UNIVERSITY OF CAPE COAST

ASSESSING PESTICIDES APPLICATION AND IMPACTS AMONG SMALLHOLDER COCOA FARMERS IN WESTERN REGION – GHANA

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ASSESSING PESTICIDES APPLICATION AND IMPACTS AMONG SMALLHOLDER COCOA FARMERS IN WESTERN REGION – GHANA

BY

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Thesis submitted to the Department Of Environmental Science of the School of Biological Sciences, College of Agriculture and Natural Sciences, University of Cape Coast, in partial fulfilment of the requirements for the award of Master of Philosophy degree in Environmental Science

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DECLARATION

Candidate's Declaration

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

Candidate's Signature………………………… Date…………………

Name: Boatemaa Ansah

Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

Principal Supervisor's Signature………………..… Date……………..……

Name: Dr. Michael Miyittah

Co-supervisor's Signature……………………...…. Date….……………...

Name: Dr. Salifu Seidu-Larry

ABSTRACT

The study assessed the risk of pesticides use among cocoa farmers in three districts of Western Region of Ghana. It employed a descriptive survey study design, where data were collected from 225 smallholders farmers using a questionnaire. The farmers' survey revealed inappropriate pesticide application is dangerous to their own health. This was buttressed by a high number of the respondents experiencing headache (66%), dizziness (58%), body weakness or being unusually tired (55%), or burning eyes (53%) after pesticide application. Information gathered from this survey also revealed that farmers sprayed the same wide range of pesticides on all crops, killing non-targeted organism such as pollinators and soil organisms. Part of the survey data was plugged into the risk model (Environmental Impact Quotient) to predict environmental impact of the pesticides. The EIQ model indicated that the use of Copper Hydroxide, Imidacloprid, and Acetamiprid in the study area pose a risk to the environment, especially to insects and pollinators. Transport of Imidacloprid (Confidor) which is widely used by farmers in controlling insects and pests in cocoa production was studied by column leaching experiment using two types of soils. The soils were treated with three different rates (0%, 0.5% and 1% by weight) of two adsorbents (Charcoal (CH) and Rice Husk Biochar (RHB)). Pesticide leachate concentrations revealed that charcoal (CH) at 1% showed maximum imidacloprid adsorption in both soils (Soil 1 – 0.32 µg/ml and Soil 2 – 0.2 µg/ml) followed by RHB at 0.5% in Soil 1- 0.25 µg/ml and RHB at 1% on Soil 2 - 0.61 µg/ml. Both adsorbents show promise to immobilize accidental pesticide spillage in soils.

KEYWORDS

Pesticides

Imidacloprid

Biochar

EIQ - Environmental Impact Quotient

HPLC - High Pressure Liquid Chromatography

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DEDICATION.

I dedicate this work to my family.

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LIST OF ABBREVIATIONS

EIQ	Environmental Impact Quotient
CH	Charcoal
RHB	Rice Husk Biochar
S	Soil
GDP	Gross Domestic Product
EU	European Union
EPA	Environmental Protection Agency
MoFA	Ministry Of Food and Agriculture
NPAS	Northern Presbyterian Agricultural Services
QCCL	Quality Control Company Limited
CPB	Cocoa Pod Borer
FAO	Food and Agriculture Organization
POPs	Persistent Organic Pollutants
NPIC	National Pesticide Information Center
KAP	Knowledge, Attitudes, and Practices
PPE	Personal Protective Equipment
RfD	Reference Dose
ADI	Acceptable Daily Intake
TDI	Tolerable Daily Intake
PTWI	Provisional Tolerable Weekly Intake
OEL	Occupational Exposure Limit
PECs	Predicted Environmental Concentrations
PNECs	Predicted No Effect Concentrations

NOECs	No Observed Effect Concentrations
LOECs	Lowest Observed Effect Concentrations
SFHAC	Sky Fruit Husk Activated Carbon
AC	Activated Carbon
CEC	Cation Exchange Capacity
C	Carbon
GSS	Ghana Statistical Service
A.I	Active Ingredients
EIQ F. U	Environmental Impact Quotient Field Use
EI	Environmental Impact
HPLC	High Performance Liquid Chromatography
MC	Moisture Content
QA/QC	Quality Assurance And Quality Control
PVC	Polyvinyl Chloride
RT	Retention Times

CHAPTER ONE

INTRODUCTION

Excessive pesticide use in cocoa production has compromised the environmental health of soils, water and cocoa beans produced, as well as potential harm to humans especially the producers (Fianko, 2011). Studies have shown that farmers are at a high risk as a result of pesticide use (Dzobo, 2016). There have also been frequent reports of pesticide poisoning among farmers which could be as a result of intentional, accidental and occupational exposure to the pesticide. This can be related to ignorance coupled with the lack of knowledge by farmers on pesticide use (Fianko, 2011). However, very few studies have been done on using risk indicators to assess the dangers associated with pesticide use among smallholder cocoa farmers. Furthermore, pesticides may persist in soil and cause some environmental damages, therefore, it is necessary to estimate the potential mobility (leaching) and transformation (leaching) of pesticides in soil and determine the possible ways to remove these chemicals from the soil or environment.

In the light of the above, this research seeks to assess smallholder cocoa farmers' knowledge on pesticide application; to ascertain the level of farmers knowledge on pesticide application; to calculate risk using Environmental Impact Quotient (EIQ) model; and finally, to determine leaching and removal of pesticide by using charcoal and rice husk biochar as pesticides absorbent materials in soils from the study areas: Wassa Amenfi West, Aowin and Suaman Districts of Western Region of Ghana.

Background to the Study

Agriculture plays a significant economic role for many countries in West Africa. Indeed, the importance of agriculture to the growth of the Ghanaian economy cannot be over-emphasized in relation to the labour force it attracts. Agriculture is the largest sector of the Ghanaian economy and the highest contributor to Ghana's GDP, employing about 60 % of the country's labour force (Oppong, Owiredu, & Churchill, 2014). The agricultural sector in Ghana is dominated by tree crops such as cocoa, coffee, oil palm and rubber. Among these tree crops, cocoa is of particular interest for Ghana and for the global chocolate industry (Danso-Abbeam, Setsoafia, Gershon, & Ansah, 2014). The cocoa sector represents more than half (70–100 %) of the income for roughly 800,000 smallholder farm families in Ghana, providing food, employment, tax revenue and foreign exchange earnings for the country (Anim-Kwapong & Frimpong, 2004; Appiah, 2004).

Despite the economic importance of cocoa, its production in Ghana is threatened by insect pests and diseases, a situation which has resulted in the decline in cocoa production, with adverse impact on the Ghanaian economy (Dormon, Van Huis, Leeuwis, Obeng-Ofori & Sakyi-Dawson, 2004). A significant component of the modern agricultural technology which has been widely adopted by cocoa farmers in Ghana to prevent or control insect pests and diseases in order to reduce or eliminate yield losses in cocoa and to maintain high product quality is pesticide.

However, the use of pesticide in agriculture, and for that matter the cocoa industry in Ghana has raised a lot of concerns about the safety of residues in cocoa beans, soils and water, as well as other potential harm to humans and the environment (e.g. destruction of natural enemies of pest and the development of pest resistance) (Adeogun & Agbongiarhuoyi, 2009; Adejumo, Ojoko, & Yusuf, 2014; Yang, Ying & Peng, 2010). In most developing countries like Ghana, these consequences have often been severe because farmers do not use approved pesticides, and do not follow recommended application rates as stipulated by government agencies for crops. They however misuse, overuse and apply pesticides indiscriminately with disregard to safety measures and regulations on chemical use (Konradsen, 2007).

Pesticides are mainly used to protect crops from insects, weeds, and diseases. The intensive use of pesticides has been one of the main contributors to modern agricultural development. They have contributed to high yields and lower product prices (Antwi-Agyakwa, 2013) and can save up to 45% of crop losses (Paintsil, 2017). Generally, pesticides play a positive role in protecting cocoa against losses, due to the destructive nature of the different forms of pests. However, the intensive use of pesticides poses an environmental hazard affecting human life and flora and fauna (Padovani, Trevisan & Capri, 2004). 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 are now to be examined for traces of pesticides and other substances that have been used in the supply chain. The commission has set threshold levels of residue poisons in commodities going through the international market, including cocoa. With respect to that, if the residual levels in any commodity surpass the set threshold levels, that particular commodity could be rejected by the importing country (Kumi & Daymond, 2015). Moreover, in view of the potential effects of pesticide use on humans, many countries have established rules to encourage the safe use and control, production, import and exporting of these pesticides.

Ghana Environmental Protection Agency (EPA) and the Pesticides and Fertilizer Regulatory Division of the Ministry of Food and Agriculture (MoFA) are responsible for the issuance of permit and the registration of pesticide use (Ntiamoah & Afrane, 2009). An average of 3,850 metric tons annually was recorded between 1973 -1990 as the global consumption of pesticides but had shot to a high of 37,712 metric tons worldwide in 2000. The report shows that in Ghana, an average of 814 tons of pesticides was imported into the country between 1995 and 2000 and a further increase from 7763 metric tons in 2002 to 27,886 metric tons in 2006. (Dey Nepal, 2010; Fianko, 2011). Comparing the use of pesticide in developing and developed countries, the frequency of pesticide poisoning has increased as a result of intentional, accidental and occupational exposure to pesticide (Singh & Gupta, 2009), that is, pesticide use in developing countries is increasing though its use in the developed countries is stable or declining. Although developed countries use 80% of the world’s total agrochemicals, they experience about 1% of the total pesticide-related deaths worldwide.

Pesticides were reported to be mishandled on farms, also very few farm workers know the names of the pesticide they were using on farms; about one third of participants of the survey did not know the amount of pesticides to be applied on their crops, (Shomar, Al-Saad,, & Nriagu, 2014). In a study conducted in the Northern Region of Ghana by The Northern Presbyterian Agricultural Services (NPAS), (2012), it was revealed that the most common health problems reported by farmers included, general body weakness, headaches, skin irritations, dizziness and difficulty in breathing. It was also observed that a collective number of farmers were dying as a result of pesticide poisoning (Dzobo, 2016).

In regards to these casualties caused by pesticide application, several methods have been employed by researchers on assessing the risk of exposure to pesticides. When a pesticide is applied to a crop or soil, it enters a dynamic ecosystem and instantly transport from one part of the system to another, some pesticides may degrade in situ or moved out of the system into other systems. Therefore, it is essential to determine the relative importance of these routes of exposures and processes, because, whereas pesticides that are completely degraded become harmless, those that move to other systems and persist may do some environmental damages (Hellawell, 2012).

A pesticide can disappear from soil by uptake by plants, volatilization, surface run-off, and leaching or taken in by invertebrates or small mammals having residues in their bodies. Comparable pathways of loss of pesticides from plants are that residues may volatilize, pass to the soil in root or be removed when the crop is harvested. Only the residues that remain in the plant or soil are metabolized, and often, for persistent pesticides, these represent only a small proportion of the whole (Peres, Moreira, Rodrigues, & Claudio, 2006). Pesticides tend to persist much longer in soils than in plants or animals. Pesticide residues become tightly adsorbed on various soil fractions, and even transient pesticides may be retained much longer than they would on unreactive surfaces (Damalas, Georgiou, & Theodorou, 2006). Since these pesticides or chemicals may reach soil directly via deliberate application, for risk assessment of these chemicals, it is important to estimate their potential for transformation in soil and for movement (leaching) into deeper soil layers.

Statement of the Problem

Pesticides are considered a vital component in maintaining high agricultural productivity in modern farming. Indiscriminate use and improper handling of pesticides in agriculture have caused serious health problems in many developing countries, which represent 30% of the global pesticide consumer market (Peres et al., 2006). Imidacloprid and bifenthrin insecticides are commonly used for spraying on the cocoa crops in Africa. Although pesticides have beneficial effects on crop yield, insufficient protective measures to counter the harmful effects of pesticide is a major health issue in the cocoa growing areas. Farmers harvesting cocoa crop are more prone to adverse health effects of pesticides because frequent spraying is required on the broad and succulent cocoa leaves for pest control (McDaniel, Solomon, & Malone, 2005).

Pesticides use has caused undesirable effects on those applying it (farmers), consumers, and the entire environment (including non-target species). Due to excessive use of pesticide, the quality of cocoa beans, soils and water bodies has been compromised as well as other potential harm to humans (Adeogun & Agbongiarhuoyi, 2009). Available literature supports the fact that cocoa farmers are involved in high risk practices regarding pesticides application.

Recently, Paintsil (2017) used EIQ model to assess the impact of pesticide use on smallholder cocoa farmers in Western Region, Ghana. This model was used to assess risk of pesticides use to consumer, farmer and the environment. However, this research extended to Wassa Amenfi West, Aowin and Suaman Districts in Western Region, Ghana. Furthermore, pesticide that are transported into soil and persist for a longer period are likely to cause some environmental damages. Therefore, it is important to estimate the potential movement (leaching) of pesticides in soil and determine the possible ways to remove these chemicals from the soil or environment. In view of this problem, this study aims at using adsorbents (charcoal and rice husk biochar since these absorbents are locally and readily available) to remove pesticides from contaminated soil in the study area.

General Objectives of the Study

The study sought to assess farmers level of knowledge and use that information to calculate the risk of pesticides use among cocoa farmers, as well as to determine effective amendments that can also adsorb pesticides that leaches into the soil.

The specific objectives of the study were:

1. to assess farmers knowledge on pesticides application on cocoa farms in the study area.
2. to calculate the risk of pesticides application using EIQ model.

3. to determine the sorption capabiliity of pesticide by Rice husk biochar and Charcoal.

Hypotheses

The study made and tested the following hypotheses:

1. Farmers have adequate knowledge on pesticides application on cocoa during pest infestation.
2. The use of EIQ model would estimate the risk of pesticides to farmers, consumers, and the environment.
3. Application of Rice husk biochar and Charcoal would adequately reduce pesticides leach in the soil.

Statistical Hypotheses

H_{01}: There is no significant difference between farmers' knowledge and the application of pesticide on cocoa farms.

H_{A1}: There is significant difference between farmers' knowledge and the application of pesticide on cocoa farms.

H_{02}: There is no significant difference in the risk of pesticide use to consumers, farmers and the environment using EIQ model.

H_{A2}: There is significant difference in the risk of pesticide use to consumers, farmers and the environment using EIQ model.

H_{03}: Use of charcoal and rice husk biochar will reduce pesticide leaching in soil.

H_{A3}: Use of charcoal and rice husk biochar will not reduce pesticide leaching in soil.

Significance of the Study

It is expected that the study would be useful to farmers and policy makers to acquire knowledge on pesticide application risk using EIQ models. The study would apply charcoal and rice husk biochar to pesticide contaminated soils from the study areas and also use soil column experiment to determine the pesticides leaching potential. The findings from this study would help support stakeholders in developing intervention program that address the issue of pests that destroy cocoa and reduce yield.

Delimitation

The study focuses on assessing the risk of pesticides use among cocoa farmers. The jurisdiction of this work was narrowed to Wassa Amenfi West, Aowin and Suaman districts in the Western Region of Ghana. The motive was that, these mentioned districts are involved in high cocoa production in Ghana.

These selected areas lie within an important cocoa belt in Ghana. These cocoa farms have been in existence for years and has been inherited from one generation to the next and this offers exclusive advantages to better understand the pesticide application, the potential health risk to farmers and pesticide fate in soil.

Definition of Terms

Some words within the study were given operational definitions as used in the context and scope of the research. They include the following:

Environmental Impact Quotient EIQ: The Environmental Impact Quotient (EIQ) is a model created to provide growers with data regarding the environmental and health impacts of their pesticide options so they can make better informed decisions regarding their pesticide selection (Kovach, Petzoldt, Degni & Tette, 1992).

Pesticide: Any substance, mixtures of substances or other agents used to control, destroy or prevent damage by or protect something from a pest. The definition also includes chemical substances that are used to attract and repel pests as well as those used to regulate plant growth or remove leaves/coats (Chandler et al., 2011).

Smallholder Farming: Small farms that rely mainly on family labor.

Soil Column Experiment: is an experiment carried out as a transport model evaluation on pesticides in soils (Lewis & Sjostrom, 2010).

Organisation of the Study

The study was organized into five chapters. Chapter one consists of the introduction, background of the study, statement of the problem, objectives, hypotheses and significance of the study. The chapter also includes delimitation of the study, limitation of the study, definition of terms as well as the organization of the study.

Chapter Two reviewed relevant literature. This includes empirical perspective. Chapter Three describes the research methods which were employed for the study. The chapter captures the research design, population, sample and sampling procedure, research instrument as well as procedure for data processing and analysis.

Chapter Four of the study concentrates on the results and discussion. The analyses were done in line with the research hypotheses. Chapter Five presents the summary, conclusions and recommendations of the study. Areas of further research were also suggested in this chapter.

Chapter Summary

This chapter is an introduction to the study. It has provided insight into the study by outlining the background to the study, objectives, hypotheses, statement of the problem and significance of the study, delimitation, limitation, operational definition of key terminologies and an outline of chapter divisions.

CHAPTER TWO

LITERATURE REVIEW

Ghana is growing to become a large consumer of pesticides as a result of the introduction of agrochemicals into the Ghanaian market (Amoah, Drechsel, Abaidoo, & Ntow, 2006). Due to tropical climatic conditions, proliferation of insects is very high; pesticides have therefore become an inevitable tool in controlling the pests of various field crops. Quite a number of pesticides are used on fruits and vegetable crops. Their persistent use leads to a buildup of toxic residues on crop produce, which may exert adverse effect on human health in addition to disturbing the ecosystem. This problem is more serious in the case of cocoa production as they are often produced by a large number of smallholder farmers and on vast land sizes. As a background to the study there is the need for a review of existing information to put this work in context.

This section therefore reviews relevant literature that serves as framework for this study. The researcher is aware that other authors have written on this topic, therefore pieces of information were gathered from journals, abstracts, the internet, books, and works people have done on pesticides use among cocoa farmers. The literature review which put this work in context has been grouped into three sections. The first sections discusses Production of cocoa in Ghana, factors that affect cocoa yield, the use of pesticides and their effects, exposure to pesticides, farmer knowledge on the effects of pesticides on human health and environment. The second section confers the environmental impact assessment of pesticide use and risk assessment models (pesticide risk indicators) emphasizing on the use of EIQ model as a risk indicator. Lastly, the third section takes in depth look at soils and persistence of pesticides - soil types and structure and the adsorption of pollutants from soils using amendments.

Production of Cocoa in Ghana

Cocoa was introduced to West Africa in the nineteenth century. It was brought to Ghana from Fernando Po in 1879 and from Sao Tome in the 1880’s. History attributes the commercial cultivation of cocoa in Ghana to Tettey Quarshie, a native who had travelled to Fernando Po and returned with Amelanodo cocoa pods (Boakye, 2012). The first documented shipment of beans from Ghana was in 1891, when 2 bags were sent from Accra to Hamburg, and since then, cocoa has been the main export crop and a major source of foreign exchange and domestic income earner (Canatus & Aikins, 2009). Until 1977, Ghana was the world’s leading producer of cocoa with the market shares ranging from 30-40%. Records indicate that production increased from a level of 36.3 metric tons in 1891 to an all-time peak of about 557,000 metric tons in 1965 giving Ghana a global output share of about 33% and the leading cocoa producer. Thereafter, production continued to drop and reached the lowest level of 158,956.00 metric tons in 1984, which constituted about 9% of world’s production (Amoah, 2013). Consequently, Ghana lost her position as the world’s number one producer. As part of efforts to arrest the decline in cocoa production, the Government of Ghana through Cocoa Board initiated a National Cocoa Diseases and Pest Control (CODAPEC) programme, popularly known as “Mass Spraying” to assist all cocoa farmers in the country to combat the capsid/mirid and the Black Pod disease. Under this programme, cocoa farms across the country were sprayed with insecticides and fungicides at no cost to the farmers. Also introduced is the Hi Tech programme. These programmes have resulted in tremendous increases in cocoa bean production from 340,562 metric tons in the 2002 season to 496,846 metric tons in 2003 and 736,000 metric tons in the 2004 seasons, respectively (Appiah, 2004; ICCO, 2007). The percentage of locally processed beans jumped from 20% to 35% with further re-capitalization and expansion programs underway to reach a target of 50% in the near future. It has therefore been the intention of government, which is committed to reaping the maximum benefit from the cocoa sector, to ensure that the country increases its cocoa production and also processes more of the beans into downstream products for both the local and export markets (Boakye, 2012).

However, along with the positive effects of the CODAPEC programme, some negative impacts on the environment have also been caused. For instance, the use of pesticides on the farms can lead to the destruction of part of the soil flora and fauna through both physical and chemical deterioration (Boakye, 2012). While the Government of Ghana stresses the need for diversifying the nation’s economic structure, it also emphasizes the important role of the cocoa sector and therefore had set a target of achieving one million metric tons of cocoa output by 2010 (NDPC, 2005).

