at a mean concentration of 4.10±0.41 ng/g. Dieldrin was also detected at a mean concentration of 8.59±0.65 ng/g only in watermelon. The differences in concentration of organochlorine pesticides in the fruit samples vary significantly from this sampling site ($p < 0.05$). Comparing the levels of OCP residues in the fruit with maximum residue limit (MRL) setforth by EU and FAO/WHO revealed that levels of gammaHCH and aldrn in watermelon exceeded the EU/MRL but the levels of aldrn was lower than their respective FAO/WHO MRL. The FAO/WHO/MRL value for gamma-HCH was not available. The mean concentrations of endrin (12.23 ng/g) and beta-HCH (11.27 ng/g) in banana were also higher than their respective EU/MRL values of 10ng/g. The FAO/WHO MRL value was higher than the levels of all the OCP residues detected in the fruits.

Table 4.5: Concentrations (ng/g) of OCP residues in fruit samples from Woraso

Pesticide	Watermelon Mean±SD	Pineapple Mean±SD	Banana 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
Aldrin	<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
Endrin	<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 for all pesticides = 0.01 ng/g, SD = Standard Deviation, NA = Not available

4.5 Occurrence of organochlorine pesticide residues in fruits samples from Woraso

Table 4.5 presented above showed that all the organochlorine pesticide residues monitored in the fruit samples from Woraso were below the detection limit.

Accordingly all the OCP residues were also below their respective EU and FAO/WHO MRL values.

Table 4.6: Concentrations (ng/g) of OCP residues in fruits samples from Market

Pesticide	Watermelon Mean±SD	Pineapple Mean±SD	Banana Mean±SD	EU/MRL (ng/g)	FAO/WHO MRL (ng/g)
Gamma - HCH	19.41±0.59	<0.01	2.38±0.03	10	NA
Beta - HCH	1.27±0.03	1.68±0.03	<0.01	10	NA
Heptachlor	<0.01	<0.01	<0.01	10	10
Delta - HCH	<0.01	<0.01	<0.01	10	NA
Aldrin	<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
Endrin	<0.01	<0.01	<0.01	10	50
p,p' - DDT	9.85±0.10	<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 for all pesticides = 0.01 ng/g, SD = Standard Deviation, NA = Not available

4.6 Occurrence of OCP residues in fruit samples from Mampong market The results for the analysis of the OCP residues in fruit samples from market are presented in Table 4.6. Three OCPs namely, gamma-HCH, beta-HCH and p,p' - DDT were detected in the fruit samples analysed. The rest were all below the detection limit. The mean concentration of OCP residues detected in all the fruits from the market ranged between 1.27± 0.03 - 19.41 ± 0.59 ng/g. Gamma-HCH recorded the highest and lowest mean levels of 19.41± 0.59 ng/g and 2.38±0.03 in watermelon and banana respectively.

p,p-DDT was detected at mean concentration of 9.41±0.10 ng/g also in watermelon. Beta-HCH recorded the maximum and minimum mean concentrations of 1.68±0.03 and 1.27±0.03 ng/g in watermelon and pineapple respectively but was not detected in banana. The mean level of gamma-HCH detected in watermelon was above the EU/MRL values. The mean levels of all the other OCP detected were lower than the EU/MRL. Comparing the mean levels of OCP residues in the fruit also with FAO/WHO showed that none were above them.

Table 4.7: Concentrations (ng/g) of OCP residues in fruit samples from all the farms

Pesticide	Watermelon Mean±SD	Pineapple Mean±SD	Banana Mean±SD	EU/MRL (ng/g)	FAO/WHO MRL (ng/g)
Gamma - HCH	13.03±7.87	<0.01	0.59±0.03	10	NA
Beta - HCH	3.83±4.17	3.73±1.65	11.27±0.32	10	NA
Heptachlor	4.10±0.41	<0.01	<0.01	10	10
Delta - HCH	0.49±0.04	<0.01	<0.01	10	NA
Aldrin	22.85±0.85	<0.01	4.30±0.41	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	8.59±0.65	<0.01	<0.01	10	50
Endrin	<0.01	<0.01	12.23±0.33	10	50
p,p' - DDT	20.58±22.5	2.59±0.08	0.78±0.56	50	200
B - endosulfan	<0.01	<0.01	<0.01	50	500
p,p' - DDD	0.79±0.06	<0.01	<0.01	50	200
Endosulfan-S	<0.01	<0.01	<0.01	50	500
Methoxychlor	11.52±0.09	1.19±0.07	0.98±0.03	10	NA

Limit of detection for all pesticides = 0.01 ng/g, SD = Standard Deviation, NA = Not available

4.7 Occurrence of OCP residues in fruit samples from all the farms

The results for mean concentration and standard deviation of the OCP residues detected in the fruit samples from all the farms are presented in Table 4.7.

4.7.1 Total-HCH

The concentrations of total-HCH detected in many of the samples were low, however gamma-HCH detected in the fruit samples from the entire sampling site ranged between 0.59±0.03-13.03±7.87 ng/g (table 4.7). The highest mean concentration (13.03 ng/g) of gamma-HCH was detected in watermelon from all the farms. This was higher than that of beta-HCH and delta-HCH isomers which recorded mean concentrations of 3.83 ng/g and 0.49 ng/g respectively in watermelon. The highest mean concentration of gamma-HCH (lindane) found in watermelon sample from all the farms was similar to that reported previously in Ghana (Bempah, *et al*., 2012). The highest mean lindane level recorded in watermelon in the analysis was also similar to 0.02 μg/g reported in tomato by Bempah and Donkor (2010), but, lower than that detected in medicinal plant (Agbeve, *et al*., 2014). The High levels of beta-HCH recorded in the pineapple and banana samples compared to gamma-HCH and delta-

HCH can be attributed to the fact that beta-HCH is the most stable and persistent HCH isomer (Manz *et al*., 2001), therefore the levels detected in pineapple and banana fruits are from previous usage of gamma-HCH (lindane).The results from the study as presented in table 4.7 also indicate that generally the mean concentrations of gamma-HCH recorded in watermelon fruits were higher than that of beta-HCH and delta-HCH. This suggests a recent usage of the gamma-HCH in watermelon cultivation, since photochemical transformation of the gamma isomer will yield the alpha, beta and delta-isomers. Therefore the relatively high level of gamma-HCH detected in some of the fruits compared to delta and beta isomers corroborate the suggestions that lindane (gamma-HCH) is still being used in the Ghanaian

agricultural sector in fruit cultivation and in other crop productions despite the fact that it has been banned in Ghana (Bempah and Donkor, 2010). However, lindane level reported in this study is low, compared to the levels reported for fruits and vegetable in China (Nakata *et al*., 2002).

4.7.2 Total-DDT

Total-DDT was detected at low levels and also below the limit of detection in most of the samples which indicated that generally p,p'-DDT and its metabolites were fading out in the environment. However total p,p'-DDT concentrations recorded in the analysis of fruit samples from all the farms were 20.58 ng/g in watermelon, 2.59 ng/g in pineapple and 0.78 ng/g in banana (table 4.7). The mean value of p,p'-DDT in all the fruit samples from all the farms were much higher than that of p,p'-DDD and p,p'-DDE (table 4.7). DDT can decompose to its metabolites and consequently the relative level of the parent DDT to its metabolites (DDD and DDE) can be used as indices for evaluating the possible pollution sources. When the ratio is less than one, it point out to recent input and vice versa. DDD+ DDE/DDT ratios for all the fruit samples analysed were all less than 1. The low ratio of levels of DDE to DDT support the fact that current DDT exposure levels reported in this study primarily originates from current use and not from previous contamination as well as environmental persistence as stated in earlier reports in Ghana (Ntow, 2005; Bempah and Donkor, 2010). These therefore give a strong indication that, despite the fact that, DDT has been banned from agricultural use, it is still being used illegally by some farmers in crop production.

4.7.3 Methoxychlor

Methoxychlor was present in most of the samples, however highest mean concentrations of 11.52 ng/g was recorded in the watermelon samples from all the farms (table 4.7). The low levels of methoxychlor detected in fruit samples confirm findings of Polyakova *et al*, (1984), who found out that 42% of methoxychlor may only persist six months post its application. Methoxychlor is not as persistent as DDT and therefore the levels in the watermelon samples could be accredited to modern usage by some farmers.

