KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

ASSESSMENT OF ORGANOCHORINE, ORGANOPHOSPHATE AND SYNTHETIC PYRETHROID PESTICIDES RESIDUES ON COCOA BEANS PRODUCED IN THE SEFWI-WIAWSO DISTRICT OF THE WESTERN REGION OF GHANA

BY

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DECLARATION

This project is presented as part of the requirement for MSc. Environmental Science Degree, awarded by Kwame Nkrumah University of Science and Technology (KNUST). I hereby declare that this project is entirely the result of hard work, research and enquiries.

I am confident that this project is not copied from any other person. All sources of information have however been acknowledge with due respect.

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ABSTRACT

To protect food and cash crops from pests and increase yield, pesticides are being used indiscriminately especially on cocoa farms in Ghana. This practice leaves high levels of pesticides residues in cocoa beans often above the Maximum Residue Levels (MRLs) and thus reduces the value of cocoa beans. This study assessed some pesticide residue levels in cocoa beans from five selected cocoa farming communities in the Sefwi-Wiawso District of the Western Region, Ghana. The results showed that 66 percent of cocoa farmers use bifenthrin, thiamethoxam and imidacloprid which are approved pesticides by the Ghana Cocoa Board. However, 34 percent of farmers use unapproved pesticides (diazinon, dithofencarb, fenvelerate, chlorpyrifos, actamiprid, fenitrothion, malathion and dimethoate). The organophosphates: ethoprophos, phorate, diazinon, fenophos, parathion, chlorfenvinphos and profenofos were not detected in cocoa bean samples from all the five communities. However methamidophos was detected in cocoa beans from all the communities except Nsawora although the level of methamidophos was below the EU MRL in all the four communities. Dimethoate was also detected in cocoa beans from Nsawora and Penakrom while pirimiphos-methyl was detected in Tanoso and Asawinso communities but the levels were below the EU MRLs. Malathion and fenithrothion were detected in Penakrom and Tanoso respectively but their levels were below the EU MRLs. Of the organochlorines only aldrin and chlorpyrifos were detected. Among the five communities, aldrin was detected in only the Nsawora community. Chlorpyrifos was however-, detected in Nsawora, Tanoso and Penakrom communities and the levels were below the EU MRLs. Some traces of banned pesticides (eg. aldrin) were detected in some cocoa bean samples but were below the EU MRLs.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of Study

Cocoa (*Theobroma cacao* L.) is one of the most important cash crops in Ghana and the industry is the mainstay of the Ghanaian economy as it provides 30 percent of Ghana's total export earnings making it the second largest source of export earnings (Gakpo, 2012). According to the Bank of Ghana, cocoa bean and products export receipts for the first quarter of 2011 was $859.4 million, accounting for about 61 percent of total export earnings as compared with $682.5 million at 48.8 percent in 2010 (Marcela and Ashietey, 2012). In September 2011,cocoa production in Ghana reached a record One Million (1,000,000) metric tonnes (MT), the highest ever. This record was 35.7 percent higher than the full-year record of 740,000 MT, obtained in the 2005/06 season (Marcela and Ashietey, 2012). Much of the increase in cocoa production could be attributed to their response to increased use of fertilizers and pesticides (Afrane and Ntiamoah, 2011).

The cocoa plant, like all living organisms, is susceptible to attack by a wide range of pests and diseases. Preventive and curative measures are therefore necessary in the cocoa industry to maintain and even increase output (Akrofi and Baah, 2007). While non-chemical means of managing pests and diseases in the industry are widely recommended for health and environmental reasons, the use of chemicals in the form of fertilizers, insecticides and fungicides is unavoidable in the effective management of cocoa farms (Moy and Wessel, 2000; Opoku *et al*., 2007; Adjinah and Opoku, 2010). Pesticides are widely used in most sectors of the agricultural production to prevent losses by pests and thus improve yields as well as quality of the produce (Cooper and Dobson, 2007). There are many kinds of benefits that may be attributed to pesticides, but these benefits often go unnoticed by the general public (Damalas, 2009). Thus, pesticides can be considered as an economic, labor-saving, and efficient tool of pest management with great popularity in most sectors of the agricultural production.

Cocoa farmers therefore use a wide range of pesticides to limit losses from pests and diseases in cocoa agriculture. Prominent among these are: Copper sulphate (a fungicide popular in the treatment of black pod infection; Benzene hexachloride (BHC) (an insecticide for control of cocoa mirids); aldrin/dieldrin or aldrex 40 (to control mealy bugs); propoxur (an insecticide which is effective in controlling cocoa mirids in West African countries). Others are lindane, diazinon, clofenotate, DDT, and brestan, most of these chemicals have been banned for use on cocoa in Ghana. Pesticide use is associated with risk and can be hazardous if not handled properly (Owusu-Ansah *et al*., 2010).

In developing countries, farmers face great risks of exposure due to the use of toxic chemicals that are banned or restricted in other countries, incorrect application techniques, poorly maintained or totally inappropriate spraying equipment and inadequate storage practices (Asogwa and Dongo, 2009). Obviously, exposure to pesticides poses a continuous health hazard, especially in the agricultural working environment. By their very nature most pesticides show a high degree of toxicity because they are designed to kill certain organisms and thus create some risk of harm to humans and the environment (Berny, 2007; Power, 2010). Although pesticides have been developed to function with reasonable certainty and minimal risk to human health and the environment, published results are not always in agreement with this fact (Damalas, 2009; Burger *et al.,* 2008). Considering that, the toxicity and quantity of a pesticide one is exposed to, are risk factors that directly affect human health, a greater risk is expected to arise from high exposure to a moderately toxic pesticide than from little exposure to a highly toxic pesticide. However, whether or not pesticide residues found in food and drinking water sources is a potential threat to human health when consumed, is still the subject of great scientific controversy (Magkos *et al.,* 2006). In addition, inappropriate use of pesticides has been linked with, adverse effects on non-target organisms, water contamination from mobile pesticides or from pesticide drift, air pollution from volatile pesticides, injury on non-target plants from herbicide drift, injury to rotational crops from herbicide residues remained in the field and crop injury due to high application rates, wrong application timing or unfavourable environmental conditions at and after pesticide application (Mariyono,2008).

Despite continuing disagreements over the degree of risk posed by pesticides, it appears that people have become increasingly concerned about pesticide use and particularly about their impacts on human health and environmental quality (Damalas, 2009). According to the Ghana Statistical Service, between 2002 and 2006 for instance, pesticide importation into the country increased from 7,763 metric tons to 27,886 metric tons with over 141 different types of pesticide products registered (Ghana EPA, 2008). However research has indicated that, there is an overuse, misuse and abuse of pesticides in farming mainly due to illiteracy and ignorance of the health effects of these chemicals (Ntow *et al.,*2006). A number of unapproved pesticides are in use on farms in Ghana most of which have been banned from use due to their environmental persistence. Pesticides such as Lindane, DDT, Aldrin, Dieldrin, Heptachlor, BHC and Endosulfan were found to be environmentally persistent (Owusu-Ansah *et al*., 2010). However due to a combination of factors including weak enforcement of bans on pesticide importation and application as well as ignorance of its harmful effects, these chemicals are available to the farmer and often used on cocoa farms (Fajewonyomi, 1995). The quality of cocoa imported into the EU and elsewhere is assessed based on traces of pesticides and other substances that have been used in the supply chain (Afrane and Ntiamoah, 2011). In 2010, over 20,000 MT of cocoa beans was rejected by Japan alone due to the presence of the following pesticides [(Fenvalerate Japanese MRL 0.01ppm, was found to be 0.07ppm), Endosulfan (MRL 0.1ppm), found to be 0.38ppm, Pirimiphos-methyl (MRL 0.05ppm), found to be 0.17ppm, Chlorpyrifos (MRL 0.05ppm), found to be 0.14 ppm, and 2,4-Dichlorophenoxyacetic acid (MRL 0.01ppm), found to be 0.06ppm]. above the Maximum Residue Levels (MRL) (Kaminaga, 2011).

1.2 **Problem Statement**

Despite the popularity and benefitial use of pesticides, there are serious concerns about health risks arising from the exposure of farmers when mixing and applying pesticides or working on treated fields and from residues in food and in drinking water (Soares and Porto, 2009). The afore mentioned incidences have caused a number of accidental poisonings, and even the routine use of pesticides can pose major health risks to farmers both in the short and the long run and can degrade the environment (Fajewonyomi, 1995). There are repeated cases of excessive levels of pesticide residues on agricultural produce and the safety of these products has become an issue of concern (Moy and Wessel, 2000).

Recent changes in regulations in the European Union (EU), North America and Japan have called for a reflection on crop protection practices in cocoa and other commodity crops (ICCO, 2007). The pesticides of interest on cocoa in these countries include Chlorpyriphos, Fenvalerate, Pirimiphos-methyl, Endosulphan, Permethrin, Methamidophos, Fenitrothion and Dimethoate. These pesticides according to the new regulations on pesticides residues in foodstuffs of vegetables and animal origin imported into their countries should not be used on cocoa (ICCO, 2007).

1.3 **General Objective**

This study assessed the extent to which cocoa farmers in the Sefwi-Wiawso District in the Western Region use approved and unapproved pesticides on their farms, and ascertained the reasons why some farmers might not be complying with regulations to use only approved pesticides.

1.4 **Specific Objectives**

- Ascertained the pesticides used by farmers on their cocoa farms, and identified some unapproved pesticides being used that contain the banned organochlorines, organophosphates and synthetic pyrethroids.

- Analyzed the concentrations of the banned organochlorines, organophosphates and synthetic pyrethroids on cocoa beans from sefwi wiawso district, and compared them to the EU, Japanese and US standards.

1.5 **Justification**

To ensure that cocoa from Ghana conform to set regulations by its major importing countries, of EU, Japan and USA, which buy more than 70 percent of Ghana"s raw cocoa beans, the Government of Ghana through its agencies; COCOBOD and EPA approved for use on cocoa only pesticides without banned Organochlorines, Organophosphates and Synthetic Pyrethroids. However, results from analysis of cocoa bean samples for shipment, after several years of the ban, indicate high levels of these chemicals on cocoa, which suggest that some farmers might still be using them, and thereby exposing the cocoa beans to high residual levels of these banned pesticides. Owing to the high residual level of banned pesticides on some cocoa beans from Ghana, about 2,000 MT of cocoa were rejected by Japan alone in 2010 . Ghana therefore risk being blacklisted by its major foreign cocoa buyers, if immediate action is not taken to halt the trend which will impact negatively on Ghana"s economy. The study therefore assessed the extent to which cocoa farmers in Ghana are complying with Government directives to use only approved pesticides on cocoa farms and identified factors that might be preventing them from doing so.

CHAPTER TWO

2.0 **LITERATURE REVIEW**

This chapter reviews various literatures on cocoa production in Ghana, the role of pesticides in cocoa production in Ghana and quality control in cocoa.

2.1 **Cocoa and Ghana**

In Ghana, cocoa has played an important role in the economy of the country for over one century. Although the crop was believed to have been brought to the colonial Gold Coast -as Ghana was then known - from Fernando Po, an island in the Gulf of Guinea, off the coast of Gabon, in 1879 and from Sao Tome in 1886, records show that in 1891, only twelve years after it first arrived here, cocoa was being exported as a cash crop (Acquaah, 1999, Adjinah and Opoku, 2010). From the 1910/1911 season, Ghana became the leading cocoa producer in the world, a position it held until 1977, when it was overtaken by the Ivory Coast. The country went from being the number one cocoa producer to a period in the early eighties when, as a result of drought, bushfires, low producer prices, diseases and general economic malaise, Ghana fell to the twelfth position and produced less than 160,000 metric tons in the 1983/1984 season (Adjinah and Opoku, 2010).