The trend was towards increasing the value added in the country, with the share of processed cocoa beans and cocoa intermediate products increasing. This led to the need for external and internal laboratory tests in the cocoa sector. The Ghana Cocoa Board has developed, through its specialized Quality Control Company Limited (QCCL), a highly recognized expertise and internationally trusted reputation in maintaining consistently high quality of exported cocoa beans. Through intensive training of small holder farmers in disease control, pruning of trees and the observance of the required best practices in the fermentation of beans, and through the enforcement of strict grading procedures, QCCL has been able over the years to maintain Ghana’s cocoa quality that meets strict specifications in commodity exchanges with price quotations for future delivery, and consistently fetches premiums on world market prices (ICCO, 2007).

Factors that Affects Cocoa Yield

Pests and Diseases of Cocoa Production

According to DropData (2014), cocoa has been described as a "virtuous crop". There is a growing appreciation of its value for land restoration, enrichment of biodiversity and provision of sustainable incomes in less advanced regions. Like other crops, nonetheless, it can be attacked by many pest species including fungi, insects and rodents, some of which (example, frosty pod rot and cocoa pod borer) have increased dramatically in geographical range. They are sometimes described as "invasive species". Though over 1500 different insects are known to feed on cocoa, only about 2% are of economic significance (Assonwa, 2015). In the wild, natural spreading of cocoa diseases relies on animals such as rats and birds breaking into ripe pods and feeding on the sugary mucilage around the beans. Substantial yield losses from such damage are experienced in almost all parts of the world where cocoa is grown and may well be 5-10% on average (SOQ, 2015). According to ICCO (2007) Cocoa is affected by a range of pests and diseases, with some estimates putting losses as high as 30% to 40% of global production. Some common insect pests affecting cocoa production include: Cocoa pod borer, Mirids, Cocoa beetle, and Flower-eating caterpillars. Some common diseases affecting cocoa production also Include: Witches broom, Frosty pod rot, Black pod disease and Vascular-streak Dieback.

Socioeconomic factors

Factors that proximately affect cocoa productivity in Ghana include; rural-urban migration of many youths who will otherwise work as farm laborers, high prices of inputs and availability on a sustainable basis, and farmer priorities. Other factors include, educational level and capacities to incorporate research recommendations into pest management strategies, poor social circumstances of farmers and lack of workable credit and loan facilities (Dormon et al. 2004). The poor road networks in the cocoa production areas also contribute to low productivity. Low producer price was identified in a study by Osei Boadu (2014) as the single socioeconomic factor all farmers agree affects their ability to hire labor as well as purchase farm inputs. The concomitant effect of a lack of purchasing power indirectly impacts productivity.

Pesticides

Pesticides are a group of chemicals made for the purpose of killing or otherwise deterring “pest” species. The word pesticide may refer to insecticides, herbicides, fungicides, or other pest control formulations. Pesticides are inherently toxic and often associated with adverse health effects in non-target organisms (US EPA, 2009). Pesticides can be classified by target organism, chemical structure and physical state. It can also be classed as inorganic, synthetic or biologicals (Tano, 2011) Examples of synthetic pesticides are organochlorine, carbamate, pyrethroid and organophosphate. The EPA (Ghana) has defined pesticides as “Any substance, mixtures of substances or other agents used to control, destroy or prevent damage by or protect something from a pest. The definition also includes chemical substances that are used to attract and repel pests as well as those used to regulate plant growth or remove leaves/coats (Dzobo, 2016).

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 (Boakye, 2012). There have been a rapid rise in the quantity of pesticides used in agriculture over the past decades (Sun, et al., 2012). Until the early 1980s, many chlorinated insecticides, mainly; aldrin, dieldrin, DDT, and lindane have been used in controlling pests of crops, vectors of some diseases and other aspects of public health in Ghana (UNEP, 2002). Some of these pesticides are still widely used by farmers because of their effectiveness and their broad-spectrum activity (Amoah et al., 2006).

Persistent Organic Pollutants (POPs) are organic chemical substances that are carbon-based and resist photochemical, biological and chemical degradation (Parimi, Meinke, French, Chandler & Siegfried, 2006). Persistent Organic Pollutants possess a particular combination of physical and chemical properties such that, once released into the environment, they remain intact for exceptionally long periods of time. They become widely distributed throughout the environment as a result of natural processes involving soil, water and, most notably, air; accumulate in the fatty tissue of living organisms including humans, and are found at higher concentrations at higher levels in the food chain; and are toxic to both humans and wildlife (UNEP- Stockholm Convention, 2001).

Pesticide residue is the residual number of active components of a particular pesticide or group of pesticides found in a commodity after the pesticide has accomplished the primary purpose of its application or the residual amount of a pesticide found in a product which has been in the area of the pesticide application (Quansah, 2015). When a pesticide product is applied on the field, the chemical is gradually lost as a result of breakdown, leaching and evaporation and the residue is the amount that remains after application (Matthews, 2008). While some pesticides have long residual activity and therefore persist in the environment, others have short residual activity, disappear from the environment or produce low residue concentration. Pesticide residues on crops are monitored with reference to maximum residue limits and are based on analysis of quantity of a given active ingredient remaining on food product samples.

Exposure and Effects of Pesticides Use on Humans and the Environment

Exposure is the contact over time and space between a person and one or more biological, chemical or physical agents (Kuppusamy et al., 2017). Types of exposures and their biological effects may be divided into two (Sarwar, 2015): High level, single exposure where signs and symptoms are acute and moderate and recurrent exposure in which there are no acute signs and symptoms but subtle symptoms at some unspecified time after exposure.

Low level but continuous exposure may lead to mutagenicity, carcinogenicity, impaired organ function, death or impaired reproductive function (Sarwar, 2015). Exposure transport media consist of air, water, soil, dust, food, product or items. Exposures includes eating contaminated food, breathing contaminated workplace air or touching contaminated surfaces. Routes of exposure comprise nasal (inhalation), integumentary or skin (dermal), mouth or oral (Ingestion) (Lorenz et al., 2012). Duration of an exposure could take quite some time, or occur generationally. Occupational exposure to pesticides in agricultural workplace occurs during the preparation and application of pesticides (Greitens & Day, 2007).

In general pesticides are toxic to non-target species including humans and animals and can result in negative health effects which may be short term or long term (Remoundou, Brennan, Hart & Frewer, 2014). The risk of exposure rises when farmers do not adhere to safety instructions on the proper use of the pesticides, Personal Protective Equipment (PPE) use and adapting sanitary practices (Damalas, Telidis, & Thanos, 2008). Dey Nepal (2010) found considerable proportion of respondents (25%) who consumed food while applying or spraying, which is a dangerous practice. Also, spraying in the wrong direction with respect to the wind could also facilitates high exposure.

Adverse health concerns that results due to exposure to pesticides varies according to the pesticide involved and the means of exposure, with the dermal route being the greatest, especially for sprayers (Khan, Mahmood, & Damalas, 2012). Pesticide exposure occur predominantly through the oral, dermal, the eyes and nasal (inhalation), through food or from the environment. Contact with pesticides has been associated with various health effects such as malignancies, neurodegenerative conditions and reproductive disorders (Hassan & Ahmad, 2014).

Sosan and Akin (2009), discovered that almost all the farmers in their study developed a distinctive symptoms of insecticide poisoning after each spraying task. These symptoms included severe headache (66%), dizziness (58%), body weakness or being unusually tired (55%), nausea (53%), restlessness (37%) and excessive sweating (41.3%), etc. In a study to show the effects of Neurotoxic pesticides on hearing loss, Gatto, Nookaew and Nielsen (2014) found that exposure to neurotoxic pesticides can cause damage to the central auditory system. Pesticide sprayers report greater signs and symptoms of exposure such as skin irritations, stomach poisoning and eye irritations than other farm workers (Atreya, 2007).

A study on 268 married male farmers in Iran showed that 68% of participants reported to their general consultants of suffering from burning and skin irritations, eye burn, headaches, vertigo, nausea and vomiting during spraying; about 6.3% had offspring with congenital abnormalities, 7% revealed compromised fertility rates after working for over 10 years as sprayers. Child bearing is a greater issue among the wives of these farmers (Neghab et al, 2014). Chronic disease such as diabetes, cardiovascular diseases (Hypertension), chronic respiratory diseases (e.g. asthma), chronic fatigue syndrome, systemic lupus erythematosus, rheumatoid arthritis, malignancies of all types, Alzheimer’s, reproductive disorders, parkinsonism, nephropathy congenital anomalies etc. are crucial circumstances affecting health of the farmers after exposure to pesticides (Khan et al., 2012). There is also proof relating reduced amount of semen to exposure to pesticides including damage to spermatogenesis (McDaniel et al., 2005). Again, male reproductive activity is prone sensitively to numerous artificial, physical and chemical agents produced by agricultural and industrial activities. Preparations of pesticides varies in captivation capacity for example emulsifiers are more voluntarily absorbed than others. Hence rate of dermal absorption differs depending on the part of the body involved.

Ethically, pesticides are released into the environment to alleviate certain targeted pests. Yet, a large amount of pesticide enters water bodies, air, sediments or food. These occur as a result of run-off after rains, escape tanks or spray drift. The airborne movement of agrochemicals onto non-target areas at or shortly after application either by air or ground level; with the potential of injury or damage to humans, animals, and plants or the environment (Gavrilescu, 2005). Pesticide deposits in air, water and foods have serious health consequences for the general public. Pesticides have been found in the air long even after use, leading to effect on humans, wildlife and biodiversity; they mount up and travel far.

Pesticide use has affected domestic animal, the loss of useful predators and parasites, residues in air, fishery and aquatic body losses, the deterioration of flora and fauna, accidental crop exposures, death of birds and honeybees and undesirable residue in food items tantamount to pesticides usage. It has been known that pesticide residues are the major contributor to the risk facing many rare species (Khan, 2016).

Farmers Knowledge, Attitude and Practices on the use of Pesticides

Knowledge, attitudes, and practices (KAP) surveys help recognize knowledge gaps, behavioral patterns, and commonly-held beliefs in order to increase understanding of issues and make clear targets and subjects for interventions that may address any combination of these factors (Lorenz et al, 2012). Knowledge, attitudes, and practices survey focusing on pesticide use has been conducted in several countries including Brazil, Ghana, South Africa, Egypt, and Thailand. In Ghana, although farmers have a high-risk perception with respect to hazards from pesticides, only 32% wear full PPE covering (Ntow, Gijzen, Kalderman, & Drechesel, 2006). A KAP study of farmers by Zyoud et al (2010) in the Palestine West Bank, showed that 98% of the participants were aware of the names of the pesticides they used on their farms. Good knowledge on pesticide information was significantly associated with secondary education level ($p < 0.001$), college education ($p<0.01$), working experience over 10 years ($p= 0.001$), using pesticides for more than 10 years ($p= 0.03$). However, poor knowledge was associated with primary education, $p<0.001$, but was not statistically significant with respect to age and gender. Earlier, they had hypothesized that good knowledge among farmers is associated with safe use of pesticides whiles reported symptoms are associated with unsafe pesticide use.

A KAP in Uganda also reported that, farmers on a small-scale basis often farm without taking proper precautions. Some farmers, even though had high knowledge levels on health effects, yet do not put them into consideration (Osterlund et al., 2014). Also, high illiteracy rates contribute to farmers making use of recommended guidelines as a problem (Remoundou, 2011). Atreya (2007) examined differences in gender on knowledge of pesticide use and practices in Nepal and found that female farmers had lower levels of education than male farmers, instructional labels were not valuable to them.

However, knowledge was not found to influence practices in Brazil because majority of farmers admitted receiving information and training from the government and claimed reading labels instructions and warning but do not take adequate protective measures. This was due to attitudes of participants as education level is low (Remoundou, 2014). Farmer education is therefore obligatory in the increase in knowledge in safety practices (Dey Nepal, 2010).

Disposal and Transportation of Pesticides

Pesticides containers pose a hazard to the environmental. A study in Greece found a common practice of discarding empty pesticide containers on fields, near, or into irrigation streams and canals, burning in open fire are well known practice of disposal farmers are involved in, coupled with using them for fuel storage, water and food storage (Haylamicheal & Dalvie, 2009). Some advanced countries have initiated disposal awareness by re -calling all outdated pesticides and sending them to treatment and disposal sites.

Another study in rural Greece reported that farmers re-sprayed excess pesticide until their tanks were empty, or sprayed it on any other crop listed on the container. Re-spraying excess mixtures have been said to be dangerous as it doubles the recommend quantities on the crops resulting to toxicity, remains in soil and harvested crops. Some farmers admitted discharging left over into nearby streams and irrigation canals. After rinsing they dispense the water into nearby uncultivated lands. The report also stated that, most containers were dumped on rubbish dumps. (Damalas et al., 2008).

Dalmalas et al. (2008) thought that, disposal of containers onto nearby fields, streams, canals is unsafe practice, totally burning will undoubtedly release other chemicals into the atmosphere and should be completely avoided. Pesticide wastes should be buried with the site chosen carefully to prevent contamination of surface water, runoff or groundwater. They therefore suggested that, pesticide wastes should be buried under at least 1/2 m of soil mixed with lime to enhance degradation. Matthews (2015) also suggested that, wastes should be added to the pit in layers not more than 10-15 cm deep and inter- mixed with lime and bio- degradable household waste, to contribute to biological degradation.

Proper handling should be considered in such a way to prevent spillage or leakage in a plastic material to hold the spillage in case of an accident. If transporting in the rear of a car or an open trunk they should be secured and the whole load covered. Passengers must also not share any compartment of the vehicle with pesticides, likewise groceries and food for animals (Hoppin, Umbach, London, Alavanja, & Sandler, 2002).

Storage of Pesticides, and use of Personal Protective Equipment.

Insecure practices are predominant among farmers and operators in developing countries. For example, in Egypt, almost all farmers stored pesticides in bedrooms; likewise, in Kenya and Palestine (Remoundou, 2014). A study on the occupational contact with insecticide and awareness of safety measures among cocoa farmers in southwestern Nigeria indicated that about 61% of the farmers stored pesticides in their homes, 31% had a separate store for pesticides, and 8% kept them on the farm (Dzobo, 2016).

In protecting pesticide, containers are made of materials that have the ability to endure the chemical. These containers are to be stored with their original labelling, including instructions on usage and discarding after use, names of the constituents, emergency information in case of accidents. It also includes temperatures at which the pesticides should be stored, since extremes temperatures can change the chemical structures of the product or damage the container (Oluwole & Cheke, 2009).

Sosan and Akingbohungbe (2009) study on the occupational insecticide contact and insight of safety actions among cocoa farmers in southwestern Nigeria showed that 44% of farmers wore overalls, 94% wore caps or hats, 28.7% wore rubber boots, and 9.3% wore cover shoes. Only 4.7% and 2.7% used hand gloves and eye goggles, respectively. Some of the farmers' habits during and after insecticide spraying operations discovered that a majority change clothing instantly afterward and wash their protective clothing after a pesticide application. More than half wash their clothes at the village stream, while others either wash their protective clothing at the village near a well.

Risk Assessment of Pesticides

Risk assessment has been defined as the process of depicting and enumerating possible adverse effects on humans and other species following contact to chemicals, heat, or other physical agents (Schwarzenbach & Gschwend, 2016). It is a tool for regulatory decision-making for risk management. Risk classification for humans involves assessment of the exposure or dose to the reference dose (RfD), the Acceptable Daily Intake (ADI), Tolerable Daily Intake (TDI), Provisional Tolerable Weekly Intake (PTWI) or the occupational exposure limit (OEL) in order to assess the likelihood that an effect will occur at any given exposure (Adejumo et al., 2014).

Risk assessment of pesticide impact on human and environmental health is not an easy and particularly accurate process because of differences in the periods and the levels of exposure, type of pesticides (regarding toxicity), mixtures or cocktails used in the field, and the geographic and meteorological characteristics of the agricultural areas where pesticides are applied (André Luiz, Gliseida, Mariana & Marcia 2011; Beesley, Jiménez & Eyles, 2010). Such differences refer mainly to the people who prepare the mixtures in the field, the pesticide sprayers, and also the population that lives near the sprayed areas, pesticide storage facilities, greenhouses, or open fields. Therefore, considering that human and environmental health risk is a function of pesticide toxicity and exposure, 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 dietary exposure of the general population to pesticide residues found on food and drinking water consists of a potential threat to human health, is still the subject of great scientific controversy (Cox, Babayev, & Huber, 2005). Regardless of the difficulties in assessing risks of pesticide use, there is the need for it to be done and this has led to the discovering of some scientific models for assessment risk with respect to pesticide use.

Valuation of risks to inadvertent species in the environment is accomplished using tools and models that incorporate pesticide behavior characteristics under various environmental conditions to come up with Predicted Environmental (or effect) Concentrations (PECs) for every environmental compartment (Adejumo et al., 2014). The PECs are compared with Predicted No Effect Concentrations (PNECs) in order to assess the possibility that an effect will occur at a particular exposure. The PECs of a particular pesticide depend on interactive features of that pesticide. The features of the pesticide, that is, hydrolysis, photolysis (water/soil), metabolism in soil (aerobic/anaerobic), mobility in soil (laboratory and field leaching), soil adsorption (Kd), volatility, ionization, bioaccumulation, water solubility, octanol/water partition coefficient (Kow), biodegradability, and so on determines its environmental fate (Melero, Madejon, Herencia & Ruiz., 2008). The PNECs are derived from the No Observed Effect Concentration, NOECs and Lowest Observed Effect Concentration, LOECs and LC50 values (OECD, 1992).

Environmental Impact Assessment and Pesticide Risk Indicators

Pesticide risk indicators are commonly used to assess potential environmental effects based on inputs such as active ingredient, use rate, toxicity information, and non-target effects (Greitens & Day, 2007). There are numerous environmental impact valuation and pesticide risk indicators in literature, these indicators guide farmers and policy makers to compare the environmental impact of different pesticides and to design effective pest control practices with minimum environmental impacts (Paintsil, 2017). Although there are several uncertainties in the capacity of these indicators to estimate pesticide toxicity to non-target organisms and other environmental outcomes, they provide valuable information when compared to costly environmental media sampling and monitoring for pesticides.

Many pesticide indicators are considered using only toxicological data and physicochemical characteristics without any consideration of exposure. Some examples of risk indicators include risk index, bioconcentration factor, risk index persistence, groundwater ubiquity score, and Hasse diagram

(Muhammetoglu, Durmaz, & Uslu, 2010). Generally, these indicators provide facts about the environmental hazard of pesticide use on a solitary compartment. Some indicators, such as hectare doses, frequency of application and Environmental Impact Quotient (EIQ) can be used globally to evaluate environmental risk on a broader perception. Pesticide risk indicators may be segmented into effects on humans, flora and fauna. To assess the risk of pesticide application at a wider level, several indicators are combined to form pesticide impact assessment systems. Some well-known examples of pesticide assessment systems include SyPEP, EYP, EIQ, SYNOPS, p-EMA, Ipest, EPRIP, and Pesticide Environmental Risk Indicator (PERI) (Adejumo et al., 2014).

The Environmental Impact Quotient (EIQ) Model

The EIQ was established to quantify the environmental influences of pesticide active ingredients used in vegetable and fruit production (Kovach et al., 1992). In this model, the potential impact of a particular pesticide is equivalent to the product of the toxicity of the pesticide and the potential for exposure. There are three principal components in this model:

1. Farm worker-based on applicators and pickers
2. Consumer-based on chronic toxicity, soil half-life, plant surface residue half-life, ability to be absorbed by plants and groundwater leaching potential, and
3. Non-human biota-based on aquatic organisms, birds, bees and beneficial arthropods.

Each component is given equal weight but individual factors within components are weighted differently (Kovach et al., 1992). The equation for determination of the EIQ for individual pesticides presented in following text is the average of the farm worker, consumer, and ecological components.

$$EIQ = (EI_{farmworker} + EI_{consumer} + EI_{nonhuman\ biota})/3$$

Once an EIQ value has been established for the active ingredient of a pesticide, the EIQ score can be turned into a field-use rating to compare environmental impacts of different pesticides and pest management strategies. The Environmental Impact Quotient (EIQ) proposed by Kovach et al., has frequently been used to compare the potential environmental effects of pesticides. The EIQ model summarizes all pesticides used during the season, thus giving a total score for the environmental load (Kovach et al., 1992). In a study conducted by (Adejumo et al., 2014) to assess environmental load of pesticides used in conventional sugarcane production in Malawi, EIQ model was to identify pest management with low environmental impact. The EIQ model was also used to evaluate the pesticides that are harmful to honeybees, fishes and aquatic life (about 73% of pesticides used by farmers in the study area). Painstil (2017), also used the EIQ model to assess pesticide risk in Bodi in the western region of Ghana. The EIQ model was able to predict ecology as the compartment most likely to be at risk due to pesticides use in the study area. As it becomes necessary to assess the risk of pesticide use on the ecosystem, it is also essential to understand the nature and behavior of these chemicals in soils so that adequate measures can be sought on how they can be cleaned up.

EIQ Related Issues

The use of indicators to describe pesticide environmental impact is advantageous for practitioners because a large amount of quantitative information can be summarized into a manageable form. In the case of the EIQ, an attempt was made to combine a large amount of risk and toxicity data into a single number, with high numbers representing greater risk. Combining such a large amount of quantitative data into a single qualitative value necessarily eliminates valuable information (Greitens & Day, 2007). The accuracy of such a method is, therefore, highly dependent on the underlying assumptions and mathematical combination of the data (Peterson & Schleier, 2014).

