

**KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY,
KUMASI**

**DIETARY EXPOSURE TO PESTICIDE CONTAMINATED VEGETABLES
GROWN IN THE YILO KROBO DISTRICT OF GHANA**

**THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES,
KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY IN
PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF
MASTER OF SCIENCE (MSc.) DEGREE IN ENVIRONMENTAL SCIENCE**

BY

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JANUARY, 2014

DECLARATION

I hereby declare that this is the result of my original research and that no part of it has been presented for another degree in this University or elsewhere.

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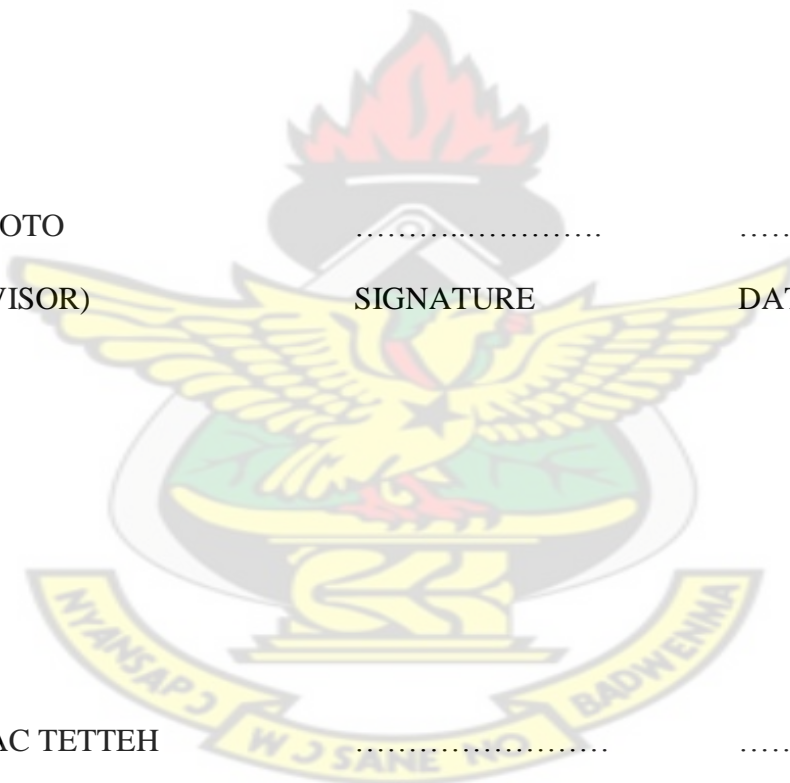
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ABSTRACT

A total of 30 farmers within the Yilo Krobo District were interviewed using questionnaire to obtain their personal details and the types of pesticides they use. Pesticide residues in vegetables from three farming communities within the District (NKurakan, Huhuhnya, and Apkamu) were analyzed using gas chromatography. Twenty-five (25) pesticide residues which were made up of 13 organophosphates, 8 organochlorine and 4 pyrethroids were measured in all the vegetables (okra, pepper and cabbage) analyzed. The results from the questionnaire administered indicated that most farmers use organophosphates pesticides. Organophosphates and pyrethroid pesticide residues were detected in 80% of the vegetables. Phorate was found in 60%, 40%, and 30% of cabbage, okro and pepper samples respectively, whiles chlorpyrifos was found in 80%, 70%, and 50% of cabbage, okro and pepper samples. Fenvalerate was detected in 3 (30%) of the pepper samples from Apkamu. Permethrin was detected in 40% of the cabbage samples from Nkurakan whiles deltamethrin was detected in 60% of the cabbage samples from Apkamu. Hazard indices of chlorpyrifos residues detected in okra revealed that life time consumption of okra from the district could pose health risk to consumers.

DEDICATION

This research work is dedicated to my father Peter Asenso, my Mother Comfort Asare, all my children and my beloved wife Stella Annor Boampong.

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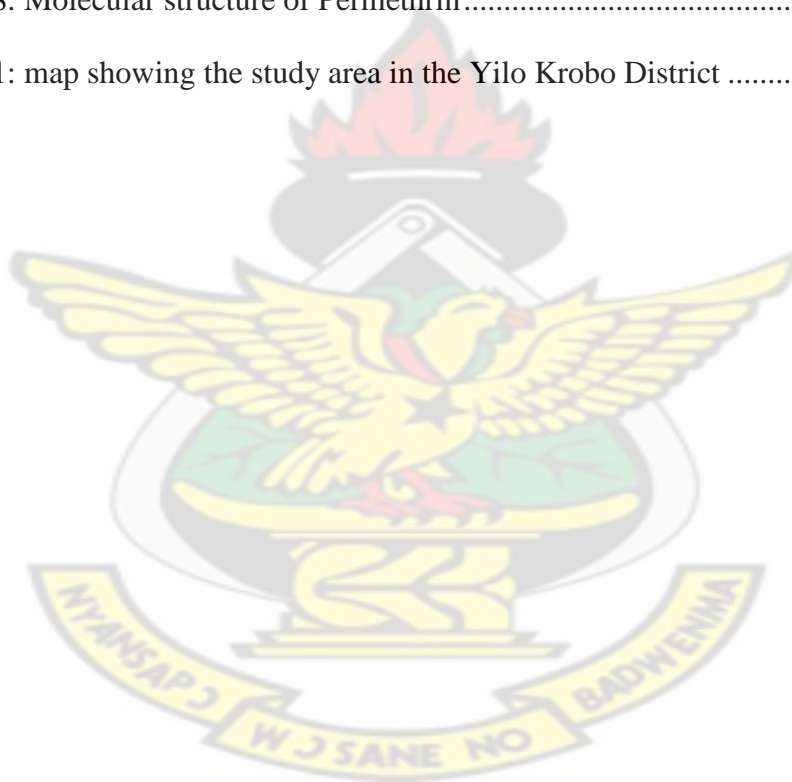


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LIST OF ABBREVIATIONS AND SYMBOLS

ADI	ACCEPTABLE DAILY INTAKE
ADHD	ATTENTION DEFICIT HYPERACTIVITY DISORDER
ADRA	ADVENTIST DEVELOPMENT AND RELIEF AGENCY
ATSDR	AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY IN THE UNITED STATES
CAC	CODEX ALIMENTARIUS COMMISSION
CCPR	CODEX COMMITTEE ON PESTICIDE RESIDUES
DDA	2, 2-BIS (4-CHLOROPHENYL)-ACETIC ACID.
DDD	DICHLORODIPHENYLDICHLOROETHANE
DDE	DICHLORODIPHENYLDICHLOROETHYLENE
DDT	DICHLORODIPHENYLTRICHLOROETHANE
DNA	DEOXYRIBONUCLEIC ACID
EADI	ESTIMATED AVERAGE DAILY INTAKE
ECD	ELECTRON CAPTURE DETECTOR
EDS	ENDOCRINE DISRUPTING CHEMICALS
FAO	FOOD AND AGRICULTURAL ORGANIZATION OF THE UNITED NATIONS
GAP	GOOD AGRICULTURAL PRACTICE(S) IN THE USE OF PESTICIDES
GC	GAS CHROMATOGRAPHY/ CHROMATOGRAPH
HCB	HEXACHLOROCYCLOBENZENE
HCH	HEXACHLOROCYCLOHEXANE
HI	HAZARD INDEX
HPTLC	HIGH PERFORMANCE THIN LAYER CHROMATOGRAPHY

HR	HEALTH RISK
IPM	INTEGRATED PEST MANAGEMENT
IUPAC	INTERNATIONAL UNION OF PURE AND APPLIED CHEMISTRY
JMPR	JOINT FAO/WHO MEETING ON PESTICIDE RESIDUES
<LD	LESS THAN LIMIT OF DETECTION OR QUANTIFICATION
MG/KG	MICROGRAM PER KILOGRAM
MG/L	MICROGRAM PER LITER
MIDA	MILLINIUM DEVELOPMENT AGENCY
ML	MICROLITERS
MOFA	MINISTRY OF FOOD AND AGRICULTURE
MRL	MAXIMUM RESIDUE LIMIT/LEVEL
ND	NOT DETECTED
OCPS	ORGANOCHLORINE PESTICIDES
OCS	ORGANOCHLORINES
ORS	ODD RATIOS
PCB	POLYCHLORINATED BIPHENYLS
PFPD	PULSED FLAME PHOTOMETRIC DETECTOR
POPS	PERSISTENT ORGANIC POLLUTANTS
PPB	PARTS PER BILLION
PSA	PRIMARY, SECONDARY AMINE
UN	UNITED NATIONS
WHO	WORLD HEALTH ORGANIZATION
rpm	REVOLUTIONS PER MINUTE

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF STUDY

Pesticides have been an inherent component of our lives for many years (Ware, 1983). It was discovered about 150 years ago that a number of natural chemicals had capabilities to control pests and consequently the use of these compounds increased with applications at anywhere pest control was desired. These agents included lime, sulfur, oil of citronella, nicotine, and arsenicals were used to control insects, while copper sulfate and sodium chloride were used to control weeds (Ware, 1983; Stevens and Sumner, 1991; Cutkomp and Eesa, 1994).

Pesticides were introduced with the aim of enhancing crop yields and also protecting crops from pests. Every year higher amounts and new pesticides are used to protect crops due the adaptation and resistance developed by pests to these chemicals, causing undesired side effects and raising the costs of food production (Ware, 1983). The increasing demand of vegetable and food crops for local consumption as well as for export has necessitated the use of pesticide in crop production to control and reduced the effect of pest in food production in Ghana (Clarke *et al.*, 1997; Taylor *et al.*, 2002). It is estimated that 87% of vegetable farmers in Ghana use pesticides.

Pesticides have played an important role for the control of insect pests in Ghana. They are heavily used in the cocoa, coffee, cotton, vegetables and other food and cash crops growing area in Ghana such as Ashanti, Brong Ahafo, Western and Eastern Regions (Amoah *et al.*, 2006; Darko and Acquah, 2006, 2007, Darko *et al.*, 2008; Ntow, 2008, Bempah and Donkor, 2010). Although organochlorines pesticides are banned from

importations, sales and use in Ghana, large reservoirs of these pesticides continue to exist in the environment due to large scale of historical use (Ntow *et al.*, 2006, Darko *et al.*, 2008; Bempah and Donkor, 2010). Several studies conducted so far in some farming communities in the Northern, Ashanti and Eastern Regions of Ghana have reported levels of pesticide residues in vegetables, water, sediments, food, human milk, blood sample, fish and lean meat (Darko and Acquaaah, 2007, 2008; Darko *et al.*, 2008; Bempah and Donkor, 2010). Though, coordinated efforts are necessary to increase food production in the country, but the quality of the food produce should be taken into consideration (Cutkomp and Eesa, 1994).

1.2 STATEMENT OF PROBLEM

The use of pesticides for food production has become part of Ghana's agricultural practices. Every year higher amounts and new pesticides formulations are used by farmers to respond to the need for increasing food production for local consumption and export (FAO, 2002). However, pesticides such as Organochlorines are resistant to environmental degradation, as a result bioaccumulate in living tissues and biomagnify in food chains and with the resultant impacts on human health and the environment (Baird, 1997). These synthetic organic pesticides therefore contribute too many acute and chronic illnesses. They are known or suspected to be hormone disruptors (Baird, 1997). Studies have shown that exposure to these pesticides can cause irreversible damage to the reproductive and immune systems of the developing foetus (Fleming *et al.*, 1994). Some studies conducted in Ghana revealed high levels of pesticide residues in the environment which are emanating from current and past use of these chemicals (Amoah *et al.*, 2006; Darko and Acquaaah, 2007, 2008; Darko *et al.*, 2008; Ntow *et al.*, 2008, Bempah and Donkor, 2010; Afful *et al.*, 2010). Farmers at Yilo Krobo District in

the Eastern Region of Ghana cultivate vegetables such as cabbage, okro, and pepper on large scales. Majority of these farmers often spray their vegetables with pesticides with the view of preventing pest from attacking their vegetables (MoFA, 2000). These pesticides may leave residues on the vegetables which can pose health risk to both farmers and consumers of these vegetables (Mukherjee, 2002).