Cocoa became attractive as a cash crop in Ghana because of the lower cost involved in its cultivation, compared to a popular crop like palm, as well as the favorable natural conditions that existed in the forest belts. Cocoa could be grown along with other crops and when soil conditions deteriorated the land could be left to the cocoa trees and other tracts tilled in the shifting cultivation systems of farming (Acquaah, 1999). Because of the prominence that the crop had began to gain in the economy, even before World War II, government was seriously alarmed when the swollen shoot disease was discovered in 1936. In the process of combating this disease, a permanent research center was established at Tafo, in the Eastern Region, and produce quality inspectorate, grading of beans, extension services and proper engagement of farmers in the growth of the crop were initiated (Acquaah, 1999). Since then government has continued to offer technical assistance, financial incentives and inputs like fertilizer and pesticides to cocoa farmers. Over the last decade, as a result of government interventions, cocoa production has picked up, reaching a peak of One Million (1,000,000) metric tons (MT) in the 2010/2011 season, This record was 35.7 percent higher than the full year record of 740,000 metric tons (MT), obtained in the 2005/2006 season (Marcela and Ashietey, 2012). Constituting 7.3% of the Gross Domestic Product of the country, it is second only to gold, which first overtook cocoa as the highest foreign exchange earner in 1992; a trend which still continues. Agriculture contributes about 35% of Ghana‟s Gross Domestic Product (GDP) and 60% of total employment. The Cocoa Industry is the single largest contributor to agricultural GDP (16.5 %). It is estimated that about 65% of the country‟s agricultural workforce work either directly or indirectly in the cocoa industry. In Ghana cocoa is grown on small farms owned by individuals and families in the forest zones of Ashanti, Brong Ahafo, Western, Eastern, Central and Volta Regions. Thus the livelihood of about two million farmers and their dependants, mostly in the rural areas, depend directly on cocoa (Opoku *et. al.,* 2006).

Cocoa has historically been a key economic sector and a major source of export and fiscal earnings (Bulir 1998; McKay and Aryeetey, 2005). In recent years, cocoa production more than doubled, from 395,000 tons in 2000 to 740,000 tons in 2005, contributing 28 percent of agricultural growth in 2006 up from 19 percent in 2001 (Bogetic *et al*., 2007). Earlier evidence of the relatively low supply elasticities of cocoa producers in Ghana makes this development even more impressive (Abdulai and Rieder, 1995). The boost in production has led to an increase of cocoa‟s share in agricultural GDP from 13.7 percent in 2000-2004 to 18.9 percent in 2005/2006. Producer prices rose by about 260 percent between 2000 and 2006, largely driven by the surge in world prices before 2003 and the reduced marketing margins since then. Together, both developments have led to an increase in producers‟ share of world prices from about 50 percent in 2002 to 75 percent in 2005/2006.

Earlier studies found a strong correlation between producer prices and the supply of cocoa in Ghana (Abdulai and Rieder, 1995), and the recent price increase is likely to have made a significant contribution to the strong cocoa performance. Growth in yields of almost 40 percent between 2000 and 2004 has slowed in recent years. The COCOBOD‟s promotion of technological packages and the increased access to credit, together with a partial liberalization of cocoa marketing, are likely to have raised productivity. Vigneri (2007) identified higher input of family labor into production and favorable weather conditions as major causes for yield increases.

Despite the recent increase in yields, huge potential exists for further improvements: FAO and the Ministry of Food and Agriculture (MOFA) estimate that achievable yields for cocoa are around 1-1.5 metric tons per hectare, more than double the average yields in 2005 (FAO, 2005; MOFA, 2007).

Area expansion has contributed to output growth from 2002 to 2004, but the area planted has since declined, from two million hectares in 2004 to 1.8 million hectares in 2006, about 25 percent of cultivated land in Ghana (MOFA, 2006; Cocoa Board, 2007). A comparison of land currently devoted to cocoa production and land that is suitable for the production of cocoa indicates that future growth in production through area expansion will be limited. Currently cocoa production is concentrated in areas that are "very suitable" or "suitable," but also extends to areas only "moderately suitable." Even moderately suitable land is limited and the majority of remaining land, especially in the North, is not suitable for cocoa production.

Cocoa exports, the second most important export good for Ghana, have more than doubled between 2002 and 2006. In 2005, cocoa beans (24.3 percent) and cocoa products (3.8 percent) accounted for about 28 percent of total exports, slightly behind gold and significantly greater than forestry products (15 percent) (BoG, 2007). Cocoa accounts for about half of agricultural exports, including forestry and fishery. In comparison, the two major non-traditional agricultural export commodities, palm oil and fruits, together account for only about 4 percent of total agricultural exports.

Despite cocoa‟s rapid export growth, Ghana‟s trade deficit has widened to about 28 percent of GDP, because of rapidly rising imports. Linkages of cocoa production to other sectors of the economy, including cocoa processing (cocoa milling and cocoa butter production), other food industries (beverages, bakery, chocolate products), trade, transportation, and other marketing activities, offer additional potential for growth. However, the share of income of cocoaproducing countries in cocoa processing remains low. Africa accounted for only 15 percent of world grindings in 2005/06, while Europe slightly increased its share in world grindings from 41 percent in 2004/05 to 42 percent in 2005/06 (ICCO, 2007). But Côte d‟Ivoire and Malaysia are exceptions and remained the top processing countries among the cocoa-producing countries, grinding about 48 percent at origin. The share of cocoa processed in Ghana, however, remains small and low.

2.2 **Pests and diseases of cocoa in Ghana**

The increasing world population cannot be sustained without the use of pesticides in food production. Their usage therefore benefits not only farmers but also consumers. Pesticides are used to reduce food losses not only during production, but also during the post-harvest storage stage (Moy and Wessel, 2000). The general pest control strategy is for the intervention to destroy the pests feasting on the crops, but at the same time not to damage the produce so much as to render them unhealthy or unprofitable. This means looking for the thin line which separates good practices from bad. Good agricultural practice (GAP) requires good timing and proper application. The crops are sprayed on the advice of specialists at an opportune time in the reproductive cycle of the pest, when the highest numbers could be eliminated. Also in order to maintain the activities of friendly insects the area of application of the insecticides should be clearly delineated.

The cocoa tree and its pod can be attacked by different species of insects, fungal diseases and rodents (Afrane and Ntiamoah, 2011). The most important of these are *Phytophthora* pod rot, commonly called "black pod", and locally known as „*anonom*‟; and the swollen shoot virus, also known locally as „*cocoa sasabro*‟. The black pod rot, a fungal disease which appears as characteristic brown necrotic lesions on the pod‟s surface and as rotting of the beans, does the most damage to cocoa. An estimated 30 percent of annual cocoa production is lost to it, especially during years of high rainfall. At 2005 cocoa bean prices this is an estimated US$1.5 billion in lost revenue (Afrane and Ntiamoah, 2011).

Other estimates put the loss specifically at 450 thousand metric tons annually, while 250, 200 and 50 thousand MT are lost to witches‟ broom, capsids, and the swollen shoot virus disease (CSSVD), respectively (Afrane and Ntiamoah, 2011). Witches‟ broom and frosty pod rot are predominant in Latin America, while the black pod and CSSV are common in West Africa. These diseases are countered by breeding disease-resistance species, good sanitation measures and the use of fungicides (Opoku *et al.*, 2007).

Most insects which attack cocoa are of the bug or *miridae* family. This is a large family of insects of which capsids, the most well-known, have achieved their notoriety for the degree of havoc they can wreck on cash crops like cocoa. They feed on plants by piercing the tissue and sucking their juices. Capsids are small, terrestrial insects, usually oval-shaped or elongate and measuring less than 12 mm. They were identified as pests at the turn of the last century and are the main insects that feed on cocoa in Africa (Mahot *et al*., 2005)

2.3 **Pesticides Defined**

Cunningham *et al*.,(2003), defined a pesticide as „any chemical that kills, controls, drives away, or modifies the behavior of a pest‟. According to FAO (1989) a pesticide is any substance or mixture of substances intended for preventing, destroying, or controlling any pest including vectors of human or animal diseases, unwanted species of plants or animals causing harm during, or otherwise interfering with, the production, processing, storage, or marketing of food, agricultural commodities, wood and wood products, or animal feedstuffs, or which may be administered to animals for the control of insects, arachnids or other pests in or on their bodies. The term includes chemicals used as growth regulators, defoliants, desiccants, fruit thinning agents, or agents for preventing the premature fall of fruits, and substances applied to crops either before or after harvest to prevent deterioration during storage or transport. The term, however excludes such chemicals used as fertilizers, plant and animal nutrients, food additives and animal drugs.

The term pesticide is also defined by FAO in collaboration with UNEP (1990) as chemicals designed to combat the attacks of various pests and vectors on agricultural crops, domestic animals and human beings. The definitions above imply that, pesticides are toxic chemical agents (mainly organic compounds) that are deliberately released into the environment to combat crop pests and disease vectors.

2.3.1 **Types and Classification of Pesticides**

There are different types of pesticides and a classification is offered according to the target organism. Based on the target organism, Draggan and Miller (2012) classified pesticides as follows:

Algicides;- Control algae in lakes, canals, swimming pools, water tanks, and other sites.

Antifouling agents; - Kill or repel organisms that attach to underwater surfaces, such as boat bottoms.

Antimicrobials; - Kill microorganisms (such as bacteria and viruses).

Attractants; - Attract pests (for example, to lure an insect or rodent to a trap). (However, food is not considered a pesticide when used as an attractant.) **Biocides;** - Kill microorganisms.

Disinfectants and Sanitizers; - Kill or inactivate disease-producing microorganisms on inanimate objects.

Fungicides; - Kill fungi (including blights, mildews, molds, and rusts).

Fumigants; -Produce gas or vapor intended to destroy pests in buildings or soil.

Herbicides; -Kill weeds and other plants that grow where they are not wanted.

Insecticides; - Kill insects and other arthropods.

Miticides (also called **Acaricides**); - Kill mites that feed on plants and animals.

Microbial Pesticides; - Microorganisms that kill, inhibit, or out compete pests, including insects or other microorganisms.

Molluscicides; - Kill snails and slugs.

Nematicides; - Kill nematodes (microscopic, worm-like organisms that feed on plant roots).

Ovicides; - Kill eggs of insects and mites.

Pheromones; - Biochemicals used to disrupt the mating behavior of insects.

Repellents; - Repel pests, including insects (such as mosquitoes) and birds.

Rodenticides; - Control mice and other rodents.

The term pesticide also includes these substances:

Defoliants; - Cause leaves or other foliage to drop from a plant, usually to facilitate harvest.

Desiccants; - Promote drying of living tissues, such as unwanted plant tops.

Insect Growth Regulators; - Disrupt the molting, maturity from pupal stage to adult or other life processes of insects.

Plant Growth Regulators; -Substances (excluding fertilizers or other plant nutrients) that alter the expected growth, flowering, or reproduction rate of plants.

Another classification of pesticides is based on their chemical structure. The groups are:

Inorganic Pesticides: they include arsenic, copper and mercury compounds, highly toxic biocides that have the ability of remaining in the environment for extended periods of time. They are generally neurotoxins and even a single dose may cause permanent damage (Cunningham *et al.,* 2003).