Several previous criticisms of the EIQ have noted problems with scaling and weighting of quantitative risk information; risks that differ by orders of magnitude can receive the same qualitative rating (Cox et al., 2005). Likewise, the scaling of quantitative information can result in a higher qualitative risk being assigned to pesticides with lower quantitative risk. In a previous criticism of the EIQ, Peterson and Schleier (2014) suggested that the EIQ “does not properly incorporate exposure.” The EIQ does, in fact, include several components that are meant to serve as proxies for exposure, such as plant surface half-life, runoff potential, and leaching potential. For example, fish toxicity is multiplied by surface runoff potential in the EIQ formula. While these factors certainly influence exposure potential, they are not actually estimating of potential exposure. Additionally, assigning a discrete score to risk implies there is no uncertainty of exposure or toxicity, and this cannot be ignored because the discrete ratings used in the EIQ are surrogates for probability of exposure and toxicity (Peterson & Schleier 2014).

One problem that the EIQ has been purported to solve is the simple reporting of weight of applied pesticide as an environmental indicator.

Certainly, a simple accounting of the amount of pesticides applied (Benbrook, 2012) has serious shortcomings when toxicity, potential exposure, and persistence data are ignored. Previous authors have found that the Field EIQ strongly correlated with the amount of pesticide applied (Greitens & Day, 2007). Greitens and Day (2007) included only 3 herbicides in their analysis, which mostly focused on insecticides and fungicides. If the Field EIQ is largely a reflection of use rate for herbicides, it may not be a significant improvement over simply reporting the amount of pesticide applied. It is, therefore, important to determine how much of the Field EIQ can be explained by herbicide use rate. None of the previously cited criticisms and analyses of the EIQ have specifically focused on herbicides. The Field EIQ continues to be used in the weed science literature to compare herbicide applications, particularly as they relate to herbicide-resistant crops and weeds (Beckie, Sikkema, Soltani, Blackshaw & Johnson, 2014; Green, 2012).

When the EIQ is used, some acknowledgement of its limitations is often included; however, because of the way it is calculated the EIQ may be more poorly suited for comparing herbicides than for other pesticide groups. For herbicides, there are two notable irregularities when calculating the EIQ. Systemicity Risk factor is defined by Kovach et al., 1992 is “the pesticide’s ability to be absorbed by plants.” All herbicides have the ability to be absorbed by plants to some extent, and systemic herbicides may translocate throughout the plant. The Systemicity Risk factor is always assigned a value of 1 for herbicides, and therefore, does not contribute to herbicide EIQ values. It is unclear why Systemicity Risk factor was considered important for other types of pesticides but effectively removed from the EIQ calculation for herbicides.

Persistent of Pesticide in Soil

The total quantity and form of a pesticide reaching soils often depends on the location and the formulation of the pesticide (Hassan & Ahmad, 2014). With respect to site of application pesticides can react with a wide variety of materials, and this relationship has a considerable impact on the persistence of these chemicals. The adsorption and absorption of pesticides depends mainly on their molecular polarity. Different sizes of soil fractions vary in their ability to adsorb or absorb pesticides, hence the site to which a pesticide is applied impact on its persistence very much. The organic matter content present in the soil can voluntarily adsorb pesticides (Khorram, et, al., 2016).

The process of pesticides formulation considerably influences its persistence. Granules and microcapsules are precisely designed to delay discharge and breakdown of the pesticide. In soils, the rate of adsorption on to various soil segments, mainly the organic matter, is inversely related to the particle size of the pesticides in the formulation (Kumi & Daymond, 2015). Although water-soluble compositions are not persistent in soils, as they can be effortlessly leached away, emulsions tend to persist longer than wet table powders or dusts, because they are easily adsorbed on to soil fractions and so not appreciably degraded (Hassan & Ahmad, 2014).

Besides, the persistence of pesticides in soil is noticeably influenced by some soil factors which include the type of soil to which they are applied, and particularly by soil characteristics such as particle size, mineral and organic content and hydrogen ion concentration. Their residual life also depends upon the biological activity of the soil, since the breakdown patterns of many pesticides are mediated by enzymes.

Biochar

Biochar is a carbon rich, solid by-product resulting from the pyrolysis of biomass under oxygen-free and low temperature conditions (Adejumo et al., 2014). Biochar’s proven ability to remain stable against chemical and biological degradation, when applied to soils, makes it a pioneer means of removing pollutants from soil (Lehmann et al., 2011). Thus, biochar has the potential to restore and remediate contaminated soils as it can adsorb both organic and inorganic pollutants. Pollutants in soil are expected to expressively be immobilized with the application of biochar in soil and afterwards decrease their availability to ground water and crops.

A remarkable decrease in dissipation of two pesticides in agricultural soil was reported by Yang et al consequently pronounced decreases in pesticide uptake by plants. (Yang, et al., 2010). The retention capability of biochar for contaminants was related to the sorption capability, which varied significantly depending on the biomass feedstock and pyrolysis conditions (Keiluweit, Nico, Johnson & Kleber, 2010). Ahmed, Lee, & Lim (2014) also reported that, large surface area of biochar and the pore volume make it efficient for sorption of contaminants.

Of the many kinds of adsorbents (filamentous fungi, sea materials, industrial waste, agricultural products, natural residues, sawdust, weeds, soil and ore materials) investigated for their potential to retain pesticide molecules, low cost adsorbents have proven to be efficient and economical in the removal of inorganic and organic pollutants from aqueous solution.

Recently, there is a notable trend there the development of activated carbon or biochar from low cost adsorbents for its superior ability to remove a broad type of agrochemical pollutants dissolved in aqueous media. Biochar has structure and properties similar to activated carbon (AC), but the surface area of activated carbon is much larger and varies from a few hundred to thousands of m^2/g. The production of biochar is economical compared to AC because of the low energy operation process without activation (Adejumo, et al., 2014).

Njoku, Foo, Asif, and Hameed (2014) investigated sky fruit husk activated carbon (SFHAC) as adsorbent for the removal of herbicide bentazone. According to their studies SFHAC was a very promising adsorbent with large active surface area. Isotherm studies showed that the data were well fitted to Freundlich model, indicating a heterogeneous surface structure. It was also observed that the bentazone adsorbed by SFHAC decrease with increasing solution pH. Rojas et al. (2014) used sunflower seed shells, rice husk, composted sewage sludge and soil to remove atrazine, alachlor, endosulfan sulfate and trifluralin molecules from aqueous solution. The study revealed that the maximum removal efficiency (73.9%) was reached using 1 g of rice husk and 50 mL of pesticide solution (200 $\mu g\ L^{-1}$). A pseudo first order model was found to be more suitable for the sorption of atrazine and alachlor while the pseudo second order best described endosulfan sulfate and trifluralin adsorption.

Mohammad (2013) investigated the role of apricot stone activated carbon. The monolayer sorption capacity of the adsorbent was found to be 20.04 mg^{-1} using Langmuir equation. The kinetic data were best described by the pseudo-second order model. The adsorption process was spontaneous and endothermic in nature. Chang et al. (2011) reported the effectiveness and feasibility of rice straw activated carbon as a low-cost adsorbent for removing carbofuran from aqueous solution. The effects of several parameters such us contact time, pH, temperature and the biosorbent dosage were studied. Adsorption capacity of carbofuran increased with increase in carbofuran concentration but decreased with increase in pH and temperature.

Huguenot et al. (2010) have tested the biosorption potential of sugar beet pulp, corncob, corncob char, perlite, vermiculite, sand and sediment for effective removal of glyphosate, diuron and 3,4-dichloroaniline (3,4-DCA) as single or mixed compounds. The major result to as that sugar beet pulp and sand require no preliminary treatment for diuron and 3,4-DCA removed , and were able to retain more than 50% of the corresponding pollutant studied. Another finding is that the interactions between herbicides led to significant differences in their sorption when tested in mixtures. The authors concluded that further investigations are required on a larger scale to test the accuracy of these low-cost sorbents in field conditions.

The efficiency of corn cob, olive kernels, soya stalks and rape seed stalks- Activated Carbon (AC) for the recovery of acaricide bromopropylat have been studied by Ioannidou, Zabaniotou, Stavropoulos, Islam and Albanis (2010). The kinetic analysis showed that pseudo second order model applicable to all samples, while the equilibrium study showed that the Langmuir model is best fitted the isotherms. The AC with the higher adsorption capacity for bromopropylate was proven to be corn cob, then olive kernel and soya stalk, while rapeseed stalks gave the lower results for the specific application.

Tartakova, Hiller and Vaculík (2013) applied biochar prepared from wheat straw (Triticum aestivum L.) with addition to agricultural soils to increase sorption of (4-chloro-2-methylphenoxy)acetic acid (MCPA) and other related processes such as leaching, dissipation and toxicity to sunflowers. Enhanced sorption of MCPA in the biocharamended soil resulted in a significant decrease in its leachability in soil columns as well as its dissipation in soil. However, the phytotoxic effects of MCPA on sunflowers remained unchanged when soil was amended by wheat straw biochar.

Charcoal as an Adsorbent

Carbon usage prolongs far back into history. Charcoal was used for drinking water filtration by ancient Hindus in India, and carbonized wood was a medical adsorbent and cleansing agent in Egypt around 1500 BC. Among all the adsorbent materials suggested in the 21st century, activated carbon is the most common one for the removal of contaminants from wastewater (Bello, Adegoke, Olaniyan, & Abdulazeez, 2015).

Charcoal is prepared by pyrolysis (or also called carbonization), which includes heating the source materials to temperatures extending between 600 and 900°C (Downie, Crosky, & Munroe, 2009). This process eliminates most non-carbon elements such as hydrogen, nitrogen, oxygen, and sulfur as volatile gaseous products. Low molecular weight volatiles are first released, followed by light aromatic volatiles and finally the hydrogen gas. The resultant product is a fixed carbonaceous char. The residual carbon atoms are grouped into condensed sheets of aromatic ring with a cross-linked structure in a random manner (Rangari, & Chavan, 2017). The mutual arrangement of these aromatic sheets is irregular and allows for free interstices between the sheets, which may be filled with tarry materials.

Any carbonaceous materials (animal, plant, or mineral origin) with a high concentration of carbon can be transformed into activated carbon (using either chemical or gas activation methods). The most common raw materials used are wood, nut shells, fruit pits, brown and bituminous coals, lignite, peat, bone, paper mill waste (lignin) and synthetic polymers (e.g., PVC). Activated carbon obtained from hard wood is preferable for adsorption because charcoal obtained from soft wood, such as pinewood, is very unstable and readily crumbles. The chemical properties of the adsorbent (e.g., activated carbon) are also very important for adsorption. Activated carbon is advantageous for the adsorption because of its large porous surface area, controllable pore structure, thermo-stability, and low acid–base reactivity have been established in terms of its versatility for the removal of different types of contaminants dissolved in aqueous media (Carlsson, Andrén, Stenström, Kirchmann & Kätterer 2012).

Adsorption by biochar greatly depends on the porous structure and surface functional groups of the activated carbon. In addition, activated charcoal is classified based on its surface characteristics, behavior, and preparation methods, that is, powdered, granular, extruded, impregnated, polymers coated or pellet-activated charcoal (Bello et al., 2015). Activated charcoal from various natural bio-waste have been prepared and used for removing various dyes. The maximum sorption capacity was found to be 101.57, 50.31, and 39.32 mg/g for charcoal prepared using groundnut shell, caw dung, and bagasse respectively (Santhi, Manonmani, & Smitha, 2010).

Therefore, charcoal addition to soil can improve soil properties and have other environmental benefits. Glaser, Lehmann & Zech (2002) concluded that charcoal could improve nutrient-retention capacity and increase soil fertility. The improved nutrient retention may also lead to less nutrient leaching. Chan, Van Zwieten, Meszaros, and Joseph (2007) observed greater water holding capacity after charcoal addition. Charcoal usually increases soil pH because it contains some ash, which can act as a liming agent.

Rice Husk Biochar as an Adsorbent

Rice husk biochar processed from pyrolysis of rice husk is considered to be one of the most cost-effective biochars for use as amendment (Ogawa & Okimori, 2010). Rice husk is generated at rice processing facilities as a by-product after collecting, drying, and dehulling rice. These waste materials have little or no economic value and often pose great disposal problems, therefore, these waste materials are used in treated and untreated forms for the removal of various contaminations. (Ola, Ahmed-Nemr, Amany-Sikaily, & Khaled, 2005)

Rice husk has been recommended as one of the most ideal raw ingredients for biochar because it can be chemically activated to remove direct Scarlet dye (Katheresan, Kansedo, & Lau, 2018). The exploitation of rice husk as an amendment for soil can be a feasible and sustainable choice. Roughly three million tons of rice husk, equivalent to 24% of brown rice weight (Ogawa, Takeuchi & Katayama, 2009), is annually produced in Japan alone. Through the expansion of modern bioenergy technologies, the connection of bioenergy production from rice husk and the usage of rice husk biochar soil remediation has a prospective to offer environmental and agronomic benefits in a sustainable manner (Shackley et al., 2012).

In summary, literature has been reviewed on the concept of pesticides use among cocoa farmers, pesticide risk indicators, transport of pesticides and removal of pesticides by adsorbents. Furthermore, the use of EIQ model, rice husk biochar and charcoal as amendments where explored to justify their use in this study.

CHAPTER THREE

MATERIALS AND METHODS

This chapter describes the research design and methods adopted to achieve the objectives of the study.

Study Area

The study was conducted in the Western Region of Ghana which has an approximate land cover of 23,921 km^2, constituting about 10% of Ghana's total land mass and 10% of its human resource. Ghana Cocoa Board Authority shows Western Region as the leading producers of cocoa since 1984- 2017 (Ghana Cocoa Board, 2018). The region receives the highest amount of precipitation nationwide and has almost 75% of its vegetation interspersed with the high forest zone of Ghana. As much as 44% of the total closed forest of the country is located within this region, hence, its high relevance when biodiversity and conservation are being considered (Painstil, 2017).

The natural vegetation of these areas is wet evergreen rainforest. The areas fall within the rain forest belt with the height of trees ranging between 15-40 m. The vegetative cover of the region is a moist semi-deciduous forest type with a three-canopy layer (Paintsil, 2017). These forests are full of climbers and lianas, which are able to reach the upper tree layer. The vegetation in these district has a high species richness. Some of the economic trees species include; Wawa (*Triplochiton scleroxylon*), Ofram (*Terminalia superba*), Onyina, (*Ceiba pentandra*), kyenkyen (*Antiaris toxicaria*), Odum (*Milicia excelsa*), Edinam (*Entandrophragma angolense*), and Esa (*Celtis mildbraedii*) (Aram, 2017).

About 70% of the working population in the region are engaged in agriculture especially cocoa production. The rest of the labour force is distributed into commerce (18%), services (5%), and industry (2%). Seventy-five percent (75%) of workers aged 18 years and above are considered self-employed (Ntow, et al., 2006).

Map of the Study Area

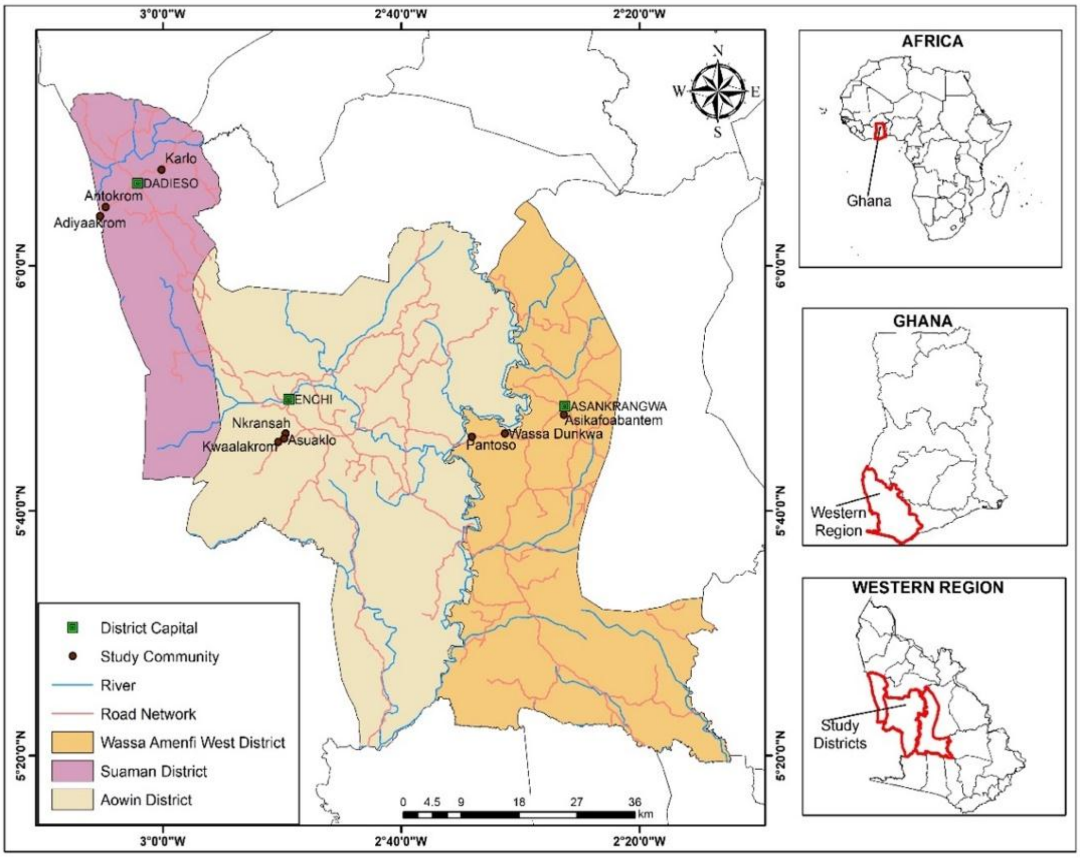

Figure 1: Map showing the Study Area**.**

Aowin Municipal

The Aowin Municipal is one of the 260 Metropolitan, Municipal and District Assemblies (MMDAs) in Ghana, and forms part of the 9 of MMDAs in the Western North Region with the administrative capital as Enchi (Ghana Statistical Service (GSS), 2014). This Municipal is located in the mid-western part of the Western Region of Ghana between latitude five degrees, twenty-five minutes and six degrees fourteen minutes North (5° 25' N and 6° 14' N) and longitude two degrees thirty minutes and three degrees five minutes West (2° 30'W and 3° 05'W). It covers a total land area of 2,610.301 square kilometres. The District shares borders with Amenfi West Municipal to the east, Juaboso and Sefwi Akontombra Districts to the north, Jomoro Municipal to the south and the Republic of La Cote d'Ivoire to the west. The population of the Municipality according to 2010 population and housing census stands at 117,886 with 61,262 males and 56,624 females (Ghana statistical service (GSS), 2014).

The District experiences two rainfall seasons. The major rains start from April to July and the minor from September to mid-November. Annual rainfall ranges from 1500 mm to1700 mm. Relative humidity is high during the major rainy season reaching its peak of 90% between May and June. Maximum temperature of 30°C is experienced between March and April with mean monthly temperature of about 27°C (Andah, Van De Giesen, Huber-Lee & Biney, 2004).

Suaman Municipal

Suaman is located in the Western Region of Ghana with the administrative capital as Dadeiso. The district covers an area of 400.14 sq km and shares boundaries with Juaboso and Bodi districts to the north, the Aowin district to the south, Sefwi Akontombra district to the east and Cote d'Ivoire to the west. From 2010 national population census, the district has a total population of 20,529, representing 4.5% of the Western region's population. The district is located in the forest belt. It receives nine months of rainfall with peaks in May and June. The annual average rainfall of the region is between

1500 mm and 1800 mm while temperatures range between 28°C and 37°C. The highest temperatures are recorded between February and March while the lowest is in August (Ghana statistical service (GSS), 2014). The district has a good drainage pattern which enhances the fertility of the soils for the production of both food and cash crops.

Economically, 72.3% of the entire district population are in economically active age (15 years and above) of which 95.7% are employed. The largest employer (94.1%) is the private informal sector. Cocoa production is the major economic activity of the people in the district with about 65–70% of the vegetation cover being cocoa plantations. This has affected land allocation for the production of other food crops (Ehiakpor, Danso-Abbeam & Baah, 2016)

Wassa Amenfi West Municipal

The Wassa Amenfi West was established under the Legislative Instrument 1757 in 2004 with the administrative capital as Asankrangwa. Amenfi West Municipal is located between Latitude 400’N and 500 40’N and Longitudes 10 45’ W and 20 10’W and it has a total land area of 1,448.56 square kilometres.

The Municipality is bounded to the west by Sefwi-Akontombra District and Aowin Municipal, the south by Jomoro Municipal, Ellembelle District and Nzema East Municipal, and the east by Prestea Huni Valley Municipal and Amenfi Central District (Ghana statistical service (GSS), 2014). The projected population for 2017 was 115,242 with males dominating by 50.5% using an annual growth rate of 2%. The major occupation of the people is farming and trading in farm produce. The topography of the

Municipality is generally undulating with summits averaging 153 metres above sea level (500ft). Three types of vegetation cover are found in the Amenfi West Municipality. These are the semi-deciduous forest found in the northern part, the tropical rainforest to the south where rainfall is heaviest and the transitional zone situated between the two. The Municipality has forest reserves covering a total area of 64,242.81 hectares, which include Bura, Angoben and Totua Forest reserves (Opoku, Frimpong, & Appiah, 2004).