4.7.4 Endrin

Endrin was below the limit of detection in the entire watermelon and pineapple samples as presented in Table 4.7. Endrin recorded highest mean concentration value of 12.23 ng/g only in banana from one farm and this value represents the mean value in all the tested fruit samples. The low level of endrin in the fruit samples analysed can be attributed to the fact that endrin is vulnerable to photodegradation and volatilization to produce metabolites of endrin (Fan and Alexeeff, 1999). Furthermore it could also be as a result of the degradation of endrin by fungi and bacteria to form the transformation product endrin ketone and endrin aldehyde (IPCS, 1992). The high mean concentration (12.23 ng/g) recorded in banana is higher than 0.006 mg/kg in banana reported in Ghana (Bempah, *et al*., 2012).

4.7.5 Aldrin/Dieldrin

Aldrin and dieldrin as indicated in Table 4.7 showed that they were mostly below the limit of detection in most of the fruit samples from the various farms. The result from this study showed that aldrin and dieldrin are not presently being used widely by the farmers. Aldrin and dieldrin recorded highest mean levels of 22.85 ng/g and 8.59 ng/g respectively present in watermelon fruit from the farms, which indicated that it were more predominantly used on watermelon cultivation compared to the other fruits.

Generally, the levels of aldrin in the fruit were higher than that of dieldrin. Aldrin being an alicyclic chlorinated hydrocarbon is anticipated to quickly transform to the epoxide form; dieldrin (GESAMP, 1993). Additionally there is continual alteration of aldrin to dieldrin by an epoxidation in organisms and therefore dieldrin is anticipated to be found in relatively higher levels than aldrin, from the present study however, concentrations of aldrin recorded was higher than dieldrin. Aldrin has been widely used in Ghana for agricultural purposes and therefore there is potential for uptake by food crops. The high amounts of aldrin compared to dieldrin detected in the fruits from the farms indicated that aldrin undergoes less microbial degradation and photodecomposition in the fruit samples studied (ATSDR, 2002).

4.7.6 Total-Endosulfan

Total-endosulfan (A-endosulfan, B-endosulfan and endosulfan-s) levels were mostly below the limit of detection in almost all of the fruit samples analysed from the farms (table 4.7). This indicated that endosulfan is not currently being used by the farmers. The low levels of endosulfan recorded can also be as result of endosulfan undergoing photocatalytic degradation post application. Endosulfan undergoes photodegradation with a half-life of nearly 7 days (USEPA, 2006). The low levels of endosulfan reported in this study also corroborate results from a study conducted by Worthing, (1991) that showed that about 50 % of the alpha and beta endosulfan were lost after 3-7 days post application of endosulfan.

4.7.7 Heptachlor/Chlordane

Chlordane and heptachlor levels were below the limit of detection in most of the fruit samples analysed. Heptachlor was only detected at 4.10 ng/g in watermelon from only one farm. The results from this study corroborate the findings of IARC,

(1991). They reported low levels of heptachlor and related compounds in foods such as fruits.

4.7.8 Tolerance Limit

The levels of OCP residues in the selected fruits the farms in Mampong municipality were compared with international permissible levels (EU, 2013; FAO/WHO, 2013). All the OCP residues levels were below the MRL guidelines of FAO/WHO and most of the levels were also below the EU/MRL (table 4.7). The low levels in the fruits can be attributed to low lipid content of the fruit (Bempah and Donkor, 2010). Watermelon recorded the most residue levels above the EU/MRL. The highest mean residue levels of gamma-HCH, aldrin and methoxychlor recorded in watermelon samples were above the EU/MRL but were relatively lower in pineapple and banana samples. Endrin and beta-HCH levels in banana exceeded EU/MRL values in banana. Pineapple samples recorded no residual content level above MRL. The results of the study indicated that despite the fact that organochlorine pesticides usage in Ghana have been banned, still some of the residue levels in fruits were found to be higher than the MRL set forth by the European Union and this could pose health problems as these fruits are consumed regularly by the public.

Table 4.8: Comparison of mean concentrations (ng/g) of OCP residues in fruit samples from farms and market

	Water melon		Pineapple		Banana	
Pesticide	**Farm**	**Market**	**Farm**	**Market**	**Farm**	**Market**
Gamma - HCH	13.03±7.87	19.41±0.41	<0.01	<0.01	0.59±0.03	2.38±0.0
Beta - HCH	3.83±4.17	1.27±1.79	3.73±1.65	1.68±0.03	11.27±0.32	<0.01
Heptachlor	4.10±0.41	<0.01	<0.01	<0.01	<0.01	<0.01
Delta - HCH	0.49±0.04	<0.01	<0.01	<0.01	<0.01	<0.01
Aldrin	22.85±0.85	<0.01	<0.01	<0.01	4.30±0.41	<0.01
Gamma- chlordane	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
A - endosulfan	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

p,p' - DDE	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Dieldrin	8.59±0.65	<0.01	<0.01	<0.01	<0.01	<0.01
Endrin	<0.01	<0.01	<0.01	<0.01	12.23±0.33	<0.01
p,p' - DDT	20.58±22.5	9.85±4.83	2.59±0.08	<0.01	0.78±0.56	<0.01
B - endosulfan	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
p,p' - DDD	0.79±0.06	<0.01	<0.01	<0.01	<0.01	<0.01
Endosulfan	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Methoxychlor	11.52±0.09	<0.01	1.19±0.07	<0.01	0.98±0.03	<0.01

Limit of detection for all pesticides = 0.01 ng/g, , SD = Standard Deviation NA = Not available

4.8 Comparison of OCPs residue in fruits from the farm and market

The mean concentrations of all the fruit samples from all the farms and market are presented in table 4.8. The results indicated that, the only OCPs residue which was recorded at relatively high levels in the fruit samples from both the farm and market, was gamma-HCH. Gamma-HCH recorded the highest mean concentration (19.41 ng/g) in watermelon fruit from the market which is quite higher than 13.03 ng/g of gamma-HCH also recorded in watermelon from the farms. These results corroborate the findings of pesticide use in Ghana by Awumbila and Bokuma (1994). They reported that 20 different pesticides were in use, with organochlorine pesticides like lindane being the one extensively spread and applied in Ghana (Bempah and Donkor, 2010). DDT recorded mean concentrations of 20.58, 2.59 and 0.78 ng/g in watermelon, pineapple and banana respectively from the farms and also recorded 9.85 ng/g only in watermelon from the market but was below the limit of detection in the other fruit samples from the market (table 4.8). Aldrin, dieldrin, methoxychlor and generally all the other organochlorine pesticides recorded higher levels in fruits from the farms as compared to the levels in fruits from the market. This could be attributed to the fact that the fruits sampled at the open markets were exposed to the sun which may have resulted in the pesticide residues on the fruits to undergo photodegradation or volatilization (Bempah and Donkor, 2010).

Table 4.9: Concentrations (ng/g) of OCPs residue in soil samples from Adidwan

Pesticide	Watermelon Farm Soil Mean±SD	Pineapple Farm Soil Mean±SD	Banana Farm Soil Mean±SD
Gamma - HCH	<0.01	<0.01	<0.01
Beta - HCH	<0.01	<0.01	<0.01
Heptachlor	<0.01	<0.01	<0.01
Delta - HCH	<0.01	<0.01	<0.01
Aldrin	5.20±0.281	<0.01	3.6±0.42
Gamma- chlordane	<0.01	<0.01	<0.01
A - Endosulfan	<0.01	<0.01	<0.01
p,p' - DDE	<0.01	<0.01	<0.01
Dieldrin	<0.01	<0.01	<0.01
Endrin	<0.01	<0.01	<0.01
p,p' - DDT	38.4±0.565	<0.01	110±0.282
B - Endosulfan	<0.01	<0.01	<0.01
p,p' - DDD	<0.01	<0.01	<0.01
Endosulfan-S	<0.01	<0.01	0.8
Methoxychlor	<0.01	<0.01	59.2±0.282

Limit of detection for all pesticides = 0.01 ng/g, SD = Standard Deviation NA = Not available

4.9 Occurrence and distribution of OCPs in soil samples from Adidwan In all the soil samples analysed in this town, a total of three OCPs were detected as presented in Table 4.9. The OCP detected in the soil samples from the farms in Adiwan were aldrin, methoxychlor and DDT. All the three OCPs detected were found in soil from banana farm and two were present in soil from watermelon farm. Soil from the pineapple farm recorded no OCP residues. The highest level OCPs detected in the soil was p,p' – DDT, which was detected at maximum and minimum mean concentrations of 110±0.282 ng/g and 38.4±0.565 ng/g in soil taken from banana and watermelon farms respectively. Aldrin was also recorded at maximum mean concentration of 5.2±0.281 ng/g in watermelon farm soil and minimum value of 3.6±0.42 ng/g in banana farm soil. Like the OCP residues detected in the fruit samples taken from the same sampling site, the levels of most of them were below the limit of detection. The differences in concentration in soil samples from this site vary significantly ($p < 0.05$).