1.3 OBJECTIVES

The purpose of the study is to determine the level of pesticide residues in some vegetables in the Yilo Krobo district in the Eastern Region of Ghana.

1.3.1 SPECIFIC OBJECTIVES

1. To measure the levels of organochlorines, organophosphate, and pyrethroid residues in cabbage, okro and pepper grown in the Yilo Krobo District.
2. To estimate the average daily intake of these pesticides per person.
3. To measure the hazard indices of the pesticide residues.

1.4 JUSTIFICATION

Yilo Krobo district is known for large scale production of vegetables which are sold at other market centers in Ghana (MOFA, 1998). It has also been reported that Ghanaians rely extensively on pesticides for pest control and disease vector eradication (Clarke *et al.*, 1997). Most major classes of pesticides, including organochlorine, organophosphorus compounds, carbamate, chlorophenoxy and pyrethroids, are known to adversely affect nervous system of laboratory animals as well as altering neurological function and causing subtle neuro-behavioural impairments (Longnecker *et al.*, 1997). Although a lot of research has been done on pesticide usage in Ghana, a

little is known about the levels of pesticide residues on vegetables in the Yilo Krobo District in the Eastern Region of Ghana. It is against this backdrop that this research is being carried to determine the level of pesticide residues in some vegetables in the Yilo Krobo district.

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CHAPTER TWO

LITERATURE REVIEW

2.1 DEFINITION OF PESTICIDES.

Pesticide is any substance or mixture of substances intended for preventing, destroying, repelling or mitigating any pest (Walter, 2005). A pesticide may be a chemical substance, biological agent (such as a virus or bacterium), antimicrobial, disinfectant or device used against any pest. Pests include insects, plant pathogens, weeds, molluscs, birds, mammals, fish, nematodes (roundworms) and microbes that destroy property, spread disease or are a vector for disease or cause a nuisance (Ritter *et al.*, 2007). Although there are benefits to the use of pesticides, there are also drawbacks, such as potential toxicity to humans and other animals (Walter, 2005). The term pesticides as defined by FAO also includes substances intended for use as a plant growth regulator, defoliant, desiccant or agent for thinning fruit or preventing the premature fall of fruit and substances applied to crops either before or after harvest to protect the commodity from deterioration during storage and transport (FAO, 2002)

2.2 CLASSIFICATION OF PESTICIDES

There are many ways of classifying pesticides: They can be classified by target organisms or by chemical structure (Walter, 2005). When classified by target pest, pesticides may be broadly defined as being insecticides, fungicides and herbicides depending on whether they are to be used to kill insects, fungi and plants respectively. Pesticides may also be classified as organic or inorganic pesticides according to the chemical structure. Inorganic pesticides are made from naturally occurring minerals and have varying modes of action including interfering with conversion of energy within cells and causing death by desiccation (Fattore *et al.*, 2002). Common inorganic

pesticides include boric acids, silicagel, sodium fluoride and those containing heavy metals such as mercury, arsenic and its compounds such as lead and calcium arsenate (Baird, 1997).

Organic pesticides consist of compounds containing carbon in addition to hydrogen. They may also contain chlorine, oxygen, sulphur, nitrogen and phosphorus in their molecule. Majority of all modern pesticides are organic pesticides and can be further divided into synthetic and natural organic pesticides.

Synthetic organic pesticides may include: organochlorines or chlorinated hydrocarbons (DDT, metoxychlor, lindane, toxaphene and mirex), Organophosphated (dichlorvos, malathion, parathion, dimethoate and coumaphos), Carbamates (carbofuran, propoxur and aldicarb) and Pyrethroids (fenvalerate, deltamethrin, cyhalothrin and cypermethrin) (Baird, 1997). The natural organics or biopesticides include microbial pesticides, biochemical pesticides, plant-derived pesticides or botanical insecticides. These biological pesticides include pyrethrum extracted from *Chrysanthemum species*, nicotine from tobacco leaves and from the roots of *Derris species* (Baird, 1997).

Pesticides can also be classified based on their biological mechanism or mode of action. Most pesticides work by poisoning pests. Broad-spectrum pesticides are those that kill an array of species, while narrow-spectrum or selective pesticides only kill a small group of species (Baird, 1997). A systemic pesticide moves inside a plant following absorption by the plant. With insecticides and most fungicides, this movement is usually upward (through the xylem) and outward. Systemic insecticides, which poison

pollen and nectar in flowers may kill bees and other needed pollinators (Fattore *et al.*, 2002).

2.3.1 SYNTHETIC ORGANIC PESTICIDES

The synthetic pesticides are now primary agent of insect control. The main synthetic groups are the chlorinated hydrocarbons, organophosphate, and carbamates.

2.3.1.1 Organochlorines (OCs)

OCs also called chlorinated hydrocarbons contain carbon, hydrogen, chlorine and sometimes oxygen. There are three major types of organochlorine pesticides namely:

1. Dichlorodiphenylethanes such as DDT, DDD or TDE, methoxychlor, rhothane, methlochlor, perthane and dicofol (kelthane).
2. Chlorinated cyclodienes such as aldrin, dieldrin, endrin, heptachlor, chlordane, and endosulfan.
3. Chlorinated benzenes or cyclohexanes such as lindane, toxaphene, mirex, HCB, and chlordecone (kepone).

The essential structural feature about OC pesticides is the presence of carbon-chlorine bonds (Baird, 1997). OC came into widespread use in the late 1940's (Baird, 1997). Despite being banned in developed countries since the 1970's or prohibited in many countries, they are still detectable in the environment due to their persistency (Manirakiza *et al.*, 2002). Because of toxicity and persistency of OCPs, the Stockholm Convention on persistent organic pollutants (POPs) has banned the production and use of these chemicals.

The banned OCs include aldrin chlordane, dichlorodiphenyltrichloroethane (DDT), dieldrin, endrin, heptachlor, hexachloro-benzene (HCB), mirex and toxaphene (UNEP, 2002; Bouwman, 2004).

Orgnochlorine pesticides are characterised by high persistence, high diffusion in the environment, low polarity, low aqueous solubility, high lipid solubility (lipophilicity), bioaccumulation and biomagfication in the food chain (Fattore *et al.*, 2002). Organochlorine pesticides once applied can reach destinations other than their target species, including non-target species, air, water and soil either by atmospheric deposition, runoff or leaching (Doong *et al.*, 2002; Afful *et al.*, 2010). The lipophilic nature of OCs coupled with its low reactivity with respect to light and chemicals as well as its low biological degradation rates have led to their accumulation in biological tissues and subsequent biomagnification in organisms progressing up the food chain (Baird, 1997; Fattore *et al.*, 2002). OCs have adverse effects on wildlife and beneficial insects and also as residues in crops although it was favoured initially. It has also been implicated in a broad range of adverse human health effects including reproductive failures, birth defects, immune system malfunction, endocrine disruptions and cancers (Hallberg, 1989, Baird, 1997).

Although OCs are classified as hazardous, farmers continue to use them because they are cheap and have broad-spectrum of activity (WHO, 1996). OC pesticides have played an important role for the control of insect pests in Ghana. They are used heavily in the cocoa, coffee, cotton, vegetables and other food and cash crops growing area in Ghana (Ntow *et al.*, 2008, Darko and Acquah, 2007, Darko *et al.*, 2008). Though the use of OCs over the last four decades has reduced, their levels in biota have declined relatively slowly and high

levels are still reported in marine top-predators (Aguilar et al., 2002). Characteristics of some commonly used OCs are mentioned in the subheading below.

2.3.1.1.1 Dichlorodiphenyltrichloroethane (DDT)

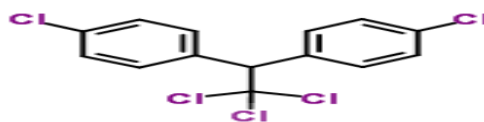


Figure 2.1: Molecular structure of DDT

Figure 2.1 above represents the molecular structure of DDT. It is the abbreviation for an obsolete chemical name (4, 4'-dichloro- diphenyltrichloroethane), whereas the current name is 1,1,1-trichloro-2,2(4chlorophenyl)- ethane. DDT was discovered in 1939 by a Swiss scientist Paul Muller as very effective synthetic organic insecticide although it was first synthesized in 1874 by Othmar Zeidler (Miller, 2002). It became the most widely used pesticide in the world because it was effective against body lice that transmit typhus, against plague-carrying fleas and mosquitoes that carry malaria and yellow fever (Dunlap, 1981; Baird, 1997). WHO estimated that DDT saved the lives of more than five million people in its malaria reduction programs, (Baird, 1997). Unfortunately, DDT was widely overused, particularly in agriculture, which consumed 80% of its production. As a result, its environmental concentration rose rapidly and began to affect the reproductive abilities of birds which indirectly incorporated it into their bodies (Burger *et al.*, 2001). This led to the banned of DDT and other organochlorine insecticides (UNEP, 2002).

In Ghana, DDT was introduced in 1948 for the control of pests and disease pathogens of cocoa and for the control of mosquito (Taylor *et al.*, 2002). Lindane, until 2006 was widely used in Ghana on cocoa plantations, vegetable farms and for the control of stem borers in maize. Endosulfan was also used on cotton plantations and on vegetables but was later restricted to cotton production in 2008 (MOFA, 1990). Organochlorine pesticides were widely used by farmers and health workers because of their cost effectiveness and their broad spectrum activity (MOFA, 1990; Clarke *et al.*, 1997; Taylor *et al.*, 2002).

2.3.1.1.2 Chlordane

Chlordane is a cyclopentatriene pesticide which was commonly used on corn and citrus crops as well as a method of termite control from 1948 to 1988 (Metcalf, 2002). Its chemical formula is $C_{10}H_6Cl_8$ and the IUPA name is Octachlor-4, 7- methohydroindane as indicated by its molecular structure in figure 2.2 below.

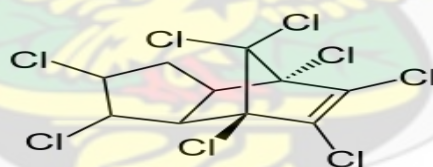


Figure 2.2: Molecular structure of Chlordane

Technical grade chlordane consists of isomers such as alpha or cis- isomer and gamma or trans- isomer. Commercial formulations contain 10% heptachlor (Nollet, 2000). Being hydrophobic, it adheres strongly to surface soil particles and can stay in the soil for 20 years. It does not easily dissolve in water and enters groundwater slowly owing to its low solubility. Chlordane bioaccumulates in animals and is also highly toxic to fish (Watanabe *et al.*, 2003). Most chlordane leaves the soil by evaporation to the air,

where it may be redistributed by air currents, contaminating areas far from their original application site (Orris et al., 2000). Studies have linked chlordane/heptachlor in human tissues with cancers of the breast, prostate, brain, and cancer of blood cells (leukemia and lymphoma) (Turyk, 2009). The non-cancer health effects of chlordane compounds include migraines, respiratory infections, diabetes, anxiety, depression and activated immune system (ATSDR, 1995).

Pathways of exposure to chlordane include ingestion of crops grown in chlordane contaminated soil, ingestion of high fat foods such as meat, fish, and dairy as well as through inhalation of air near chlordane treated homes and landfills (ATSDR, 1995). Chlordane is excreted slowly through faeces and urine, as well as through breast milk in nursing mothers and is able to cross placenta and become absorbed by developing foetus in pregnant women (ATSDR, 1995). The metabolite oxychlordane is found to be more bioaccumulative and toxic than the parent compounds in vertebrates (Bondy et al., 2003).

2.3.1.1.3 Hexachlorohexanes (HCHS)

HCHs are used worldwide in insecticide formulations, and technical HCH consists of eight different chemical forms or isomers. The IUPAC name of HCH is 1, 2, 3, 4, 5, 6-hexachlorocyclohexane as indicated by its molecular structure in figure 2.3 below. It has molecular formula $C_6H_6Cl_6$. Studies have shown that only one of the eight isomers, gamma isomer, has an insecticidal property which is currently sold separately under the name lindane (Baird, 1997).