Natural Organic Pesticides: mainly plant extracts. Some examples are nicotine and nicotinoid alkaloids from tobacco, rotenone from the roots of derris and cube‟ plants and pyrethrum, a complex of chemicals extracted from *Chrysanthemum cinerariaefolium* (Cunningham *et al.,* 2003). Even if natural, many of these compounds are toxic to humans and other life forms. Rotenone has been linked to nerve damage and Parkinson‟s disease (IPM, 2003).

Fumigants: generally small molecules such as carbon tetrachloride, carbon disulfide, ethylene dichloride, ethylene dibromides that gasify easily and penetrate rapidly into some materials. They are used to sterilize soil and prevent degradation of stored grain. These compounds are very dangerous for workers, and their use has been severely restricted or banned (Cunningham *et al.,* 2003).

Chlorinated hydrocarbons: they are synthetic organics containing chlorine. They inhibit nerve membrane ion transport and block nerve signal transmission. They may be persistent in the environment and are subjected to bioaccumulation. Many have been banned or restricted throughout the world, but some continue to be actively used. They include DDT, Chlordane, Aldrin, Paradichlorobenzene, 2, 4-dichlorophenoxyacetic acid and 2, 4, 5trichlorophenoxyacetic acid (Cunningham *et al.,* 2003).

Organophosphates: Synthetic organics containing phosphorus complexes. They inhibit cholinesterase, an enzyme that regulates the peripheral nervous system; extremely toxic to mammals, birds and fish (generally 10-100 times more poisonous than most chlorinated hydrocarbons) (Cunningham *et al.,* 2003). They degrade easily, so their bioaccumulation is rare. Some examples are parathion, malathion, dichlorvos, dimethyldichlorovinylphosphate (DDVP) and tetraethylpyrophosphate (TEPP).

Carbamates: Derivatives of carbamide acid, they act in the same way as organophosphates and have low bioaccumulation rates. Generally toxic to bees, they include carbaryl, aldicarb, aminocarb and carbofuran.

Microbial Agents/Biological Controls: These are living organisms that control pests. Bacteria, viruses and insects have been used as „natural‟ controls. They can act in 4 ways: as parasites of the pest, as predators, as pathogens or as weed feeders (Weeden *et al.,* 2005)

2.4 **Historical Background of Pesticides use in Agriculture**

The historical background of pesticides use in agriculture is dated back to the beginning of agriculture itself and it became more pronounced with time due to increased pest population paralleled with decreasing soil fertility (Muir, 2002). However, the use of modern pesticides in agriculture and public health is dated back to the 19th century. The first generation of pesticides involved the use of highly toxic compounds, arsenic (calcium arsenate and lead arsenate) and a fumigant hydrogen cyanide in the 1860's for the control of such pests like fungi, insects and bacteria. Other compounds included Bordeaux mixture (copper sulphate, lime and water) and sulphur. Their use was abandoned because of their toxicity and ineffectiveness. The second generation involved the use of synthetic organic compounds. The first important synthetic organic pesticide was dichlorodiphenyltrichloroethane (DDT) first synthesized by a German scientist Ziedler in1873, (Othmer, 1996) and its insecticidal effect discovered by a Swiss chemist

Paul Muller in 1939. In its early days DDT was hailed as a miracle because of its broad-spectrum activity, persistence, insolubility, inexpensive and ease of application (Keneth, 1992). *P, p'*-DDT in particular was so effective at killing pests and thus boosting crop yields and was so inexpensive to make its use quickly spread over the globe.

DDT was also used for many non-agricultural applications as well. For example, it was used to delouse soldiers in the World War II and in the public health for the control of mosquitoes which are the vectors for malaria. Following the success of DDT, such other chemicals were synthesized to make this era what Rachel Carson (1962) in her book "The Silent Spring" described as the era of "rain of chemicals".The intensive use of pesticides in agriculture is also well known to be coupled with the "green revolution". Green Revolution was a worldwide agricultural movement that began in Mexico in 1944 with a primary goal of boosting grain yields in the world that was already in trouble with food supply to meet the demand of the then rapidly growing human population. The green revolution involved three major aspects of agricultural practices, among which the use of pesticides was an integral part. Following its success in Mexico, green revolution spread over the world.

Pest control has always been important in agriculture, but green revolution in particular needed more pesticide inputs than did traditional agricultural systems because, most of the high yielding varieties were not widely resistant to pests and diseases and partly due to monoculture system

(Vocke, 1986). Each year pests destroy about 30-48% of world‟s food production. For example, in 1987 it was reported that, one third of the potential world crop harvest was lost to pests (Hellar, 2002). Insect pests and rodents also account for a big loss in stored agricultural products. Insects that feed on the internal parts of grains cause damage to the endosperm and the germ, which result in grain weight loss, reduction in nutritive value of the grain and deterioration in the end use quality of the grain. Insects that feed on the external parts of grains, damage grains by physical mystification and by excrement contamination with empty eggs, larval molts and empty cocoon. A common means of pest control in stored agricultural products has always been the use of insecticides such as malathion, chlorpyrifos-methyl or deltamethrin impregnated on the surfaces of the storage containers (McFarlane, 1989).

Pesticides have also been used on cocoa for more than 50 years, with notable early research carried out independently in the former West African Cocoa Research Institute (now the research institutes of Ghana and Nigeria), Brazil, Cameroon, Costa Rica, Côte d'Ivoire, Indonesia, Malaysia and Togo. By the early 1970s a number of effective control techniques had become "established", and there was little incentive for change until environmental awareness increased in the 1990s. Most notable amongst these were concerns over the use of lindane for the control of cocoa insect pests; this was eventually phased out - but in some countries, not until the early 21st century. Many farmers believe that pesticides work, at least against some cocoa pest problems, and continue to use them depending on the pest and country (Bateman, 2009).

2.5 **Effects of Pesticide Use on Public Health and Environment**

Pesticide use is associated with risk and can be hazardous if not handled properly. Cocoa farmers using pesticides containing Aldrin, Gamma BHC, Cuprous oxide, Copper sulphate, Paraquat dichloride etc. face constant exposure to these pesticides (Fajewonyomi, 1995).

According to Takaji *et al*.,(1997), risks associated with pesticide use can be divided into two:

I. **Risk associated with human beings**: that is, toxicity categorized as acute toxicity, chronic toxicity, carcinogenicity, teratogenicity and biological concentration. Human exposure to pesticides is an important health and social issue as it usually results in serious health problems such as epilepsy, stroke, respiratory disorders, cancer, leukemia, brain and liver tumors, convulsions etc. Death has been known to occur in some places as a result of exposures to these pesticides.

II. **Risk associated with the environment**: This manifests in the disturbance of the ecosystem, principally in the form of pollution of river water, groundwater, drinking water, soil and air, reduction of fish and wildlife populations, destruction of natural vegetation etc.

Cocoa farmers and farm workers may have come into contact with pesticides during the application process or when entering recently treated areas. There is a high probability that pesticide use and pesticide-induced side effects (costs) will grow more rapidly in developing countries as a whole than in the developed ones (Yudelman *et al*., 1998). This is because of weak regulations banning the importation and use of dangerous chemicals and the inactivity or absence of government and non - government environmental control agencies. Despite the fact that the Dirty Dozen pesticides are banned, severely restricted or unregistered in many countries and despite their having been listed as hazardous by the World Health Organization (WHO), Fajewonyomi (1995) stated that many of them are still widely promoted and applied especially in developing countries where weak controls and dangerous work conditions make their impact even more devastating.

Papworth and Paharia (1978) stated that since pesticides by their very nature are toxic and can be hazardous to users if not handled properly, their regulation through registration is of great value to developing countries. It is not the increasing use of pesticides that warrants regulation through suitable legislations but the tendency, through ignorance, for overuse, misuse or abuse of pesticides. Snelson (1978) stated that registration as used in this context implies the acceptance by a statutory authority of extensive document proof submitted in support of all claims for efficacy and safety made for the proposed product. Registration enables authorities to exercise control on use levels claims, labeling, packaging and advertising and thus to ensure that the interest of end users are well protected. After discovering that application of pesticides causes severe contamination of vegetables with residues in HoChin Minh city, Vietman, Nguyem *et al*. (1998) suggested that instruction sessions should be organized by the local authorities to show farmers how to correctly apply pesticides on their vegetable fields, set up demonstration field using insecticides correctly, distribute leaflets on accurate and safe use of insecticides on vegetables to all vegetable growers, run broadcast from the city broadcasting outfit to educate farmers about safe and accurate application of pesticides to protect their own health and that of consumers.

Wetterson (1988) reported that a number of governments and companies within the agrochemical industry provide little, if any, health and safety information on pesticides beyond a label, which reaches pesticide users in the field. In some countries, the labels may be in a language not understood by the users who may not be literate. Davis *et al*., (1992) modeled three regulatory incentive systems that may induce farmers to protect farm workers from pesticide-related hazards. These are ex post regulation via a tort-liabilities and workers compensation system respectively and ex ante regulation (fines) by administrative agencies. Kolstad *et al*., (1990) define ex ante policies as those that affect an activity before an externality is generated and ex post policy as one that regulates an externality only after it has been generated and harm has occurred.

Despite the good results of using pesticides in agriculture and public health, their use is usually accompanied with deleterious environmental and public health effects. Pesticides hold a unique position among environmental contaminants due to their high biological activity and toxicity (acute and chronic). Although some pesticides are described to be selective in their modes of action, their selectivity is only limited to test animals. Thus pesticides can be best described as biocides (capable of harming all forms of life other than the target pest) (Zacharia, 2011).

2.6 **Pesticide Use in Cocoa Production in Ghana**

The cocoa plant like all living organisms, can also be attacked by a wide range of pests and diseases. When this happens expected production targets are not met, and the economies of the producer nations are adversely affected. Preventive and curative measures are therefore necessary in the cocoa industry to maintain and even increase output (Akrofi and Baah, 2007).

While non-chemical means of managing pests and diseases in the industry are widely recommended for health and other reasons, the use of some amounts of chemicals in the form of fertilizers, insecticides and fungicides is unavoidable in the effective management of cocoa farms (Moy and Wessel, 2000; Opoku *et al*., 2007; Adjinah and Opoku, 2010). Their use is therefore expected to increase with time. Indeed in the twenty-year period from 1986-2006, the use of fertilizer world-wide increased by almost 250% (UNEP, 1991). The same trend applies to pesticides, although they are more difficult to monitor partly because of the secrecy that goes with the continued production and use of banned substances. The trends suggest quite clearly however, that much of the increase in world food production can be attributed to the response of crops to increased use of fertilizers and pesticides (UNEP, 1991). Fortunately, there has always been a clear appreciation of the potential deleterious effects of the chemicals used in the cocoa industry since the 60s, and standards have been set by FAO and WHO for acceptable levels of residues in the beans exported to other countries.

Pesticides have been used in the public health sector for disease vector control and in agriculture to control and eradicate crop pests for the past several decades in Ghana (Owusu-Ansah *et al*., 2010). The majority of pesticides used in agriculture are employed in the forest zones located in the Ashanti, Brong Ahafo, Western, Central and Eastern Regions of Ghana. Endosulfan, marketed as thiodan, is widely used in cotton growing areas, on vegetable farms, and on coffee plantations.

Organochlorine pesticides such as DDT, lindane and endosulfan are also employed to control ectoparasites of farm animals and pets in Ghana (Owusu-Ansah *et al*., 2010).