Table 4.10: Concentrations (ng/g) of OCPs residue in soil samples from Atonsuagya

Pesticide	Watermelon Farm Soil Mean±SD	Pineapple Farm Soil Mean±SD	Banana Farm Soil Mean±SD
Gamma - HCH	<0.01	<0.01	<0.01
Beta - HCH	<0.01	4.00±0.03	<0.01
Heptachlor	<0.01	<0.01	<0.01
Delta - HCH	<0.01	<0.01	<0.01
Aldrin	<0.01	<0.01	<0.01
Gamma- chlordane	<0.01	<0.01	<0.01
A - endosulfan	<0.01	<0.01	<0.01
p,p' - DDE	<0.01	<0.01	<0.01
Dieldrin	<0.01	<0.01	<0.01
Endrin	<0.01	<0.01	<0.01
p,p' - DDT	<0.01	8.80±0.282	<0.01
B - endosulfan	<0.01	<0.01	<0.01
p,p' - DDD	<0.01	<0.01	<0.01
Endosulfan-S	<0.01	<0.01	<0.01
Methoxychlor	143.2±0.141	75.6±0.565	<0.01

Limit of detection for all pesticides = 0.01 ng/g, , SD = Standard Deviation NA = Not available

4.10 Occurrence and distribution of OCPs in soil samples from Atosnsuagya.

Table 4.10 presents the results of OCP residues detected in soil samples from Atonsuagya. Three OCPs namely methoxychlor, beta-HCH and p,p'-DDT were

detected in the soil samples analysed in this sampling site. Methoxychlor was detected with highest mean concentration of 143.2±0.141 ng/g present in soil samples from watermelon farm and lowest mean concentration of 75.6±0.565 ng/g recorded in soil samples from pineapple farm but was not detected in soil samples from banana farm. p,p'-DDT recorded highest mean concentration of 8.80±0.282 ng/g only in soil samples from pineapple farm but was not detected in soil from watermelon and banana farms. Mean concentration of 4.00±0.03 ng/g of beta-HCH was detected in soil from pineapple farm but was below the limit of detection in soil from banana and watermelon farms. The levels of most of the OCP residues were below the limit of detection. The differences in the levels of OCP residues in soil samples from this site vary significantly ($p<0.05$).

Table 4.11: Concentrations (ng/g) of OCPs residue in soil samples from Bosomkyekye

Pesticide	**Watermelon Farm Soil Mean±SD**	**Pineapple Farm Soil Mean±SD**	**Banana Farm Soil Mean±SD**
Gamma - HCH	<0.01	<0.01	<0.01
Beta - HCH	<0.01	<0.01	<0.01
Heptachlor	<0.01	<0.01	<0.01
Delta - HCH	<0.01	<0.01	<0.01
Aldrin	<0.01	22.4±0.565	<0.01
Gamma- chlordane	<0.01	<0.01	<0.01
A - endosulfan	<0.01	<0.01	<0.01
p,p' - DDE	<0.01	<0.01	<0.01
Dieldrin	<0.01	<0.01	<0.01
Endrin	<0.01	<0.01	<0.01

p,p' - DDT	<0.01	46.4±0.282	<0.01
B - endosulfan	<0.01	<0.01	<0.01
p,p' - DDD	<0.01	<0.01	<0.01
Endosulfan-S	<0.01	<0.01	<0.01
Methoxychlor	<0.01	<0.01	<0.01

Limit of detection for all pesticides = 0.01 ng/g, SD = Standard Deviation , NA = Not available

4.11 Occurrence and distribution of OCP residues in soil samples from Bosomkyekye

Table 4.11 presents the results of OCP residues detected in the soil samples from Bosomkyekye. The results showed that two OCP residues namely aldrin and p,p' - DDT were detected in the soil samples taken from pineapple farm but was not detected in the soil taken from watermelon and banana farm. The highest mean concentration of OCPs residue recorded was p,p'–DDT (46.40±0.282 ng/g), which was found in the soil samples from pineapple farm but was below detection limit in soil from banana and watermelon farms. The metabolites of p,p' – DDT in all the samples analyzed was also below the limit of detection. Aldrin also recorded highest mean concentration of 22.40±0.565 ng/g in soil samples taken from pineapple farm but was below the limit of detection in the soil samples from watermelon and banana farms. The rest of the OCPs residues were also below the limit of detection.

Table 4.12: Concentrations (ng/g) of OCPs residue in soil samples from Kyerefamso

Pesticide	Watermelon Farm Soil Mean±SD	Pineapple Farm Soil Mean±SD	Banana Farm Soil Mean±SD
Gamma - HCH	<0.01	<0.01	<0.01
Beta - HCH	23.6±0.424	<0.01	<0.01
Heptachlor	<0.01	<0.01	<0.01

Delta - HCH	<0.01	<0.01	<0.01
Aldrin	2.4±0.268	<0.01	<0.01
Gamma- chlordane	<0.01	<0.01	<0.01
A - endosulfan	<0.01	<0.01	<0.01
p,p' - DDE	<0.01	<0.01	<0.01
Dieldrin	<0.01	<0.01	<0.01
Endrin	<0.01	11.2±0.141	<0.01
p,p' - DDT	<0.01	<0.01	<0.01
B - endosulfan	<0.01	<0.01	<0.01
p,p' - DDD	<0.01	<0.01	<0.01
Endosulfan-S	<0.01	<0.01	<0.01
Methoxychlor	<0.01	40.8±0.282	<0.01

Limit of detection for all pesticides = 0.01 ng/g, SD = Standard Deviation NA = Not available

4.12 Occurrence and distribution of OCPs in soil samples from Kyerefamso

Table 4.12 presents the mean and standard deviation of concentrations of OCP residues detected in the soil samples analysed from Kyerefamso. Four OCPs namely beta-HCH, aldrin, endrin and methoxychlor out of the fifteen OCPs monitored were detected in the soil samples. The OCP residues that recorded the highest mean concentration was methoxychlor, which was detected at mean concentration of 40.80±0.282 ng/g in soil samples from pineapple farm but was absent in soil samples from watermelon and banana farms. Beta-HCH recorded the second highest mean concentration of 23.60±0.424 ng/g detected in soil samples from watermelon farms. Endrin and aldrin recorded highest mean concentrations of 11.20±0.141 ng/g and 2.40±0.268 ng/g respectively present in soil samples from pineapple and watermelon farms. The differences in concentration of OCP residues in all the soil samples analysed in this sampling site were not significant. ($p>0.05$).

Table 4.13: Concentrations (ng/g) of OCPs residue in soil samples from Woraso

Pesticide	Watermelon Farm Soil Mean±SD	Pineapple Farm Soil Mean±SD	Banana Farm Soil Mean±SD
Gamma - HCH	<0.01	<0.01	<0.01
Beta - HCH	<0.01	<0.01	<0.01
Heptachlor	<0.01	<0.01	<0.01
Delta - HCH	<0.01	<0.01	<0.01
Aldrin	9.2±0.282	<0.01	8.0±0.07
Gamma- chlordane	<0.01	<0.01	<0.01
A - endosulfan	<0.01	<0.01	<0.01
p,p' - DDE	<0.01	<0.01	<0.01
Dieldrin	<0.01	<0.01	<0.01
Endrin	<0.01	<0.01	<0.01
p,p' - DDT	44.8±0.141	<0.01	32.8±0.282
B - endosulfan	<0.01	<0.01	<0.01
p,p' - DDD	<0.01	<0.01	<0.01
Endosulfan-S	<0.01	<0.01	0.8±0.01
Methoxychlor	64±0.593	<0.01	56.8±0.07

Limit of detection for all pesticides = 0.01 ng/g, SD = Standard Deviation NA = Not available

4.13 Ocurrence and distribution of OCP residues in soil samples from Woraso

Table 4.13 presented the results OCP residues that were detected in the soil samples from Woraso. Four out of the fifteen OCPs monitored were detected in the soil. The OCP residues with highest mean concentration recorded was methoxychlor which recorded maximum mean concentrations of 64.00±0.593 ng/g and minimum mean concentration of 56.8±0.07 ng/g present in soil samples from watermelon and banana farms respectively. p,p'-DDT recorded mean concentrations of 44.80±0.141 ng/g and 32.8±0.281 ng/g in soil samples from watermelon and banana farms respectively but was not detected in soil from pineapple farm. Aldrin recorded highest mean concentration of 9.20±0.282 ng/g in watermelon farm soil. The differences in concentration of OCP residues in the soil samples from this site vary significantly ($p<0.05$).