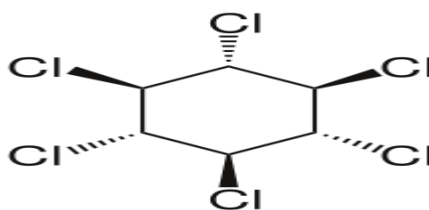


Figure 2.3: Molecular structure of Beta-Hexachlorocyclohexane

Lindane or gamma HCH is the active ingredients in several commercial preparations, formulated as a shampoo or lotion used to rid children of lice and scabies (Baird, 1997; US EPA, 2003). It has been used to treat food crops, forestry products, as a soil treatment, and also used to treat livestock and pets as well as to treat seeds and seedling. Lindane is also persistent organic pollutant which is relatively long-lived in the environment and therefore can be transported long distances by natural processes, as a result bioaccumulate in food chains, though it is rapidly eliminated when exposure is discontinued (UNEP, 2009). Lindane eventually breaks down in soil, sediment and water into less harmful substance by algae, fungi and bacteria; however, the process is relatively slow especially under aerobic condition and dependent on ambient environmental conditions (ATSDR, 2005). Volatilisation is also very slow in water, although it represents the major source of release of lindane from soil.

Most lindane exposure to humans has resulted from its agricultural uses and the intake of foods, produced from treated agricultural commodities (US CDC, 2005). Most of the adverse human health effects reports for lindane have been related to agricultural uses and occupational exposure of seed treatment workers (UNEP, 2007). Exposure to large amounts of lindane can harm the nervous system, producing a range of symptoms from headache and dizziness to seizures, convulsion and more rarely death (ATSDR, 2005; US CDC, 2005). Prenatal exposure to b-HCH and isomer of lindane has been

associated with altered thyroid hormone levels and could affect brain development (Alvarez-Pedrerol et al., 2008).

Based primarily on evidence from animals studies, most evaluation of lindane have concluded that it may possibly cause cancer (US EPA, 2004; ATSDR, 2005). U.S Department of Health and Human Service concluded that all isomers of hexachlorocyclohexane, including lindane, may reasonably be anticipated to cause cancer in humans (US EPA, 2003; ATSDR, 2005). The most common side effects are burning sensations, itching, dryness and rash. An international ban on the use of lindane in agriculture therefore became implemented in 2009 under the Stockholm Convention on Persistent Organic Pollutants. In Ghana lindane was marketed as Gammalin 20 and was used for the control of capsids on cocoa farms and stem borers in maize (Mensah, 2009).

2.3.1.2 Organophosphate pesticides (OPs)

Organophosphorous pesticides are widely used in agriculture for crop protection. Human toxicities for this class of pesticides have shown both acute and chronic effects poisoning (US EPA, 2003). OP compounds can be considered as derivatives of inorganic phosphorus compounds in which one or more of the hydrogen atoms have been replaced by organic groups. The OPs have diverse physical properties due to their different structures and chemical composition (Krieger et al., 2001). They break down readily and are non-persistent in the environment, have greater selective toxicity and are therefore widely used as a replacement for the persistent organochlorine. Minton and Murray (1988) have divided organophosphates into three groups. The first and most toxic group has a LD₅₀ in the range of 1-30 mg/kg e.g. chlorfenvinphos, the second group has LD₅₀ range of 30-50 mg/kg e.g. dichlorvos and the least toxic group,

e.g. malathion has a range of 60-1300 mg/kg. OPs kill insects by inhibiting the enzyme that regulates acetylcholine, a neurotransmitter which plays a vital role in the transmission of nerve impulses. The organophosphates attach to the acetylcholinesterase preventing it from functioning; a build-up of acetylcholine occurs causing overstimulation of the nerves and interference with the nerve impulse transmission at nerve endings (Krieger et al., 2001). Characteristics of some commonly used OPs are mentioned in the subheading below.

2.3.1.2.1 Chlorpyrifos

The IUPAC name of Chlorpyrifos is O,O-diethyl O-3,5,6-trichloropyridin-2-yl phosphorothioate as indicated by its molecular structure in figure 2.4 below. It acts on the nervous system of insects by inhibiting acetylcholinesterase. Chlorpyrifos is moderately toxic to humans and chronic exposure has been linked to neurological effects, developmental disorders, and autoimmune disorders (Walter, 2005). Exposure during pregnancy retards the mental development of children, and most use in homes has been banned since 2001 in the U.S. (Pennington *et al.*, 2004).

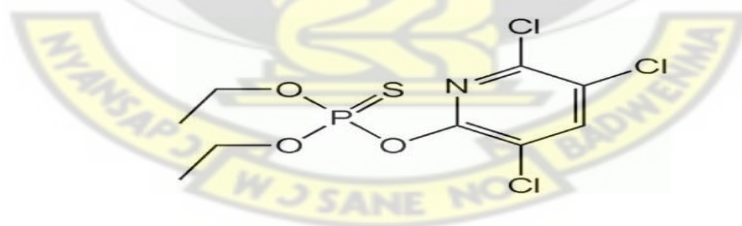


Figure 2.4: Molecular structure of Chlorpyrifos

2.3.1.2.2 Phorate

Figure 2.5 below indicates the molecular structure of phorate. The IUPAC name for phorate is O, O-Diethyl S-[(ethylsulfanyl) methyl] phosphorodithioate and its molecular formula is C₇H₁₇O₂PS₃ (US EPA, 2003).

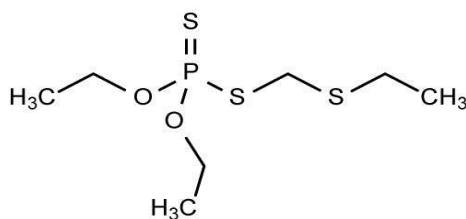


Figure 2.5: Molecular structure of Phorate

Phorate is an organophosphate pesticide and acaricide. At normal conditions, it is a pale yellow mobile liquid poorly soluble in water but readily soluble in organic solvents (US EPA, 2003). It is relatively stable and hydrolyses only at very acidic or basic conditions. It is very toxic both for target organisms and for mammals including human. It inhibits acetylcholinesterase and pseudocholinesterase (Krieger et al., 2001). It is non-biocumulative and has no residual action, but some metabolites may persist in soil (Krieger et al., 2001). Phorate is absorbed readily through all ways. Its toxicity is high. Oral LD₅₀ to rats is 1.1 to 3.2 mg/kg (US EPA, 2003).

2.3.1.2.3 Malathion

Figure 2.6 below represents the molecular structure of malathion. Its IUPAC name is Diethyl 2-[(dimethoxyphosphorothioyl)sulfanyl]butanedioate and its molecular formula is C₁₀H₁₉O₆PS₂ (US EPA, 2003). Malathion is an organophosphorus pesticide that is widely used in agriculture and in public health pest control programs such as mosquito eradication (Pennington *et al.*, 2004). In the US, it was the most commonly used organophosphate insecticide (US EPA, 2003). It binds irreversibly to cholinesterase and it is an insecticide of relatively low human toxicity (Walter, 2005).

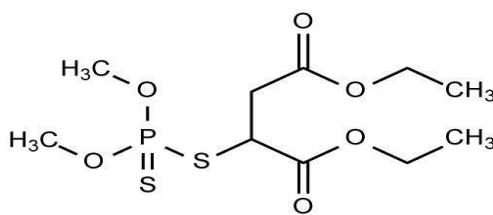


Figure 2.6: Molecular structure of Malathion

2.3.1.3 Pyrethroids

Pyrethroids are derivative of naturally occurring pyrethrin, which is obtained from dried flower heads of *Chrysanthemum cinerariaefolium*. They have been modified to increase their stability in the environment. Some synthetic pyrethroids are toxic to the nervous system (EPA, 1999). Pyrethroid use as pesticide has been increasing in recent years as a replacement for organophosphate pesticides that are being phased out because of water-quality concerns (Mukherjee, 2002). Pyrethroids share a common chemical structure consisting of cyclopropane carboxylic acids, with variations in the alcohol portion of the compounds (EPA, 1999).

Pyrethroid products usually contain a mixture of isomers and do not consist of a single pure compound. Pyrethrins and Pyrethroids have been associated with a range of toxicological effects (Baird, 1997). Several pyrethroids (bifenthrin, cypermethrin, tetramethrin) are classified as possible human carcinogens (U.S. EPA, 2008). Many of these compounds (bifenthrin, bioallethrin, cyhalothrin, cypermethrin, deltamethrin, fenvalerate, permethrin, pyrethrin, resmethrin, and sumithrin) have been identified as having either clear evidence or potential for endocrine disruption (DHI, 2007). Characteristics of some commonly used pyrethroids have been discussed below.

2.3.1.3.1 Fenvalerate

Figure 2.7 below represents the molecular structure of fenvalerate. Its molecular formula is

$C_{25}H_{22}ClNO_3$. It has a systematic name cyano (3-phenoxyphenyl) methyl 2-(4-chlorophenyl)-3-methylbutanoate.

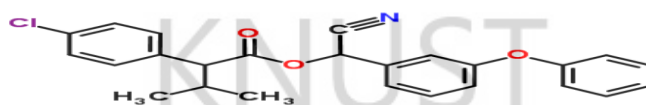


Figure 2.7: Molecular structure of Fenvalerate

Fenvalerate has toxic effects on both peripheral and central nervous system caused by interference with sodium ion permeability in stimulated nerve membranes (Baird, 1997). The toxic signs include restlessness, tremors, piloerection, choreo-athetosis and salivation (Walter, 2005).

2.3.1.3.2 Permethrine

The IUPAC name of permethrine is 3-Phenoxybenzyl (1*RS*)-*cis*, *Trans*-3-(2, 2-dichlorovinyl)-2, 2-dimethylcyclopropanecarboxylate and its molecular formula is $C_{21}H_{20}Cl_2O_3$ (US EPA, 2003) as indicated by its molecular structure in figure 2.8. Permethrin is a common synthetic chemical which is widely used as an insecticide and acaricide (Krieger et al., 2001). It functions as a neurotoxin, affecting neuron membranes by prolonging sodium channel activation. It is not known to rapidly harm most mammals or birds, but is dangerously toxic to cats and fish (Baird, 1997). In

general, it has a low mammalian toxicity and is poorly absorbed by the skin (Pennington *et al.*, 2004).

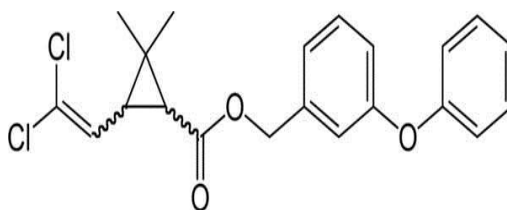


Figure 2.8: Molecular structure of Permethrin

2.4 HEALTH EFFECTS OF PESTICIDES

Pesticides are designed to kill pest, however many pesticides can pose risks to human health. Pesticide exposure can cause a variety of adverse health effects. These effects can range from simple irritation of the skin and eyes to more severe effects such as affecting the nervous system, mimicking hormones causing reproductive problems, and also causing cancer (Longnecker *et al.*, 1997; Scollon *et al.*, 2004). Most studies on non-Hodgkin lymphoma and leukaemia have showed positive associations with pesticide exposure (Bassil *et al.*, 2007). Strong evidence also exists for other negative outcomes from pesticide exposure including neurological, birth defects, foetal death (Sabon *et al.*, 2007; Jurewicz and Hanke, 2008).

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

Long-term studies on possible poisoning caused by pesticides have been carried out by researchers in Ghana and the findings indicate that most chemical poisoning was directly related to the misuse of pesticides (Afful *et al.*, 2010). The main causes for deaths were carbamates, organophosphorus pesticides and organochlorines. The most serious problems farmers associated with pesticide use were general ill health after spraying and acute poisoning (Afful *et al.*, 2010).