Cocoa farmers use a wide range of pesticides to limit losses from pests and diseases in cocoa agriculture. Prominent among these are: Copper sulphate (a fungicide popular in the treatment of black pod infection; Benzene Hexachloride (BHC) (an insecticide for control of cocoa mirids); Aldrin/Dieldrin or Aldrex 40 (to control mealy bugs); propoxur, (an insecticide which is effective in controlling cocoa mirids in West African countries) (Owusu-Ansah *et al*., 2010). Others are Kokotine, Apeco, Perenox, Arkotine, Didimac 25, Basudin and Brestan. Pesticide use is associated with risk and can be hazardous if not handled properly. Cocoa farmers using pesticides containing Aldrin, Gamma BHC, Cuprous oxide, Copper sulphate, etc. face constant exposure to these pesticides. Since 1957 when Lindane was recommended, spraying with synthetic insecticides has been the only effective method for controlling capsids on cocoa in West Africa. Spray treatment with Gammalin 20 (Lindane) at 280g a.i. /ha or 1.4litres/ ha and Unden 20 (Propoxur) at 210g a.i. / ha or 1.1 litres/ ha applied at monthly intervals from August to December, was the only protection measure recommended in Ghana (Owusu-Ansah *et al*., 2010).

Although, organochlorines are banned from importation, sales and use in Ghana, there are evidence of their continued usage and presence in the ecosystem. Work already done in some farming communities in the Ashanti Region of Ghana and some other countries indicate the presence of organochlorine pesticide residues in fish, vegetables, water, sediments, (Human) mother‟smilk and blood samples (Owusu-Ansah *et al*., 2010). Lindane is listed among the Prior Informed Consent (PIC) pesticides, and all agricultural uses of lindane have been banned in 52 countries due to its hazardous nature. Many organochlorines which over the years have been linked to major health and environmental problems have been banned or are no longer used.

Included in this catalogue are aldrin, dieldrin and endrin which have virtually disappeared, however DDT, heptachlor and toxaphene which have been banned in many countries are still used quite extensively particularly in some developing countries. Lindane is a neurotoxin that interferes with *Gamma*-Aminobutyric Acid (GABA) neurotransmitter functions by interacting with the GABA receptor chloride channel complex at the picrotoxin binding site. It has an oral LD50 of 88 mg/kg in rats and a dermal LD50 of 1000 mg/kg. In humans, lindane primarily affects the nervous system, liver and kidneys, and may be a carcinogen and/or endocrine disruptor (Owusu-Ansah *et al*., 2010).

The goal of maintaining high levels of agricultural productivity and profitability while reducing pesticides use presents a significant challenge. There are repeated cases of excessive levels of pesticide residues being found in agricultural produce and the safety of these products has become an issue of concern. Changes in regulations in the European Union (EU), North America and Japan have called for a reflection on crop protection practices in cocoa and other commodity crops (ICCO, 2007). The quality of cocoa imported into the EU and elsewhere is assessed based on traces of pesticides and other substances that have been used in the supply chain.

The cocoa bean has a high content of butter or fat which absorbs the active ingredients in pesticides. The acceptable levels of active ingredients in foods are determined by the committee on Pesticide Residue of FAO/WHO, known as the Codex Alimentarius Commission, CAC. Created in 1963 the CAC implements the Joint FAO/WHO Food Standards Programme which is aimed at protecting the health of consumers and ensuring fair trade practices in the international food trade (Moy and Wessel, 2000). The commission has set maximum levels of residue poisons in commodities going through the international market, including cocoa. If for any reason the residual levels in any commodity exceed the Codex levels, that particular commodity could be rejected by the importing country.

Secondly, the accumulation of any chemicals in the cocoa fat may change the taste of the beans and eventually that of the chocolate made from them. This is known as tainting. It is therefore, the task of entomologists to ensure that recommended chemicals do not leave any residues, and that the dosage is the minimum that would give the optimum control under the agricultural conditions in the country. In Ghana, significant gains have been made in the control of pests and diseases of the cocoa industry through the nationwide use of pesticides under government sponsorship and supervision. The growing global concerns about the effects of the increasing use of agricultural chemicals on farmers, consumers of agricultural produce and the ecology require a re-examination of the issues related to their application in the cocoa industry (Owusu-Ansah *et al*., 2010).

2.7 **Socio-economic impacts of pesticides use on the cocoa industry**

In terms of output the CODAPEC programme was a tremendous success, because it was able to resuscitate cocoa production in Ghana. The country continues to benefit not only because of increased output, but also because of the high prices the crop is currently enjoying on the international market. Thus the benefits to the economy as a whole were obvious. What was not so obvious was the direct benefit to the cocoa farmers.

In order to assess the impact of the programme on these farmers, Abankwa *et al.,*(2010), conducted a study in a typical cocoa-growing district, Ahafo Ano South, located at the northwestern section of the Ashanti Region of Ghana. The study found that while the farmers could not take their children to better basic schools, they were able to afford school uniforms and other basic educational needs for them. They also found that farmers were able and more willing to visit hospitals instead of self-medicating or using herbal treatment.

The improvements brought about by the programme seemed to benefit more farmers with higher levels of education, the study showed. One poignant conclusion of the study was that, while the price of cocoa was reviewed upwards every year over the first five years of the programme, these increments did not translate into increased purchasing power of farmers. They were not able to afford assets like radios, televisions, mattresses and vehicles any better, five years after the programme was started (Abankwa *et al.,* 2010).

2.8 **Overview of Quality Standards in the Cocoa Industry**

Consumers of cocoa and cocoa products all over the world are becoming increasingly aware of food safety concerns as related to the use of chemicals in the production and processing of cocoa and as related to other issues and procedures that may be detrimental to their health. As a result, some countries have enacted legislative and regulatory measures and established sanitary and phytosanitary standards that have to be met by imported food or food substances, in order to continue to have access to their markets. The food safety concerns that affect cocoa are pesticides residues, Ochratoxin "A" (OTA), Polycyclic Aromatic Hydrocarbons (PAH), Free Fatty Acid (FFA), heavy metals such as lead, cadmium and others substances. Ochratoxin "A" (OTA) is a toxin which is produced by a fungus and has been linked to kidney damage. It is also currently viewed as a potential carcinogenic substance. Studies have shown that OTA development in cocoa happens during the early post-harvest handling of cocoa beans, with damaged cocoa pods being most implicated. Polycyclic Aromatic Hydrocarbons (PAH) are a group of chemicals produced during the incomplete combustion of organic substances such as coal, oil, gas and wood. It is reported that the consumption of products that have been contaminated with PAH or have been in direct contact for a long period with PAH may cause lung or skin cancer. Cocoa is contaminated with PAH during drying, especially when artificial drying is used. Free Fatty Acid (FFA) results from the degradation of fat. FFA in cocoa is caused by poor preparation of cocoa beans, mould and prolonged periods of storage before export. FFA is essentially a quality issue that affects the price of beans, although they have been associated with several cardiovascular risk factors. Studies on pesticide residues and other heavy metals such as lead and cadmium have shown that they can directly influence human behavior by impairing mental and neurological functions and alter numerous metabolic body processes.

In the EU, measures have been taken for the following contaminants: mycotoxins (aflatoxins, ochratoxin A, fusarium-toxins, patulin), „heavy" metals (cadmium, lead, mercury, inorganic tin), dioxins and PCBs, polycyclic aromatic hydrocarbons (PAH), 3-MCPD and nitrates) (Bateman, 2010).

In September 2008, a European Union Legislation on Maximum Residue Levels (MRLs) on Pesticides (Regulation 149/2008/EEC) came into effect. The Regulation set maximum levels on the amount of pesticides permitted on imported foods including cocoa beans. Consequently, all cocoa beans imported into the EU from September 2008 must conform to the new Regulation. In the U.S.A, the Environmental Protection Agency (EPA) established the Food Quality Protection Act of 1996 which regulates the amount of pesticide residues permitted on food for consumption. The EPA also requires that all approved pesticides are clearly labeled with instructions for proper use, handling, storage and disposal. In Japan, the Ministry of Health, Labor and Welfare (MHLW) established a new legislation that came into effect from May 2006, setting new MRLs for food products. Cocoa is of vital importance to the economies of the producing countries in Africa namely, Cameroon, Côte d'Ivoire, Ghana, Nigeria and Togo. In 2008, these countries exported about 1.3 million metrictons of cocoa beans to the EU and about 0.3 million metrictons to the USA, representing about 50% and 9% of total world exports respectively.

The crop contributes major proportions of national foreign exchange earnings and regionally, providing employment to millions of people in Africa. But cocoa is still produced predominantly by a large number of resource-poor smallholder farmers. Therefore, the SPS regulations of cocoa consuming countries have the potential of constituting a trade barrier, as most cocoa producing countries may not have the capacity to adequately meet these SPS regulations. This will disrupt cocoa trade, limit market access and have a significant economic impact on cocoa producing countries.

2.9 **Pesticide Residues in Cocoa**

In the EU, samples of cocoa beans are first de-husked before residue analysis takes place, whereas at the time of writing, whole beans are analyzed in Japan ("beans without pods"), which is more likely to result in residue violations (Bateman, 2010).

The Europe Commission Regulation 396/2005/EC of the European Parliament and of the Council proposed maximum residue levels of pesticides for food products applied from 1st Sept, 2008. This was amended by regulation EC 149/2008.

Table 2.1 The maximum residue limits of substances used as ingredients of agricultural chemicals in cocoa

Pesticide (AI)	Maximum Residue Levels (MRL) (mg/kg)
1,3-Dicloropropene	0.05
1 Methylcyclopropene	0.02
Buthylate	0.05
Carbetamide	0.05
Chlorfenvinphos (CF)	0.05
Chlorpyrifos-methyl (F)	0.10
DDT (F)	0.50
Fenitrothion	0.20
Lindane (F)	1.00

Source: Bateman, 2010

In Japan, the Ministry of Health, Labor and Welfare (MHLW) established new legislation, the Food Sanitation Law, was modified on 29th May 2006, with analysis of cocoa included on a "positive list" published by the Ministry of Health, Labor and Welfare. The Maximum residue Level (MRL) list was updated on February 5, 2007. Some samples were found to have excessive residue levels and shipments were rejected (although the method of analysis used was different to that proposed elsewhere).

Table 2.2. The maximum residue limits of substances used as ingredients of agricultural chemicals in cocoa

Pesticide (AI)	Maximum Residue Levels (MRL) (ppm)
Glyphosate	0.20
Chlothianidin	0.02
Chlorothalonil	0.05
Dichlorvos and Naled	0.50
Deltamethrin and Tralomethrin	0.05
Bioresmethrin	0.10
Fenitrothion	0.10
Pyrethrins	1.00

Source: Bateman, 2010.

The US FDA tests cocoa beans without shell. Multi-residue methods – hundreds of pesticides per analysis were used.

Table 2.3.**US Tolerances for Cocoa Beans**

Form of Cocoa Bean	Pesticide	MRL (ppm)
Cacao	Carfentrazone-ethyl	0.10
Cacao bean and roasted bean	Chlorantraniliprole	0.08
Cacao bean	Glyphosate	0.20
Cacao bean	Paraquat	0.05
Cacao bean, chocolate and cocoa powder	Chlorantraniliprole	1.50
Cacao bean, dried	Pyriproxyfen	0.02
Cacao bean, dried	Oxyfluorfen	0.05
Cacao bean, dried	Phosphine	0.10
Cacao bean, roasted bean, postharvest	Cryolite (Fluorine compounds)	20.00
Cacao bean, roasted bean, postharvest	Inorganic bromide residues resulting from fumigation with methyl bromide	50.00
Cacao bean, roasted bean, postharvest	Pyrethrins	1.00
Cacao bean, roasted bean, postharvest	Sulfuryl fluoride	0.20
Cacao bean, roasted bean, postharvest	Piperonylbutoxide	8.00
Cacao bean, dried bean & cocoa powder	Propylene oxide	200.00
Cocoa bean, dried bean	Chlorothalonil	0.05

Source: www.icco.org *(2013)*

CHAPTER THREE

MATERIALS AND METHODS

3.1 **Study Area**

Sefwi Wiawso District is located in the Western Region of Ghana. It shares boundaries with the BrongAhafo Region to the Northeast, Bibiani-Anhwiaso-Bekwai District to the East, Wassa Amenfi West and Aowin Suaman Districts to the South, Sefwi Akontombra District to the West and Juabeso District to the Northwest. About three-quarters of the economically active population are engaged in agriculture. Major crops cultivated in the district include cocoa, maize, cassava, plantain, cocoyam and oil palm. Cocoa is the most dominant cash crop in the district, and productivity is very high. All farming activities are rain-fed. The map of Ghana showing the districts of the western region, including sefwi-wiawso and the map of sefwi wiawso district, indicating the study areas are shown below in *figures 3.1a* and *3.1b* respectively.