Table 4.14: Concentration of OCP residues in soil from all the farms

Pesticide	Watermelon Farm Soil Mean±SD	Pineapple Farm Soil Mean±SD	Banana Farm Soil Mean±SD
Gamma - HCH	<0.01	<0.01	<0.01
Beta - HCH	23.6±0.424	4.00±0.03	<0.01
Heptachlor	<0.01	<0.01	<0.01
Delta - HCH	<0.01	<0.01	<0.01
Aldrin	5.60±3.95	22.40±0.07	5.80±2.56
Gamma- chlordane	<0.01	<0.01	<0.01
A - endosulfan	<0.01	<0.01	<0.01
p,p' - DDE	<0.01	<0.01	<0.01
Dieldrin	<0.01	<0.01	<0.01
Endrin	<0.01	11.20±0.141	<0.01
p,p' - DDT	42.67±4.41	22.08±22.63	71.40±75.63
B - endosulfan	<0.01	<0.01	<0.01
p,p' - DDD	<0.01	<0.01	<0.01
Endosulfan-S	ND	<0.01	0.80±0.01
Methoxychlor	90.40±49.0	64.00±24.04	58.00±1.70

Limit of detection for all pesticides = 0.01 ng/g, SD = Standard Deviation, NA = Not available

4.14 Occurrences and distribution of organochlorine pesticide residues in soil from all farms.

Among all the OCPs residues, methoxychlor recorded the highest mean concentrations in the soil samples analysed (table 4.14). Half-lives of methoxychlor in soil may be determined by the soil conditions as it can be greater than 100 days in aerobic soils and less than 30 days in anaerobic soils (Muir *et al*, 1984). It has also been proven that 42 % of methoxychlor might persist six months after its application (Polyakova *et al.*, 1984). Again some studies about the fate of methoxychlor in soil microflora have also showed that it is moderately persistent, between thirty days and a year (Botwe, 2011). Consequently methoxychlor is not as persistent as DDT and hence the high levels detected in the soil samples can be accredited to recent input in the environment.

Dechlorination of DDT can reduce it to DDD and also dehydrochlorination of DDD will yield DDE (Yao *et al.,* 2006). The metabolites of DDT are more persistent and more stable than the parent compound (Yao *et al.*, 2006). The ratios of metabolite and parent compound can be used to estimate the DDT degradation pathway in soil. In general, a value of (DDD + DDE) / DDT levels above 1 indicates that the DDT contaminant is from previous use (microbiologically degraded DDT) and a value below 1 shows new pesticide application (Zhang *et al.*, 2006). The mean concentration of DDT recorded in soil samples from all the farms as presented in Table 4.13 indicated that it was much higher than their metabolites, which were below the limit of detection. Accordingly, the average value of (DDD + DDE) /DDT ratio was much lower than 1, indicating that the contaminant could be caused by a new DDT entry in to the environment. The results from this analysis indicated that DDT although has been banned is stilled being used by some farmers. This finding is in agreement with the fact that in 2008, the EPA discovered that 71 tonnes of banned pesticides were imported in the country (2008). Furthermore the results from a study carried out in Bawku municipality and Garu-Tempane district all in Upper East Region, found four banned or restricted chemicals (DDT, aldrin, lindane and dieldrin) on sale in local agro-dealer shops (Larry, 2012). The results from this study confirm the fact that, the absence of effective governmental control mechanisms as well as lack of technical capacity on the part of state agencies has resulted in the nonenforcement of the regulations of pesticides usage in Ghana which has resulted in the illegal use of DDT by some farmers in crops cultivation.

Most of total- HCH -isomers (beta, delta and gamma) was below the limit of detection in soil samples from most of the sampling sites. The low levels of HCH detected indicated that generally HCH is fading out in the soil. However highest mean concentrations of 23.60 and 4.00 ng/g of beta-HCH were recorded at Kyerefamso and Atonsuagya respectively. The high value of beta-HCH detected in the soil samples as compared to the other isomers can be attributed to the fact that, beta-HCH is the most stable and persistent HCH-isomer with respect to microbial degradation (Manz *et al*., 2001; Concha- Gra˜na *et al.*, 2006). Therefore the levels detected in the soil are from previous usage of lindane. However highest mean concentration of 23.6 ng/g of beta-HCH recorded is similar to lindane levels in soil reported in Ghana (Owusu-Boateng and Amuzu, 2013).

Gamma - HCH	13.03±7.87	<0.01	<0.01	<0.01	0.59±0.03	<0.01
Beta - HCH	3.83±4.17	23.6±0.424	3.73±1.65	4.00±0.03	11.27±0.32	<0.01
Heptachlor	4.10±0.41	<0.01	<0.01	<0.01	<0.01	<0.01
Delta - HCH	0.49±0.04	<0.01	<0.01	<0.01	<0.01	<0.01
Aldrin	22.85±0.85	5.60±3.95	<0.01	22.40±0.07	4.30±0.41	5.80±2.56
Gamma- chlordane	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
A - endosulfan	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
p,p' - DDE	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Dieldrin	8.59±0.65	<0.01	<0.01	<0.01	<0.01	<0.01
Endrin	<0.01	<0.01	<0.01	11.20±0.141	12.23±0.33	<0.01
p,p' - DDT	20.58±22.5	42.67±4.41	2.59±0.08	22.08±22.63	0.78±0.56	71.40±75.63

Table 4.15: Comparison of mean concentration in fruit and soil

Pesticide	Watermelon Fruit Mean±SD	Watermelon Farm Soil Mean±SD	Pineapple Fruit Mean±SD	Pineapple Farm Soil Mean±SD	Banana Fruit Mean±SD	Banana Farm Soil Mean±SD
B - endosulfan	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
p,p' - DDD	0.79±0.06	<0.01	<0.01	<0.01	<0.01	<0.01
Endosulfan-S	<0.01	<0.01	<0.01	<0.01	<0.01	0.80±0.01
Methoxychlor	11.52±0.09	90.40±49.0	1.19±0.07	64.00±24.04	0.98±0.03	58.00±1.70

Limit of detection for all pesticides = 0.01 ng/g, SD = Standard Deviation NA = Not available

4.15 Comparison of OCP residues in fruit and soil sample

Organochlorine pesticide residues in fruit can partly be attributed to the uptake of the pesticides from the soil by the root of the fruit plants. Soil samples therefore were analysed to determine the OCP residues present in it and compared to that present in fruit samples. The results as presented in Table 4.15 indicated that some of OCP residues that were present in the fruit were absent in the soil and vice versa, indicating that the contamination of the fruit by some of these chemicals in the fruit samples analysed might not be as a result of the uptake of the chemicals from the soil by the plants but rather, what was sprayed on the fruit.

Generally the results as presented in table 4.15 indicated that the concentration of the pesticide residues in the soils were much higher than that present in most of the fruit samples analysed. Major fractions of the pesticides that are used for agriculture and other purposes accumulate in the soil. The uncritical and frequent use of pesticides additionally increases the soil accumulation problem. Soil therefore acts as filter, buffer and exhibit degradation potentials for pesticides pollutant owing mainly to the soil organic matter content (Burauel and Baßmann, 2005). The behaviour of pesticide in soil can be determined by physicochemical factors of the soil such as soil pH, organic matter content and soil texture (Hayar, *et al*., 1997). Therefore, the persistence of these pesticides in the soil or general low uptake of the pesticides by the plants from the soil can be attributed to the influence of physicochemical properties such as, soil moisture, organic matter content, redox status, soil pH, temperature and soil texture (Vig *et al.*, 2001).