Several studies have reported the occurrence of pesticide residues in Ghana. Ntow *et al.*, (2008) assessed the accumulation of persistent organochlorine contaminants in milk and serum of farmers in Ghana. Concentrations of persistent organochlorine pesticides such as dichlorodiphenyltrichloroethane and its metabolites (DDTs), hexachlorocyclohexane isomers (HCHs), hexachlorobenzene (HCB) and dieldrin in samples of human breast milk and serum collected from vegetable farmers in Ghana during 2005 were determined.

Amoah *et al.*, (2006) analysed pesticide contamination of vegetables in Ghana's urban markets. A total of 180 vegetable samples were randomly purchased from nine major markets and twelve specialized selling points in three major Ghanaian cities: Accra, Kumasi and Tamale. Chlopyrifos (Dursban) was detected on 78% of the lettuce, lindane on 31%, endosulfan on 36%, 13 lambdacyhalothrin on 11%, and DDT on 36%. Most of the residues measured exceeded the maximum residue limit for consumption.

Bempah *et al.*, (2010) collected a total of 309 fruits and vegetable samples from markets in Ghana and investigated the presence of organochlorine, organophosphorus and synthetic pyrethroid pesticide residues. The results showed the predominance of organochlorine followed by organophosphorus and synthetic pyrethroid pesticides in

most of the analyzed samples. The detected concentrations of them were most significant in vegetable samples. The results obtained showed that 39.2 % of the fruits and vegetable samples analyzed contained no detectable level of the monitored pesticides, 51.0 % of the samples gave results with trace levels of pesticide residues below the maximum residue limit (MRL), while 9.8 % of the samples were above the MRL.

2.5 PESTICIDE RESIDUE TOLERANCES

Tolerance is the maximum amount of a pesticide residue that can remain on a raw product when it is used and still be considered safe. EPA establishes tolerances for each pesticide based on the potential risks to human health posed by that pesticide. In the USA tolerances are referred to as maximum residue limits, or MRLs, in many other countries. Some risk assessments are based on the assumption that residues will always be present in food at the maximum level permitted by the tolerance (US EPA, 2008).

CHAPTER THREE

MATERIALS AND METHODS

3.1 DESCRIPTION OF STUDY AREA

The study area covered Nkurakan, Huhunya, and Akpamu, all in Yilo Krobo District in the Eastern Region of the Republic of Ghana (Figure 3.1). The District lies approximately between latitude 6° 00'N and 6° 30'N and between longitude 0° 30' and 1° 00'W. It covers an estimated area of 805km², with Somanya as its capital. There are so many vegetable growing communities in the Yilo Krobo district, however, Nkurakan, Huhunya and Akpamu, were chosen due to the fact that cabbage, okra, and pepper cultivation is done on a large scale in these communities (MOFA 2000). The main economic activity in the Yilo Krobo District is agriculture. A household survey conducted in 2000 indicated that 58.0% of the population was engaged in this sector (MOFA, 2000).

The vegetation of the Yilo Krobo district is characterized by a semi-deciduous rain forest and savanna grassland. The semi-deciduous rain forest stretches across a wider part of the district and occupies about 85% of the estimated area. The Lower part of the district is covered with savanna grassland with scattered tree species such as Neem, Cassia, and Mangoes. It occupies about 15% of the estimated area (MOFA 2000). A wide range of vegetables including tomatoes, cabbage, garden eggs, pepper and okra are grown in the district. These vegetables are grown for local consumption and export. Vegetable cultivation is therefore a very important income generating activity in the area (MOFA, 2000).

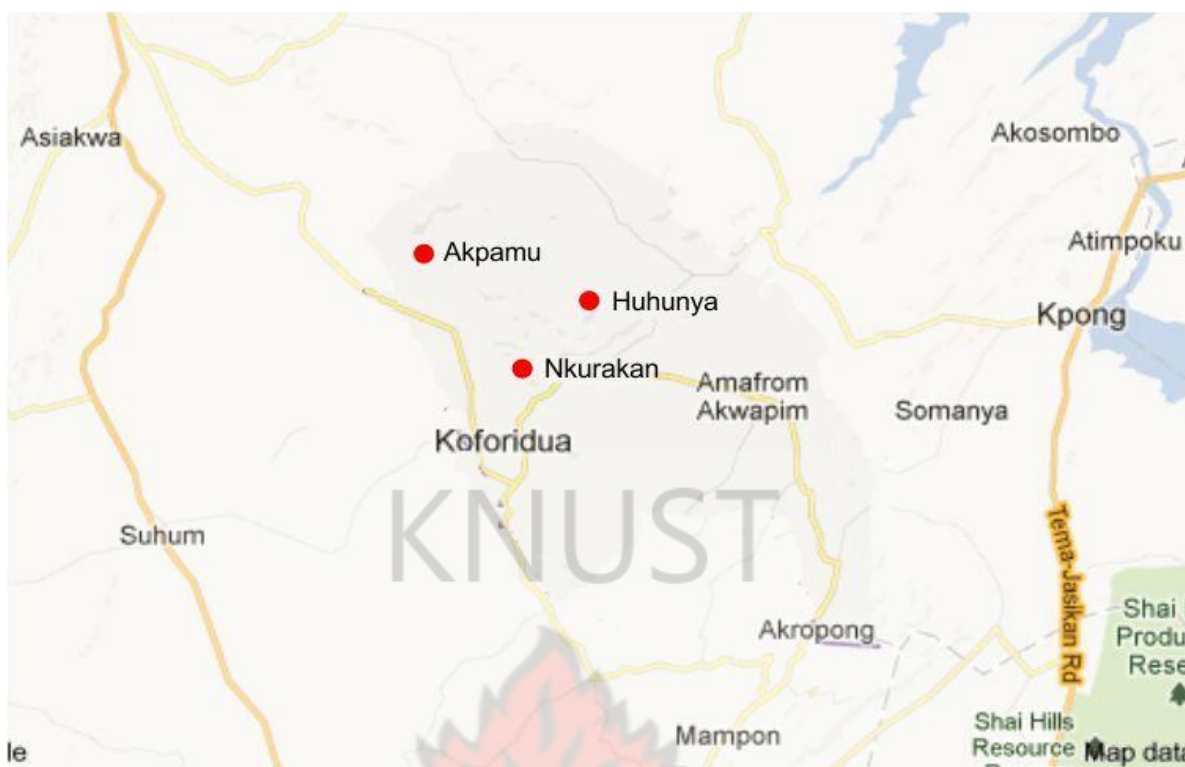


Figure 3.1: map showing the study area in the Yilo Krobo District

3.2.1 SAMPLING OF VEGETABLES

Fresh vegetables (okra, cabbage and pepper) were collected from the farm gates of each of the three communities. A total of 30 vegetable samples each (okra, pepper and cabbage) were collected due to their commercial importance and potential consumption. The samples were sealed in polypropylene bags and labeled with a unique sample identity. They were transported to the laboratory and kept refrigerated at 4 °C until further analysis. Sampling of vegetables was repeated for three times.

3.2.2 SAMPLING OF RESPONDANT

10 farmers from each community under study were selected and interviewed using questionnaires which were made up of both closed and open-ended questions to obtain

the personal details of farmers as well as their knowledge on pesticide usage. Thus a total of 30 respondents were sampled.

3.3.1 GLASS WARES AND CLEANING PROCESS

All the glassware used for extraction and cleaning were thoroughly washed with tap water and detergent. The glass wares were rinsed twice with tap water and twice with distilled water. They were again rinsed with acetone. The glass wares were placed in an oven to dry.

3.3.2 SAMPLE PREPARATION

Each vegetable sample was cut into small pieces and then homogenized using a Foss homogenizer (2096). The homogenizer was washed thoroughly and wiped dried using tissue before the preparation of the next sample to avoid cross –contamination.

3.3.3 Extraction of pesticide residues

Extraction was done using the QuEChERS (Quick Easy Cheap Effective Rugged Safe) method by weighing 10 g of each homogenous sample into cleaned 50 ml centrifuge tubes. Ten (10) ml of acetonitrile was then added as the main extracting solvent and vortex for 1 minute. A mixture of salts was then added (4 g anhydrous magnesium sulphate was added to absorb water, followed by 1 g sodium chloride which helped in the separation of the aqueous phase from the organic layer, after which 0.5 g of disodium hydrogen citrate sesquihydrate, and 1 g of tri-sodium citrate dehydrate were added as buffer). The mixture was vigorously shaken after the addition of the salts and vortex for 1 minute and centrifuged for 5 minutes at 3000 rpm.

3.3.4 EXTRACT PURIFICATION (CLEAN-UP)

Six (6) ml aliquot of the organic phase was then cleaned-up through depressive solid phase extraction (depressive SPE) using 900 mg of anhydrous magnesium sulphate and 150 mg of primary secondary amine (PSA). This was done by transferring the 6 ml aliquot into 15 ml centrifuge tube containing a mixture of the magnesium sulphate and the PSA. It was vortex for 30 seconds and then centrifuged for 5 minutes at 3000 rpm. A 4 ml aliquot of the cleaned extract was transferred into 25 ml round - bottomed flask and acidified by adding 40 μ l of 5 % formic acid (prepared in acetonitrile), and the extract was concentrated below 40°C on a rotary evaporator just to dryness. The residue was then re-dissolved in ethyl acetate by adding 1 ml of the ethyl acetate with the aid of a pipette, and transferred into a 1.5 ml GC vial for gas chromatography (GC) analysis.

3.4 GAS CHROMATOGRAPHIC (GC) ANALYSIS

The organochlorine and synthetic pyrethroid residues were analyzed by Varian Gas Chromatograph CP- 3800 equipped with ^{63}Ni electron capture detector (ECD). The GC conditions used for the analysis were: capillary column coated with VF-5ms (30 m + 10 EZ Guard, 0.25 mm, 0.25 μ m film thickness). Carrier gas and make-up gas was nitrogen at a flow rate of 1.0 and 29 mL/min, respectively. The temperature of injector operating in splitless mode was held at 270 °C, and that of the electron capture detector was set at 300 °C. The column oven temperature was programmed as follows; 70 °C for 2 min. and increased steadily at a rate of 25 °C/min to 180 °C /min and increased at 5 °C/min up to 300 °C. The injection volume of the GC was 1.0 μ L. The organophosphorus residues were analyzed by Varian Gas Chromatograph CP- 3800 equipped with pulse flame photometric detector (PFPD). The GC conditions used for the analysis were: capillary column coated with VF-1701ms (30 m, 0.25 mm, 0.25 μ m

film thicknesses). Carrier gas was nitrogen at a flow rate of 2.0 mL/min with Air 1, Air 2 and H₂ flow rates of 17, 10 and 14 mL/min respectively.

The temperature of injector operating in splitless mode was held at 270 °C and the PFPD was set at 280 °C. The column oven temperature was programmed as follows; 70 °C for 2 min. and increased steadily at a rate of 25 °C/min to 200 °C /min and increased at 20 °C/min up to 250 °C.

3.4.1 LIMIT OF DETECTION (LOD)

Extracts of fortified samples were serially diluted by a factor of 2 to give different concentrations. 1.0 µl of each concentration was injected and the least concentration that gave response was noted, and LOD was calculated by the formula:

$$\text{LOD} = \frac{V_1}{V_2} \times \text{Concentration fortified}$$

V₁ — volume injected

V₂ — final volume of fortified extract

The detection limit for organochlorine pesticides was determining to be 0.005 mg/kg, while that of both organophosphorus and pyrethroid pesticides were 0.01 mg/kg.

3.5 DATA ANALYSIS

The responses which were obtained from the study were analyzed statistically using Ms-Excel and SPSS version 16. Element of descriptive statistics of samples generated included mean, range, minimum, maximum and standard deviation. The concentration of OPs, OCs and synthetic pyrethroids pesticide residues in okra, pepper and cabbage samples were compared with the MRLs recommended by European Union (2013).