Assessment of Farmers Knowledge on Pesticides Application on Cocoa Farms in the Study Area.

Sampling Procedure

For the purposes of assessing risk of pesticides use, descriptive survey using multi-stage sampling was employed as the sampling technique for this study (Okoffo, Mensah & Fosu-Mensah, 2016). The multi-stage sampling employed in this study entailed four (4) stages. In the first stage, the Western Region of Ghana was purposively selected due to the high production of cocoa in the region. In the second stage, Aowin, Suaman and Wassa Amenfi West districts which are known to be some of the major cocoa growing areas in the Western Region were randomly selected out of the several cocoa producing districts in the Region. In the third stage, three (3) major cocoa growing communities were randomly selected from a list of cocoa producing communities in the districts selected, namely; Suaman district: Antokrom, Karlo and Adiyaakrom; Aowin district: Asuaklo, Nkransah, Kwaalakrom; and Wassa Amenfi West district: Pantoso, Asikafoabentem, Wassa Dunkwa. In the final stage, twenty- five (25) cocoa farmers were randomly selected from each of the three selected cocoa growing communities. A total of 225 cocoa farmers were randomly sampled for the study. That is, [3 districts × 3 communities × 25 farmers] = 225 farmers.

Data Collection Instrument

A questionnaire was adapted from Paintsil (2017), details can be found at the appendix A. However, a brief description has been provided here. The questionnaire was divided into five (5) main sections. **Section A**, considered the demographics and form related characteristics namely sex, age, occupation, education level, household size, the number of household members below the age of 18, the age of farm and size of the farm. **Section B**, consisted of information related to knowledge of pesticides, names of known pesticides, forbidden known pesticides, knowledge of routes of exposure and transfer in the environment. **Section C**, involved information on the pesticide use patterns (a table containing pesticide name, active ingredient, amount per application per area, application interval and application equipment; this information was complemented with information on pesticide properties and reference values from databases associated with models), the reason for using pesticides, the source of pesticides used, common crop pests and diseases, types of pesticides used, the source of knowledge of the application, factors that influence application times. **Section D**, considered their attitudes towards pesticide use and whether they agreed or disagreed with some issues. These included; having adequate knowledge before handling chemicals is necessary, health risks associated with chemical use are minimal, precautions must be adhered to during pesticide application, chemicals help secure good crops, chemical use should be limited to safeguard the environment. Finally, **Section E**, involved protective measures adopted during pesticide application. The quantities of pesticides they administered and the intervals were recorded, reasons why the applied chemicals on farms as well as what influenced spraying periods were collected. The duration for distribution of questionnaire was in 5 working days.

Main Determinants

The main variables of interest include (i) knowledge on the effects of pesticides on human health and environment, (ii) protection and safety practices and (iii) health symptoms experienced after spraying (headache, burning eyes, skin rash, itching and chest pain). For knowledge of the effect of pesticide on human health and environment farmers answered questions on whether pesticide use/exposure has effect on health, whether the use of pesticide affect the soil, whether pesticide affects the surrounding river, whether they are aware that pesticide affect the natural environment and whether they are aware that pesticide can remain in the soil for a long time. Questions on protection and safety inquired whether they used the following Personal Protective Equipment (PPE) while spraying: boots, hat, nose mask, gloves, overalls, and goggles.

Calculation of Risk of Pesticides Application using EIQ Model.

The method of Environmental Impact Quotient (EIQ) (Kovach et al. 1992) was used in this work to assess the environmental loading of the commonly used pesticides in cocoa production in the study areas.

Section C of the questionnaire which had information on the pesticide use patterns (a table containing pesticide name, active ingredient, amount per application per area, application interval and application equipment; this information was complemented with information on pesticide properties and reference values from databases associated with models) was employed in the EIQ assessment. The EIQ model summarizes all pesticides used during the season, thus giving a total score for the environmental load (Kovach et al., 1992). Pesticide data: active ingredients (A.I.) quantity (in grams, g), application rates (g.a.i.) per hectare (ha) obtained from the questionnaire survey was entered into the EIQ model. Individual farmer application information collected in the questionnaires (Section C; Q.32) in cycle with required information on pesticide data sheets were used in calculations. The EIQ value is the average of the farm worker, consumer, and ecological components. The equations of the different components are given as (variables and explained in Table 1):

EI farmworker = $C\,[(DT \ast 5) + (DT \ast P)$ …………………………..……… (Eqn.1)

EI consumer = $(C \ast ((S+P)/2 \ast SY) + (L)$ ……………….……………….. (Eqn.2)

EI ecology = $(F \ast R) + (D \ast ((S+P/2) \ast 3+(B \ast P \ast 5)$ ……………………... (Eqn.3)

$EIQ=\{[C(DT \ast 5)+(DT \ast P)]+[(C \ast ((S+P)/2 \ast SY)+(L)]+[(F \ast R)+(D \ast ((S+P/2) \ast 3+(B \ast P \ast 5)]\}/3$ ……………………………………………………………..(Eqn.4)

Table 1-Symbols for Variables in Equations 1, 2, 3, and 4

Elements	Symbols
Bird Toxicity	D
Dermal Toxicity	DT
Chronic Toxicity	C
Mode of Action	SY
Fish Toxicity	F
Leaching Potential	L
Surface Loss Potential	R
Soil Half-Life	S
Bee Toxicity	Z
Beneficial Arthropod Toxicity	B
Plant Surface Half-Life	P

All calculations of the EIQ were done using Cornell University's online EIQ calculator (NYSIPM, 2017). EIQ Field use rating is also employed in this risk calculation to provide an accurate comparison of pesticides and pest management strategies. This equation is given as shown in Eqn.5:

EIQ F.U.= EIQ $*$%active ingredient (AI)$*$application rate (R) kg/ha…(Eqn. 5)

Total impacts from all pesticides applied in a growing season was estimated by summing up the product of individual EIQ Field use rating and application frequency, using the equation 5, 6 and 7:

$$\text{Field Total EI} = \sum [\text{EIQ F. U.} * Application\ frequency] \ldots\ldots\ldots\ldots \text{(Eqn. 6)}$$

$$\text{Field Total EI} = \sum [\text{EIQ} * \%\ \text{Active Ingredient (AI)} * \text{application rate } (R) * Application\ frequency] \ldots\ldots\ldots\ldots \text{(Eqn. 7)}$$

Determination of the sorption capability of pesticide by Rice husk biochar and Charcoal.

This part of the research experiment work basically depends on determination of the concentrations of Imidacloprid in soils with respect to time. Imidacloprid was selected for this study because it is one of the frequently used insecticide on cocoa production in the study area. Pesticide standard was obtained from The Ghana Standard Board Authority. Solvent used (HPLC Standard) were purchased from Merck (Darmstadt, Germany). Leachates collected from soil columns were analyzed by UV spectrophotometer (Shimadzu UV 1601) and High-Performance Liquid Chromatography (Shimadzu LC-20 AD HPLC).

Insecticide used

Imidacloprid, commonly called Confidor; N-[1-[(6-chloropyridin-3-yl)methyl]-4,5-dihydroimidazol-2-yl]nitramide, density of 1.54 g/cm^3, molecular formula; $C_9H_{10}ClN_5O_2$, molecular weight of 255.662g/mol, and a colorless crystal solid. It has a melting point of 144 °C, solubility in water is 31.7 [ug/mL] at 20 °C. It has Vapor Pressure of $4X10^{-7}$ mPa ($3X10^{-12}$ mm Hg) at 20°C; $9X10^{-7}$ mPa ($7X10^{-12}$ mm Hg) at 25 °C and Log $_{Kow}$ is 0.57 at 21° C. It is stable under recommended storage conditions and stable to hydrolysis at pH 5-11 (Yola, Eren, & Atar, 2015; Tomlin CDS, 2005).

Soil and Amendment Collection

Soils were obtained from Wassa Amenfi West and Suaman. In Wassa Amenfi West district, soil was taken at coordinates; N 05° 46.364", W O2° 31.995" and named soil 1 (S1). Likewise, Soil was taken from the Suaman district at coordinates; N 06° 04' 54.5", W 003° 04' 48.9" and was also named soil 2 (S2). These soils were selected because of their exposure to pesticides over a long period of time. Random samples were taken from the top layer (A-horizon) to a maximum depth of 1 - 30 cm and were thoroughly mixed to yield a composite sample. The rice husk biochar used was obtained from Soil Research Institute, Centre for Scientific and Industrial Research (CSIR) in Kumasi - Ashanti Region. Charcoal was obtained from the open market (feedstock – Acacia; 300°C). The soils and adsorbents were air-dried at room temperature (between 20-25°C) and sieved through a 2 mm stainless steel screen. Soil pH, moisture content, organic carbon content and particle size distribution were determined using the following procedures.

Soil and Amendment Characterization

pH determination

Twenty grams (20 g) of air dry soil (passed through 2 mm sieve) was weighed into a 50ml beaker. 20 ml of distilled water was added to the soil and allowed to stand for 30 minutes. This was stirred occasionally with a glass rod. Standardized pH meter with electrode was inserted into the partly settled suspension and the pH was measured. Soil pH measures in water was then reported.

Moisture Content (MC) determination

An empty beaker was weighed to determine it's mass (M1). The beaker was then filled with the fresh soil sample. Then Beaker and it's content was then weighed to determine the mass of beaker and content (M2). The beaker together with it's content was then oven-dried at 105 degree Celsius till a constant dry weight (M3) was obtained. The percentage moisture content was then estimated as follows:

$$\%MC = \frac{\text{(Weight of fresh soil - Wt of oven-dried soil)}}{\text{(Weight of oven-dried soil)}} \times 100$$

But, Weight of fresh soil sample = M2-M1

Weight of oven-dried sample = M3-M1

Determination of Cation Exchange Capacity

(Five grams) 5 g of soil sample was weighed and transferred into a 50 ml centrifuge tube. Then 2. 25 ml of 1.0 M sodium acetate solution was added and the tube screwed and kept in a mechanical shaker for 5 minutes. The sample was then place in a centrifuge at 2000 rmp for 5minutes or more, until the supernatant liquid is clear. The liquid is decanted completely and the extraction was repeated three more times and decants discarded. Steps 2-4 were repeated with ethanol until the Electrical Conductivity of the decant read less than 40 ms/cm. Steps 2-4 were repeated using ammonium acetate solution to displace the adsorbed Na. The decant was collected into a 100ml volumetric flask fitted with a funnel and filter paper. The volume was made up with the ammonium acetate solution. The Na concentration was determined with the flame photometer. Series of Na standards solutions ranging from 0 – 10 meq/litre of Na were prepared.

A standard curve was made by plotting Na concentration on the X-axis and the flame photometric readings on the Y-axis. The sample extracts were aspirated into the flame photometer and the readings recorded, corresponding to which the concentration of Na is read from the standard curve. Lithium Chloride (LiCl) was added to each standard to yield a final concentration of about 5 meq/litre of LiCl .

Calculation

$$\text{The exchangeable Na in} \frac{\text{meq}}{\text{100gsoil}}$$

$$= \frac{\text{Na conc. of extract in} \frac{\text{meq}}{\text{litre}}}{Weight\ of\ Soil}$$

$$\times \frac{\text{100 x vol. of extract (100meq)}}{1000}$$

$$= \frac{y \times 10}{\text{Weight of soil}}$$

The displaced Na is actually a measure of the CEC of the soil. Therefore, the meq Na/100g soil is meq exchangeable cations (Ca, Mg, Na and K)/100 soil.

Organic Carbon Content Determination

The organic carbon content of the soil was determined using the Walkley- Black (1934) method. This involves a wet combustion of the organic matter with a mixture of potassium dichromate and sulphuric acid. After the reaction, the excess dichromate was titrated against ferrous sulphate. Half gram (0.5 g) of soil samples was weighed in duplicates and transferred in to 500 ml Erlenmeyer flask, a blank was also included and the weights were recorded. By means of pipette, 10 ml of 0.167 M potassium dichromate ($K_2Cr_2O_7$) was added to the soil and was gently swirled. Twenty milliliter (20 ml) of concentrated H_2SO_4 was also added and the flask was allowed to stand for 30 minutes. After 30 minutes of standing, the content was diluted with 200 ml of distilled water, swirling was repeated to ensure thorough mixing. In order to complex Fe^{3+} which would otherwise interfere in the end point, 10 ml and 0.2 g of H_3PO_4, NaF respectively were added before the addition of diphenyamine indicator. The excess Cr_2O_7 was back titrated with 0.5 M ferrous solution to green end point.

Calculation:

The organic carbon content of soil was calculated as:

$$\%\ \text{Organic Carbon} = \frac{(B - S) \times \text{Molarity of F} \times 0.003}{\text{Weight of Soil}} \times \frac{100}{77} \times 100$$

Where,

B = Blank titre value

S = sample titre value

F = Molarity of $K_2Cr_2O_7$

0.003 = 12/4000 = milliequivalent weight of carbon

100/77 = the factor converting the carbon actually oxidized to total carbon

100 = the factor to change from decimal to percentage.

Soil particle size distribution

Using the standard method described in Methods of Soil Analysis (1996), organic matter was destroyed by hydrogen peroxide and the remaining mineral soil dispersed by shaking in the presence of sodium hexametaphosphate; the soil was analysed by sedimentation using a pipette sampling technique. Ten grams (10 g) of air-dry soil was weighed into 500 ml beaker and 10 ml of H_2O_2 was added. The beaker was allowed to stand till frothing ceased and another 10 ml of H_2O_2 was added. The content was gently heated on Bunsen flame and stirred at the same time to break the froth. Additional, H_2O_2 was added with gentle heating using in total 100 ml of peroxide solution. Finally, the temperature was raised to boiling to complete the destruction of the organic matter and the content was allowed to cool.

To disperse the soil, the peroxide- treated soil was transferred quantitatively into 500 ml bottle with a screw cap using distilled water. Ten milliliter (10 ml) of dispersing agent (prepared by adding 50 g of sodium hexametaphosphate and 7 g of anhydrous sodium carbonate in a litre of water) was added. The content was made up to 200 ml and then shaken overnight on a mechanical shaker. After dispersing the soil, the content of the bottle was transferred to a 500 ml measuring cylinder and made up to 500 ml with distilled water.

Sampling of silt and clay followed, by drawing 20 ml of suspension with a special pipette after thorough mixing with plunger and allowed to settle for 32 seconds. The sedimentation started again after stirring for 8 h and clay was sampled at a depth of 10 cm. Each of the 20 ml of suspensions was transferred into labelled weighed beakers and dried at 105˚C. After drying, the beakers were cooled in a desiccator and reweighed. These gave the mass of silt

+ clay + a small residue of the dispersing agent and mass of clay + a small residue of the dispersing agent.

After another 8 h, the sand was sampled by pouring away most of the supernatant liquid and quantitatively transferring the sediment known to be sand into a beaker. Stirring, settling and decanting was done repeatedly until the supernatant was clear. The sand was transferred into a weighed beaker, dried at 105 ˚C, cooled in a desiccator and reweighed. The mass of oven-dry soil was also determined and used for the calculation. The textural class of the soil was determined using the textural triangle after calculating the percentage of each particle size in the samples.

Calculation

The total mass of silt in the soil sample = mass of silt in 20 ml × 500/20,

Where ; MS = mass of sand

MdS = mass of oven-dry soil.

TSi = total silt in soil sample

TC = total clay in soil sample

Treatments and Experimental Design

Imidacloprid (Confidor) - 200g/L was mixed with the soils and air dried for three days. The adsorbents (Charcoal (CH) and Rice Husk Biochar (RHB)) were mixed with the soils at the rate of 0%, 0.5%, and 1% by weight (0% treatment was used as the control for the study). The various soil mixtures (soil and amendments), were moistened, thoroughly mixed, and equilibrated in plastic bags for 8 days at room temperature. All treatments were replicated three times. In a completely randomized design, samples were uniformly packed into PVC columns (5 cm inner diameter x 17 cm long) to an average depth of 13 cm at a bulk density of, 1.33 g cm^{-3}. Samples were gently tapped into the column to ensure uniform distribution and hydraulic conductivity. Columns were equipped with a 2 cm drainage hole at the base, covered with screening to prevent soil loss. The study was performed under laboratory conditions and with 30 columns. Columns were supported on racks and loosely covered with clear plastic wrap to reduce moisture loss through evaporation between leaching events.

Treatments and total number of columns from the experiment,

Soil 1: 2 amendments (charcoal and rice husk biochar) at 2 rates (0.5% and 1 %) plus 3 control with 3 replicates [number of sample = 15].

Soil 2: 2 amendments (charcoal and rice husk biochar) at 2 rates (0.5% and 1 %) plus 3 controls with 3 replicates [number of sample = 15].

Therefore, 2 soil types [2 amendments x 2 rates x 3 replicates] + 6 controls = 30 columns.

Figure 2: Soil Column Leaching Experimental Setup.

Table 2: **Label of Samples as used in text.**

Soils/ Adsorbent/ Rates	Labels
Soil 1 (Wassa Amenfi West)	S_1
Soil 2 (Suaman)	S_2
Charcoal	CH
Rice Husk Biochar	RHB
0%	c
0.5%	a
1%	b

Leaching Protocol

Leaching consisted of the application of 80 mL of water (pH of 6.8 to mimic the pH of rainfall in Western Region) to each column weekly for six weeks. Each leachate volume (80 mL) corresponded to ~1 pore volume. This was determined by irrigating the soil with water (10ml) intermittently until the first drop was collected from the column.

Leachate was collected and the volume and pH were measured within 24 hours of collection (Silveira, Miyittah, & O'Connor, 2006). Experimental Room evaporation was observed to be about (10-12 ml) per leaching period.

Chemical Analyses of Leachates

Detection of imidacloprid was observed with UV at 270 nm, Mobile phase solution used was prepared from 900 ml of distilled water added to 10 ml acetonitrile. These mixtures were stirred to obtain a uniform solution. Solid phase extraction was used to filter and prepare samples for HPLC analysis. Samples were poured into vials. Twenty micro-liters (20µl) of each leachate sample was injected into the HPLC with cleaning by mobile phase after each sample.

Analysis of imidacloprid concentration in Leachates was carried out using a high-performance Liquid Chromatography (HPLC) (US EPA, 2000; Wauchope et al., 2002) with the following operating parameters: Shimadzu-LC 20AT with PDA detector fitted with reversed-phase Column, 5µ Luna C18 (2); 250 × 4.6 mm (RP) and Flow rate, 1 ml/min at ambient temperature; Labsolution software system was used throughout the experiment to acquire and process chromatographic data.

Quality Assurance and Control

Good laboratory practices were followed to ensure accuracy and quality of the experimentation including collecting and analytical procedures. Quality assurance and quality control (QA/QC) were met through 10% repeats, spikes, and blanks for each procedure. A 10% relative standard deviation was required for all repeats. Runs consisted of unknown samples included within series of injections of known material (imidacloprid) in order to check wavelength, retention times (RT) and intensities of signals.

Pure imidacloprid was prepared with Acetonitrile and H_2O (10/90) at 5 mg/ml. Four calibration samples were prepared by spiking blank extracts with the prepared standard solution. Fortification levels of 0.1, 1, 2 and 5 µg/ml were prepared to give a standard calibration curve for imidacloprid. Spike recoveries were within an acceptable range of 90% to 120%.

Quantification of imidacloprid was performed by using different levels of standard. The calibration graph was obtained by plotting concentration versus peak area over linear range of 0.1 µg/ml to 5 µg/ml. The equation of calibration curve was obtained by plotting peak areas in ‘‘y’’ axis against concentrations of imidacloprid in ‘‘x’’ axis, which was y = 1.1313x + 0.02, with a correlation coefficient (r^2) of 0.9999. The sensitivity of the method was expressed in terms of the attained limit of detection (LOD), which was evaluated as three times the signal-to-noise ratio, 0.063 µg/ ml.

The limit of quantification (LOQ) of the method as a signal-to-noise ratio from untreated samples equal to ten was calculated as 0.22 µg/ml (Table 4 and 5). The linearity of the detector response was tested for imidacloprid by using High Performance Liquid Chromatography (HPLC) in solvent over the range of 0.1 µg/ml to 5 µg/ml (Fig 3). The retention time was at 3.30 minutes under the operating condition of the chromatogram.

Table 3: Wavelength and Retention Time for Imidacloprid Using HPLC (Shimadzu LC-20 AD).

Pesticide Name	Wavelength (nm)	Retention Time (min)
Imidacloprid	270	3.30

Table 4: Peak Area (Absorbance x Width at Half Height) and Concentrations *of Standards (ug/ml) of Imidacloprid.*

Concentration (µg/ml)	Peak Area (mAU)	Found Concentration (µg/ml)	Recovery %
0.1	0.112	0.094	93.947
1.0	1.156	1.015	101.522
2.0	2.311	2.036	101.753
5.0	5.665	4.997	99.941

A summary of the obtained recovery values are given in Table 4. The resulting mean recovery rate of 98.6% with relative standard deviations (RSD) of 3.26% (Table 5).