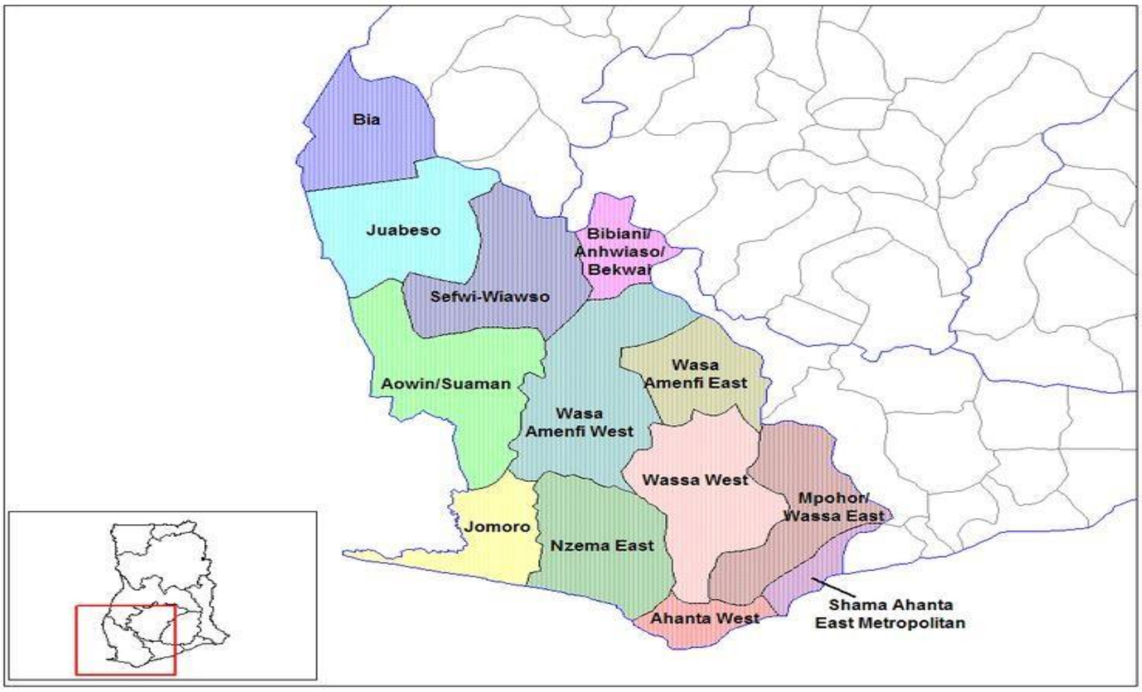

Figure 3.1a. A Map Of Ghana Showing The Districts Of The Western Region, Including Sefwi- Wiawso

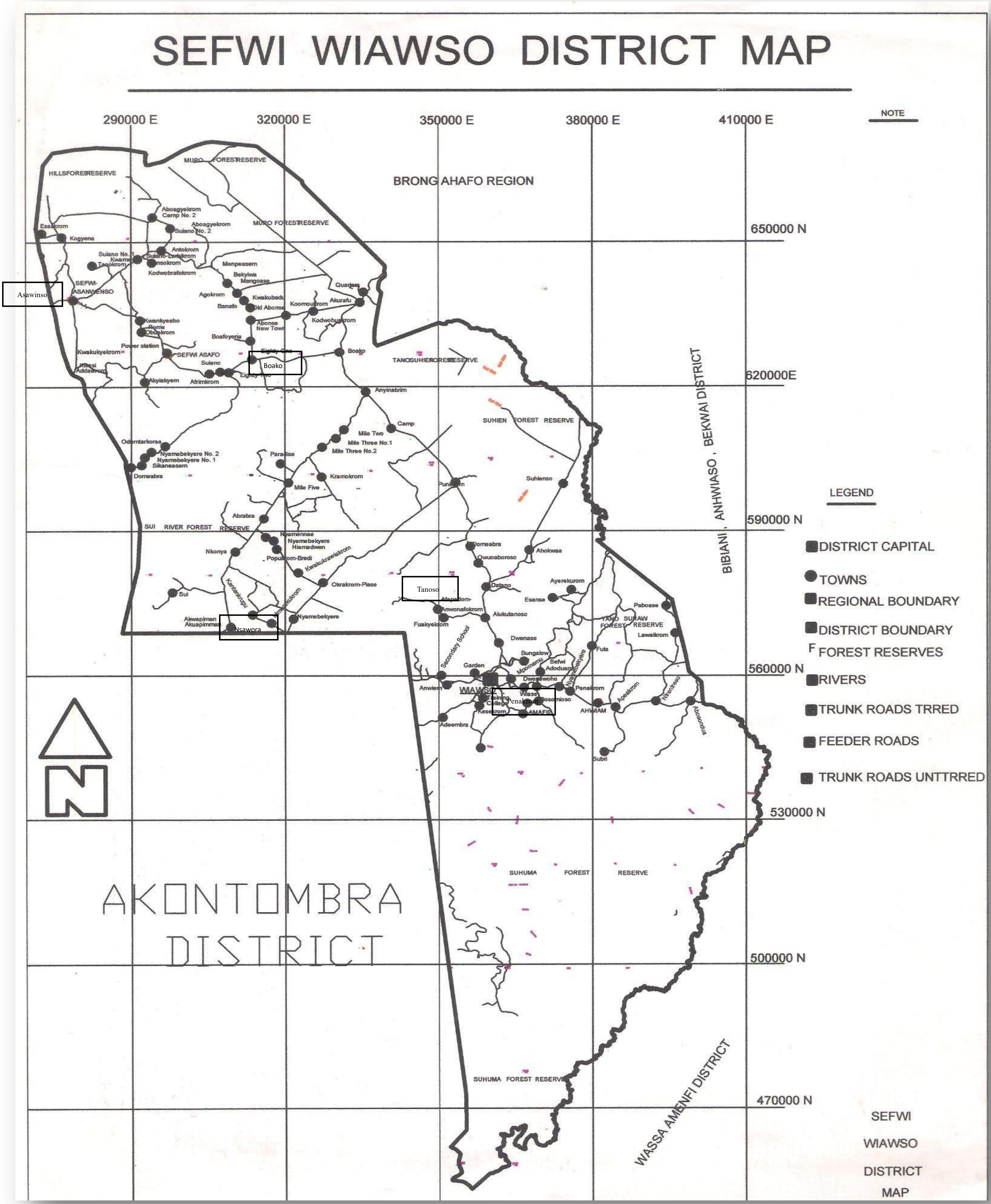

Figure 3.1b Map of Study Area (Sefwi-Wiawso District)

3.2 **Data Collection**

Primary data was collected from the field through the administration of well-structured questionnaires to respondents, from whom information relevant to the study was sought. Secondary data was obtained from articles, thesis both published and unpublished, reports, periodicals and books.

3.3 **Sample Size and Sampling Technique**

The sample frame for the study comprised of farmers from five cocoa farming communities. A non-probability (Judgmental or Purposive) sampling procedure was used. Five major cocoa growing communities in Sefwi-Wiawso District were selected for the study, as indicated in *Figure 3.2*.

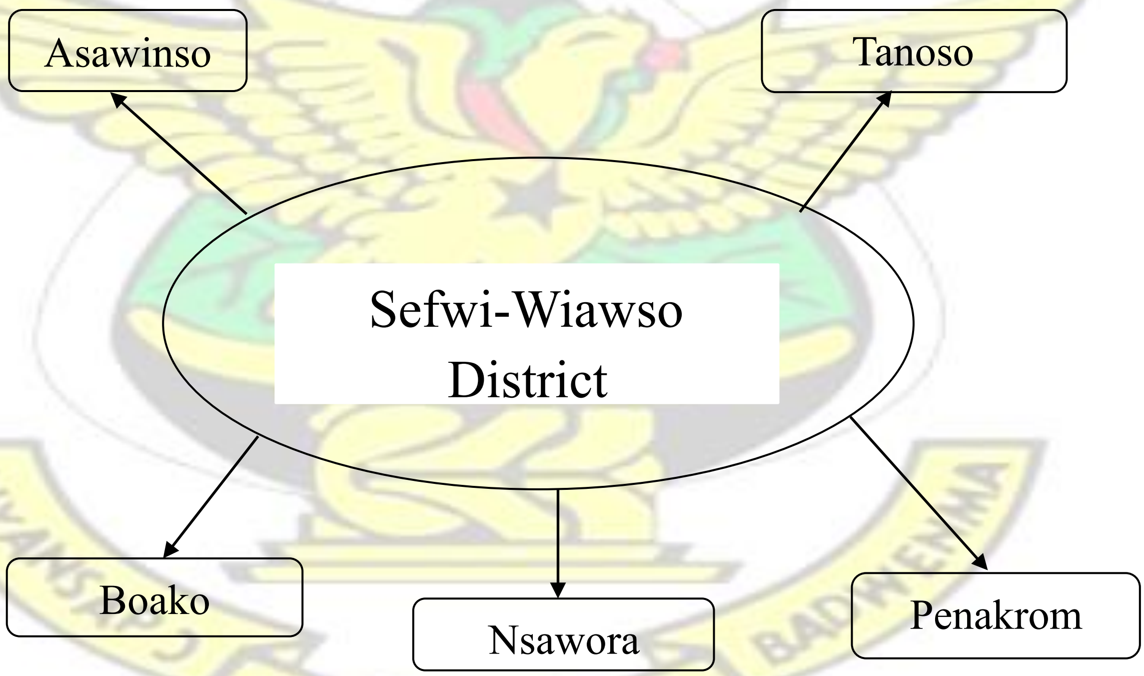

Fig. 3.2 The five (5) communities in Sefwi-Wiawso District, where the study was conducted.

Twenty (20) selected farmers from each of these communities were interviewed using a structured questionnaire. The questionnaire sought information on

- Respondent"s socio-economic characteristics such as; sex, age, level of education etc.
- Pesticides used by respondents and rate of application.
- What informed respondents choice of pesticide and rate of application.

Secondly, from each of the respondent"s farm, two cocoa pods were collected for laboratory analysis to assess the pesticide residue level.

3.4.1 **Laboratory Analysis**

3.4.1.1 **Substance Analyzed**

Cocoa beans were removed from their pods and and fermented for seven days, as prescribed by Cocobod and air dried. The shells were removed without heating using the procedure described by Syoku-An (2006) and pulverized into particles that was passed through a 420 µm standard sieve.