MRL of a pesticide is the maximum concentration of its residue that is legally permitted to remain in food after it has been treated with the pesticides (FAO, 2002).

3.6 ESTIMATION OF AVERAGE DAILY INTAKE (EADI)

The Estimated Average Daily Intake was calculated by multiplying the mean residual concentration of pesticide residues in vegetables (mgkg^{-1}) by the daily vegetable consumption rates (kgday^{-1}) (Darko and Akoto, 2008). The consumption rates of vegetables in Ghana were used as follows; okra is 0.041 kgday^{-1} , and pepper is 0.003 kgday^{-1} (FAO, 2003), but that for cabbage was not available.

The hazard indices were calculated by dividing the EADI with their corresponding values of WHO/FAO acceptable daily intakes, ADI (FAO/WHO, 2010), assuming average adult's body weight of 60 kg. If hazard index (HI) is greater than 1, it indicates that lifetime consumption of vegetable containing the measured level of insecticide residues could pose health risks (Darko and Akoto, 2008).

Estimated Average Daily Intake (EADI) = $C_c \times V_c$

Where:

- C_c = mean concentration of pesticide in vegetable (mgkg^{-1})
- V_c = daily vegetable consumption rate (kgday^{-1})

$$\text{Hazard index (HI)} = \frac{\text{EADI}}{\text{ADI}}$$

CHAPTER FOUR

RESULTS

4.1 PERSONAL DETAILS AND KNOWLEDGE OF FARMERS ON PESTICIDE USAGE

4.1.1 AGE OF FARMERS

Table 4.1a below represents the ages of farmers interviewed in the Yilo Krobo District, and most (53.4%) of the farmers' ages were between the ranges of 25-34 years.

Table 4.1a: Age of Farmers

Age	Frequency	% Frequency
15 – 24	6	20.0
25 – 34	16	53.4
35 – 44	4	13.3
45+	4	13.3
TOTAL	30	100

4.1.2 GENDER OF FARMERS

Table 4.1b represents the gender of farmers which were interviewed in the Yilo Krobo District. Most of the farmers (93.3%) were males, and only two (2) representing 6.7% were females.

Table 4.1b: Gender of Farmers

Sex	Frequency	% Frequency
Males	28	93.3
Females	2	6.70
TOTAL	30	100

4.1.3 LEVEL OF EDUCATION OF FARMERS

Table 4.1c below represents the level of education of farmers who were interviewed in the Yilo Krobo District, and all of them (100%) had acquired some form of formal education.

Table 4.1c: Level of Education of Farmers

Levels	Frequency	% Frequency
Primary	7	23.3
Secondary	14	46.7
Tertiary	9	30.0
TOTAL	30	100

4.1.4 APPLICATION OF PESTICIDES BY FARMERS

Table 4.1d below represents the use of pesticides by farmers on vegetables in the Yilo Krobo District, and all of them (100%) responded that they apply pesticides on their vegetables.

Table 4.1d: Application of Pesticides by Farmers

Responses	Frequency	% Frequency
Yes	30	100
No	0	0
TOTAL	30	100

4.1.5 SOURCE OF PESTICIDES

Table 4.1e below represents the farmers' source of pesticides, and all of them (100%) responded that they purchase them from the Agro chemical stores in the markets.

Table 4.1e: Source of Pesticides

Sources	Frequency	% Frequency
Agro store	30	100
Others	-	-
TOTAL	30	100

4.1.6 TYPE OF INSECTICIDES USE BY FARMERS

Table 4.1f below represents the type of pesticides used by farmer interviewed. Most of them (80%) use organophosphate pesticides whiles the rest of them (20%) use pyrethroid. However, no farmer uses neither carbamates nor organochlorines.

Table 4.1f: Type of Pesticide Use by Farmers

Insecticides type	Frequency	% Frequency
Organophosphates	24	80
Organochlorines	0	0
pyrethroids	6	20
Carbamates	0	0
TOTAL	30	100

4.1.7 FREQUENCY OF PESTICIDE APPLICATION ON VEGETABLES

Table 4.1g below shows the frequency at which farmers apply pesticides on vegetables.

Most of them (56.7%) responded that they apply pesticides twice (before and after flowering of vegetables). One-third of the respondents (33.3%) indicated that they apply pesticides depending on the frequency of pest infestation

Table 4.1g: Frequency of Pesticides Application on Vegetables

Frequency of application	Frequency	% Frequency
Once	3	10.0
Twice	17	56.7
Depending On The Frequency In Infestation	10	33.3
TOTAL	30	100

4.4.8 MODE OF APPLICATION OF PESTICIDES ON VEGETABLES

Table 4.1h below represents the mode of application of pesticides by farmers, and all of them (100%) spray the pesticides on the vegetables.

Table 4.1h: Mode of Application of Pesticides on Vegetables

Methods	Frequency	% Frequency
Spraying	30	100
Sprinkling	0	0
Others	0	0
TOTAL	30	100

4.1.9 USAGE OF PERSONAL PROTECTIVE EQUIPMENTS (PPE'S) BY FARMERS

Table 4.1i and table 4.1j below represent the usage and type of protective equipment by farmers. Majority of them (96.7%) use some form of PPE's (at least coat and boot). Only a few of them (3.3%) do not use any PPE's. Table 4.1j indicates that most of the farmers (70%) use overall and boot. Six (6) of them (20%) use overall, boot and gloves. Very few farmers (6.7%) protect themselves from inhalation of chemicals by covering their noses. None of them uses all the PPE's (overall, boots, gloves, nose mask and goggles). Thus, none of them protects their eyes by wearing goggles during spraying (Table 4.1j).

Table 4.1i: PPE's Usage by Farmers

Responses	Frequency	% Frequency
Yes	29	96.7
No	1	3.3
TOTAL	30	100

Table 4.1j: Type of PPE's Use by Farmers

PPEs	Frequency	% Frequency
Coat, and boot	21	70
Coat, Boot, and Gloves	6	20
Coat, Boot, Gloves and Nose mask	2	6.7
Coat, Boot, Gloves, Nose mask and Goggles	0	0
None	1	3.3
TOTAL	30	100

4.1.10 SYMPTOMS EXPERIENCED AFTER APPLICATION OF PESTICIDES

Table 4.1k below represents symptoms of health problems experienced by farmers after spraying of pesticides. Majority of the farmers (90%) experienced no symptoms while a few of them (10%) experienced some symptoms such as; watery eyes, headache, nausea, skin irritation and dizziness after spraying of insecticides. .

Table 4.1k: Symptoms Experienced After Application of Pesticides

Responses	Frequency	% Frequency
Yes	3	10.0
No	27	90.0
TOTAL	30	100

4.1.11 PRE-HARVEST INTERVAL

Table 4.1l below represents period of which farmers wait before they harvest their vegetables after spraying of pesticides. A sizeable number of them (40%) wait for one week before harvesting of vegetables after spraying of pesticides.

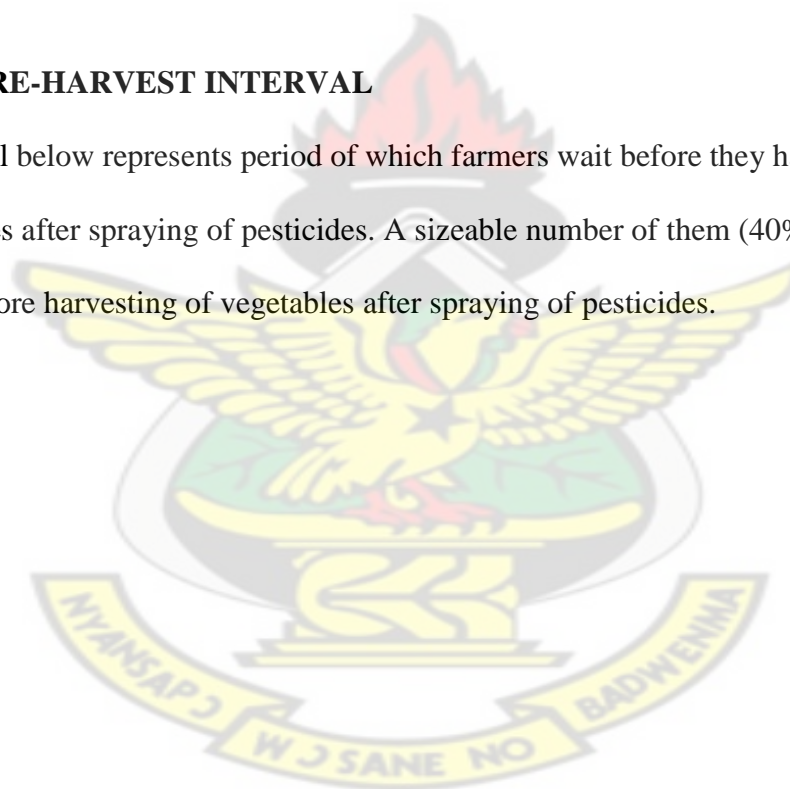


Table 4.11: Pre-Harvest Interval

Periods(weeks)	Frequency	% Frequency
1	12	40.0
2	7	23.3
3	5	16.7
4	2	6.7
5	1	3.3
6	2	6.7
7	1	3.3
TOTAL	30	100

4.1.12 DISPOSAL OF PESTICIDE CONTAINERS BY FARMERS

Table 4.1m below shows how farmers interviewed dispose of pesticide containers. Most of the farmers (93.3%) throw the containers on the ground after using its content; and only two (2) representing 6.7% burn them.

Table 4.1m: Disposal of Pesticides Containers by Farmers

Method	Frequency	% Frequency
Burn	2	6.7
Bury	0	0.0
Leave on field	28	93.3
TOTAL	3	100

4.2 RESULTS OF PESTICIDE RESIDUE ANALYSIS.

4.2.1 ORGANOPHOSPHORUS RESIDUES DETECTED IN OKRA AT NKURAKAN, HUHUNYA, AND AKPAMU COMPARED WITH EU MRLS.

Tables 4.2a, 4.2b and 4.2c below give account of thirteen organophosphorus pesticides that were investigated in okro from Nkurakan, Huhunya and Akpamu respectively. Eight of these were not detected (Table 4.2a). Three of these (methamidophos, ethoprophos, and malathion) were below the detection limit of the instrument of 0.01 mg/kg. Chlorpyrifos and phorate were detected in samples from all the three communities. The mean residual concentration of the OPs residues ranged from 0.01 mg/kg to 0.33 mg/kg. The highest mean concentration of 0.33 ± 0.001 mg/kg was recorded for chlorpyrifos at Akpamu while the least concentration of 0.01 ± 0.001 mg/kg was recorded for phorate at Huhunya.

The hazard indices for chlorpyrifos at Nkurakan, Huhunya and Akpamu were 1.03 mg/kg/day, 1.23 mg/kg/day and 1.353 mg/kg/day as shown in tables 4.2a, 4.2b and 4.2c respectively, all were greater than one (> 1) and therefore posed health risk. The hazard indices for phorate at Nkurakan, Huhunya and Akpamu were 0.88 mg/kg/day, 0.586 mg/kg/day and 0.88 mg/kg/day respectively were below one (< 1) and therefore presented no health risk.