Table 5: Assay Validation Sheet

Parameter	Value
Accuracy	98.571 ±3.26
Slope	1.1313
Intercept	0.02
Linearity range	0.1 – 5.0 µg/ml
Correlation coefficient	0.9999
SE of intercept	0.0144
SD of intercept	0.0249
LOD	0.0627
LOQ	0.2205

The study reveals that the extraction of samples with acetonitrile are suitable for imidacloprid analysis. The separation and quantification of imidacloprid by HPLC was better at wavelength of 270 nm with mobile phase of acetonitrile and water (10:90 v/v). The adapted method was applied to a preliminary dissipation study of imidacloprid in mulberry leaves under field condition (Paramasivam et al., 2014).

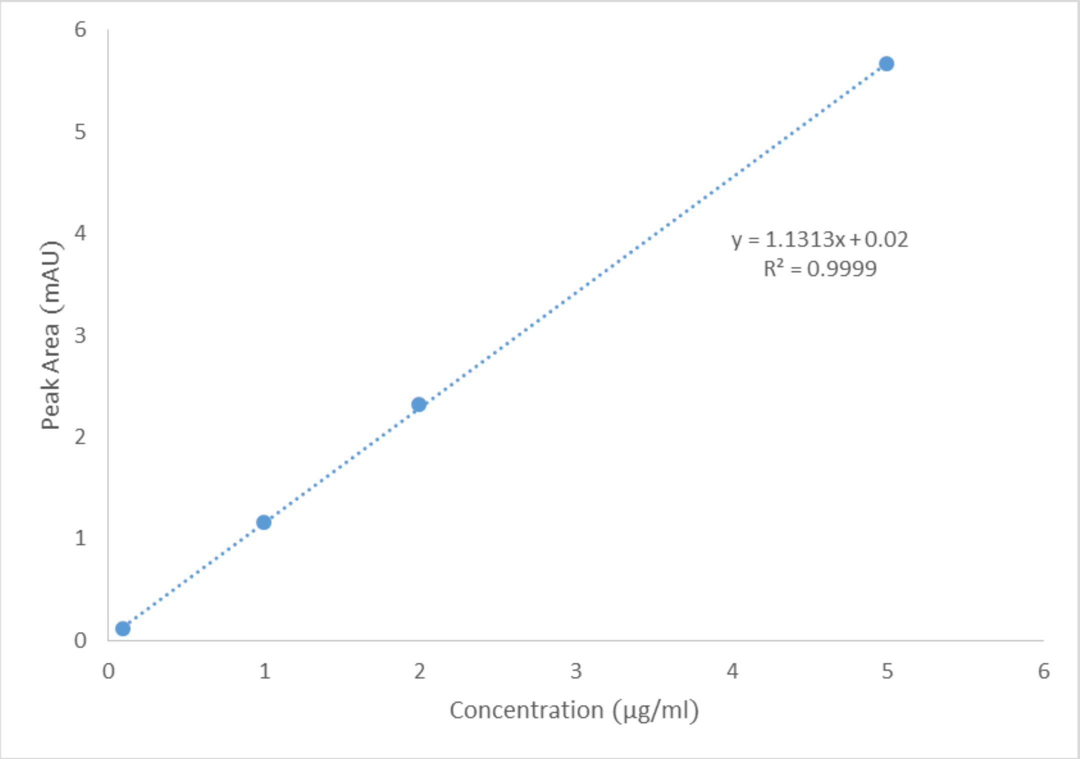

Figure 3: The Calibration Curve for Imidcloprid.

Statistical Analysis of results

Microsoft Excel, Statistical Package for the Social Sciences (SPSS) Version 21(IBM, Chicago, IL, USA) and STATA 13 (Stata Corp, College Station, TX, USA) were used for the analysis of data from questionnaire. Descriptive Statistics (frequency and percentage), inferential statistics (One-way analysis of variance) and Pearson correlation were used to analyse and present the results of this study.

A logistic regression was also carried out. This regression was considered appropriate when there is a binary outcome variable. Therefore, Cramer’s values, odds ratio, P values and confidence interval values were used. The contributory role of the use of the personal protective equipment on self-reported exposure to pesticides application was estimated with a logistic regression using odds ratios (OR); OR = 1 implies that the factor does not affect odds of exposure to pesticides during application; OR > 1 implies that predictor is associated with higher odds of exposure to pesticides during application; and OR < 1 implies that predictor is associated with lower odds of exposure to the pesticide. The main outcome variable is dichotomous and examines whether respondents experienced the named health symptoms in the questionnaire, coded as no = 0 and yes = 1. Under this binary response, there are three potential alternatives: the logit model, negative model and complementary log–log model. Both logit and probit links have the same property, which is link π (χ) = log [- log (1 - π (χ). This means that the response curve for p(x) has a symmetric appearance about the point p(x) = 0.5 and so p(x) has the same rate for approaching 0 as well as for approaching 1 (Quansah et al, 2015; Hoppin et al., 2002).

Significant differences in the leachate samples (effects within treatments, within weeks, between treatments and weeks) were determined using Fisher's Protected LSD procedure at a significant level (α) of 0.05. Statistical tests were performed using SPSS Version 21(IBM, Chicago, ILUSA) and Microsoft Excel. Differences within each treatment were examined using an ANOVA at a significant level (α) of 0.05.

Chapter Summary

For the purposes of assessing farmers knowledge on pesticides application on cocoa farms and to calculate the risk of pesticides use in order to achieve the first and second objectives of the study, descriptive survey was used. Questionnaire was used for data collection from smallholder cocoa farmers. Sampling of farmers was random and purposive. Farmers that apply pesticides to their farms were the group of interest. Two hundred and twenty five (225) was the sample size of smallholder farmers used in the study. Information collected from farmers were also used as input for risk assessment using a risk indicator tool called the Environmental Impact Quotient (EIQ).

Finally, a soil column leaching experiment was also carried out to determine transport and removal of pesticide (imidacloprid) - one of the common pesticides being used frequently in the study area. The amount of pesticide in the leachates from the experiment were analysed using HPLC and pH meter.

Results from this section has been statiscally analysed using Microsoft Excel, Statistical Package for the Social Sciences (SPSS) Version 21(IBM, Chicago, IL, USA) and STATA 13 (Stata Corp, College Station, TX, USA) and has been presented in tables and figures for interpretation and relationships in the next chapter.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

This chapter discusses the analysis, presentation and interpretation of the findings of the study. The analysis and interpretation of data were carried out based on the findings from the research hypotheses of the study. It also discusses the major findings and analyzes the data critically with reference to relevant literature in an attempt to explore deeper meanings of the responses, to unravel the issues and understand the phenomenon.

To Assess Smallholder Cocoa Farmers' Knowledge on Pesticide Application

Statistical Analysis of Demographic Background of Respondents (n=225)

Table 6: Socio-demographic characteristics of study population

Respondent Characteristics	N (%)		Inferential Statistics
	Male	Female	
Sex	154 (68.44)	71 (31.56)	
District			
Wassa Amenfi West	57 (76)	18 (24)	X^2 (2) = 5.4738, Pr = 0.065, Cramer's V = 0.1560
Aowin	44 (58.67)	31 (41.33)	
Sauman	53 (70.67)	22 (29.33)	
Age			
10 – 20	1 (50)	1 (50)	X^2 (5) = 3.0022, Pr = 0.700, Cramer's V = 0.1155
21 – 30	15 (75)	5 (25)	
31 – 40	41 (62.12)	25 (37.88)	
41 – 50	35 (68.63)	16 (31.37)	
51 – 60	44 (74.50)	15 (25.42)	
61 and above	18 (66.67)	9 (33.33)	
Level of Education			
No formal	47 (63.51)	27 (36.49)	
Primary	54 (68.35)	25 (31.65)	X^2 (2) = 1.7233, Pr = 0.422, Cramer's V = 0.0875
Secondary	53 (73.61)	19 (72)	
Economic Activities			
Farming	147 (95.45)	67 (94.37)	X^2 (1) = 0.1238, Pr = 0.725, Cramer's V = 0.0235
Small business	7 (4.55)	4 (5.63)	
	Mean	**Std. Err.**	**[95% Conf. Interval]**
Farm size	9.025	0.512	8.017 - 10.033

N= Number of respondents; X^2 = Pearson chi square; Pr= P – value; Cramer's V value (0-1) indicates how strong the values are associated with closeness to 1 which implies greater association. Values in parentheses indicates (%) of farmers.

This section presents the demographic background of the respondents from the selected districts. The demographic data of respondents include sex, age, educational level, family position and economic activity. From Table 6, there was no statistical significant relationship among the districts ($P< 0.05$), age ($P< 0.05$), level of education ($P< 0.05$) and economic activities ($P< 0.05$) on the sex of the respondents. This suggested that, district, age, level of education and economic activities did not systematically differ between the sex of the respondents.

The demographic analysis suggest that the dominant gender involved in cocoa farming in the study area is male. This might be due to the labor intensive nature of cocoa farming hence less attractive to most females. The male to female ratio in this study is in line with the finding of (Ali, Awuni, & Danso-Abbeam, 2018; Boateng, Nana, Codjoe & Ofori, 2014; Bosompem, Kwarteng, & Mensah, 2012). This could also be ascribed to the physical stress on the farm activities put on the body as reported by Paintsil (2017) and Tijani (2006). Likewise, this could be attributed to the fact that males, mostly household heads, traditionally control assets such as land and tree crops than females (Ansari, Moraiet, & Ahmad, 2014). Majority of the study participants were males 68.4% (N= 154) while 31.5% (N= 71) were females. Approximately, 33% (N= 74) of the respondent had no formal education, 35.1% (N= 79) had only primary education and 32% (N= 72) had secondary education. The main economic activity for the sampling group is farming, (95.11%, N= 214). The highest age range was between 31-40 (Table 6).

Most farmers surveyed were between the ages 31 and 40 years, however farmers were within the economically active age range (18-65). Only

8.89 % of the farmers were between the ages of 21–30 years (Table 6). The results of this study is in line with those reported by Bosompem et al. (2012) and Boateng et al. (2014) who indicated that most cocoa farmers (in cocoa growing districts like Birim-South West and Atiwa districts of Ghana) aged 40 years and above (as in Table 6).

Education information of respondents showed that a good number of farmers had received basic and secondary level education. Majority of the farmers did not further their studies beyond the secondary level. Nonetheless, the proportion of illiterates was equally low. This case is similar to the findings of Paintsil (2017) and Peprah (2011) who reported that, farmers were of the view that a high level of education is not necessary for carrying out farming. A study from Nigeria (Oluwole & Cheke, 2009) also confirmed this by having a similar report where majority of farmers surveyed had no formal education. The results suggest that, the inability of a farmer to undertake good agricultural practices could be as a result of poor educational facilities in rural Africa. In addition, three-fourth of the respondents had either no or just primary level of education, indicating that, farmers could not read labels on chemical containers and that understanding of the complexity of pesticides chemistry would be a challenge.

Peprah (2011) reported that pest and diseases pose greater challenges in agro ecosystem. The damage cause by pest has led to farmers using pesticides in crops production. In his report, 87% of farmers used chemicals to control pest and diseases on fruits and vegetable cultivation in Ghana which is close to Dinham (2003) estimate of 89%. Likewise, in this study, all 225 respondents surveyed used pesticide in cocoa production. According to the survey most farmers admitted that the reason for using pesticides was to protect cocoa plants from insects and diseases.

Farmers Knowledge on Pesticide Toxicology

The result of the study of farmers knowledge on the routes of entry of pesticides into the human body, organisms and the environment are shown in Table 7. There was a statistical significant difference between educational level of farmers and their knowledge on pesticide entering their bodies through inhalation (X^2= 10.28, df =2, $P < 0.05$), through the skin (X^2= 7.59, df = 2, $P < 0.05$), and knowing whether pesticide residue is left on fruits and vegetables after the application (X^2= 10.054, df =2, $P < 0.05$). However, X^2 of variables that were not significant were positively associated with greater percentage of the farmers saying YES to the questions, indicating that knowledge is relevant and is influential in the application of pesticides. In general, most farmers have good knowledge on the effects of pesticides on human health (explaining how their bodies react after the application of pesticides) and the environment.

Table 7: Relationship between Farmers Level of Education and Knowledge on Pesticide Toxicology's - N (%)

Question asked	No formal Education	Primary Education	Secondary Education	Inferential Statistics
Can pesticides cause negative effects?				
No	17 (43.59)	13 (33.33)	9 (23.08)	X^2 (2) = 2.8589 ,Pr = 0.239
Yes	57 (30.65)	66 (35.48)	63 (33.87)	Cramer's V = 0.1127
Do all pesticides have the same health effects?				
No	53 (71.62)	21 (28.38)	51 (70.83)	X^2 (2) = 0.0753, Pr = 0.963
Yes	55(69.62)	24 (30.38)	21 (29.17)	Cramer's V =0.0183
Can pesticides be dangerous to use?				
No	10 (45.45)	8 (36.36)	4 (18.18)	X^2 (2) = 2.6365, Pr = 0.268
Yes	64 (31.54)	71 (34.98)	68 (33.5)	Cramer's V = 0.108
Can pesticides enter the body through inhalation?				
No	9 (12.16)	2 (2.53)	1 (1.39)	X^2 (2) = 10.2818, **Pr = 0.006**
Yes	65 (87.84)	77 (97.47)	71 (98.61)	Cramer's V = 0.2138
Can pesticides enter the body through skin?				
No	9 (64.29)	4 (28.57)	1 (7.14)	X^2 (2) = 7.5390, Pr = **0.023**
Yes	65 (30.81)	75 (35.35)	71 (33.65)	Cramer's V = 0.1830
Can pesticide residue be left in the air?				
No	6 (46.15)	5 (38.46)	2 (15.38)	X^2 (2) = 1.9726, Pr = 0.373
Yes	68 (32.08)	74 (34.91)	70 (33.02)	Cramer's V = 0.0936
Can pesticide residue be left in the soil?				
No	8 (10.81)	14 (17.72)	8 (11.11)	X^2 (2) = 2.0316, Pr = 0.362
Yes	66 (89.19)	65 (82.28)	64 (88.89)	Cramer's V = 0.0950
Can pesticide residue be left in the fruit and vegetables?				
No	20 (55.56)	9 (25.00)	7 (19.44)	X^2 (2) = 10.0541, **Pr = 0.007**
Yes	54 (28.57)	70 (37.04)	65 (34.39)	Cramer's V = 0.2114

N= Number of respondents; X^2 = Pearson chi square; Pr= P – value; Cramer's V value (0-1) indicates how strong the values are associated with closeness to 1 which implies greater association. Values in parentheses indicates (%) of farmers.

Pesticide Use (acquisition, reason for application, and knowledge of application)

The farmers indicated local agrochemical stores as their main source of pesticides. Interviews revealed Akate master, Confidor, Ridomil and Nodox as the commonly used pesticides. All farmers consented to using motorised sprayers for insecticide application whiles the knapsack sprayer was the preferred equipment for fungicide application. Application strategies employed by majority of the farmers involved the application of different chemicals individually (89.78%), however, the remaining group (10.22%) indulged in the improper farming practice of mixing different chemicals to have rapid knockdown effects of pests. Approximately, eighty eight percent (88.44%) of farmers do not read instruction on labels before using pesticides. Eighty percent (80%) of farmers identified the presence of pests as the driving factor for their decision to apply chemicals (Table 8). Only 29.78% followed recommended calendar spraying schedules no matter the observations made in the field.

For the reason that most farmer are unable to read instructions on labels on containers, majority obtain pesticide knowledge from agricultural extension officers, although others use their own experience or are being taught by fellow farmers. Agricultural extension officers act as conduits between the ministry of agriculture and farmers and farm workers. They are the first point of call for farmers in the event where they require assistance with farm practices (Painstil, 2017). This observation was in line with results recorded by Tijani, (2006) and Zhu, (2015). Who reported that most farmers receive application techniques knowledge from Extension agents just as it was observed in this study. Oluwole & Cheke (2009) also reported farmers' personal experience as the major source of knowledge in another region. Upon further inquiries information on pesticide application strategy, 89.8% responded against mixing more than one pesticides type and applying to cocoa farms.

Table 8: Pesticide Application Information by Cocoa Farmer

Questions and predefined answers	Response N (%) Yes	No
Why do you use pesticides?		
To protect crops against insects and diseases	180 (80)	45 (20)
To make crops grow better	53 (23.56)	172 (76.44)
Because others use pesticides	5 (2.22)	220 (97.78)
Because I was advice to use it	10 (4.44)	251 (95.56)
Where do you get/buy the pesticide?		
Agrochemical shops in town	61 (27.11)	164 (72.89)
Local government shops in the village	93 (41.33)	132 (58.67)
Extension officers	85 (37.78)	140 (62.22)
General shops	15 (6.67)	210 (93.33)
Cooperative societies	0	225 (100)
Timing of pesticide application		
Presence of pests	144 (64)	81 (36)
Degree of pest infection	17 (7.56)	208 (92.44)
Date of planning	3 (1.33)	222 (98.67)
On calendar spray schedules	67 (29.78)	158 (70.22)
Sources of farmers' knowledge on pesticide application		
Agrochemical; shops	11 (4.89)	214 (95.11)
Extension officers	156 (69.33)	69 (30.67)
Pesticides labels on packages	23 (10.22)	202 (89.78
Fellow farmers	40 (17.78)	185 (82.22)
Own experience	23 (10.22)	202 (89.78)
Pesticide application strategy		
Mix more than one type of chemical	23 (10.22)	202 (89.78)
Depending on the instruction on the label	26 911.56)	199 (88.44)

Values in parentheses indicates (%) of farmers.

Table 9: Relationship between Pesticides Storage Location and Farmers Level of Education

Pesticide Storage Location	Education No Formal	 Primary	 Secondary	 Inferencial Statistics
				$X^2(14)$ = 24.0500, Pr =
Agrochemical store	4 (26.7)	5 (33.3)	6 (40)	0.045
Animal houses	2 (22.2)	4 (44.4)	3 (33.3)	Cramer's V = 0.2312
In the food store	8 (24.2)	13 (39.4)	12 (36.4)	
Living house	8 (20.5)	9 (23.1)	22 (56.4)	
In the kitchen	2 (28.6)	3 (42.1)	22 (28.6)	
In the bush	26 (36.6)	26 (36.6)	19 (26.8)	
In the toilet	6 (37.5)	5 (31.3)	5 (31.3)	
In the Bathroom	18 (51.4)	14 (40)	3 (8.6)	

X^2 = Pearson chi square; Pr= P – value; Cramer's V value (0-1) indicates how strong the values are associated with closeness to 1 which implies greater association. Values in parentheses indicates (%) of farmers.

From Table 9, the non- parametric Pearson's chi square test suggests that, there was statistical significant association between Storage of Pesticides and their education levels (X^2= 24.0500, df = 14, $P > 0.05$) with Cramer's V (0.2312) indicating a weak relationship.

Results presented in table 9 was very similar to Paintil (2017). This could be attributed to the choice of study area where both study areas share almost similar demographic characteristics. Oluwole & Cheke (2009) also gave support to this assertion with data form rice farmers whiles Zhu (2015) observed a similar trend in vegetable farmers within the cocoa belts. Contrarily, Tijani (2006) reported a different pattern to all studies mentioned here. That is, majority of the farmers storing pesticides in designated stores and a minority keeping them in their bedrooms. Since keeping near living room has been reported to be one of the main causes of food poisoning, advice was however given at group meeting to find a better storage option.

The commonest way of disposing off empty pesticide containers and remnants from spraying equipment was throwing them on the farm (Figure 5). Empty pesticide containers and sachets were found disposed of indiscriminately on farms where observations were conducted. Five of the respondents (2%, N=5) revealed that they put empty pesticide containers to other use once they were emptied of the content. Some farmers (8%, N=18) also mentioned digging holes on farm and burying containers as their preferred disposal method.

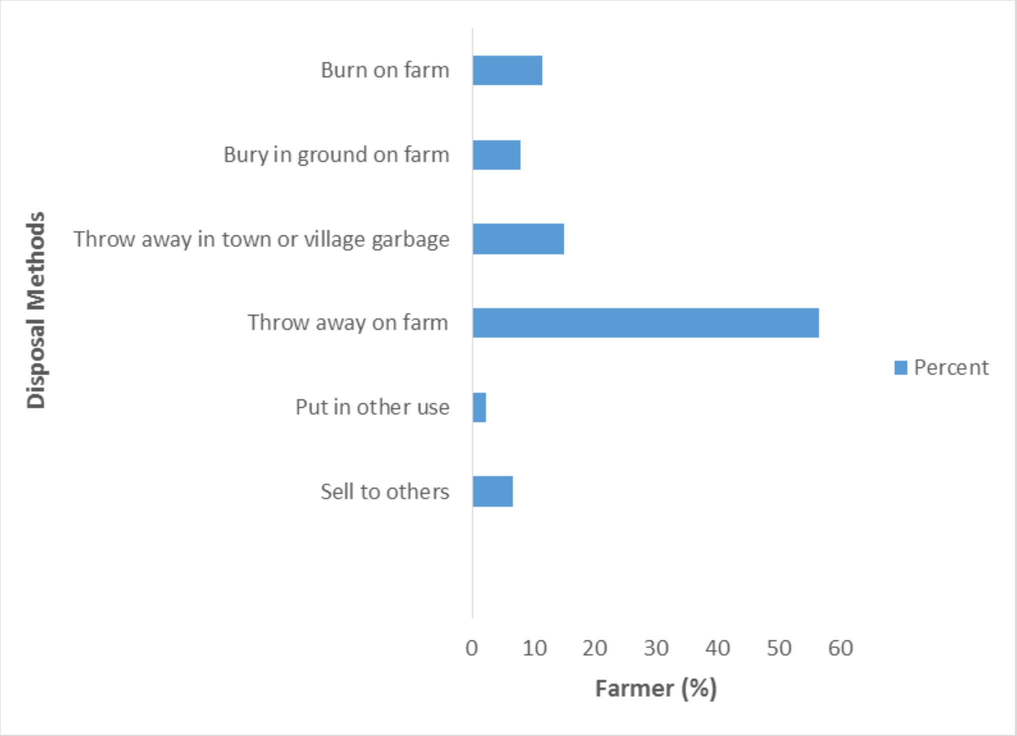

Figure 4: Disposal of Empty Pesticide Containers.