Pearson correlation coefficients were established between the residual concentration levels in fruit samples as against that in the soil using SPSS (version 18) to study the general correlation trend of uptake of these chemicals by the fruit from the soil. From the results as presented in (table 4.16), the OCPs residual concentration levels in pineapple and banana fruit samples exhibited a negative correlation against the OCP levels in soil, whiles a positive correlation was established between concentrations in watermelon fruit against soil samples, although the correlation was not quite strong. These correlation results substantiate the findings of Schroll, *et al.,* (1994). In their study on the uptake of organic pollutants from soil, they establish strong relationships between soil and plant contamination only in root crops. The result from the study is also in agreement with the fact that root crops accumulate organochlorine pollutants to a greater extent than the other food crops (Cabidoche and Lesueur-Jannoyer, 2012). Watermelon fruit is usually found on the surface of the soil in the farms as compared to banana and pineapple. This indicated that watermelon fruit like root crops do have some direct contact with the soil; therefore there can be adsorption of OCPs by the skin of watermelon fruit from the soil. Organochlorine pesticides when adsorbed by the skin of food crop are integrated gradually by diffusion through the skin into the internal part (Trapp *et al*., 2007; Juraske, *et al.,* 2011). This might be the result of positive correlation between OCP levels in watermelon fruit and soil compared to the other fruit samples analyzed in the study.

Table 4.16: Correlation between mean concentrations of OCP residues in fruit and soil samples

	WF	PF	BF
WS	**0.478**	-	-
PS	-	**-0.986**	-
BS	-	-	**-0.061**

(WF= watermelon fruit, WS= soil around watermelon, PF= pineapple fruit, PS= soil pineapple soil, BF= banana fruit, BS= soil around banana).

4.16 Non-carcinogenic risk for individual pesticides in fruits from all the farms

The estimated daily dose (ED) for all the organochlorine pesticides detected were calculated and divided by the reference dose (R_fD) for each organochlorine pesticide to characterize the non-carcinogenic risk of dietary exposure using the concept of hazard index (HI). The results for the health risk assessment for systemic effects associated with the individual organochlorine pesticide residues in fruit samples are summarized in Tables 4.17-4.19. The table comprises of reference dose (R_fD),

estimated daily dose (ED) values and corresponding hazard indices (HI) for adults and children. When HI is greater than 1, it shows that lifetime consumption of these fruits containing the measured level of organochlorine pesticide residues could pose health risks (Wang *et al*., 2011). The highest ED was recorded for aldrin in watermelon (table 4.17). The ED of aldrin in watermelon for children (0.1462 ng/g) was higher than the ED for adult (0.0244 ng/g). The hazard index calculated from these dietary exposures of aldrin was greater than 1 for children and less than 1 for adult. Generally, the average

intake levels of OCP for children were higher than adults. The estimated dose of aldrin through the consumption of watermelon by children being higher than the reference dose (R_fD) of aldrin in this study suggested that, there is the potential for adverse health effect on children through dietary exposure of these OCP residues. Therefore, there is the need for continuous assessment of chemical exposure through diet and their toxic potency (Giesy *et al.*, 2000). The results from the health risk assessment from this study supports the findings that, the estimated exposure levels are age-dependent and therefore children have higher food consumption per kilogram of their body weight and as a consequence have higher estimated exposure levels (EFSA, 2009). The hazard indices values showed that, all the rest of the organochlorine pesticide residues did not show any health risk associated with the fruits, indicating that there may be low or no potential for systemic toxicity in adult and children in consuming these fruits. The non-carcinogenic health risks assessment results from this study is similar to one reported recently in Ghana (Akoto *et al.*,
2015).

Table 4.17: Health risks assessment of individual OCP residues in watermelon samples from all farms

Pesticide	Watermelon						
	Reference Dose (R_fD) (ng/g/day)	Children			Adult		
		Estimated Dose (ED) (ng/g/day)	Hazard Index (HI)	Health Risks (HR)	Estimated Dose (ED) (ng/g/day)	Hazard Index (HI)	Health Risks (HR)
Gamma - HCH	0.3	8.34×10^{-2}	2.78×10^{-1}	No	1.39×10^{-2}	4.63×10^{-2}	No
Beta - HCH	3.0	2.45×10^{-2}	8.17×10^{-3}	No	4.09×10^{-3}	1.36×10^{-3}	No
Heptachlor	0.1	2.62×10^{-2}	2.62×10^{-1}	No	4.37×10^{-3}	4.37×10^{-2}	No
Delta - HCH	3	3.14×10^{-2}	1.05×10^{-3}	No	5.23×10^{-4}	1.74×10^{-4}	No
Aldrin	0.1	1.46×10^{-1}	1.46	Yes	2.44×10^{-2}	2.44×10^{-1}	No
Gamma- chlordane	0.5	-	-	-	-	-	-
A - endosulfan	6	-	-	-	-	-	-
p,p' - DDE	20	-		-	-		-
Dieldrin	0.1	5.50×10^{-2}	5.50×10^{-1}	No	9.16×10^{-3}	9.16×10^{-2}	No
Endrin	0.2	-	-	-	-		-
p,p' - DDT	20	1.32×10^{-1}	6.59×10^{-3}	No	2.20×10^{-2}	1.10×10^{-3}	No

B - endosulfan	6	-	-	-	-	-	-
p,p' - DDD	20	5.06×10^{-3}	2.53×10^{-4}	No	8.43×10^{-4}	4.22×10^{-5}	No
Endosulfan-s	6	-		-	-		-
Methoxychlor	3	7.37×10^{-2}	2.46×10^{-2}	No	1.23×10^{-2}	4.10×10^{-3}	No

Table 4.18: Health risks assessment of individual OCP residues in pineapple samples from all farms

Pesticide	**Pineapple**						
	Reference Dose (R_fD) (ng/g/day)	**Children**			**Adult**		
		Estimated Dose (ED) (ng/g/day)	**Hazard Index (HI)**	**Health Risks (HR)**	**Estimated Dose (ED) (ng/g/day)**	**Hazard Index (HI)**	**Health Risks (HR)**
Gamma - HCH	0.3	2.39×10^{-3}	7.96×10^{-2}	No	3.98×10^{-3}	1.33×10^{-2}	No
Beta - HCH	3.0	-	-	-	-	-	-
Heptachlor	0.1	-	-	-	-	-	-
Delta - HCH	3	-	-	-	-	-	-
Aldrin	0.1	-	-	-	-	-	-
Gamma- chlordane	0.5	-	-	-	-	-	-
A - endosulfan	6	-	-	-	-	-	-
p,p' - DDE	20	-	-	-		-	-

Dieldrin	0.1	-	-	-		-	-
Endrin	0.2		-	-		-	-
p,p' - DDT	20	1.66×10^{-2}	8.29×10^{-4}	No	2.76×10^{-3}	1.38×10^{-4}	No
B - endosulfan	6	-	-	-	-	-	-
p,p' - DDD	20	-	-	-	-	-	-
Endosulfan-s	6		-	-	-	-	-
Methoxychlor	3	7.62×10^{-3}	2.54×10^{-3}	No	1.27×10^{-3}	4.23×10^{-4}	No

Table 4.19: Health risks assessment of individual OCP residues in banana samples from all farms

Pesticide	Banana						
	Reference Dose (R_fD) (ng/g/day)	Children			Adult		
		Estimated Dose(ED) (ng/g/day)	Hazard Index (HI)	Health Risks (HR)	Estimated Dose(ED) (ng/g/day)	Hazard Index (HI)	Health Risks (HR)
Gamma - HCH	0.3	3.78×10^{-3}	1.26×10^{-2}	No	6.29×10^{-4}	2.10×10^{-3}	No
Beta - HCH	3.0	4.15×10^{-2}	1.38×10^{-2}	No	6.86×10^{-3}	2.29×10^{-3}	No
Heptachlor	0.1		-	-		-	-
Delta - HCH	3		-	-		-	-
Aldrin	0.1	2.75×10^{-2}	2.75×10^{-1}	No	4.59×10^{-3}	4.59×10^{-2}	No
Gamma- chlordane	0.5	-	-	-	-	-	-

A - endosulfan	6	-	-	-	-	-	-
p,p' - DDE	20		-	-	-	-	-
Dieldrin	0.1		-	-		-	-
Endrin	0.2	7.83×10^{-2}	3.91×10^{-1}	No	7.83×10^{-2}	3.91×10^{-1}	No
p,p' - DDT	20	4.99×10^{-3}	2.50×10^{-4}	No	8.32×10^{-4}	4.16×10^{-5}	No
B - endosulfan	6	-	-	-	-	-	-
p,p' - DDD	20	-	-	-	-	-	-
Endosulfan-s	6	-	-	-	-	-	-
Methoxychlor	3	6.77×10^{-3}	2.26×10^{-3}	No	1.05×10^{-3}	3.48×10^{-4}	No