Table 4.2a: Organophosphates residues detected in Okra at Nkurakan compared with EU MRL. n=10

Pesticide	Range	Mean \pm SD	EU MRL	ADI	EADI	HI	HR
	(mg kg ⁻¹)	(mg kg ⁻¹)	(mg kg ⁻¹)	(mg kg ⁻¹ day ⁻¹)	(mg kg ⁻¹ day ⁻¹)		
Methamidophos	<LD	-	0.01	0.004	-	-	-
Diazinon	ND	-	0.02	0.005	-	-	-
Dimethoate	ND	-	0.02	0.002	-	-	-
Chlorpyrifos	0.24-0.26	0.25 \pm 0.014	0.50	0.01	0.0103	1.03	YES
Parathion-et	ND	-	0.05	0.004	-	-	-
Profenofos	ND	-	0.05	0.03	-	-	-
Chlorfenvinphos	ND	-	0.02	0.0005	-	-	-
Ethoprophos	<LD	-	0.02	0.0004	-	-	-
Phorate	0.01-0.02	0.015 \pm 0.007	0.05	0.0007	0.00062	0.88	NO
Fonofos	ND	-	0.01	NA	-	-	-
Fenitrothion	ND	-	0.01	0.006	-	-	-
Pirimiphos-m	ND	-	0.05	0.03	-	-	-
Malathion	<LD	-	0.02	0.3	-	-	-

* SD=Standard Deviation: n=Number of Samples: ND=Not Detected: <LD=Less than limit of Detection

Table 4.2b: Organophosphates residues detected in Okra at Huhunya compared with
EU MRL. n=10

Pesticide	Range (mg kg ⁻¹)	Mean ± SD (mg kg ⁻¹)	EU MRL (mg kg ⁻¹)	ADI (mg kg ⁻¹ day ⁻¹)	EADI (mg kg ⁻¹ day ⁻¹)	HI	HR
Methamidophos	<LD	-	0.01	0.004	-	-	-
Diazinon	ND	-	0.02	0.005	-	-	-
Dimethoate	ND	-	0.02	0.002	-	-	-
Chlorpyrifos	0.22-0.34	0.30 ± 0.001	0.50	0.01	0.0123	1.23	YES
Parathion-et	ND	-	0.05	0.004	-	-	-
Profenofos	ND	-	0.05	0.03	-	-	-
Chlorfenvinphos	ND	-	0.02	0.0005	-	-	-
Ethoprophos	<LD	-	0.02	0.0004	-	-	-
Phorate	0.01-0.01	0.01 ± 0.001	0.05	0.0007	0.00041	0.5857	NO
Fonofos	ND	-	0.01	NA	-	-	-
Fenitrothion	ND	-	0.01	0.006	-	-	-
Pirimiphos-m	ND	-	0.05	0.03	-	-	-
Malathion	<LD	-	0.02	0.3	-	-	-

* SD=Standard Deviation: n=Number of Samples: ND=Not Detected: <LD=Less than
limit of Detection

Table 4.2c: Organophosphates residues detected in Okra at Akpamu compared with EU

MRL. n=10

Pesticide	Range (mg kg ⁻¹)	Mean ± SD (mg kg ⁻¹)	EU MRL (mg kg ⁻¹)	ADI (mg kg ⁻¹ day ⁻¹)	EADI (mg kg ⁻¹ day ⁻¹)	HI	HR
Methamidophos	<LD	-	0.01	0.004	-	-	-
Diazinon	ND	-	0.02	0.005	-	-	-
Dimethoate	ND	-	0.02	0.002	-	-	-
Chlorpyrifos	0.32-0.36	0.33 ±0.001	0.50	0.01	0.0135	1.353	YES
Parathion-et	ND	-	0.05	0.004	-	-	-
Profenofos	ND	-	0.05	0.03	-	-	-
Chlorfenvinphos	ND	-	0.02	0.0005	-	-	-
Ethoprophos	<LD	-	0.02	0.0004	-	-	-
Phorate	0.01-0.02	0.015 ±0.007	0.05	0.0007	0.00062	0.88	NO
Fonofos	ND	-	0.01	NA	-	-	-
Fenitrothion	ND	-	0.01	0.006	-	-	-
Pirimiphos-m	ND	-	0.05	0.03	-	-	-
Malathion	<LD	-	0.02	0.3	-	-	-

*SD=Standard Deviation: n=Number of Samples: ND=Not Detected: <LD=Less than limit of Detection

4.2.2 ORGANOCHLORINE RESIDUES DETECTED IN OKRA, PEPPER AND CABBAGE AT NKURAKAN, HUHUNYA, AND AKPAMU COMPARED WITH EU MRLs

Table 4.3 below shows eight organochlorine pesticide residues that were investigated in okro, pepper, and cabbage samples from the study areas. All of these eight pesticide residues were not detected. This could be attributed to OCs not being used nowadays

in Ghana for vegetable production since these products are mainly for export, and the ban of OCs for crop production in Ghana.

Table 4.3: Organochlorines residues levels in Okra, pepper and cabbage samples from Nkurakan, Huhunya and Akpamu compared with EU MRL. n=10

Pesticide	Range (mg kg ⁻¹)	Mean ± SD (mg kg ⁻¹)	EU MRL (mg kg ⁻¹)	ADI (mg kg ⁻¹ day ⁻¹)	EADI (mg kg ⁻¹ day ⁻¹)	HI	HR
Delta-HCH	ND	-	0.02	N/A	-	-	-
Heptachlor	ND	-	0.01	0.0001	-	-	-
Aldrin	ND	-	0.01	0.0001	-	-	-
Gamma-chlordane	ND	-	0.01	0.0005	-	-	-
P,p'-DDT	ND	-	0.05	0.0200	-	-	-
Methoxychlor	ND	-	0.01	0.0050	-	-	-
Gamma-HCH	ND	-	0.01	0.0030	-	-	-
Endrin	ND	-	0.01	0.0002	-	-	-

*SD=Standard Deviation: n=Number of Samples: ND=Not Detected: <LD=Less than limit of Detection

4.2.3 PYRETHROID RESIDUES DETECTED IN OKRA AT NKURAKAN, HUHUNYA, AND AKPAMU COMPARED WITH EU MRLs

Table 4.4 below represents four pyrethroid pesticide residues that were investigated in okro from the study areas. Allethrin was not detected, however, three of these (fenvalerate, deltamethrin, and permethrin) were detected below the detection limits of the instrument. Fenvalerate, deltamethrine, and permethrine were detected below the detection limits of the instrument in 5 (50%) of the okra samples from each of the three communities.

Table 4.4: Pyrethroid residues detected in Okra sampled from Nkurankan, Huhunya and Akpamu compared with EU MRL. n=10

Pesticide	Range (mg kg ⁻¹)	Mean ± SD (mg kg ⁻¹)	EU MRL (mg kg ⁻¹)	ADI (mg kg ⁻¹ day ⁻¹)	EADI (mg kg ⁻¹ day ⁻¹)	HI	HR
Allethrin	ND	-	0.010	NA	-	-	-
Fenvalerate	<LD	-	0.02	0.02	-	-	-
Deltamethrin	<LD	-	0.050	0.01	-	-	-
Permethrin	<LD	-	0.300	0.05	-	-	-

*SD=Standard Deviation: n=Number of Samples ND=Not Detected: <LD=Less than limit of Detection

4.2.4 ORGANOPHOSPHORUS RESIDUES DETECTED IN PEPPER AT

NKURAKAN, HUHUNYA, AND AKPAMU COMPARED WITH EU MRLs

Tables 4.5a, 4.5b and 4.5c below give account of thirteen organophosphorus pesticides that were investigated in pepper from the study area. Six of these (diazinon, dimethoate, profenofos, fonofos, chlorfenvinphos, and ethoprophos) were not detected. Three of these (methamidophos, parathion-ethyl, and pirimiphos-methyl) were below the detection limit of the instrument (0.01 mg/kg) in each of the three communities. Four (chlorpyrifos, phorate, fenitrothion, and malathion) were found to be above the instrument's detection limit, but none of them was higher than their corresponding EU MRL value. Chlorpyrifos was detected above the instrument's detection limit in pepper samples from each of the three communities. Malathion, fenitrothion, and phorate were detected in pepper samples from Nkurankan, Huhunya and Akpamu respectively.

The hazard indices for chlorpyrifos and malathion at Nkurakan were 0.0819 mg/kg/day and 0.015 mg/kg/day respectively (Table 4.5a). The hazard indices for chlorpyrifos and fenitrothion at Huhunya were 0.0045 mg/kg/day and 0.10 mg/kg/day respectively (Table 4.5b). The hazard indices for chlorpyrifos and phorate at Akpamu were 0.102 mg/kg/day and 0.042 mg/kg/day respectively (Table 4.5c). All the indices were below one (< 1) and therefore presented no health risk.

Table 4.5a: Organophosphates residues levels in Pepper from Nkurakan compared with EU MRL. n=10

Pesticide	Range (mg kg ⁻¹)	Mean ± SD (mg kg ⁻¹)	EU MRL (mg kg ⁻¹)	ADI (mg kg ⁻¹ day ⁻¹)	EADI (mg kg ⁻¹ day ⁻¹)	HI	HR
Methamidophos	<LD	-	0.10	0.004	-	-	-
Diazinon	ND	-	0.10	0.005	-	-	-
Dimethoate	ND	-	0.50	0.002	-	-	-
Chlorpyrifos	0.04-0.4	0.273 ± 0.012	1.00	0.01	0.000819	0.0819	No
Parathion-et	<LD	-	0.10	0.004	-	-	-
Profenofos	ND	-	0.10	0.03	-	-	-
Chlorfenvinphos	ND	-	0.05	0.0005	-	-	-
Ethoprophos	ND	-	0.02	0.0004	-	-	-
Phorate	<LD	-	0.10	0.0007	-	-	-
Fonofos	ND	-	0.01	NA	-	-	-
Fenitrothion	ND	-	1.00	0.006	-	-	-
Pirimiphos-m	<LD	-	0.10	0.03	-	-	-
Malathion	0.01-0.01	0.01 ± 0.001	0.02	0.002	0.00003	0.015	No

*SD=Standard Deviation: n=Number of Samples ND=Not Detected: <LD=Less than limit of Detection

Table 4.5b: Organophosphates residues detected in Pepper from Huhunya compared with EU MRL. n=10

Pesticide	Range (mg kg ⁻¹)	Mean ± SD (mg kg ⁻¹)	EU MRL (mg kg ⁻¹)	ADI (mg kg ⁻¹ day ⁻¹)	EADI (mg kg ⁻¹ day ⁻¹)	HI	HR
Methamidophos	<LD	-	0.10	0.004	-	-	-
Diazinon	ND	-	0.10	0.005	-	-	-
Dimethoate	ND	-	0.50	0.002	-	-	-
Chlorpyrifos	0.01-0.02	0.015±0.007	1.00	0.01	0.000045	0.0045	No
Parathion-et	<LD	-	0.10	0.004	-	-	-
Profenofos	ND	-	0.10	0.03	-	-	-
Chlorfenvinphs	ND	-	0.05	0.0005	-	-	-
Ethoprophos	ND	-	0.02	0.0004	-	-	-
Phorate	<LD	-	0.10	0.0007	-	-	-
Fonofos	ND	-	0.01	NA	-	-	-
Fenitrothion	0.2-0.2	0.2±0.001	1.00	0.006	0.0006	0.1	No
Pirimiphos-m	<LD	-	0.10	0.03	-	-	-
Malathion	-	-	0.02	0.002	-	-	-

*SD=Standard Deviation: n=Number of Samples ND=Not Detected: <LD=Less than limit of Detection

Table 4.5c: Organophosphates residues detected in Pepper from Akpamu compared with EU MRL. n=10

Pesticide	Range (mg kg ⁻¹)	Mean ± SD (mg kg ⁻¹)	EU MRL (mg kg ⁻¹)	ADI (mg kg ⁻¹ day ⁻¹)	EADI (mg kg ⁻¹ day ⁻¹)	HI	HR
Methamidophos	<LD	-	0.10	0.004	-	-	-
Diazinon	ND	-	0.10	0.005	-	-	-
Dimethoate	ND	-	0.50	0.002	-	-	-
Chlorpyrifos	0.2-0.38	0.34±0.01	1.00	0.01	0.00102	0.102	No
Parathion-et	<LD	-	0.10	0.004	-	-	-
Profenofos	ND	-	0.10	0.03	-	-	-
Chlorfenvinphos	ND	-	0.05	0.0005	-	-	-
Ethoprophos	ND	-	0.02	0.0004	-	-	-
Phorate	0.01-0.01	0.01± 0.001	0.10	0.0007	0.00003	0.042	No
Fonofos	ND	-	0.01	NA	-	-	-
Fenitrothion	ND	-	1.00	0.006	-	-	-
Pirimiphos-m	<LD	-	0.10	0.03	-	-	-
Malathion	-	-	0.02	0.002	-	-	-

*SD=Standard Deviation: n=Number of Samples ND=Not Detected: <LD=Less than limit of Detection

4.2.5 PYRETHROID RESIDUES DETECTED IN PEPPER AT AKPAMU

COMPARED WITH EU MRLs

Table 4.6 below represents four pyrethroid pesticide residues that were investigated in pepper from Akpamu. Two of these (allethrin and deltamethrin) were not detected. Permethrin was detected below the detection limit of the instrument in 4 (40%), fenvalerate was detected above the detection limit of the instrument in 3 (30%) of the pepper samples. The mean residual concentration of fenvalerate 0.014 ± 0.001 mg/kg and was below its EU MRL value of 0.050 mg/kg. The hazard index of fenvalerate in pepper was 0.0021 mg/kg/day which was less than one (< 1) and therefore posed no health risk.