It was also detected that the most prominent container and sachet disposal strategies currently employed were throwing on field, village landfills, burning on farm and burying in a hole (Figure 5). This trend is similar to data reported by Paintsil (2017), Tijani (2006) and Oluwole & Cheke (2009). However, some farmers also put the empty containers to other use such as storing salts, palm oil, flour and other products meant for consumption. A study in Greece found a common practice of dumping empty pesticide containers by fields, near, or into irrigation streams and canals, burning in open fire are well known practice of disposal farmers use, coupled with using them for fuel storage, water and food storage (Haylamicheal & Dalvie, 2009).

A previous study by Damalas et al. (2008) on assessing farmers' practices on disposal of pesticide waste after use indicated that some farmers released left over into nearby streams and irrigation canal. Some also, after rinsing pours the water into nearby uncultivated lands. This represents a fairly similar situation in this study (Figure 5). Sixty percent (60%, N=135) of respondents discharged the remnants of mixed chemical on the farm.

The least chosen disposal option in this study was to throw used containers in rivers, lakes or irrigation canals (Figure 5). Damalas et al. (2008) noted that re-spraying surplus mixtures is said to be risky as it doubles the recommend dosages on the crops leading to toxicity, residues in soil and harvested crops. This also includes the disposal of remnants on uncultivated lands. The best way recommended to dispose of left - over is to find other similar farms that will need application of the same chemical.

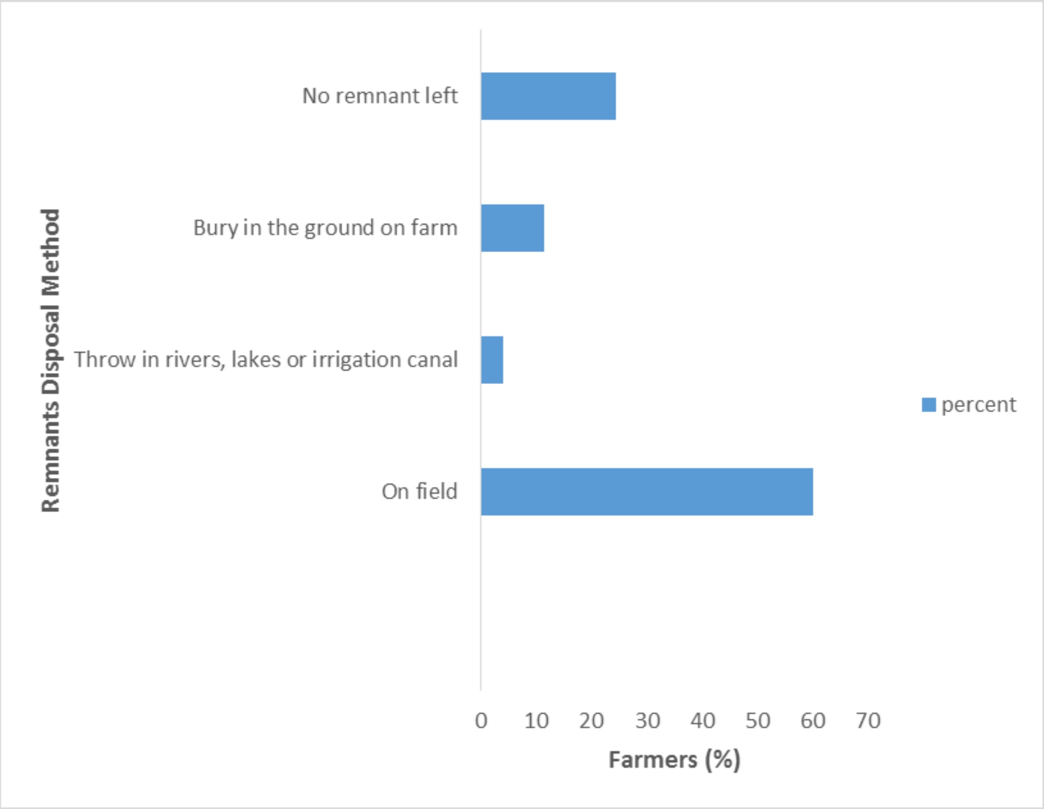

Figure 5: Disposal of Remnants.

Disposal of remnants after spraying farmland, 28% (N=65) of farmers returned home with the empty equipment for cleaning, with 47% (N=105) however clean their sprayers on their farms. A small proportion of respondents (24%, N=54) washed remnants directly into streams and rivers (Figure 7). futhur enquire was made to know duration between spraying of farm and consumption of produce from farm, 53% (N= 120) responded that, they wait for more than a week before consuming or selling farm products after applying pesticide (Figure 8).

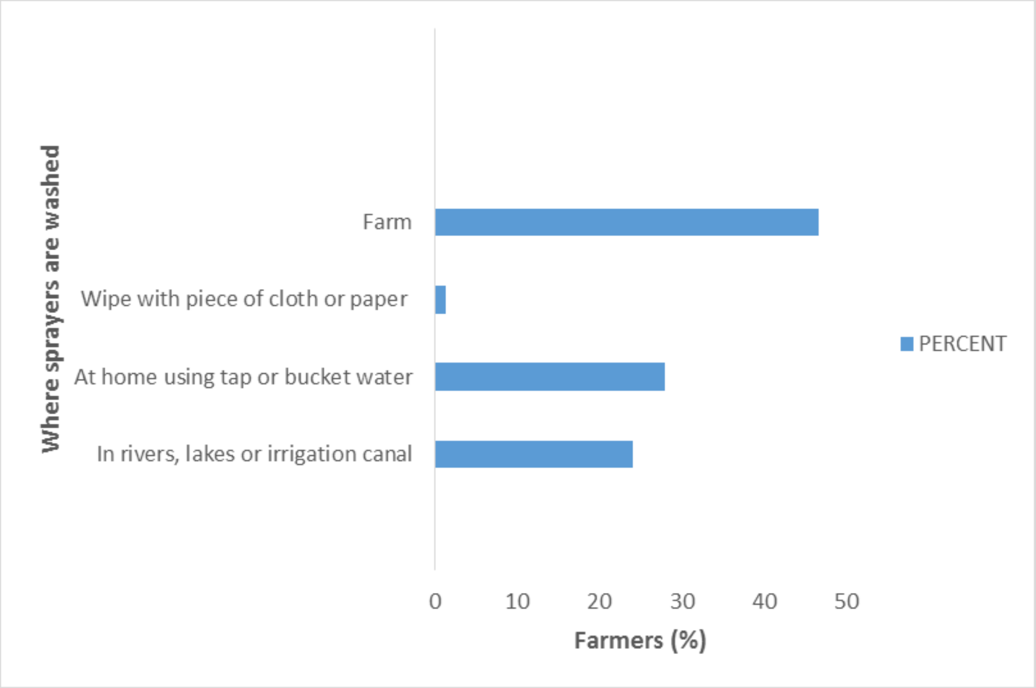

Figure 6: Washing of Sprayers.

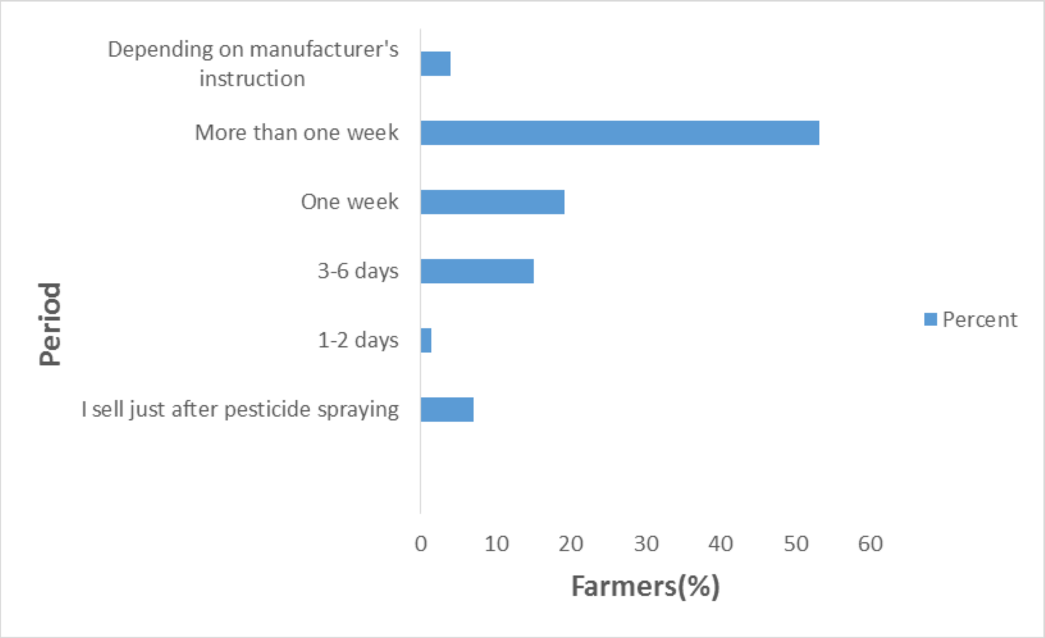

Figure 7: Period from Last Spraying to Selling or Eating Crops.

Attitudes towards Pesticide Use

Among the respondents, 55.11% of respondents strongly agreed to the statement ‘pesticide use is important to secure good crops’, whiles the rest of the 44.11% simply agreed with the statement. About 98.67% also agrredthat proper knowledge is needed for the application of pesticides. Majority of the respondents agreed that precaution being taken in the administration of chemicals (52.89% strongly agreed, 47.11% agreed). Thirty two (32%) of the respondents disagreed with the statement ‘there are minimal health risks associated with pesticide use’ while majority 68%) agreed with the statement (Table 10).

Table 10: Attitudes towards Pesticide Use

Farmers' perception on the effectiveness of spraying	**Respondents**	
	N	%
Proper knowledge is necessary		
Strongly Disagree	1	0.44
Disagree	2	0.89
Agree	96	42.67
Strongly Agree	126	56
Minimal Health Risks attached to pesticide use		
Strongly Disagree	1	0.44
Disagree	71	31.56
Agree	81	36
Strongly Agree	72	32
Precautions should be used		
Agree	106	47.11
Strongly Agree	119	52.89
Important to secure good crops		
Agree	101	44.89
Strongly Agree	124	55.11
Limit pesticide use		
Strongly Disagree	16	7.11
Disagree	63	28
Agree	85	37.78
Strongly Agree	61	27.11

The Use of Personal Protective Equipment (PPE)

Sixty five (65) farmers revealed that they use full working gear during applications of pesticide while 102 partially protect themselves before applying chemicals on farms. The most common PPE used by this partial group was the boot. Fifty five (55) farmers failed to put on any of this human safety equipment (Figure 9).

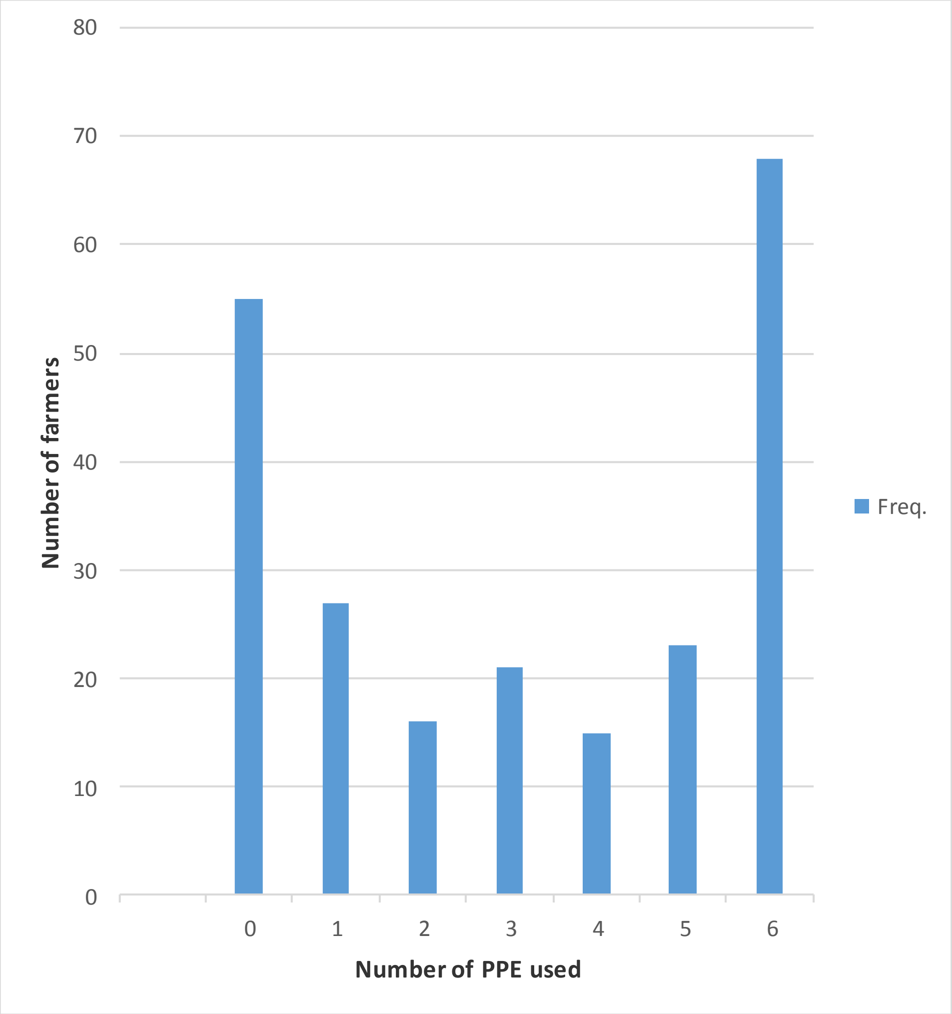

Figure 8: Frequency of PPE Used by Farmers.

Pearson Correlation between Farmer's Educational Background and the Use of Multiple Personal Protective Equipment (PPEs)

Table 11 represents the Pearson correlation between the use of multiple PPE and educational background of the farmers. In Figure 8 majority of the farmers likely not to use any PPE during the application of pesticides are those with no formal educational background, whiles those likely to use all six PPEs listed in the administered questionnaire are farmers with primary education, followed by those with secondary education.

Table 11: Pearson Correlation between the Use of Multiple PPEs and Educational Background of the Farmers during the Application of Pesticides.

Multiple PPEs	No Formal Education (N)	Primary Education (N)	Secondary Education (N)	Total (N)
0	22	21	12	55
1	9	6	12	27
2	8	4	4	16
3	4	7	10	21
4	3	7	5	15
5	7	9	7	23
6	21	25	22	68
Total (N)	74	79	72	225

Chi square (x^2) = 11.98, Pearson correlation (Pr) = 0.447

Also, high illiteracy rates could contribute to farmers' difficulty in understanding and following instructions and safety advice on pesticide use.

Knowledge was not found to influence practices in Brazil because majority of farmers admitted receiving information, training and claimed reading labels-instructions and warning but do not take adequate protective measures (Remoundou, et al., 2014). This was attributed to low levels of education of participants. High levels of knowledge and perception of risk were not enough to influence farmers' self-protective behavior (Remoundou, et al., 2014). Peprah (2011) reported that, farmers exposure to chemicals is because of non-use of PPE especially cover cloths during spraying and sometime leakages from knapsack spray can. Also spraying during windy conditions can cause drifting of the chemicals to unapproved areas.

In this study, 66% of the farmers reported general body weakness; headache, skin itching, burning eyes and skin rash after spraying pesticide. The contributory role of PPE on self-reported exposure to pesticides during application was estimated with a generalized linear model. An association was found between the use of PPE and self -reported symptoms such as body itching and burning eyes (Table 12). This confirms the previous study by Sosan & Akingbohungbe (2009), who likewise found that almost all the farmers in their study who engaged in poor practices confirmed typical symptoms of pesticide poisoning after each spraying task. These symptoms comprised severe headache (66%), dizziness (58%), body weakness or being unusually tired (55%), burning eyes (53%), restlessness (37%) and excessive sweating (41.3%).

Atreya (2007) also found that pesticide sprayers reported greater number of signs and symptoms of exposure such as skin irritations, stomach poisoning and eye irritations than other farm workers. Another study conducted on 268 by Neghab et al. (2014) on married male farmers in Iran showed that 68% of participants reported to their general practitioners of suffering from burning and skin irritations, eye burn, headaches, vertigo, nausea and vomiting during spraying.

Table 12: Common Health Symptoms Associated with Frequent Pesticide Poisoning

Symptoms	Response N (%)	
	NO	YES
Have you experienced any of the following Symptoms after chemical application?		
Headache	107 (47.6)	118 (52.44)
Burning eyes	77 (34.22)	148 (65.80)
Skin rash	152 (67.6)	73 (32.44)
Itching	116 (51.6)	109 (48.44)
Chestpain	130 (57.80)	95 (42.22)

N= number of farmers; (%) - percentage number of farmers

Common health symptoms associated with pesticide poisoning were reported to have been observed by the farmers, about half of them reported to have experienced a headache and burning eyes sensation. Skin rash, skin itching and chest pain were also experienced by most of the respondents (Table 12).

Table 13:Relationship between Reported Health Symptoms and Personal Protective Equipment (n=225)

Headache	Odds Ratio	Std. Err.	P>z	[95% Conf.	Interval]
MPPE(ref: 0)					
1.00	0.89	0.42	0.81	0.35	2.26
2.00	1.12	0.64	0.85	0.37	3.41
3.00	2.23	1.20	0.14	0.78	6.39
4.00	2.23	1.37	0.19	0.67	7.40
5.00	1.45	0.73	0.46	0.54	3.87
6.00	1.18	0.43	0.64	0.58	2.41

Itching	Odds Ratio	Robust Std. Err.	P>z	[95% Conf.	Interval]
MPPE(ref: 0)					
1.00	2.35	1.13	0.08	0.92	6.05
2.00	0.74	0.45	0.61	0.22	2.42
3.00	1.78	0.92	0.27	0.64	4.92
4.00	1.42	0.83	0.55	0.45	4.49
5.00	3.04*	1.58	0.03	1.10	8.40
6.00	1.62	0.60	0.19	0.78	3.34

Burning Eyes	Odds Ratio	Robust Std. Err.	P>z	[95% Conf.	Interval]
MPPE (ref: 0)					
1.00	2.55***	0.79	0.00	1.39	4.66
2.00	2.23*	0.82	0.03	1.09	4.57
3.00	1.92*	0.64	0.05	1.00	3.68
4.00	1.22	0.48	0.61	0.56	2.65
5.00	2.33**	0.75	0.01	1.24	4.39
6.00	1.14	0.29	0.61	0.69	1.86

Chest Pain	Odds Ratio	Robust Std. Err.	P>z	[95% Conf.	Interval]
MPPE (ref: 0)					
1.00	1.16	0.44	0.70	0.55	2.44
2.00	0.83	0.42	0.71	0.31	2.23
3.00	0.90	0.40	0.81	0.38	2.14
4.00	1.39	0.62	0.46	0.58	3.34
5.00	2.63	0.92	0.01	1.33	5.21
6.00	1.23	0.36	0.48	0.69	2.19

* P < 0.05, ** P < 0.01, *** P < 0.001, Std. Err.- standard error

Table 13 shows bivariate regression model to enable the prediction of health symptoms after application of pesticides when using multiple protective equipment. There are strong associations reported health symptoms and use of PPE. The odd ratio is a useful parameter to measure the strength of the association between PPE and health symptoms.

Farmers who use five PPE were more likely (OR= 3.04, $p < 0.05$) to report having itching body after application of pesticides as compared to those using no PPE. Participants who uses only one PPE (OR= 2.55, $p < 0.001$), two PPE (OR= 1.92, $p < 0.05$) and five PPE (OR= 2.33, $p < 0.01$) were also more likely to experience burning eyes after applying pesticides unto the cocoa farms as compared to using no PPE.

Risk of Pesticides Application Using EIQ Model.

Environmental pesticide load

The calculated Environmental Impact (EI) per hectare values for commonly used pesticides in cocoa production in the three selected districts in the Western Region are indicated in Table 14. The range of Active ingredient (A.I.). EIQ values recorded were 28.7 – 47.2, with lowest EIQ value for Acetamiprid and highest for Cyhalothrin Lambda. EI per hectare for an active ingredient is a function of application rate therefore, the lowest EI per hactre recorded was for the active ingredient Thiamethoxam, 0.79 and the highest Acetamiprid, 551.04.