Table 4.20: Combined risk of multiple OCPs in the fruit from the various farms

Farm	Hazard Index (HI)						Total HI Children	Total HI Adult
	Watermelon		Pineapple		Banana			
	Children	Adult	Children	Adult	Children	Adult		
Adidwan	-	-	7.66×10^{-3}	1.28×10^{-3}	1.36×10^{-2}	2.27×10^{-3}	2.13×10^{-2}	3.55×10^{-3}
Atonsuagya	1.88×10^{-2}	3.13×10^{-2}	2.56×10^{-3}	4.27×10^{-4}	1.25×10^{-2}	2.08×10^{-5}	1.90×10^{-1}	3.17×10^{-3}
Bosomkyekye	7.28×10^{-2}	1.21×10^{-2}	8.28×10^{-3}	1.38×10^{-3}	3.78×10^{-4}	6.29×10^{-5}	8.15×10^{-2}	1.36×10^{-2}

Kyerefamso	2.71	4.52×10^{-2}	8.29×10^{-4}	1.38×10^{-4}	6.86×10^{-1}	1.14×10^{-1}	3.40	5.67×10^{-1}
Woraso	-	-	-	-	-	-	-	-
All farms	2.97	4.96×10^{-2}	1.93×10^{-2}	3.22×10^{-3}	7.00×10^{-1}	1.17×10^{-1}	3.69	6.16×10^{-1}

4.17 Overall risk effect of OCP residue in fruit

The overall potential risk for noncarcinogenic effects posed by a particular pathway combination was analysed by using the approach of US EPA, 2000 as adopted by Akoto *et al*., (2015). This was calculated as the sum of all the combined risk effects of all the individual pesticides present in the fruits. The combined health risk estimated by the individual OCP residues detected in the fruit samples from the various farms are presented in Table 4.18. The combined health risks due to OCPs in pineapple and banana consumed by children and adult in Adidwan, Atonsuagya, Bosomkyekye and Kyerefamso were all less than 1 suggesting that people in these towns have no significant health risk through the consumption of these fruits. The combined health risk due to OCP residues in watermelon from all the towns were less than 1 except in Kyerefamso, where the combined risk due to OCP residues in watermelon consumed by children was 2.714, which signifies potential health risk to children who consumes watermelon produced in Kyerefamso.

The overall potential risk for noncarcinogenic health effects for children and adults through consumption of these selected fruits from all the selected towns in the Mampong municipality for children and adult were 3.694 and 0.615 respectively, specifying that children may have adverse health effects for consuming these fruits that are produced in the municipality. The overall potential risk for non-carcinogenic health effects was found by summing all the combined health risks for the individual OCP residues in the fruits from various sampling sites (Saha and Zaman, 2012). The relative contributions of the various fruits to the overall health risk were 80.51, 18.96 and 0.53 % for watermelon, banana and pineapple respectively, hence, watermelon was the fruit that was mostly contaminated by the OCPs thereby contributing most to the potential health risk, with banana being secondary and pineapple being the least. The fruits that are produced in Adidwan, Bosomkyekye, Atonsuagya and Kyerefamso contributed 0.57, 2.20, 5.14 and 92.09 % to the overall health risk. There were no risks detected in fruits from Woraso.

Table 4.21: Cancer risks for OCP residues in watermelon from all farms

Pesticide	OSF [per (ng/g/day)]	Watermelon Fruit					
		Children			Adult		
		ED(ng/g/day)	CBC(ng/gday)	HR	ED(ng/g/day)	CBC(ng/gday)	HR
Gamma - HCH	1300	8.34×10^{-2}	2.03×10^{-1}	4.11×10^{-2}	1.39×10^{-2}	1.22	1.14×10^{-2}
Beta - HCH	1800	2.45×10^{-2}	2.81×10^{-1}	8.72×10^{-2}	4.09×10^{-3}	1.69	2.42×10^{-2}
Heptachlor	4500	$2.62\text{-}\times10^{-2}$	7.03×10^{-1}	3.73×10^{-2}	4.37×10^{-3}	4.22	1.04×10^{-3}
Delta - HCH	NA	$3.14\text{-}\times10^{-1}$			5.23×10^{-4}	-	-
Aldrin	17000	1.46×10^{-2}	2.66×10^{0}	5.51×10^{-2}	2.44×10^{-2}	1.59×10^{1}	1.53×10^{-3}
Gamma- chlordane	350	-	5.47×10^{-2}	-	-	3.28×10^{-1}	-
A - endosulfan	NA	-	-	-	-	-	-
p,p' - DDE	340	-	5.31×10^{-2}	-	-	3.19×10^{-1}	-
Dieldrin	16000	5.5×10^{-2}	2.50	2.2×10^{-2}	9.16×10^{-3}	1.50×10^{1}	6.11×10^{-4}
Endrin	NA	-		-	-		-
p,p' - DDT	340	1.32×10^{-1}	5.31×10^{-2}	2.48	2.20×10^{-2}	3.19×10^{-1}	6.89×10^{-2}

B - endosulfan	NA	-	-	-	-	-	-
p,p' - DDD	240	5.06×10^{-3}	3.75×10^{-2}	1.35×10^{-1}	8.43×10^{-4}	2.25×10^{-1}	3.75×10^{-3}
Endosulfan-s	NA	-	-	-	-	-	-
Methoxychlor	NA	7.37×10^{-2}	-	-	1.23×10^{-2}	-	-

Table 4.22: Cancer risks for OCP residues in Pineapple from all farms

	OSF [per (ng/g/day)]	Pineapple Fruit					
		Children			Adult		
Pesticide		**ED (ng/g/day)**	**CBC (ng/gday)**	**HR**	**ED (ng/g/day)**	**CBC (ng/gday)**	**HR**
Gamma - HCH	1300	2.39×10^{-2}	2.03×10^{-1}	1.18×10^{-1}	3.9810^{-3}	1.22	3.27×10^{-3}
Beta - HCH	1800	-	2.81×10^{-1}	-	-	1.69	-
Heptachlor	4500	-	7.03×10^{-1}	-	-	4.22	-
Delta - HCH	-	-	-	-	-	-	-
Aldrin	17000	-	2.66	-	-	1.59×10^{1}	-
Gamma- chlordane	350	-	5.47×10^{-2}	-	-	3.28×10^{-1}	-

A - endosulfan	NA	-	-	-	-	-	-
p,p' - DDE	340	-	5.31×10^{-2}	-	-	3.19×10^{-1}	-
Dieldrin	16000	-	2.50	-	-	1.50×10^{1}	-
Endrin	NA	-			-		-
p,p' - DDT	340	1.66×10^{-2}	5.31×10^{-2}	3.12×10^{-1}	2.7610^{-3}	3.19×10^{-1}	8.66×10^{-3}
B - endosulfan	NA	-	-	-	-	-	-
p,p' - DDD	240	-	3.75×10^{-2}	-	-	2.25×10^{-1}	-
Endosulfan-s	NA	-	-	-	-	-	-
Methoxychlor	NA	7.62×10^{-3}	-	-	1.2710^{-3}	-	-

Table 4.23: Cancer risks for OCP residues in banana from all farms

Pesticide	OSF [per (ng/g/day)]	Banana Fruit					
		Children			Adult		
		ED (ng/g/day)	CBC (ng/gday)	HR	ED (ng/g/day)	CBC (ng/gday)	HR
Gamma - HCH	1300	3.78×10^{-3}	2.03×10^{-1}	1.86×10^{-2}	0.00398	1.22	5.16×10^{-4}
Beta - HCH	1800	4.15×10^{-2}	2.81×10^{-1}	1.48×10^{-1}	-	1.69	5.62×10^{-3}
Heptachlor	4500	-	7.03×10^{-1}	-	-	4.22	

Delta - HCH	-	-	-		-	-	
Aldrin	17000	2.75×10^{-2}	2.66	1.04×10^{-2}	-	1.59×10^{1}	2.89×10^{-4}
Gamma- chlordane	350	-	5.47×10^{-2}	-	-	3.28×10^{-1}	
A - endosulfan	NA	-	-	-	-	-	-
p,p' - DDE	340	-	5.31×10^{-2}	-	-	3.19×10^{-1}	-
Dieldrin	16000	-	2.50	-	-	1.50×10^{1}	-
Endrin	NA	7.83×10^{-2}		-	-	-	-
p,p' - DDT	340	4.99×10^{-3}	5.31×10^{-2}	9.39×10^{-2}	0.00276	3.19×10^{-1}	2.61×10^{-3}
B - endosulfan	NA	-	-	-	-	-	-
p,p' - DDD	240	-	3.75×10^{-2}	-	-	2.25×10^{-1}	-
Endosulfan-s	NA	-	-	-	-	-	-
Methoxychlor	NA	6.77×10^{-3}	-	-	0.00127	-	-

4.18 Carcinogenic risk

Carcinogenic health risks were assessed for the organochlorine pesticides due to their potential to cause cancer. The results for the carcinogenic risks have been summarized in Tables 4.21 – 4.23. The table contains the cancer benchmark concentrations (CBC) determined using the cancer slope factors obtained from US EPA (US EPA, 2014).