Table 4. 6: Pyrethroid residues detected in Pepper samples from Akpamu compared with EU MRL. n=10

Pesticide	Range (mg kg ⁻¹)	Mean \pm SD (mg kg ⁻¹)	EU MRL (mg kg ⁻¹)	ADI (mg kg ⁻¹ day ⁻¹)	EADI (mg kg ⁻¹ day ⁻¹)	HI	HR
Allethrin	ND	-	0.01	NA	-	-	-
Fenvalerate	0.01-0.02	0.014 ± 0.001	0.05	0.02	0.000042	0.0021	No
Deltamethrin	ND	-	0.05	0.01	-	-	-
Permethrin	<LD	-	0.10	0.05	-	-	-

*SD=Standard Deviation: n=Number of Samples ND=Not Detected: <LD=Less than limit of Detection

4.2.6 ORGANOPHOSPHORUS RESIDUES DETECTED IN CABBAGE AT

NKURAKAN, HUHUNYA, AND AKPAMU COMPARED WITH EU MRLs

Tables 4.7a, 4.7b and 4.7c below give accounts of thirteen organophosphorus pesticides that were investigated in cabbage from the study sites. Eight of these were not detected.

Three of these were detected below the detection limit of the instrument in all cabbage samples from each of the three communities. Two were however found to be above the instrument's detection limit. Chlorpyrifos and phorate were detected in 7 (70%) of the cabbage samples from all the three communities. The mean residual concentration of the OPs residues ranged from 0.015 mg/kg to 0.34 mg/kg. The highest mean concentration of 0.34 ± 0.002 mg/kg was recorded for chlorpyrifos at Akpamu (Table 4.7c), while the least concentration of 0.015 ± 0.007 mg/kg was recorded for chlorpyrifos at Huhunya (Table 4.7b).

The hazard indices for chlorpyrifos and phorate at Nkurakan, Huhunya and Akpamu were not calculated because the FAO/WHO per capita food consumption rate of cabbage in Ghana was not available. However, the mean residual concentration of chlorpyrifos detected at Akpamu was quite high (0.34 ± 0.001 mg kg⁻¹).

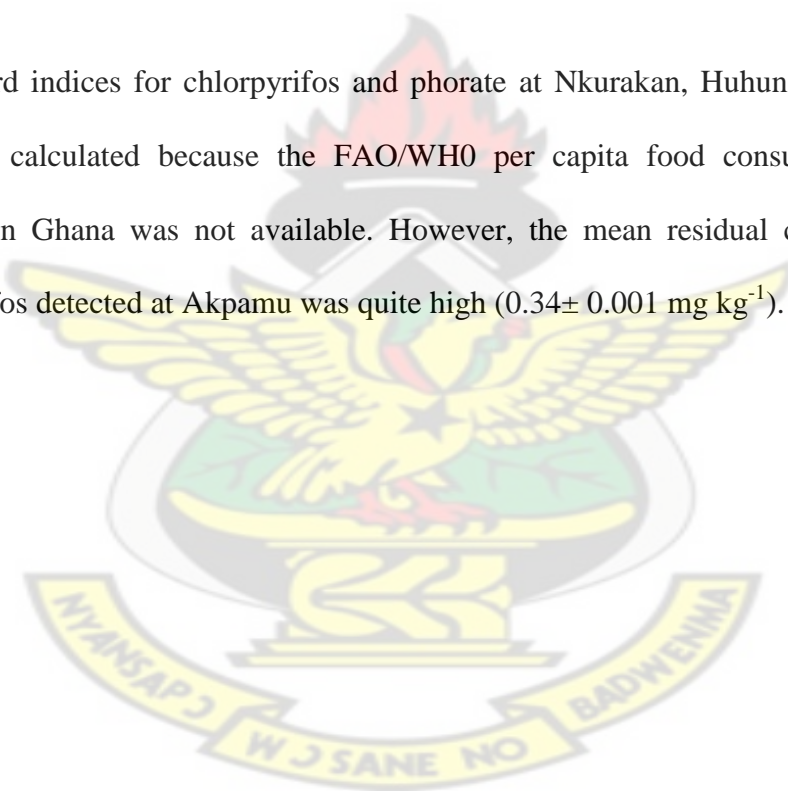


Table 4.7a: Organophosphates residues detected in Cabbage from Nkurakan compared with EU MRL. n=10

Pesticide	Range (mg kg ⁻¹)	Mean ± SD (mg kg ⁻¹)	EU MRL (mg kg ⁻¹)	ADI (mg kg ⁻¹ day ⁻¹)	EADI (mg kg ⁻¹ day ⁻¹)	HI	HR
Methamidophos	<LD	-	0.01	0.004	-	-	-
Diazinon	ND	-	0.50	0.005	-	-	-
Dimethoate	ND	-	0.02	0.002	-	-	-
Chlorpyrifos	0.01-0.03	0.02±0.014	0.02	0.01	-	-	-
Parathion-et	ND	-	0.05	0.004	-	-	-
Profenofos	ND	-	0.05	0.03	-	-	-
Chlorfenvinphos	ND	-	0.05	0.0005	-	-	-
Ethoprophos	ND	-	0.02	0.0004	-	-	-
Phorate	0.01-0.01	0.01 ± 0.001	0.05	0.0007	-	-	-
Fonofos	ND	-	0.01	NA	-	-	-
Fenitrothion	ND	-	0.01	0.006	-	-	-
Pirimiphos-m	<LD	-	0.01	0.03	-	-	-
Malathion	<LD	-	0.02	0.002	-	-	-

*SD=Standard Deviation: n=Number of Samples ND=Not Detected: <LD=Less than limit of Detection

Table 4.7b: Organophosphates residues detected in Cabbage from Huhunya compared with EU MRL. n=10

Pesticide	Range (mg kg ⁻¹)	Mean ± SD (mg kg ⁻¹)	EU MRL (mg kg ⁻¹)	ADI (mg kg ⁻¹ day ⁻¹)	EADI (mg kg ⁻¹ day ⁻¹)	HI	HR
Methamidophos	<LD	-	0.01	0.004	-	-	-
Diazinon	ND	-	0.50	0.005	-	-	-
Dimethoate	ND	-	0.02	0.002	-	-	-
Chlorpyrifos	0.01-0.02	0.015 ± 0.007	0.02	0.01	-	-	-
Parathion-et	ND	-	0.05	0.004	-	-	-
Profenofos	ND	-	0.05	0.03	-	-	-
Chlorfenvinphos	ND	-	0.05	0.0005	-	-	-
Ethoprophos	ND	-	0.02	0.0004	-	-	-
Phorate	0.01-0.03	0.02 ± 0.004	0.05	0.0007	-	-	-
Fonofos	ND	-	0.01	NA	-	-	-
Fenitrothion	ND	-	0.01	0.006	-	-	-
Pirimiphos-m	<LD	-	0.01	0.03	-	-	-
Malathion	<LD	-	0.02	0.002	-	-	-

*SD=Standard Deviation: n=Number of Samples ND=Not Detected: <LD=Less than limit of Detection

Table 4.7c: Organophosphates residues detected in Cabbage from Akpamu compared with EU MRL. n=10

Pesticide	Range (mg kg ⁻¹)	Mean ± SD (mg kg ⁻¹)	EU MRL (mg kg ⁻¹)	ADI (mg kg ⁻¹ day ⁻¹)	EADI (mg kg ⁻¹ day ⁻¹)	HI	HR
Methamidophos	<LD	-	0.01	0.004	-	-	-
Diazinon	ND	-	0.50	0.005	-	-	-
Dimethoate	ND	-	0.02	0.002	-	-	-
Chlorpyrifos	0.01-0.38	0.34±0.002	0.02	0.01	-	-	-
Parathion-et	ND	-	0.05	0.004	-	-	-
Profenofos	ND	-	0.05	0.03	-	-	-
Chlorfenvinphos	ND	-	0.05	0.0005	-	-	-
Ethoprophos	ND	-	0.02	0.0004	-	-	-
Phorate	0.01-0.04	0.02 ± 0.001	0.05	0.0007	-	-	-
Fonofos	ND	-	0.01	NA	-	-	-
Fenitrothion	ND	-	0.01	0.006	-	-	-
Pirimiphos-m	<LD	-	0.01	0.03	-	-	-
Malathion	<LD	-	0.02	0.002	-	-	-

*SD=Standard Deviation: n=Number of Samples ND=Not Detected: <LD=Less than limit of Detection

4.2.7 PYRETHROID RESIDUES DETECTED IN CABBAGE AT NKURAKAN, HUHUNYA, AND AKPAMU COMPARED WITH EU MRLs

Tables 4.8a, 4.8b and 4.8c below represent four pyrethroid pesticide residues that were investigated in cabbage from the study area. Allethrin was not detected in the cabbage samples from the three communities. Fenvalerate detected was below the detection limit of the instrument in all samples from the three communities. Permethrin and deltamethrin were detected in 4 (40%) and 6 (60%) of the cabbage samples from Nkurakan and Akpamu (Tables 4.8a and 4.8c). The mean residual concentrations of

deltamethrin residues detected in cabbage were 0.02 ± 0.001 mg/kg and 0.04 ± 0.001 mg/kg for samples from Nkurakan and Akpamu respectively. The mean residual concentration of permethrin residues detected in the cabbage samples was 0.02 ± 0.004 mg/kg and 0.01 ± 0.00 mg/kg for samples from Nkurakan and Akpamu as indicated in tables 4.8a and 4.8c respectively. All the residues detected were below their corresponding EU MRL values of 0.050 mg/Kg and 0.10 mg/kg for permethrin and deltamethrin respectively. The hazard indices for permethrin and deltamethrin were not calculated because the FAO/WHO per capita food consumption rate of cabbage in Ghana was not available.