3.4.1.2 **Extraction Procedure**

During the extraction, 20 mL of water was added to 10 gm (10,000 mg) of the sample and allowed to stand for 15 min. Fifty milliliters (50 mL) of acetonitrile was added and the sample homogenized. The sample was filtered by suction. Twenty milliliters (20 mL) of acetonitrile was then added to the residue on the filter paper. This was followed by homogenization and suction filtration. Both filtrates were mixed and acetonitrile added to make a 100 mL solution. Twenty milliliters (20 mL) of the extracted solution was measured and 100 mg of sodium chloride and 20 mL of 0.5 mol/L phosphate buffer (pH 7.0) added. This was homogenized for 10 min and allowed to stand until the solution was clearly separated into layers. The aqueous layer was then discarded. An octadecylsilanized silica gel mini column (1000 mg) was conditioned with 10 mL of acetonitrile. The extract was introduced into the column and eluted with 20 mL of acetonitrile. The effluent was dried over sodium sulfate (anhydrous) and filtered. The filtrate was concentrated to dryness at 40 °C on the rotary evaporator and the residue dissolved in 20 mL of acetonitrile/toluene 3:1 (v/v).

3.4.1.3 **Clean-up**

A graphite carbon/aminopropylsilanized silica gel layered mini column 1:1 (w/w) was conditioned with 10 mL of acetonitrile/toluene 3:1 (v/v) and the solution obtained during the extraction step was applied to the column. The column was eluted with 20 mL of acetonitrile/toluene 3:1 (v/v) and the entire volume of effluent collected. The effluent was concentrated to 1 mL at 40 °C. 10 mL of acetone was added to the concentrated solution and concentrated to 1 mL at 40°C. Thereafter, 5 mL of acetone was added to the concentrated solution and evaporated to dryness. The extract was dissolved in acetone/*n*-hexane 1:1 (v/v) to make a 1 ml solution, and transferred into labelled 15 mL srew cap tube, closed and placed in freezer for at least 30 min. The final extracts were analysed by GC/MSD

3.4.1.4 **Calibration curves of the reference standards**

Acetone solution of reference standard of the pesticide mixtures was prepared for each. Portions of the mixture were diluted with acetone/*n*-hexane 1:1 (v/v) to the appropriate concentrations of the reference standards (Syoku-An, 2006). 2 μL of each diluted portion was injected into a Gas Chromatography (GC)/ Mass Selective Detector (MSD). Peaks in the resulting chromatograms were used to prepare calibration curves.

3.4.1.5 **Gas Chromatographic and Mass Spectrometric Determination**

The final extracts were analysed by Gas Chromatograph-Varian CP-3800 (Varian Association Inc. USA) equipped with 1177 type injector, Saturn 2200 Mass Spectrometer (MS) as detector and

8400 Varian autosampler was used for confirmation of pesticides. The GC conditions and detector response were adjusted so as to match the relative retention times and response as spelt out by Japanese analytical methods for agricultural chemicals. Sample extract of 2 µL aliquots was injected and the separation was performed on a fused silica gel capillary column made of 5% phenyl-methyl silicon, with dimensions of (30 m in length x 0.25 mm i.d x 0.25 µm film thickness). The injector and detector temperature were set at 250 °Cand 300 °C respectively. The oven temperature was programmed as follows: 50 °C held for one minute, ramped at 25 °C /min to 125 °C, then finally ramped at 10 °C /min to 300 °C and held for 10 min. The carrier gas was helium at a flow rate of 1.2 mL/min. The MS detector with an Ion trap analyser was set to scan mass range of 40 m/z- 450 m/z at EI 70 eV. The total run time for a sample was 31.5 min.

3.4.1.6 **Quantification of Pesticide Residues.**

The residue levels of all the pesticides were quantitatively determined by the external standard method using peak area. Measurement was carried out within the linear range of the detector. The peak areas whose retention times coincided with the standards were extrapolated on their corresponding calibration curves to obtain the concentration.

3.5 **Data Analysis**

The collected data was analysed using both qualitative and quantitative techniques. The quantitative data was analyzed using descriptive statistics such as percentages, frequencies, means etc. MicroSoft Excel was used to help analyze and organize the data collected.

CHAPTER FOUR

4.0 RESULTS

4.1 Pesticides Used by Cocoa Farmers

From the field survey, it was observed that cocoa farmers in the five communities use eleven different pesticides on their cocoa farms to control pest infestation (*Table 4.1*).

Table 4.1 Pesticides used by cocoa farmers in the five study communities

Trade Name	Common Name
Confidor	Imidacloprid
Akate Master	Bifenthrin
AkateSuro	Diazinon
Actara	Thiamethoxam
Sumitox	Fenvalerate
Defender	Acetamiprid
Sumico	Carbendazin + Dithofencarb
Simpyrifos 48% EC	Chlorpyrifos
Canphephos	Fenitrothion
Cypade	Malathion
Glyhader	Dimethoate

Project results of (2013) field Survey on pesticides used by cocoa farmers in sefwi wiawso district.

Table 4.2 Percentage of farmers who use approved and unapproved pesticides in the Sefwi Wiawso District

Unapproved Pesticide	Farmers (%)	Approved Pesticides	Farmers (%)
Diazinon	10.7	Imidacloprid	23.3
Fenvelerate	6.8	Bifenthrin	27.2

Acetamiprid	2.9	Thiamethoxam	15.5
Carbendazin+Dithofencarb	4.9		
Chlorpyrifos	1.9		
Fenitrothion	2.9		
Malathion	1.9		
Dimethoate	1.9		
Total	**34**		**66**

Of the cocoa farmers in the Sefwi Wiawso district, only 66% used the three approved pesticides while the rest used eight different unapproved pesticides (Table 4.2). Among the approved pesticides used by the cocoa farmers, Bifenthrin recorded the highest usage (27.2%) followed by Imidacloprid (23.3%) and Thiamethoxam (15%). A total of eight (8) unapproved pesticides were identified in the survey, among these eight pesticides, Diazinon recorded the highest usage (10.7%) whilst, Malathion, Chlorpyrifos and Dimethoate recorded the least (1.9%)

4.2 Level of Patronage of the Unapproved Pesticides in the Five Communities

Unapproved pesticides were used in all the five study communities in the Sefwi Wiawso District. However, the level of patronage of the unapproved pesticides varied from one community to the other. Unapproved insecticides patronage is as shown in the diagram of *Figure 4.1.*

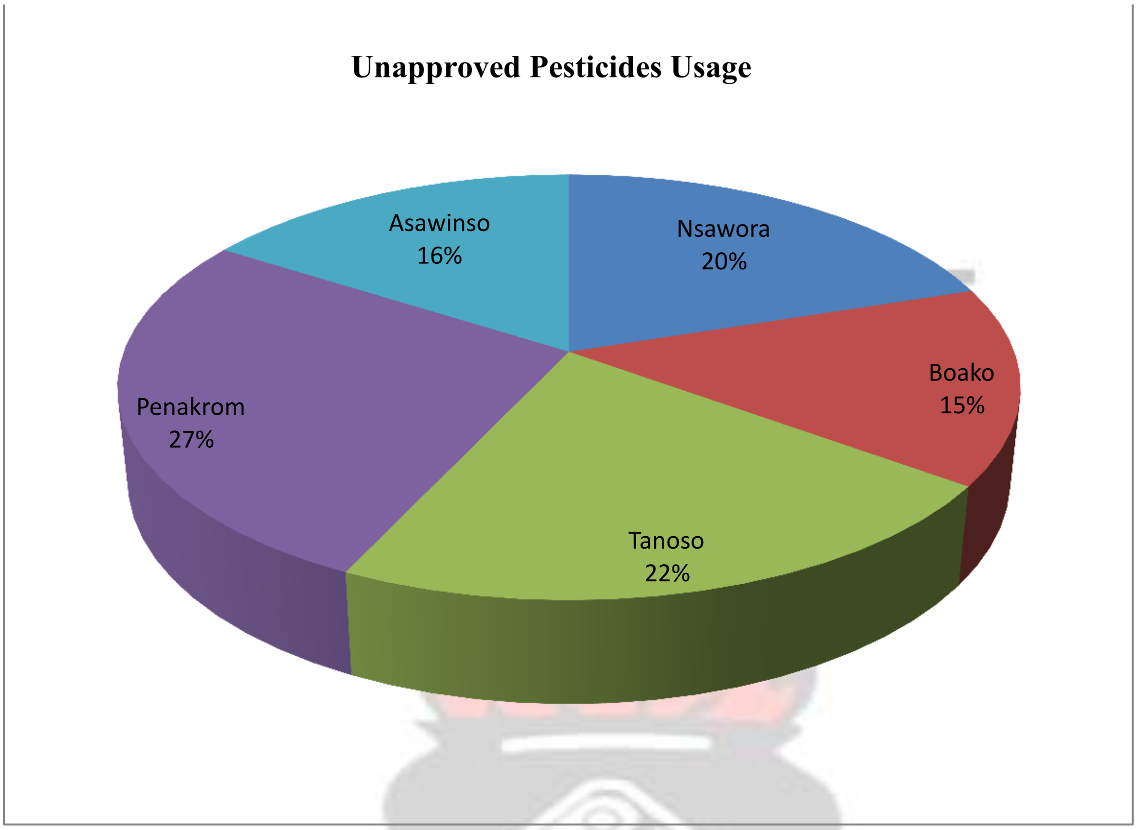

Figure 4.1 Farmers who used unapproved pesticides in the various communities

All the five cocoa growing communities in the Sefwi Wiawso District used appreciable volumes of unapproved pesticides. Of the 44% farmers who use unapproved pesticides in the district, farmers from Penakrom recorded the highest (27%) followed by Tanoso (22%), Nsawora (20%), Asawinso (16%) and Boako (15%), as indicated in *Fig. 4.1*.

Farmers had varying reasons for their continuous use of unapproved pesticides; these include the price (27%), the availability (42%) and the efficacy (19%) of the pesticides, as indicated in *Fig. 4.2* (a pie chart showing the factors that leads to pesticide selection by farmers).

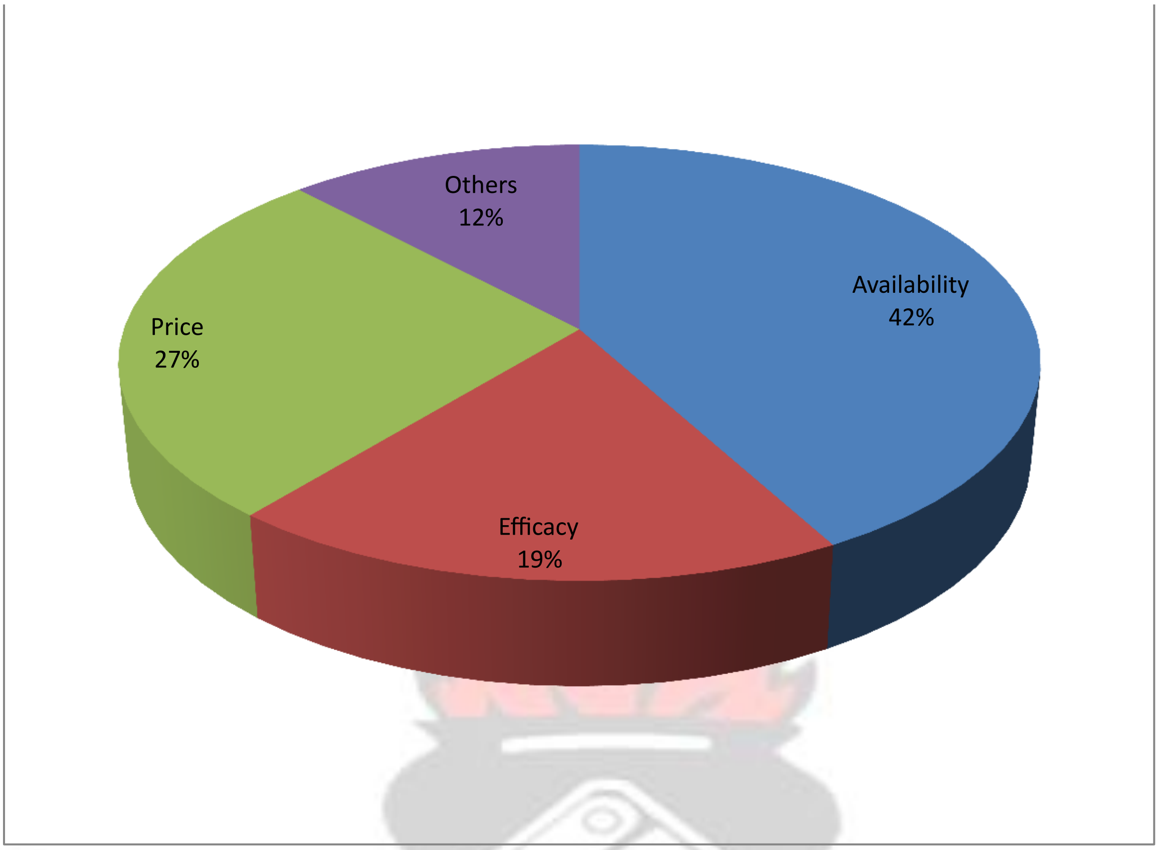

Fig. 4.2. Factors that lead to pesticide selection by farmers

4.4 Levels of Organophosphate residues in Beans from the Five Communities

Cocoa bean samples from all the five cocoa growing communities in the Sefwi Wiawso District did not contain most of the organophosphates tested for. The cocoa bean samples did not contain ethoprophos, phorate, diazinon, fonophos, parathion, chlorfenvinphos and profenofos (Table 4.3).