Hazard Ratios (HR) were used in the evaluation of potential carcinogenic risk to humans. Hazard ratio values for p,p'-DDT indicated that, its contamination in watermelon could pose potential carcinogenic effect for children since the HR was greater than 1. The carcinogenic risk of the OCP residues in fruits in general were of less concern, since all of the OCPs except p,p'-DDT carcinogenic rates in individual fruits were above the acceptable risk level. Organochlorine pesticides are persistent and also can bioaccumulate and subsequently magnify in levels in the organism so, it is necessary for constant monitoring of OCP residues in food commodities in order to evaluate if there is any potential health risks from these pesticides exposure to assure food safety.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

1. The results from this study indicated that some fruits and soils in the Mampong municipality are contaminated with organochlorine pesticides. Fifteen OCPs were monitored in the fruit and soil samples, out of which nine were detected in the fruits and six in the soil. The nine OCPs detected in the fruits were; gamma-HCH, beta-HCH, heptachlor, delta-HCH, aldrin, dieldrin, p,p'–DDT, p,p'–DDD and

methoxychlor and the six OCPs also detected in soil were beta-HCH, aldrin, endrin, p,p'–DDT, endosulfan-s and methoxychlor.

2. The six of the organochlorine pesticides that were detected in the fruit and soil samples are among the banned pesticides of the environmental protection agency (EPA) of Ghana. These banned organochlorine pesticides are: lindane (gammaHCH), endrin, heptachlor, aldrin, dieldrin, and DDT (Afful *et al.*, 2010). The occurrence of organochlorine pesticide residues in the soil and fruits could be due to its illegal use or due to historic use since these chemicals are banned from agricultural use. DDT recorded the highest mean conecntration of organochlorine pesticide residues in fruit whilst methoxychlor recorded the highest residues level in soil. Watermelon fruit was the most frequently contaminated fruit sample.

3. There were no significant variations in the levels of pesticides in the three fruit samples from all the farms ($p>0.05$). The differences in concentrations of the OCP residues in the soil from all the farms were significant ($p<0.05$). The differences in residual concentrations of pesticides could be due to different agricultural practices adopted by farmers and also accessibility of the pesticides.

4. Comparing the results of OCP residues in fruit from the farm gate to those from the market indicates that generally most of the organochlorine pesticides recorded higher levels in fruits from the farms as compared to the levels in fruits from the market.

5. Comparing the residue levels in fruits with that in soil samples taken around the fruit showed that some of the residues that were detected in the fruit were absent in the soil indicating that the contamination of the fruit by some of these chemicals in the fruit samples analysed might not be as a result of the uptake of the chemicals from the soil by the plants but rather, what was sprayed on the fruit. The results generally also indicates that the concentration of the pesticides residues in the soils were much higher than that present in most of the fruit samples analysed.

6. The concentrations of organochlorine pesticide residues were generally low, however, the concentration of OCPs residue such as gamma-HCH, aldrin and methoxychlor in watermelon fruits from some of the farms exceeded the maximum residue limits (MRLs) adopted by the European Union (EU,2013). The mean concentrations of OCPs such as beta-HCH and endrin in banana samples from some of the farms were also higher than their respective EU/MRL values. Gamma-HCH recorded mean concentration in watermelon samples from market being higher than the EU/MRL. The mean concentrations of all the OCP residues detected in the fruits from all the farms and market were below FAO/WHO MRL

7. The indices showed that all the organochlorine pesticide residues with the exception of aldrin did not pose any potential health risk associated with the fruits.

8. The overall potential risk for non-carcinogenic health effects for children and adults through consumption of the selected fruits from all the selected towns in the Mampong municipality for children and adult were 3.694 and 0.615 respectively.

9. The relative contributions of the various fruits to the overall health risk were 80.51, 18.96 and 0.53 % for watermelon, banana and pineapple respectively; the fruits that are produced in Adidwan, Bosomkyekye, Atonsuagya and Kyerefamso also contributed 0.57, 2.20, 5.14 and 92.09 % to the overall health risk. There were no risks detected in fruits from Woraso.

10. The carcinogenic risk of the OCP in fruits in general were also of less concern, since all of the OCPs except p,p' - DDT carcinogenic rates in individual fruits were below the acceptable risk level .

5.2 Recommendations.

1. Future monitoring programs are recommended to acquire adequate information regarding the levels of OCP residues in fruits and in general all the agricultural products produced in the municipality.

2. The persistence of these pesticides in the soil or uptake of the pesticides by the plants from the soil can be attributed to the influenced of physio-chemical and biological processes such as soil moisture, organic matter content, redox status, soil pH, temperature and soil texture, therefore similar study should be conducted on

the soils from the municipality to determine the relationship between the residue levels and these physiochemical and biological properties.

3. The Ministry of Food and Agriculture and the other regulatory authorities such as the Environmental Protection Agency should ensure strict enforcement of the laws and regulations on the use of banned pesticides in Ghana to avoid the illegal smuggling and use of organochlorine pesticides.

4. There is the need to conduct a regular research on dietary intake of various food substances for the entire population of Ghana to ascertain a food consumption rates so that a more complete health risk assessment could be established in the future.

5. Continuous sensitization on the harmful effects of organochlorine pesticides and farmer education on safe pesticide use should be intensified to reduce the levels of pesticides residues in fruits and all agricultural products.

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APPENDICES

Appendix A

ANOVA ANALYSIS

OCP RESIDUE IN FRUIT FROM ATONSUAGYA

Source of Variation	*Sum of Squares*	*df*	*Mean Square*	*F*	*P-value*
Between Groups	**104.460**	**1**	**104.460**	**19.080**	**0.001**
Within Groups	**71.174**	**13**	**5.475**		
Total	**175.634**	**14**			

Appendix B

ANOVA ANALYSIS

OCP IN FRUIT FROM BOSOMKYEKYE

Source of Variation	*Sum of Squares*	*df*	*Mean Square*	*F*	*P-value*
Between Groups	**.146**	**1**	**0.146**	**0.137**	**0.718**
Within Groups	**13.898**	**13**	**1.069**		
Total	**14.044**	**14**			

Appendix C

ANOVA ANALYSIS

OCP RESIDUE IN FRUIT FROM KYEREFAMSO

Source of Variation	*Sum of Squares*	*df*	*Mean Square*	*F*	*P-value*
Between Groups	**1778.010**	**1**	**1778.010**	**30.833**	**0.000**
Within Groups	**749.647**	**13**	**57.665**		

Total	**2527.657**	**14**

ANOVA ANALYSIS

Appendix D

OCP RESIDUE IN FRUIT FROM MARKET

Source of Variation	*Sum of Squares*	*df*	*Mean Square*	*F*	*P-value*
Between Groups	**.628**	**1**	**.628**	**0.020**	**0.890**
Within Groups	**412.617**	**13**	**31.740**		
Total	**413.245**	**14**			

Appendix E

ANOVA ANALYSIS

OCP RESIDUE IN FRUIT FROM ALL FARMS

Source of Variation	*Sum of Squares*	*df*	*Mean Square*	*F*	*P-value*
Between Groups	**80.450**	**1**	**80.450**	**1.336**	**0.269**
Within Groups	**783.002**	**13**	**60.231**		
Total	**863.453**	**14**			

Appendix F ANOVA ANALYSIS

CORRELATION OF OCP RESIDUES IN FRUIT FROM FARM AGAINST MARKET

	WF	WM	PF	PM	BF	BM
WF	**1**					
WM	**0.435**	**1**				
PF	**0.413**	**0.172**	**1**			
PM	**-0.016**	**-0.039**	**0.782****	**1**		