Table 4.8a: Pyrethroid residues detected in Cabbage sampled from Nkurankan compared with EU MRL. n=10

Pesticide	Range (mg kg ⁻¹)	Mean \pm SD (mg kg ⁻¹)	EU MRL (mg kg ⁻¹)	ADI (mg kg ⁻¹ day ⁻¹)	EADI (mg kg ⁻¹ day ⁻¹)	HI	HR
Allethrin	ND	-	0.01	NA	-	-	-
Fenvalerate	<LD	-	0.10	0.02	-	-	-
Deltamethrin	0.02-0.02	0.02 ± 0.001	0.10	0.01	-	-	-
Permethrin	0.01-0.03	0.02 ± 0.004	0.05	0.05	-	-	-

*SD=Standard Deviation: n=Number of Samples ND=Not Detected: <LD=Less than limit of Detection

Table 4.8b: Pyrethroid residues detected in Cabbage sampled from Huhunya compared with EU MRL. n=10

Pesticide	Range (mg kg ⁻¹)	Mean ± SD (mg kg ⁻¹)	EU MRL (mg kg ⁻¹)	ADI (mg kg ⁻¹ day ⁻¹)	EADI (mg kg ⁻¹ day ⁻¹)	HI	HR
Allethrin	ND	-	0.01	NA	-	-	-
Fenvalerate	<LD	-	0.10	0.02	-	-	-
Deltamethrin	<LD	-	0.10	0.01	-	-	-
Permethrin	<LD	-	0.05	0.05	-	-	-

*SD=Standard Deviation: n=Number of Samples ND=Not Detected: <LD=Less than limit of Detection

Table 4.8c: Pyrethroid residues detected in Cabbage sampled from Akpamu compared with EU MRL. n=10

Pesticide	Range (mg kg ⁻¹)	Mean ± SD (mg kg ⁻¹)	EU MRL (mg kg ⁻¹)	ADI (mg kg ⁻¹ day ⁻¹)	EADI (mg kg ⁻¹ day ⁻¹)	HI	HR
Allethrin	ND	-	0.01	NA	-	-	-
Fenvalerate	<LD	-	0.10	0.02	-	-	-
Deltamethrin	0.02 - 0.06	0.04±0.001	0.10	0.01	-	-	-
Permethrin	0.01 - 0.01	0.01±0.001	0.05	0.05	-	-	-

*SD=Standard Deviation: n=Number of Samples ND=Not Detected: <LD=Less than limit of Detection

CHAPTER FIVE

DISCUSSION

From the result, the ages of most of the farmers interviewed were between 25-34 years as reflected in table 4.1a. This indicates that appreciable number of the youth in the Yilo Krobo District is engaged in farming. All the farmers testified the use pesticides as shown in table 4.1d. Some of these farmers spray pesticide on vegetables ignoring pre-harvest time intervals. About 40% of the farmers wait for only one week before harvesting of vegetables after spraying of pesticides (Table 4.1l). Sometimes farmers spray pesticides on vegetables a day prior to harvesting. Thus, farmers do not wait sufficiently for the pesticide residues to degrade before harvesting of vegetables. This practice in particular exposes consumers to pesticide residues. As farmers spray their vegetables, they do not adequately wear personal protective equipments and this exposes them to pesticides causing a wide range of health effects to some farmers (Table 4.1k). Most farmers (93.3%) throw pesticide containers on the ground after spraying (Table 4.1m) and this could dangerously affect non-target organism by leaching and run-off.

According to Clarke1997, Ghanaians rely extensively on OPs for pest control and disease vector eradication. Most of these farmers (80%) use OPs pesticides while the rest of them (20%) use pyrethroid, however, none of them use neither carbamates nor organochlorines as in table 4.1f. This could be attributed to OCs not being used nowadays in Ghana for vegetable production since these products are mainly for export, and the ban of OCs for crop production in Ghana

The concentration of OPs, OCs and synthetic pyrethroid pesticide residues in okra, pepper and cabbage samples were analysed and compared with the MRLs recommended by European Union (2013). OPs and pyrethroid pesticide residues were detected in 80% of the vegetables (okra, pepper and cabbage) sampled and analysed from Yilo Krobo District. Chlorpyrifos and phorate were the most commonly detected OP pesticides. Phorate was found in 60%, 40%, and 30% of cabbage, okro and pepper samples respectively analysed from the Yilo Krobo District, while chlorpyrifos was found in 80%, 70%, and 50% of cabbage, okro and pepper samples respectively analysed from the district. The mean residual concentration of the OP residues ranged from 0.01 mg/kg to 0.34 mg/kg. The highest mean concentration of chlorpyrifos (0.34 ± 0.01 mg/kg) was recorded at Akpamu in cabbage samples as shown in table 4.7c. The hazards indices for pesticide residues detected in okra revealed that chlorpyrifos posed health risk upon life time consumption of okra from Yilo Krobo District, since the hazard indices of chlorpyrifos analyzed in okra at Nkurakan, Huhunya and Akpamu (1.03 mg/kg/day, 1.23 mg/kg/day and 1.35 mg/kg/day respectively) were all greater than one (>1) as shown in tables 4.2a, 4.2b and 4.2c respectively.

Four (4) pyrethroid pesticide residues (allethrin, permethrin, fenvalerate and deltamethrin) were investigated; Fenvalerate was detected in 3 (30%) of the pepper samples from Akpamu. The mean residual concentration of fenvalerate detected in pepper at Akpamu was 0.014 ± 0.001 mg/kg and was below its EU MRL value of 0.050 mg/Kg. The hazard index of Fenvalerate in pepper at Akpamu was 0.0021 mg/kg/day which were found to be less than one (< 1) and therefore posed no health risk. Permethrin was detected in 40% of the cabbage samples from Nkurakan, while deltamethrin was detected in 60% of the cabbage samples from Akpamu. The mean

residual concentrations of deltamethrin residues detected in cabbage were 0.02 ± 0.001 mg/kg (Table 4.8a) and 0.04 ± 0.001 mg/kg (Table 4.8c) for samples from Nkurakan and Akpamu respectively. The mean residual concentrations of permethrin residues detected in cabbage were 0.02 ± 0.004 mg/kg (Table 4.8a) and 0.01 ± 0.001 mg/kg (Table 4.8c) for samples from Nkurakan and Akpamu respectively. All the residues detected were below their corresponding EU MRL values of 0.050 mg/kg and 0.10 mg/kg for permethrin and deltamethrin respectively. The hazard indices for permethrin and deltamethrin in cabbage samples were not calculated because the FAO/WHO per capita food consumption rate of cabbage in Ghana was not available.

Though residues and metabolites of many OCs are very stable, with long half lives in the environment (UNEP, 2002), and therefore the use of OC pesticides for agricultural purposes have been banned in developed world and some developing nations like Ghana. According to Darko and Acquah (2007), there are evidences of their continues usage in many developing nations like Ghana due to inadequate regulations and management on the production, trade and use of these chemicals. Several studies have reported organochlorine pesticide residues in different food commodities in Ghana (Darko and Acquah, 2007; Darko and Akoto, 2008; Bempah et al., 2010). OC pesticide residues expected and investigated in this study were not detected. This confirms the results obtained from the questionnaire administered in this study which revealed that most of the farmers (80%) at Yilo Krobo District use OPs pesticides whiles rest of them (20%) use pyrethroid, however, none of them use neither carbamates nor organochlorines as indicated in table 4.1f.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

From the analysis carried out, it can be concluded that most farmers (80%) at the Yilo Krobo District use OPs pesticides while few (20%) use pyrethroids, however, none of them use neither carbamates nor organochlorines. OPs and pyrethroid pesticide residues were detected in 80% of the vegetables (okra, pepper and cabbage) sampled and analysed from Yilo Krobo District. Chlorpyrifos and phorate were the most commonly detected OPs pesticides. Phorate was found in 60%, 40%, and 30% of cabbage, okra and pepper samples respectively analysed from the Yilo Krobo District, while chlorpyrifos was found in 80%, 70%, and 50% of cabbage, okra and pepper samples respectively. OC residues investigated were not detected. Pyrethroid pesticide residues were detected in vegetable samples from Nkurakan and Akpamu. Fenvalerate was detected in 3 (30%) of the pepper samples from Akpamu. Permethrin was detected in 40% of the cabbage samples from Nkurakan while deltamethrin was detected in 60% of the cabbage samples from Akpamu. The hazard indices of the detected pesticide residues showed that chlorpyrifos posed health risk upon life time consumption of okra from Yilo Krobo District.

6.2 RECOMMENDATION

From the conclusion, the following recommendations are necessary;

- Pesticide residues analysis of all other vegetables grown in the district is highly recommended to other researchers to assess the level of pesticide residues in these vegetables.

- A year round pesticide residue monitoring programme in the Yilo Krobo District by the EPA is recommended to acquire adequate information regarding the levels of pesticide residues in all vegetables grown in the district.
- It is recommended that consumers of okra from the Yilo Krobo District should be sensitised by educational institutions that chlopyrifos could posed health risk upon life time consumption of okra from the district.

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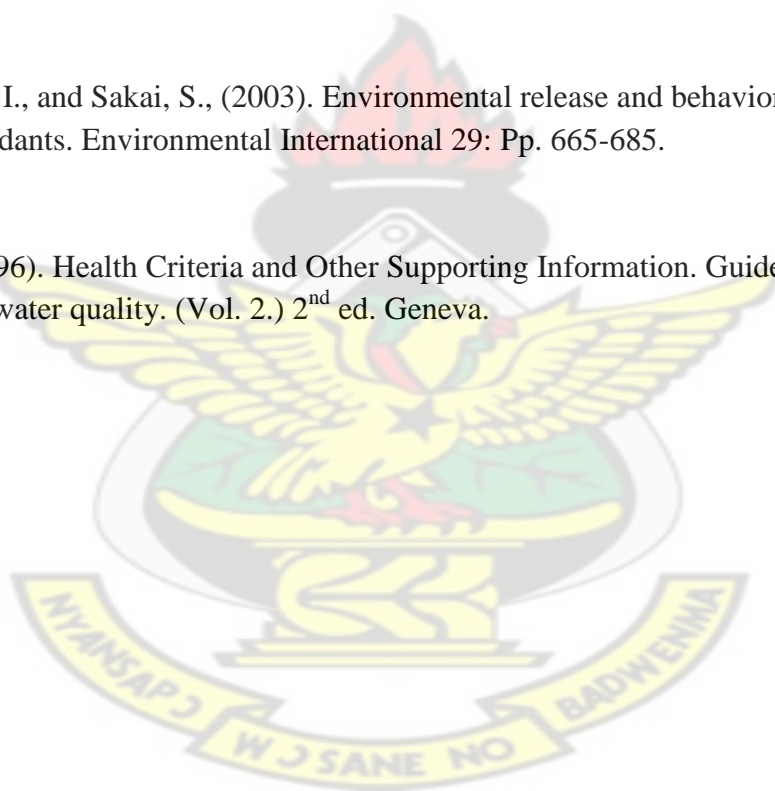
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APPENDIX 1

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY,

KUMASI

DEPARTMENT OF THEORITICAL AND APPLIED BIOLOGY

THE RESEACHER WILL BE GRATEFUL IF YOU COULD PROVIDE ANSWERS TO THE QUESTIONS BELOW TO THE BEST OF YOUR ABILITY AND AS CANDID AS POSSIBLE. THE INFOMATION THAT YOU PROVIDE ON THIS SHEET WILL BE KEPT STRICTLY CONFIDENTIAL AND FOR ACADEMIC PURPOSES ONLY. KINDLY READ THROUGH CAREFULLY AND TICK OR WRITE WHERE APPROPRIATE.

SECTION A

TO BE ANSWERED BY FARMERS

1. How old are you? 15-24 [] 25-34 [] 35-44 [] 45+ []
2. What is your gender? Male [] Female []
3. What is the level of your education? 1⁰ [] 2⁰ [] 3⁰ []
4. What types of vegetable do you grown? Cabbage [] Okro []
Pepper []
If others please specify.....
5. Do you control pest and diseases by applying pesticides on your vegetables?
Yes [] No []
6. What type of pesticides do you use for your vegetable production?
.....
7. Where do you get your pesticides from?

8. When do you normally apply pesticides on vegetable?
Before [] During [] After insects infestation. []
9. How often do you spray pesticides on your vegetables? One [] Twice []
Depending on the frequency of infestation []
, others specify.....
10. How do you apply pesticides on your vegetables? Spraying [], Sprinkling []
,Others specify.....
11. (A). Do you put on Personal Protective Equipment before applying insecticides
on your vegetables? Yes [] No []. (B) If yes, please specify
which of the PPEs you
use.....
12. What do you think will happen to you if you are exposed to
pesticides?.....
13. Have you experienced any Symptoms after applying pesticide on your
vegetable? If yes specify.....
14. How many days do you wait before harvesting vegetables after applying
pesticides?.....
15. What hygienic practices do you undertake after applying
pesticides?.....
16. How do you dispose pesticide empty containers after application? Burn []
Bury [] Put into bin []
Others specify.....

PICTURE 1

PICTURE SHOWING THE RESEARCHER AND SOME FARMERS ON FIELD



PICTURE 2

PICTURE SHOWING FARMERS AND THEIR VEGETABLES AT THE FARM

GATE OF THE STUDY AREA