However, methamidophos was detected in cocoa beans from all the communities except that from Nsawora. The level of methamidophos was however, below the EU MRL (GSA, 2013) in all the four communities. Dimethoate was detected in cocoa beans from Nsawora and Penakrom while Pirimiphos-methyl was detected in samples from Tanoso and Asawinso communities.

However, their levels were below the EU MRLs (GSA, 2013). Malathion and Fenithrothion were also detected samples from in Penakrom and Tanoso respectively but their levels were below the EU MRLs (GSA, 2013) (Table 4.3).

Table 4.3 Levels of Organophosphate residues in cocoa beans from the five communities in the Sefwi Wiawso District

Organophosphate	EU MRLs (mg/kg)	Nsawora	Boako	Tanoso	Penakrom	Asawinso
Methamidophos	**0.02 (max)**	*BLD	**<0.01**	**<0.01**	**<0.01**	**<0.01**
Ethoprophos	**02 (max)**	BLD	BLD	BLD	BLD	BLD
Phorate	**0.10(max)**	BLD	BLD	BLD	BLD	BLD
Dimethoate	**0.05 (max)**	**<0.05**	BLD	BLD	**<0.05**	BLD
Diazinon	**0.02 (max)**	BLD	BLD	BLD	BLD	BLD
Fonofos	**0.01 (LOD)**	BLD	BLD	BLD	BLD	BLD
Pirimiphos-methyl	**0.05 (max)**	BLD	BLD	**<0.05**	BLD	**0.02**
Fenitrothion	**20 (max)**	BLD	BLD	**0.05**	BLD	BLD
Malathion	**0.02 (max)**	BLD	BLD	BLD	**<0.01**	BLD
Parathion	**10 (max)**	BLD	BLD	BLD	BLD	BLD
Chlorfenvinphos	**0.05 (max)**	BLD	BLD	BLD	BLD	BLD
Profenofos	**0.10 (max)**	BLD	BLD	BLD	BLD	BLD

***=Below Detection Level.**

4.4 Levels of Organochlorine residues in Beans from the Five Communities

Cocoa bean samples from all the five cocoa growing communities did not contain most of the organochlorines tested for (Table 4.4). Aldrin and Chlorpyrifos were howeverdetected. Aldrin was detected in only the Nsawora community and Chlorpyrifos was detected in Nsawora, Tanoso and Penakrom communities. Their levels were below the EU MRL (GSA, 2013).

Table 4.4 Levels of Organochlorines in Cocoa Beans from Five Communities in the Sefwi Wiawso District

Organochlorine	EU MRLs (mg/kg)	Nsawora	Boako	Tanoso	Penakrom	Asawinso
Beta-HCH	**0.02 (max)**	BLD	BLD	BLD	BLD	BLD
Delta-HCH	**0.02 (max)**	BLD	BLD	BLD	BLD	BLD
Lindane	**1.00 (max)**	BLD	BLD	BLD	BLD	BLD
Heptachlor	**0.02 (max)**	BLD	BLD	BLD	BLD	BLD
Chlorpyrifos	**.10 (max)**	**<0.01**	BLD	**0.08**	**0.01**	BLD
Aldrin	**0.05 (max)**	**<0.01**	BLD	BLD	BLD	BLD
Gamma Chlordane	**.02 (max)**	BLD	BLD	BLD	BLD	BLD
p,p'' – DDE	**0.50 (max)**	BLD	BLD	BLD	BLD	BLD
Dieldrin	**0.50 (max)**	BLD	BLD	BLD	BLD	BLD
Endrin	**0.01 (max)**	BLD	BLD	BLD	BLD	BLD
Alpha-Endosulfan	**0.10 (max)**	BLD	BLD	BLD	BLD	BLD
Endosulfan Sulfate	**0.10 (max)**	BLD	BLD	BLD	BLD	BLD
Beta-Endosulfan	**.10 (max)**	BLD	BLD	BLD	BLD	BLD
p,p'' – DDD	**0.50 (max)**	BLD	BLD	BLD	BLD	BLD
p,p'' – DDT	**0.50 (max)**	BLD	BLD	BLD	BLD	BLD
Methoxychlor	**0.10 (max)**	BLD	BLD	BLD	BLD	BLD

BLD=Below Detection Level

4.5 Levels of Pyrethroids in Cocoa Beans from the Five Communities

Cocoa beans sampled from all the five communities in the study area did not contain detectable levels of any of the Pyrethroids tested for (*Table 4.5*).

Table 4.5 Levels of Pyrethroids in cocoa beans from Five Communities

Pyrethroid	EU MRLs (mg/kg)	Nsawora	Boako	Tanoso	Penakrom	Asawinso
Allethrin	**0.05 (LOD)**	*BLD	BLD	BLD	BLD	BLD
Bifenthrin	**0.10 (max)**	BLD	BLD	BLD	BLD	BLD
Lambda-Cyhalothrin	**0.05 (max)**	BLD	BLD	BLD	BLD	BLD
Permethrin	**0.01 (max)**	BLD	BLD	BLD	BLD	BLD
Cyfluthrin	**0.01 (max)**	BLD	BLD	BLD	BLD	BLD
Cypermethrin	**0.01 (max)**	BLD	BLD	BLD	BLD	BLD
Fenvelerate	**0.05 (max)**	BLD	BLD	BLD	BLD	BLD
Deltamethrin	**0.05 (max)**	BLD	BLD	BLD	BLD	BLD

***=Below Detection Level**

CHAPTER FIVE

5.0 DISCUSSION

5.1 Pesticides Used by Farmers

The study has shown that cocoa farmers in the five communities of the Sefwi Wiawso District use 11 different types of pesticides in controlling pest in their farms with the greater number using bifenthrin (27.2%), imidacloprid (23%) and thiamethoxam (15%). In a similar study, Owusu-Ansah *et al*. (2010), showed that cocoa farmers use a wide range of pesticides both approved and unapproved ones to limit losses from pests and diseases in cocoa production. Most farmers are known to use Copper Sulphate, Benzene Hexachloride (BHC), Aldrin / Dieldrin or Aldrex 40 and Propoxur.

Although the FAO approves the use of pesticides in preventing, destroying, or controlling pests, pesticides to be used on cocoa must be approved for use and not detrimental to the environment (FAO, 1989).

5.2 Unapproved Pesticides used by Farmers

The study indicated that, 34% of cocoa farmers in all the five cocoa growing communities surveyed used unapproved pesticides to control pest. In all, unapproved pesticides were used by 27% of farmers in Penakrom, 22% in Tanoso, 20% in Nsawora, 16% in Asawinso, and 15% in Boako. From the study, diazinon (10%) was the most used unapproved pesticide by farmers in all the five communities*, (Table 4.2).*

According to ICCA (2011), fenvelerate and diazinon are unapproved pesticides by EU, yet it is being used by most farmers in Ghana. Despite the fact that many of these pesticides are banned and severely restricted or unregistered, farmers continue to use them especially in developing countries where regulatory controls are weak, higher prices of approved pesticides, unavailability of the approved pesticides and the efficacy of the unapproved pesticides in controlling pests (Yudelman *et al*., 1998).

5.4 **Levels of Organophosphate Pesticide Residues Detected in Cocoa Bean Samples**

Methamidophos was detected in cocoa beans from all the communities except Nsawora although the levels were below that of the EU MRL. Dimethoate was also detected on cocoa beans from Nsawora and Penakrom while Pirimiphos-methyl was detected in Tanoso and Asawinso communities but the levels were within the EU MRLs. Malathion and Fenithrothion were detected in Penakrom and Tanoso respectively but their residual levels were below the EU MRLs.

Yeboah *et al* (2012), in a similar study in Tema and Takoradi, Ghana, warehouses of Cocoa Board detected methamidophos in 4 out of 24 samples and Dimethoate in 18 out of 20 (90%) samples. Pirimiphos-methyl is one of the three organophosphates screened routinely for shipment to Japan from Ghana. The residue levels in cocoa bean samples were however, below the EU MRLs. This could be attributed to the fact that, most farmers are adhering to Good Agricultural Practices (GAP) which include; applying the right substance in the right way at the right time (Bateman, 2010).

Yeboah *et al.* (2012) observed that among all the organophosphates screened, samples recorded average residue concentrations below the EU and Japan MRLs except methamidophos, malathion and profenofos. It was observed that although methamidophos, malathion were detected in some samples, their residue levels were below the EU MRLs. This contradicts what was reported by Yeboah *et al.* (2012). Diazinon and Phorate though approved pesticide for use in Ghana, were not detected in any of the samples. This contradicts the 5.0 μg/kg and 5.2 μg/kg mean residues levels for Diazinon and Phorate respectively obtained by Yeboah *et al.* (2012) in cocoa bean samples used their study, which might imply that farmers are now practicing GAP and applying the right chemicals at the right time.

Fenithrothion and Dimethoate were detected but the residue levels were within the EU MRLs. This result is comparable to the results obtained by Yeboah *et al.* (2012). Though the residue level of Fenithrothion was within the EU MRL, its presence has serious health implications because it is among the class of pesticides banned by the EU and Japan. Bateman (2010) reported that Fenithrothion and parathion are WHO category II pesticides which are moderately hazardous and are banned for use in the cocoa industry by the European Union and Japan.

Chlorfenvinphos, Parathion, Fonofos, Ethoprophos were not detected in all the samples from the communities. Diazinon was not detected in any of the samples from the five communities. This confirms the report by Aikpokpodion *et al.* (2012), that none of the cocoa beans obtained from Cross River State (Nigeria), had detectable level of Diazinon. This contradicted what was reported by Obida *et al.* (2012) that, Diazinon was detected in pre storage bean samples however, the residues level was within the MRLs. The absence of Diazinon in cocoa bean samples may be due to numerous factors which include but not limited to: non availability of approved pesticides to farmers, non-application of the pesticide and / or the concentration may be lower than the limit of quantification.