ANOVA ANALYSIS

BF	**0.195**	**0.350**	**0.757****	**0.744****	**1**	
BM	**0.145**	**0.885****	**-0.121**	**-0.071**	**0.183**	**1**

Appendix G

OCP RESIDUES IN SOIL FROM ADIDWAN

Source of Variation	*Sum of Squares*	*df*	*Mean Square*	*F*	*P-value*
Between Groups	**1026.780**	**1**	**1026.780**	**38.347**	**0.000**
Within Groups	**348.089**	**13**	**26.776**		
Total	**1374.869**	**14**			

Appendix H

ANOVA ANALYSIS

OCP RESIDUES IN SOIL FROM ATONSUAGYA

Source of Variation	*Sum of Squares*	*df*	*Mean Square*	*F*	*P-value*
Between Groups	**18843.312**	**1**	**18843.312**	**828.010**	**0.000**
Within Groups	**295.845**	**13**	**22.757**		
Total	**19139.157**	**14**			

Appendix I

ANOVA ANALYSIS

OCP RESIDUE IN SOIL FROM KYEREFAMSO

Source of Variation	*Sum of Squares*	*df*	*Mean Square*	*F*	*P-value*

ANOVA ANALYSIS

Between Groups 5.047 1 5.047 0.128 0.726 Within Groups 512.607 13 39.431 Total 517.653 14

Appendix J

OCP RESIDUE IN SOIL FROM WORASO

Source of Variation	*Sum of Squares*	*df*	*Mean Square*	*F*	*P-value*
Between Groups	**5212.443**	**1**	**5212.443**	**1442.642**	**0.000**
Within Groups	**46.971**	**13**	**3.613**		
Total	**5259.413**	**14**			

Appendix K

ANOVA ANALYSIS

OCP RESIDUE IN SOIL FROM ALL AREAS

Source of Variation	*Sum of Squares*	*df*	*Mean Square*	*F*	*P-value*
Between Groups	**7917.436**	**2**	**3958.718**	**52.298**	**0.000**
Within Groups	**908.336**	**12**	**75.695**		
Total	**8825.772**	**14**			

Appendix L MEAN CONCENTRATIONS (ng/g) OF ORGANOCHLORINE PESTICIDES IN SOIL AND FRUIT SAMPLES FROM ADIDWAN

Pesticide	Watermelon		Pineapple		Banana	
	Fruit	Soil	Fruit	Soil	Fruit	Soil
Gamma - HCH	<0.01	<0.01	<0.01	<0.01	0.59	<0.01
Beta - HCH	<0.01	<0.01	3.59	<0.01	<0.01	<0.01
Heptachlor	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Delta - HCH	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Aldrin	<0.01	5.2	<0.01	<0.01	<0.01	3.6
Gamma-chlordane	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
A - endosulfan	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
p,p' – DDE	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Dieldrin	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Endrin	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
p,p' - DDT	<0.01	38.4	<0.01	<0.01	<0.01	110
B - endosulfan	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
p,p' – DDD	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Endosulfan	<0.01	<0.01	<0.01	<0.01	0.98	0.8
Methoxychlor	<0.01	<0.01	<0.01	<0.01	<0.01	59.2

Limit of detection for all pesticides = 0.01 ng/g

Appendix M MEAN CONCENTRATIONS (ng/g) OF ORGANOCHLORINE PESTICIDES IN SOIL AND FRUIT SAMPLES FROM ATONSUOGYA

Pesticide	Watermelon		Pineapple		Banana	
	Fruit	Soil	Fruit	Soil	Fruit	Soil
Gamma - HCH	7.55	<0.01	<0.01	<0.01	<0.01	<0.01
Beta - HCH	0.20	<0.01	<0.01	4.00	<0.01	<0.01
Heptachlor	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Delta - HCH	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Aldrin	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Gamma- chlordane	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
A - endosulfan	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
p,p' - DDE	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Dieldrin	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Endrin	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
p,p' - DDT	5.16	<0.01	<0.01	8.80	0.39	<0.01
B - endosulfan	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
p,p' - DDD	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Endosulfan	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Methoxychlor	11.53	143.2	1.20	75.6	<0.01	<0.01

Limit of detection for all pesticides = 0.01 ng/g

Appendix N MEAN CONCENTRATIONS (ng/g) OF OCP RESIDUE IN SOIL AND FRUIT SAMPLES FROM BOSOMKYEKYE

Pesticide	Watermelon		Pineapple		Banana	
	Fruit	Soil	Fruit	Soil	Fruit	Soil
Gamma - HCH	3.38	<0.01	<0.01	<0.01	<0.01	<0.01
Beta - HCH	<0.01	<0.01	3.88	<0.01	<0.01	<0.01
Heptachlor	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Delta - HCH	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Aldrin	<0.01	<0.01	<0.01	22.4	<0.01	<0.01
Gamma-chlordane	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
A - endosulfan	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
p,p' - DDE	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Dieldrin	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Endrin	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

p,p' - DDT	2.16	<0.01	<0.01	46.4	1.18	<0.01
B - endosulfan	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
p,p' - DDD	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Endosulfan	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Methoxychlor	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Limit of detection for all pesticides = 0.01 ng/g

Appendix O MEAN CONCENTRATIONS (ng/g) OF ORGANOCHLORINE PESTICIDES IN SOIL AND FRUIT SAMPLES FROM KYEREFAMSO

Pesticide	Watermelon		Pineapple		Banana	
	Fruit	Soil	Fruit	Soil	Fruit	Soil
Gamma - HCH	19.03	<0.01	<0.01	<0.01	<0.01	<0.01
Beta - HCH	8.20	23.6	<0.01	<0.01	11.27	<0.01
Heptachlor	4.10	<0.01	<0.01	<0.01	<0.01	<0.01
Delta - HCH	0.49	<0.01	<0.01	<0.01	<0.01	<0.01
Aldrin	22.84	2.4	<0.01	<0.01	4.23	<0.01
Gamma- chlordane	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
A - endosulfan	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
p,p' - DDE	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Dieldrin	8.59	<0.01	<0.01	<0.01	<0.01	<0.01
Endrin	<0.01	<0.01	<0.01	11.2	12.23	ND
p,p' - DDT	48.22	<0.01	2.59	<0.01	<0.01	<0.01
B - endosulfan	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
p,p' - DDD	0.78	<0.01	<0.01	<0.01	<0.01	<0.01
Endosulfan	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Methoxychlor	<0.01	<0.01	<0.01	40.8	<0.01	<0.01

Limit of detection for all pesticides = 0.01 ng/g

Appendix P MEAN CONCENTRATIONS (ng/g) OF ORGANOCHLORINE PESTICIDES IN SOIL AND FRUIT SAMPLES FROM WORASO

Pesticide	Watermelon		Pineapple		Banana	
	Fruit	Soil	Fruit	Soil	Fruit	Soil
Gamma - HCH	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Beta - HCH	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Heptachlor	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Delta - HCH	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Aldrin	<0.01	9.2	<0.01	<0.01	<0.01	8.0
Gamma- chlordane	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
A - endosulfan	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
p,p' - DDE	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Dieldrin	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Endrin	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
p,p' - DDT	<0.01	44.8	<0.01	<0.01	<0.01	32.8
B - endosulfan	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
p,p' - DDD	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Endosulfan	<0.01	<0.01	<0.01	<0.01	<0.01	0.8
Methoxychlor	<0.01	64	<0.01	<0.01	<0.01	56.8

Limit of detection for all pesticides = 0.01 ng/g

Appendix Q

RECOVERY RESULTS

Pesticide	**Mean±SD**	**% Recovery**
Gamma-HCH	**0.39 ± 0.186676**	**104**
Beta-HCH	**0.336 ± 0.091924**	**89.6**
Heptachlor	**0.394 ± 0.178191**	**105.07**
Delta-HCH	**0.279 ± 0.089803**	**74.27**
Aldrin	**0.42 ± 0.237588**	**112**
Gamma-chlordane	**0.412 ± 0.252437**	**109.73**
A-endosulfan	**0.292 ± 0.041719**	**77.73**
p,p'-DDE	**0.304 ± 0.091217**	**80.93**
Dieldrin	**0.289 ± 0.068589**	**76.93**
Endrin	**0.389 ± 0.138593**	**103.73**
p,p'-DDD	**0.331 ± 0.138593**	**88.27**
B-endosulfan	**0.375 ± 0.17607**	**99.86**
p,p'-DDT	**0.376 ± 0.190919**	**100.27**
Endosulfan s	**0.349 ± 0.012021**	**92.93**
Methoxychlor	**0.382 ± 0.002121**	**101.73**