Based on WHO (2010) classification of pesticides, 80% of the pesticides used by farmers were moderately hazardous (III) while the rest were slightly hazardous (II) (Table 14).

Table 14: Active Ingredients, WHO Toxicity Class and EIQ Values for Pesticides Used by Smallholder Cocoa Farmers in the Study Area

Pesticide	Active Ingredient	WHO Toxicity Class	Application Rate (a.i. ml/ha) range	EIQ value	EI per ha
Confidor	Imidacloprid(200 g/L)	II	24	36.7	352.32
Akate Power	Thiamethoxam(20 g/L)	II	0.6	33.3	0.79
Akate Master	Bifenthrin(27 g/L)	II	0.81	44.4	19.4
Lambda	Cyhalothrin Lambda (9.7%)	II	0.291	47.2	2.66
Champion	Copper Hydroxide (77%)	III	2.31	33.2	118.12
Buffalo	Acetamiprid (200 g/L)	III	24	28.7	551.04

a.i. – Active Ingredient, WHO (2010) - World Health Organization, EIQ Environmental Impact Quotient and EI – Environmental Impact.

*Environmental Impact Rating Levels - : < 25- (very low risk): < 50 - (low risk): 50- 99-(Moderate): 100 – 199 (high risk): and 200+ (very high risk).

EIQ model was used to identify pest management systems with a low environmental impact (Donga & Eklo, 2018). Pesticides with low EI per ha values are considered to be more environmentally nonthreatening and can be integrated in Intergrated Pesticide Management (IPM) programs. The commonly pesticides used by the respondents in this study were insecticides. Eighty (80%) of the pesticides used by farmers were moderately hazardous (III) while the rest were slightly hazardous (II).

Based on the EI values obtained in this study, the most recommended pesticide for controlling insect pest would be Thiamethoxam, Cyhalothrin Lambda and Bifenthrin since their EI values were < 25; the use of Copper Hydroxide, Imidacloprid, and Acetamiprid should be banned or use with proper monitoring. The use of some compounds such as Copper Hydroxide, Imidacloprid, and Acetamiprid needs to be firmly regulated to reduce negative impact on humans and other non-target organisms. Thiamethoxam had the lowest EI per hectare (0.79) < 25 which implies that, its application is good and the concentrations emitted into the environment are small quantities. Whereas Copper Hydroxide, Imidacloprid, and Acetamiprid EI values were high in this study (Table 14). This therefore becomes toxic and hazardous to insects in the study area and could lead to biodiversity loss.

Imidacloprid has been reported to be highly toxic and persist longer in the environment therefore, residues have a high chance of causing adverse effect to insects (pollinators) (Sanchez & Goka, 2014). Furthermore, in Sanchez & Goka (2014) study on Imidacloprid and Thiamethoxam efect on honey bees in their study area, they reported that, Imidacloprid (10.3-16% for honey bees) and Thiamethoxam (3.7-29.6% for honey bees) to have residue load in the environment. These two insecticides are neonicotinoids and their corresponding percentages represent the probability to which honey bees are at risk to exposure in 2 days. These two insecticides were stated to pose a higher risk to insects (bee worker and larvae) when feeding on contaminated nectar. Nevertheless, Thiamethoxam is of great concern when they feed on contaminated pollens or nectar therefore it is advisable that its use is managed properly as in this study it does not pose threat to the environment.

During the survey, farmers reported that yield of cocoa beans have reduced tremendously over time. Therefore, Ghana COCOBOD authority has initiated a program where cross pollination is artificially done by humans (recruited personnel by Ghana COCOBOD) on cocoa trees. Reduced yield confirms the fact that pesticide use has driven or killed most insects (pollinators) on farm lands and therefore the bearing of good cocoa fruits cannot be obtained through a natural process. The large number of application rate of pesticides in the study areas pose a clear risk to the environment especially insects and pollinators. It istherefore important to establish pesticide monitoring programs.

Sorption capability of pesticide by Rice husk biochar and Charcoal

Imidacloprid is extensively used pesticide for cocoa production in Ghana- imidacloprid. Harvested cocoa beans, farm workers and the presence of other vegetables and fruits on farm lands may have residue of imdacloprid. These farm produce intake may be a significant route of human exposure to pesticides. Pesticide sprayed into the crop eventually fall onto the soil surface and through runoff maybe transferred to surface water bodies. The resultant effect is that, it may percolate into soil affecting soil macro and microorganisms and groundwater. The retention of pesticides in soils is mainly due the adsorption by organic carbon presence in the soil, soil pH, texture, moisture, ambient temperature and sunlight hours. Table 15 shows physico- chemical properties of the soil and biochars used in the present study.

Table 15: Chemical and physical Properties of the Soils and Amendments Used

Sample	pH	MC (%)	CEC ($cmol_c$/kg)	OC (%)	Textural class
Soil 1 (S_1)	4.48	1.39	13.67	1.29	Loam
Soil 2 (S_2)	5.38	3.48	23.38	2.52	Clay- loam
Charcoal (CH)	9.92	5.22	93.12	3.67	-
Rice Husk Biochar (RHB)	7.07	6.17	121.16	3.36	-

MC- Moisture Content (%), CEC - Cation Exchange Capacity ($cmol_c$/kg), OC - Organic Carbon (%).

Characterization of Charcoal and Rice Husk Biochars and Soil Samples.

The properties of the soils, charcoal (CH) and rice husk biochar (RHB) are presented in Table 15. Soil 1 (S1) was loam in texture, contained 1.29% OC; 13.67 $cmol_c$/kg CEC, 1.39% MC and pH of 4.48. Soil 2 (S2) was clay – loam in texture, with 2.52% OC; 23.38 $cmol_c$/kg CEC, 3.42% MC and pH of 5.38. The CEC of the absorbents were determined to be 121.16 $cmol_c$/kg and 93.12 $cmol_c$/kg for RHB and CH, respectively. The CEC for RHB was however very high and this could be due to the age of the RHB. Generally fresh RHB have a very low CEC, which increases over time (Ogawa & Okimori, 2010). The high biochar CEC of could be due to the high amounts of oxygen-containing functional groups (e.g. -CO [O] and -OH) (Jeffrey & Saenger 2012). Other studies have credited the high CEC of biochar to carboxylic groups formation due to oxidation of the edges of the aromatic backbone of biochar (Glaser et al., 2002). This imply that RHB with CEC of 121.1 $cmol_c$/kg contains higher these oxygen-containing functional groups than CH with 93.12 $cmol_c$/kg CEC.

The pH of the two biochars were more than 7.0 and that could be due to the type of pyrolysis (Streubel et al., 2011). The general consensus is that, pyrolysis between 300ºC to 600^{o}C, organic acids and phenolic substances are released during the cracking of hemicellulose and cellulose. These acids then combine with basic cations in the feedstock to form alkali salts with a concomitant increase in pH of the biochar (Tetteh, 2014). It is evident that type of feedstock has accounted for differences in pH in the biochar types.

Column Leaching Experiment - Soil 1

Table 16: Result of the Measured Parameters (Soil Weight (SW), Bulk Density (BD), Volume (V) and pH of Weekly Leachate) of S1 during Leaching Experiment

No.	Treatment	SW	BD	VWK1	pHWK1	VWK2	pHWK2	VWK3	pHWK3	VWK4	pHWK4	VWK5	pHWK5	VWK6	pHWK6
1	S_1CH_b	300.47	1.30	64.68	7.64	65.84	7.84	63.50	7.69	53.10	8.36	56.30	7.87	53.40	7.38
2	S_1CH_a	300.50	1.31	66.80	7.71	66.08	7.69	63.20	7.96	58.80	8.17	55.70	7.77	54.20	7.48
3	S_1RHB_b	300.30	1.31	64.49	7.76	62.24	7.85	62.60	7.95	58.10	8.19	60.20	7.47	63.80	7.36
4	S_1RHB_a	300.30	1.35	66.89	7.57	61.03	8.05	58.50	8.09	56.90	8.20	54.00	7.67	62.70	7.42
5	S_1C	300.27	1.31	63.44	7.37	63.78	7.59	54.10	7.99	57.90	8.16	55.00	7.20	59.40	6.90
	LSD	0.51	0.16	5.07	0.37	6.27	0.39	13.6	0.57	23.00	0.22	10.37	0.56	13.67	0.66
	SE	0.16	0.05	1.56	0.11	1.92	0.12	4.00	0.18	7.05	0.07	3.18	0.17	4.19	0.20
	CV	0.10	6.30	4.10	2.60	5.20	2.70	11.50	3.80	21.50	1.40	9.80	3.90	12.40	4.80

Values are means of three replicates. S_1CH_b – soil type 1 with 1% charcoal, S_1CH_a - soil type 1 with 0.5% charcoal, S_1RHB_b - soil type 1 with 1% rice husk biochar, S_1RHB_a - soil type 1 with 0.5% rice husk biochar, S_1C – soil type 1 with 0% amendment; soil weight - (SW); bulk density - (BD); volume-(V); WK –week and pH; LSD - Least Significant Difference; SE - Standard Error; CV - Coefficient of Variation.

The result of the mean of the measured parameter of S1 (soil weight (SW), bulk density (BD), volume and pH of weekly leachate) from Wassa Amenfi West district are presented in Table 16.

From Table 16, means of soil weight of the various sample treatments were statistically to each other. The measured BD was consistent throughout the columns twhich will ensure uniform hydraulic conductivity. However, the mean pH for week 1, 2 and 5 were significantly different from each other. In week 1, S_1C was statistically significantly different from S_1RHB_b but it was not significant different from S_1CH_a, S_1CH_b and $S_1RHB_{a.}$ Likewise in week 2, S_1C was significantly different from S_1RHB_a but not significantly different from S_1RHB_b, S_1CH_b and S1CHa. In week 4, all sample treatments recorded high pH values compared to value for the other weeks. And finally in week 5, there was no significant difference between S_1CH_b and S_1CH_a, S_1RHB_a and S_1RHB_b but was there was significant difference between S_1C. S_1C and S_1RHB_b and $S_1RHB_{a.}$

It was observed that pH values fluctuated across the weeks, with recorded pH values ranging between 6.90 – 8.3 during the 6 weeks perriod. The pH of S1 before the leaching experiment was 4.48, CH was 9.92 and RHB, 7.07. Therefore it can be deduced that, the increase in pH in the weekly leachates could be as a result of adding absorbent to the soil. This is similar to findings reported by Lehmann et al. (2011); Mandal et al. (2017) and Jeffrey & Saenger (2012) that biochars have the ability to increase soil pH.

Table 17: Cumulative Means and Standard Deviations of Imidacloprid Concentrations Leached from Soil 1 with added Adsorbents

Soil 1	Mean (µg/ml)	Std. Deviation
S1C	0.83	0.71
S1CHa	0.75	0.59
S1CHb	0.73	0.64
S1RHBa	0.75	0.55
S1RHBb	1.09	0.40

From the Table 17 above, the treatment S1CHb had the lowest mean concentration of 0.73µg/ml. This explains how variation of imidacloprid concentration spread around the mean which may indicate that S1CHb adsorbent may have performed well in removing imidacloprid from the soil 1.

Table 18: Mean Concentrations of Imidacloprid in Weekly Leachates ± SE (µg/ml) in Soil1 (S_1)

Treatments	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
S1CHa	N/A	N/A	1.38 ± 0.54	0.87 ± 0.59	0.41 ± 0.35	0.32 ± 0.35
S1CHb	N/A	N/A	0.73 ± 0.22	1.19 ± 0.74	0.82 ± 0.21	0.25 ± 0.21
S1RHBa	N/A	N/A	0.44 ± 0.66	1.43 ± 0.05	0.29 ± 0.41	0.76 ± 0.41
S1RHBb	N/A	N/A	1.29 ± 0.34	0.94 ± 0.17	0.84 ± 0.17	1.27 ± 0.17
S1C	N/A	N/A	1.26 ± 0.68	0.66 ± 0.54	1.26 ± 0.81	0.12 ± 0.02
Repeated Measures Analysis	*p*					
Treatments	<.347					
weeks	<.021					
Treatment* weeks	<.023					

Weekly values are means of three replicates. S1CHa- (Wassa Amenfi West soil + Charcoal at 0.5 %), S1CHb -(Wassa Amenfi West soil + Charcoal at 1 %), S1RHBa - (Wassa Amenfi West soil + Rice Husk Biochar at 0.5 %), S1CHb - (Wassa Amenfi West soil + Rice Husk Biochar at 1 %), S1C (Wassa Amenfi West soil with no amendment), Repeated Measures Analysis performed with SPSS.20 GLM, significance at p<0.05. ± indicate standard error of the means. N/A; Week 1 and 2 data is lost accidentally.

From table 18, the analysis of variance for the treatments was not significant with (F=1.15; P= 0.35). Thus, there is no significant evidence to reject the null hypothesis and conclude that there is no significant difference in adding charcoal and rice husk biochar in removing pesticides from soil 1. This is to say that the addition of CH and RHB did not completely remove imidacloprid rather reduce its concentration in the soil. However, there was significant difference in weeks, (F =3.60; P= 0.021). The interactions between treatments and weeks was significant (F= 2.33; P= 0.023). There was significant difference among interactions of treatment and weeks since p-value = 0.02 is less than alpha –value =0.05.

Imidacloprid adsorption in soil 1 with 1% charcoal (S_1CHb) clearly increased across the weeks (0.73 µg/ml to 0.25µg/ml) compared to sorption in 0.5% charcoal (S1CHa - 1.38 µg/ml to 0.32 µg/ml). It was again observed that 0.5% RHB recorded a low concentration of 0.29 µg/ml compared to RHB at 1% (0.74 µg/ml). However, under both CH and RHB conditions, S1 with no amendment also reduced imidalcoprid concentration across the weeks (1.26 µg/ml – 0.12). S1CHa had a steady reduction of the pesticide with respect to time, therefore at week 6, the removal of imidacloprid from S1 with CH at 1% was effective. Likewise, at week 6, the removal of imidacloprid was effective with RHB at 0.5% (0.29 µg/ml) as compared to RHB at 1% (0.74 µg/ml). In general, CH at 1% (0.25 µg/ml) in soil 1 recorded the least concentration of imidacloprid as compared to RHB at 0.5% (0.29 µg/ml).

Table 19: Post Hoc Multiple Comparisons within Weeks (Soil1)

(I) weeks	(J) weeks	Mean Difference (I-J)	Sig.
Week 3	week 6	.4800*	0.044
Week 4	week 6	.4773*	0.046

Tukey HSD; Based on observed means. The error term is Mean Square (Error) = 0.231. * $p<0.05$.

A Post Hoc comparison to evaluate pairwise difference within weeks means was conducted with the use of Tukey HSD test (Table 19). The test revealed significant (P= 0.044) difference between week 3 and week 6 with estimated means of 1.023 and 0.543 for week 3 and week 6 respectively. Weeks 4 and 6 were also statistically significant with (P= 0.046) and mean values of 1.021 and 0.543 respectively. A comparison of the means within weeks suggested that week 6 may have provided suitable conditions for application of adsorbents to decrease imidacloprid leaching in soil 1, followed by weeks 4 and 3.

Table 20: Pairwise Comparisons of Interactions (Treatment and Weeks)

Weeks	(i) Soil 1	(j) Soil 1	Mean Difference	p-values
Week 3	S1C	S1CHb	0.817	0.044
	S1CHa	S1CHb	0.943	0.021
	S1CHb	S1RHBb	0.85	0.036
Week 5	S1C	S1CHa	0.847	0.037
	S1C	S1CHb	0.963	0.019
Week 6	S1C	S1RHBb	1.153	0.005
	S1CHa	S1RHBb	0.95	0.02
	S1RHBa	S1RHBb	1.017	0.013

S1CHa- (Wassa Amenfi West soil + Charcoal at 0.5 %), S1CHb - (Wassa Amenfi West soil + Charcoal at 1 %), S1RHBa - (Wassa Amenfi West soil + Rice Husk Biochar at 0.5 %), S1CHb - (Wassa Amenfi West soil + Rice Husk Biochar at 1 %), S1C (Wassa Amenfi West soil with no amendment), Alpha level (α) =0.05

A pairwise comparisons of interaction between treatment and weeks showed that in week3 treatment S1C and S1CHb were significantly different (P= 0.044) with mean Difference (M.D) = 0.817. This indicates the least concentration of imidacloprid was recorded in week 3. This is to say that the amount of imidacloprid removed may depends on the environmental conditions present in week 3.

In week 5, the interaction between treatment S1C and S1CHa was also statistically significant (P= 0.037; M.D = 0.847). indicating that in week 5, treatment interaction between S1C and S1CHa resulted in more removal of pesticide from the soil. Furthermore, the interaction between S1CHa and

S1RHBb, (P= 0.020; M.D = 0.950), indicating that the removal of imidacloprid depends on the environmental conditions present within that weeks.

Column leaching experiments – Soil 2.

The result of means of the measured parameter for the S2 (soil weight (SW), bulk density (BD), volume and pH of weekly leachate) taken from Suaman district arepresented in Table 21.

The mean soil weight and bulk density of the soils were similar. Volume of leachates collected from week 1 to week 6 were also statistically similar to each other. In contrast, pH values for leachates for week 2, 3 and 6 were different from each other. Means pHof leachates in week 2 ranged between 8.00 (S2CHb) and 7.68 (S2RHBb). Analysis of variance showed no significant difference in pH values of leachate among S2CHb, S2RHBa, S2CHa, and S2C but S2CHb was significantly (P> 0.05) different from S2RHBb. Likewise, S2RHBb, S2CHa, S2C and S2RHBb were not significantly different from each other. In week 3, the pH of the leachate from S2RHBa was significantly different from that from S2C but was not different from that of S2CHb, S2RHBb and S2CHa. In week 6, the mean pH value pf leachate from S2RHBa (7.33) did not differ from that from S2CHb (6.99) and S2C (6.97), but differed from S2CHa (6.68) and S2RHBb (6.63).

It was also observed that pH values of leachates fluctuated across the weeks with pH values ranging between 6.63 – 8.0 during the six nweeks period. The pH of S2 before the experiment was 5.38, therefore it can be assumed that, the increase in pH in the weekly leachates could be attributed to addtion of absorbent to the soil. This is similar to findings reported by

Lehmann et al. (2011); Mendez et al. (2012) and Spokas, Koskinen, Baker & Reicosky (2009) that biochars have the ability to increase soil's pH. However, there was a reduction in pH recorded in week 6 for all the treatment except for the control.

Table 21: Result of the Measured Parameters (Soil Weight (SW), Bulk Density (BD), Volume (V) and pH of Weekly Leachate) of S2 during Leaching Experiment.

No.	Treatment	SW	BD	VWK1	PWK1	VWK2	PWK2	VWK3	PWK3	VWK4	PWK4	VWK5	PWK5	VWK6	PWK6
1	S_2CH_b	300.47	1.23	70.08	7.34	60.10	8.00	63.26	7.88	60.80	8.00	63.70	7.04	49.00	6.99
2	S_2CH_a	300.53	1.25	70.47	7.21	64.40	7.68	61.74	7.71	60.70	7.50	60.90	7.00	58.60	6.68
3	S_2RHB_b	300.30	1.26	70.62	7.06	62.60	7.52	60.99	7.74	63.00	7.49	54.00	6.87	58.60	6.63
4	S_2RHB_a	300.57	1.16	67.12	7.40	66.30	7.69	59.28	7.92	62.30	7.99	58.40	7.30	64.80	7.33
5	S_2C	300.43	1.32	65.87	7.03	58.50	7.66	60.25	7.66	58.70	7.67	48.30	7.25	57.00	6.97
	LSD	0.46	0.08	5.31	0.40	11.56	0.42	6.48	0.24	8.80	0.63	16.56	0.88	24.61	0.38
	SE	0.14	0.03	1.63	0.12	3.54	0.13	1.99	0.07	2.70	0.19	5.08	0.27	7.55	0.12
	CV	0.10	3.6	4.10	2.90	9.80	2.80	5.60	1.60	7.70	4.30	15.40	6.60	22.70	2.90

Values are means of three replicates. S_2CH_b – soil type 2 with 1% charcoal, S_2CH_a - soil type 2 with 0.5% charcoal, S_2RHB_b - soil type 2 with 1% rice husk biochar, S_2RHB_a - soil type 2 with 0.5% rice husk biochar, S_2C – soil type 2 with 0% amendment; soil weight - (SW); bulk density - (BD); volume-(V); WK –week and Ph; LSD - Least Significant Difference; SE - Standard Error; CV - Coefficient of Variation.

Table 22: Cumulative Means and Standard Deviations of Pesticides

Soil 2	Mean	Std. Deviation
S2C	0.68	0.65
S2CHa	0.44	0.42
S2CHb	0.63	0.51
S2RHBa	1.00	0.67
S2RHBb	1.43	1.83

Concentrations Recorded from Soil 2 with added Adsorbents

From the Table 22, the total mean treatment of S2CHa had the least standard deviation= 0.42 and the lowest mean of 0.44. This explains how variation of imidacloprid remains spread around the mean which may indicate that S2CHa treatment may have performed well in removing imidacloprid from the soil 2.