5.4.2 **Levels of Organochlorine Pesticide Residues in Cocoa Bean Samples**

Of the Organochlorines, tested for, only Aldrin and Chlorpyrifos were detected (Table 4.4).

Aldrin was detected in only Nsawora community, whilst Chlorpyrifos was detected in Nsawora, Tanoso and Penakrom communities. The levels were however, within the EU MRLs. This confirms the study by Frimpong *et al.* (2012) that, amongst the samples analyzed, none of the mean residue concentrations of organochlorines was above the EU MRLs and Japan MRLs. Beta-HCH, Delta-HCH and lindane were not detected in all cocoa beans analyzed. However, Frimpong *et al.* (2012), observed appreciable residue amounts of Beta-HCH, Delta-HCH and lindane in about 16-46% of the total samples analyzed.

Lindane may not have been detected because it has officially been banned since 2002 for use on farms in Ghana, (Adu- Kumi *et al*., 2010). Endosulfan was not detected in any of the samples tested for in our study but was detected by (Frimpong *et al* (2012) and this can be attributed to their persistence in the environment (Perterson and Batley, (2010). Daanu (2011) however detected Alpha-endosulfan, Beta-endosulfan and Endosulfan sulfate in samples from cocoa beans.

From Table 4.4, p,p‟-DDT, p,p‟-DDE and p,p‟-DDD were not detected in all the cocoa bean samples from all the five cocoa growing communities in the Sefwi Wiawso district . This disagrees with what was reported by Frimpong *et al.* (2012) who out of the 45 samples analyzed, 15 had p,p‟-DDE, 32 had p,p‟-DDD and 4 had p,p‟-DDT. They however observed that the residues levels of these pesticides were below the EU and Japan MRLs. Heptachlor was not detected in all cocoa bean samples. This might be because they are banned pesticides in Ghana (EPA Ghana, 2009).

Aldrin was detected in cocoa bean sample from Nsawora community but the residue level was below the EU and Japan MRL and this agrees with work by Frimpong *et al.* (2012) and Daanu (2011). Dieldrin, Gamma-chlordane and Endrin were not detected in any of the samples in our study but were detected in the study by Frimpong *et al.* (2012) and Daanu (2011) Chlorpyrifos was detected in cocoa samples from all the nine sites but the residue level was below the EU and Japan MRLs.

Bateman (2010) reported that Aldrin, p,p‟-DDD, p,p‟-DDE, p,p‟-DDT and endosulfan sulfate are WHO/EPA category II pesticides banned for use in cocoa production by the EU and Japan. This might have accounted for their low residue levels and / or their absence in this study. Chlorpyrifos was however, detected in three out of five communities. This shows that Chlorpyrifos is still being used by farmers (Menlah, (2008).

Amoah *et al.* (2006) also obtained similar results and reported that chlorpyrifos was detected on 78%, lindane on 31%, endosulfan on 36%, Lambda cyhalothrin on 11% and DDT on 36 % of lettuce samples. Although chlorpyrifos residue level obtained in this study was acceptable on the basis of MRLs, it has serious health implications. .

5.4.3 **Levels of Synthetic Pyrethroid Pesticide Residues in Cocoa Bean Samples**

Of the synthetic pyrethroids screened (Allethrin, Bifenthrin, Lambda-cyhalothrin, Permethrin, Cyfluthrin, Cypermethrin, Fenvalerate, Deltamethrin) in this study non was detected in all the five communities. This contradicts the work of Frimpong *et al.* (2012), who observed appreciable residue levels of Permethrin, Fenvelerate, Cyfluthrin, Cypermethrin and Bifenthrin on cocoa beans samples from the Tema and Takoradi Warehouses.

The low levels of pyrethroid pesticide residues obtained in this study could be due to the education of farmers on Good Agricultural Practices (GAP), on which type of pesticides to use, at what level and at what time (Bateman. 2010).

The growing global concerns about the effects of the increasing use of agricultural chemicals on farmers, consumers of agricultural produce and the ecology require a re-examination of the issues related to their application in the cocoa industry (Owusu-Ansah *et al*., 2010)

CHAPTER SIX

6.0 **CONCLUSIONS AND RECOMMENDATIONS**

6.1 **CONCLUSSIONS**

Sixty six percent of cocoa farmers from the five communities in the Sefwi Wiawso district use bifenthrin, thiamethoxam and imidacloprid which are approved pesticides by the Ghana Cocoa Board. However, 34% of farmers used unapproved pesticides (diazinon, dithofencarb, fenvelerate, chlorpyrifos, acetamiprid, fenitrothion, malathion and dimethoate). Diazinon is the most commonly used pesticide among the unapproved pesticides.

The following organophosphates: Ethoprophos, Phorate, Diazinon, Fonophos, Parathion, Chlorfenvinphos and Profenofos were not detected in cocoa bean samples from all the five communities. Methamidophos was detected on cocoa beans from all the communities except Nsawora. However, the residual level of Methamidophos was within the EU MRL in all the four communities. Dimethoate was also detected on cocoa beans from Nsawora and Penakrom while Pirimiphos-methyl was detected in Tanoso and Asawinso communities but their levels were below the EU MRLs. Malathion and Fenithrothion were detected in Penakrom and Tanoso respectively but their levels were below the EU MRLs.

Among the organochlorines, tested for, only aldrin and chlorpyrifos were detected. Aldrin was detected in samples from Nsawora community while chlorpyrifos was detected in samples from Nsawora, Tanoso and Penakrom communities. The levels were below the EU MRL.

No pyrethroid pesticide residue was detected in cocoa beans sampled from all the five communities in the Sefwi Wiawso district.

6.2 RECOMMENDATIONS

- Further research on this topic should be conducted to determine the pesticides residue in soils in order to establish the relationship between pesticide residues in cocoa beans and in the soils from the various farms.
- The enforcing agencies (e.g. EPA, Ghana) should put in place more stringent measures to restrict the importation, sale and use of banned and unapproved pesticides in the country.
- Farmers should be continuously educated on GAP to mitigate the problem of pesticide residues in cocoa beans.
- If possible, the Quality Control Company Limited (QCC) in collaboration with COCOBOD and Government of Ghana should institute award systems and pay premium prices on cocoa beans from communities with low or non-detectable levels of unapproved pesticide residues to encourage compliance to GAPs.

APPENDIX A

Project Questionnaire Sample

*Questioner*____________________ *Questionnaire Number*_______

This is a Master's student of the Kwame Nkrumah University of Science and Technology undertaking a research on "*Assessment of Pesticide Residues on Cocoa Beans Produced in Sefwi-Wiawso District in the Western Region of Ghana*". You are assured of the confidentiality of your response

*Name of Community*__________________ ______________________________

Part 1: Background to the Household & Farm

☑

Sex: M ☐ F ☐	Age	Below 25 ☐ 25-29 ☐ s 30-34 ☐ 35-39 ☐ 40-44 ☐ 45-49 ☐≥ 50 ☐

Marital status	Single ☐ Married ☐ Divorced ☐ Separated ☐ Widowed ☐
Highest level of education	None ☐ Primary ☐ Secondary ☐ Tertiary ☐
Occupation (all that apply)	Farmer ☐ Others (please specify)

Part 2: Pesticide Use

Do you use chemical pesticides on your cocoa farm	Yes ☐ No ☐	If no, why?

If you use chemical pesticides, for what purpose do you use them? *(Tick any that apply)*	1. Control of weeds ☐ 2. Diseases☐ 3. Insect pests ☐ 4. Others (please specify):
Which Chemicals are you using? *Note: If the respondent does not know the name, or if it is a brand-name product that you do not recognize, you may need to ask if you can see the container.*	Brand name / Local name Purpose Chemical (if known)
What informed your choice of chemical?	
What do you consider most before buying a pesticide?	price ☐ availability ☐ toxicity ☐ recommended by neighbour ☐

Where do you buy these products? *(Tick any that apply)*	local shop ☐ open market ☐ other (please specify) other ☐ (specify)
Who sprays / applies the pesticides? *(Tick any that apply)*	Father ☐ Mother ☐ Son ☐ Daughter ☐ Hired labour ☐ Others ☐ (specify)
How often do you apply the pesticide?	Weekly ☐ Monthly ☐ Yearly ☐
At what rate do you apply the pesticide?	
What informed this rate?	

How do you apply your chemicals?	From a bottle ☐backpack sprayer ☐Knapsack sprayer ☐Mist blower☐other ☐ (specify)

What do you wear when spraying? (Please specify types; e.g. gloves, rubber or gloves, cotton; etc.)

Normal clothes ☐ Boots ☐ Bare feet ☐ Gloves ☐ Handkerchief over mouth ☐ Cotton overalls ☐ Disposable coveralls☐ Hat ☐ Mask ☐ Goggles ☐ Spectacles ☐

Does the protective equipment or clothing used belong to you? Yes ☐ No ☐

If no, where do you get it from?

Have you been trained in the proper use of protective equipment or clothing? Yes ☐ No ☐

Do you usually read the labels on pesticide containers? Yes ☐ No ☐

Have you ever bought chemical pesticides without a label or without instructions? Yes ☐ No ☐

Have you ever used chemicals with instructions in a language you don't understand? Yes ☐ No ☐

Do you understand the instructions for use? Yes ☐ No ☐ sometimes ☐ don't know ☐

Can you always carry out the instructions? Yes ☐ No ☐ sometimes ☐ don't know ☐

Do you know the doses of every pesticide you use? Yes ☐ No ☐

Does your pesticide use solve your pest problem	Yes ☐ No ☐ don't know ☐
Does the amount of pesticide used on your farm increase or decrease each year?	Increase ☐ Decrease ☐ It varies ☐ don't know ☐
Where do you store your pesticides? My bedroom ☐ Community store ☐ Kitchen ☐ Others (Specify)	

Part 3: Health and Environmental Impacts of the Pesticides

Is the use of pesticides:	Always good ☐ Sometimes good ☐ Sometimes harmful ☐ Always harmful ☐ Not effective ☐ Don't know ☐ Other ☐ (please specify)
What are the benefits to you from pesticide use?	
Can chemical pesticides can be dangerous? Yes ☐ No ☐	
If harmful, what is the damage?	To human health ☐ To animal health ☐ To wildlife ☐ To water bodies ☐ To All of these ☐ To the health of cocoa trees ☐
What can be done to minimize the negative effects of the chemical pesticides?	

Have you, or anyone else in the household ever felt any discomfort or illness after pesticide application?		Yes ☐ No ☐ sometimes ☐ don't know ☐
If yes, what was your feeling? *NB. Let respondent give an answer and then mark down against alternative answers: try not to lead / prompt with possibilities*	1. Nausea 2. Vomiting 3. Head ache 4. Skin irritation 5. Eye irritation 6. Long-term problems 7. Other (please specify)	
How did the incident happen?	During preparation / mixing ☐ During transport ☐ During disposal ☐ During application or spraying ☐ As result of poor storage ☐ Other ☐ (please specify)	
Have you ever been told about the dangers or learnt of any bad effects (e.g. on human health) as a result of using chemical pesticides?		Yes ☐ No ☐
If yes, who did you learn this from?	Cotton company officer ☐ Health office ☐ Environmental Protection Authority ☐ Other ☐ (please specify)	
Have you heard of any pesticide poisoning incident happening in the community in the last 12 months?		Yes ☐ No ☐

Reporting:

Is there a channel for reporting any pesticide incidents that occur?	Yes ☐ No ☐ don't know ☐
To whom would you report any incidents to? *(Tick any that apply)*	Cocoa office ☐ Health office ☐ Environmental Protection Agency ☐ Farmers group ☐ Others ☐ (specify)

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