Table 23: *Mean Concentrations of Imidacloprid in Weekly Leachates ± SE (µg/ml) in soil 2 (S2)*

Treatment	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
S2C	N/A	N/A	1.54 ± 0.49	0.85 ± 0.31	0.10 ± 0.07	0.22 ± 0.05
S2CHa	N/A	N/A	0.22 ± 0.08	0.80 ± 0.56	0.12 ± 0.06	0.61 ± 0.43
S2CHb	N/A	N/A	0.79 ± 0.57	0.47 ± 0.55	0.90 ± 0.64	0.37 ± 0.30
S2RHBa	N/A	N/A	0.89 ± 0.76	1.61 ± 0.22	0.90 ± 0.66	0.62 ± 0.78
S2RHBb	N/A	N/A	0.61 ± 0.38	1.33 ± 0.19	1.26 ± 0.64	2.51 ± 3.89
Repeated Measures Analysis	*p*					
Treatments	< 0.134					
Weeks	<0.797					
Treatment*weeks	<0.458					

Weekly values are means of three replicates. S2CHa- (Wassa Amenfi West soil + Charcoal at 0.5 %), S2CHb -(Wassa Amenfi West soil + Charcoal at 1 %), S2RHBa - (Wassa Amenfi West soil + Rice Husk Biochar at 0.5 %), S2CHb - (Wassa Amenfi West soil + Rice Husk Biochar at 1 %), S2C (Wassa Amenfi West soil with no amendment), Repeated Measures Analysis performed with SPSS.20 GLM, significance at p<0.05. ± indicate standard error of the means. N/A; Week 1 and 2 data is lost accidentally.

Two way analysis of variance was conducted to evaluate the null hypothesis that; Use of charcoal and rice husk biochar will assist pesticide leaching in soil 2 included five treatments. This has been presented in Table 23. No significant difference was observed among the treatments (P< 0.134). There was also no significant difference within the weeks, (F=0.339, P= 0.797) indicating there is no significant evidence to reject the null hypothesis. The interactions between treatments and weeks was not significant (F= 1.010, P = 0.233).

Adsorption of Imidacloprid by biochar was at a moderate rate in this study. At week 6, adsorption by CH at 0.5% (0.2 µg/ml) was higher as compared to CH at 1% (0.69 µg/ml). Adsorption of Imidacloprid in RHB treatment was however inconsistent as week 5 recorded the least concentration of 0.12 µg/ml and 0.11 µg/ml for S2RHBa and S2C, respectively. S2RHBb had a steady reduction in concentration along the weeks and recorded the least concentrateion (0.37 µg/ml) at the end of the experiment as compared to S2RHBa (0.61 µg/ml).

At the end of the experiment (week 6), CH at 1% showed maximum imidacloprid adsorption in both soils (S1 – 0.32 µg/ml and S2 – 0.2 µg/ml) followed by RHB at 0.5% in S1 (0.25 µg/ml) and RHB at 1% on S2 (0.61 µg/ml). These results showed that, charcoal was more effective in removing the pesticide from soil. Biomass chemical composition as well as its structure, size, shape and feed density govern the status of pyrolysis outputs (Mandal, et al., 2017). Also, pH of charcoal might have influence this outcome. The pH of the absorbents used in the study were 9.92 and 7.07 for charcoal and rice husk biochar, respectively. At this pH, (7.07- 9.92) imidacloprid will exist as a cation.

Biochars have a net negative charge at this pH range, as suggested by zeta potential measurement, therefore imidacloprid having positive charge will be more strongly adsorbed (Mandal et al., 2017). Likewise, the CEC is not a constant, but appears to be affected by a number of factors. Cation exchange capacity values of the same adsorption complex may increase with increasing pH (Gaskin, Speir & Morris, 2007).

High pesticide sorption potential of biochars has also been attributed to their high surface area and porosity (Mandal et al., 2017). Rice husk biochars has been reported to contain relatively bigger pores than charcoal (Mandal et al., 2017). However, charcoal was a better adsorbent for imidacloprid in this study.

Biochar is said to contain two major adsorption domains: rubbery and glassy; contaminant sorption in rubbery domain is dominated by partitioning phenomenon (linear and non-competitive) whereas sorption in the glassy domain is mainly dominated by the pore-filling mechanism (nonlinear and solute–solute competitive) (Zhang & Zhang, 2014). Therefore, imidacloprid can interact both specifically (H-bonding and charge-transfer interactions) as well as non-specifically (hydrophobic-like interactions) with surface active groups of the adsorbent (Mandal et al., 2017). Probably, both carbonized and non-carbonized fractions of biochar contributed to imidacloprid sorption in the biochar.

To Conclude, Imidacloprid has slightly high potential for leaching and transport to groundwater and consequently care should be given to their monitoring in the soil and groundwater for better control of their present and future impacts.

Mobility results of Imidacloprid in soil obtained in this study were also highly influenced by the soils composition perhaps leading to lower sorption rates and higher leaching. Rice husk biochar and charcoal on the two soil types (clay- loam soil and loamy soil) showed that biochar incorporation in soil can have opposing effects on the leaching of pesticides depending on the adsorption strength.

For both loamy (S1) and clay-loam (S2) soils there were no significant effects of the treatments, rice husk biochar and charcoal on leachates across the weeks. However, there was a statistically significant difference within the weeks and treatments*weeks in soil 1. Soil 2 however, has a high content of clay therefore having high surface area with the ability to absorb more pesticide. In view of this, treatment effect in S2 was less significant.

Results from this study suggests that material originating from the added biochar slightly reduced the transport of imidacloprid. Therefore, studies of biochar effects on the transport of strongly sorbed pesticides are needed. Since imidacloprid pesticide is an organic chemical, charcoal could effectively be used to up this product in soil hence reduce the leaching of imidacloprid in soils. Charcoal is known to be highly porous therefore its addition to soil might have increased the soil's porosity thus increasing its drainage (Jeffrey & Saenger 2012). Once a pesticide adsorbs onto charcoal, it is becomes biologically inactive and cannot cause injury or hazard to organisms (Zhang & Zhang, 2014).

Again, it was observed that the concentration of imidacloprid which is an organic pesticide reduced with time using charcoal as amendment. Significant effects of charcoal amendments on leaching have also been reported by Si, Wang, Hu & Zhou (2011). They studied leaching of isoproturon under constant unsaturated water flow in repacked soil columns amended with charcoal. In their study a charcoal concentration of 0.01 kg^{-1} reduced leaching by 10 – 36% in three soils used when about four pore volumes of water had passed through the columns. On the other hand, in the quest to remove Arsenic and Chromium from water, Agrafioti, Kalderis & Diamadopoulos (2014) used biochars derived from rice husk, organic solid wastes and sewage sludge. At the end of their study, Rice Husk Biochar had a low removal efficiency than the corn cob biochar and sawdust .

Nevertheless, this work suggests that, charcoal has great potential as low-cost adsorbent to prevent contamination of groundwater and minimizing environmental impact caused by the pesticides.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The final chapter provides a brief overview of the study, highlighting the summary of the findings of the study as well as the conclusions, recommendations and suggestions for further research. Thus, the chapter focuses on the implications of the findings from the study for policy formulation. The recommendations were made based on the key findings and major conclusions from the study.

Summary of Findings

The first objective of the study investigated smallholder cocoa farmers' knowledge on pesticides application on cocoa farms. The following major findings emerged: The study revealed that all respondents surveyed use pesticides in cocoa production and the common reason for using pesticides was to protect cocoa plants from insects and diseases. Again, the study revealed that the dominate gender involved in cocoa farming in the study area is male. Most farmers surveyed were between the ages 31 and 40 years.

The study established that a good number of farmers had received basic and secondary level education. Majority of the farmers did no further studies beyond the secondary level. Nonetheless, the proportion of illiterates was equally low. In addition, three-fourth of the respondents had either no or just primary level of education. Hence, farmers could not read labels on chemical containers and understanding the complexity of pesticides chemistry which would be a challenge.

The farmers also indicated local agrochemical stores as their main source of pesticides. For the reason that most farmers are unable to read instructions on labels on containers, majority obtain pesticide knowledge from agricultural extension officers. Though, others use their own experience or are being taught by fellow farmers. Agricultural extension officers act as the interface between the ministry of agriculture and farmers.

The study showed that 89.8% responded against mixing more than one pesticide types. The study further showed that most farmers had a good knowledge of the effects of pesticides on human health and the environment, 92.44%, 94.67% and 93.70% were positive that pesticide could enter the body via mouth, inhalation and skin, respectively. Majority were also aware that residues of pesticide are being left in soils, groundwater, fruits and vegetables.

Moreover, discussions and interview in the study revealed that majority of the farmers keep chemicals on their farm lands. However, a good number of farmers kept chemicals within living home, kitchen, in the food store and animal house. Minority kept them in agrochemical stores.

Another outcome of the study was that container and sachet disposal strategies employed were throwing on field, village landfills, burning on farm and burying in a hole. However, some farmers also put the empty containers to other uses such as storing salts, palm oil, flour and other products meant for consumption.

The study theorized that most farmers seldom wear full PPE during pesticide spraying thereby exposing their body to pesticides. Most farmers who do not use any PPE in the study were noted to be farmers who had no formal education. Farmers with either primary or secondary level of education used all or some form of PPE during spraying. High illiteracy rates contribute to farmers' difficulty in understanding and following instructions and safety advice on pesticide use. This was attributed to low levels of education of participants.

The study also indicated that 66% of the farmers had fallen sick from general body weakness; headache, skin itching, burning eyes and skin rash. It was also revealed that, farmers sprayed the same wide range of pesticides on all crops.

Calculating the risk of pesticides application using EIQ model was the second objective. The study revealed that the commonly pesticides used by the respondents in this study were insecticides. Eighty percent (80%) of the pesticides used by farmers were moderately hazardous (III), while the rest were slightly hazardous (II).

Also, with respect to the EI values obtained in this study, the recommended pesticide for insect pest control would be Thiamethoxam, Cyhalothrin Lambda and Bifenthrin, while a ban should be placed on Copper Hydroxide, Imidacloprid, and Acetamiprid. Thiamethoxam had the lowest EI per hectare (0.79) < 25. Whereas Copper Hydroxide, Imidacloprid, and Acetamiprid had very high EI values (118.80, 352.32 and 551.04, respectively) in this study.

Determination of transport and removal of pesticides by adsorbents (rice husk biochar and charcoal) from two soils was the third objective of the study. The key findings that emerged from this objective was that the adsorption on soil is highly influenced by soil pH, type, texture, moisture and organic matter content. The adsorption of imidacloprid on biochar and charcoal in this study showed that the biochar greatly varied in their capacity to adsorb pesticides. The removal efficiency of the different adsorbents used varied. Sorption of the pesticide was concentration dependent and the initial concentration decreased with increasing in time (weeks). At the end of the experiment (week 6), among charcoal (CH) at 1% showed maximum imidacloprid adsorption in both soils (S1 – 0.32 µg/ml and S2 – 0.2 µg/ml) followed by RHB at 0.5% in S1- 0.25 µg/ml and RHB at 1% in S2 - 0.61 µg/ml. Both unamended soil types had low concentration of the pesticide at the end of the experiment which could be due to biodegradation of pesticide in the soil.

Conclusion

This study concluded that farmers have good knowledge of the effect of pesticides on human health and the environment, but this did not translate into good hygiene and work ethic practices. The spraying of broad-spectrum pesticides on crop which kills non-target organism such as pollinators and soil organisms is a threat to the agro ecosystem. The reuse of pesticide empty containers as storage containers in households exposes the farmers to health hazards.

Upon using EIQ model to calculate risk of pesticides application in the study area, Copper Hydroxide, Imidacloprid, and Acetamiprid insecticides were identified to likely cause high mortality to pollinator on field, therefore their rate of application should be monitored intensively. The large number of application rate of pesticides in the study area pose a risk to the environment especially to insects and pollinators.

The study further concluded that biochars from different feedstocks greatly varied in their physicochemical properties and their ability to adsorb imidacloprid from soil. Among the biochars used the charcoal at 1% was the best adsorbent. Pesticide adsorption on biochars might have been affected by their aromaticity, polarity, pore volume, pore diameter, surface area, pH and surface acidity.

This work therefore suggests that charcoal has great potential as low-cost adsorbent to prevent contamination of groundwater and minimizing environmental impact caused by the pesticides.

Recommendations

In view of the above findings, it is recommended that Ministry of Agriculture and COCOBOD be financially empowered to carry out vigorous training and frequent monitoring of farmers work practices.

There should be a strategy put in place by the chemical vendors to incenticize the collection of used storage pesticide containers.

A separate unit should be set up to monitor the spraying of chemicals to invested cocoa farms. This is to avoid the cocoa farmers having contact with the chemicals.

Finally, the use of broad-spectrum pesticides should be discouraged for the reason that non selective insecticide application is highly deleterious to the environment. In view of this, pesticides should therefore be applied to target specific pest to minimize the devastating effect of non-target organisms. Samples of cocoa beans and pods produced in the study area should be collected to test for pesticide residue.

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APPENDICES

APPENDIX A

QUESTIONNAIRE ADMINISTERED DURING STUDY

ASSESSMENT OF PESTICIDE USES IN SEFWI, GHANA

Personal particulars of the respondent

Village:……………. District: ………….. Date: ………….. Questionnaire no ………….

a) BACKGROUND

1. Are you

☐ Male
☐ Female

2. What is your age? …………………

3. Which ethnic group do you belong? ……................................

4. What is your occupation? ……………………………

5. What is your religion?

☐ Christian
☐ Muslim
☐ Traditionalist
☐ Other (specify) ……………..

6. What formal education do you have?

☐ No formal education
☐ Primary education
☐ Secondary education Level
☐

7. What is your position in the family?

☐ Father
☐ Mother
☐ Daughter
☐ Son
☐

Other (Specify) …………

8. What is the main economic activity in your household?

☐ Farming

☐ Day worker

☐ Small business

☐ Other (Specify) ……………

Certificate/diploma

9. How many people live in your household? ……………………...

10. How many of the household members are below 18 years old?

…………………………………….

11. What is the app. size of your farm:……..

☐ Degree level

☐ Other (specify) …………..

12. Which of the following crops can be found within your farm?

Tick (√) against		Crops	Tick(√) against		Crops
For own use	For sale		For own use	For sale	
		Tomatoes			Cowpeas
		Onion			Maize
		Cabbages			Rice
		Spinach			Plantain
		Green pepper			Sugarcane
		Carrot			Oranges
		Cocoyam			Mangoes
		Yam			Pawpaw
		Egg plant			Millets
		Okra			Sweet potatoes
		Melon			Cucumber
		Beans			Others: (i)
		Cassava			ii…………
		Cotton			iii. …………
		Cocoa			

b] PESTICIDE KNOWLEDGE

13. Which pesticides do you know by name?

……………………………………

……………………….....................

……………………………………

15. Can pesticides cause negative health *effects?*

☐ *Yes*

☐ No

☐ I don't know

16. Do all pesticides have the same health *effect?*

☐ Yes

☐ No

☐ I don't know

17. Can pesticides be dangerous to use?

☐ Yes

☐ No

☐ I don't know

18. Can pesticides enter the body through inhalation?

14. Which forbidden pesticides do you *know?*

…………………………………..

……………………….................

…………………………………..

☐ Yes

☐ No

☐ I don't know

19. Can pesticides enter the body through the skin?

☐ Yes

☐ No

☐ I don't know

20. Can pesticides enter the body through the mouth?

☐ Yes

☐ No

☐ I don't know

21. Can pesticide residues be left in the air?

☐ Yes

☐

No

☐ I don't know

22. Can pesticide residues be left in the soil?

☐ Yes

☐ No

☐ I don't know

23. Can pesticide residues be found the groundwater?

☐ Yes

☐ No

☐ I don't know

24. Can pesticide residues be found in fruits?

☐ Yes

☐ No

☐ I don't know

25. Can pesticide residues be found in vegetables?

☐ Yes

☐ No

☐ I don't know

26. Do you read manufacturer notifications?

☐ Yes

☐ No

☐ I don't know

27. Do you respect manufacturer notifications?

☐ Yes

☐ No

☐ I don't know

(C) PESTICIDE USE

28. Have you ever used pesticides?

☐ Yes, I currently do (go to no.

☐ Yes, in the past (go to no. 30)

☐ No (go to no. 33)

29. Why do you use pesticides?

☐ To protect crops against insects

☐ To make crops grow better

☐ Because others use pesticides

☐ Because I was advised to use pesticides

☐

Others

☐ I don't know

30. Why did you stop using pesticides?

☐ Did not show good response

☐ Scarcity availability of pesticides

☐ High buying costs

☐ Others ....

☐ I don't know

31. Where do get/buy the pesticides that youuse?

☐ Agrochemical shops in Arusha

☐ town

Local agrochemical shops in

the village

☐ Extension officers

☐ General shops

☐ Cooperative societies

☐ Others ………………….

32. If you currently use other pesticides (answered "Yes" on no 28), mention the insecticides, fungicides and herbicides you use

Type of pesticides	**Crop that use**	**Season of use**	**Amount per each application pr. Area**	**Interval of use(last spraying before harvest could be interesting to know or post-harvest)**	**Application methods, e.g. knapsack sprayers**
Insecticides:					
Fungicides:					
Herbicides:					

33. What are the common crop pests you encounter in your farm?

(i) ………………………………

(ii) ………………………………

(iii) . ………………………………

(iv) …………………………………

34. What are the common crop diseases you encounter in your farm?

(i) …………………………………

(ii) ………………………………..

(iii) . ………………………………

(iv) ………………………………

35. What makes you to decide the time to apply pesticides to your farm?

- ☐ Presence of pests
- ☐ Degree of pest infestation
- ☐ Date of planting
- ☐ On calendar spray schedules
- ☐ On economic thresholds
- ☐ Don't know
- ☐ Others ……………………

36. Where did you get the knowledge on pesticides application methods and rate?

- ☐ Agrochemical shops
- ☐ Extension officers
- ☐ Pesticides labels on packages
- ☐ Fellow farmers
- ☐ Own experience

37. How do you dilute/mix the pesticide before application?

- ☐ Mix more than one types of pesticides with water in one container
- ☐ Mix one type of pesticide
- ☐ with water in a container
- ☐ Depending with instructions on the label
- ☐ Don't know
- ☐ Others ……………………

D) ATTITUDES TOWARDS PESTICIDE USE

To what degree do you agree or disagree with following statements:

38. Proper knowledge is necessary when using pesticides.

☐ Strongly agree
☐ Agree
☐ Disagree
☐ Strongly disagree

39. There are minimal health risks attached to pesticide use.

☐ Strongly agree
☐ Agree
☐ Disagree
☐ Strongly disagree

40. Pesticides should be used with precautions.

☐ Strongly agree
☐ Agree
☐ Disagree
☐ Strongly disagree

41. Pesticides use is important to secure good crops.

☐ Strongly agree
☐ Agree
☐ Disagree
☐ Strongly disagree

42. Pesticides use should be limited.

☐ Strongly
☐ agree Agree
☐ Disagree
☐ Strongly disagree

E) PROTECTIVE MEASURES

43. During the last three months, when you applied pesticides...

a) ...did you wear gloves?

☐ Yes ☐ No

b)... did you wear goggles?

☐ **Yes** ☐ No

c) ... did you wear something on your head?

☐ Yes ☐ No

d) ... did you wear oral/nose mask?

☐ Yes ☐ No

e)... did you wear special boots?

☐ Yes ☐ No

f) ... did you wear overall?

☐ Yes ☐ No

44. Have you ever used protective gears during handling (mixing, spraying) of pesticides?

☐ Yes (go to no. 40)

☐ No (go to no.41)

45. If answered "yes", mention the gears you have ever used

………………………………………

………………………………………

………………………………………

………………………………………

46. In your opinion, is the trend of pesticide use increasing, constant or decreasing?

☐ Increasing

☐ Constant

☐ Decreasing

47. In your opinion, what are the reasons for the increase, constant or decrease?:

(a) Increase

…………………………………

…………………………………

…………………………………

…………………………………

(b) Decrease

…………………………………

…………………………………

…………………………………

…………………………………

(c) Constant

…………………………………

…………………………………

…………………………………

…………………………………

48. Where do you store the pesticides?

- ☐ In the agrochemical store
- ☐ Animal houses
- ☐ In the food store
- ☐ Living house
- ☐ In the kitchen
- ☐ In the bush
- ☐ In the toilet
- ☐ Others…….
- ☐ I don't know

49. Where do you dispose empty pesticide containers?

- ☐ Sell to others
- ☐ Put in other uses/give to others
- ☐ Throw away on farm
- ☐ Throw away in town or village garbage
- ☐ Bury in ground on farm
- ☐ Burn on farm
- Others ………………

50. Where do you dispose remnants of pesticides after end of application?

- ☐ On field
- ☐ Throw in rivers, lakes or irrigation canal
- ☐ Bury in the ground on farm
- ☐ Others…………………

51. Where do you wash the sprayers after application of pesticides?

- ☐ In rivers, lakes or irrigation canal
- ☐ At home using tap or bucket water
- ☐ I don't wash
- ☐ Wipe with piece of cloth or paper and throw it away
- ☐ Other ....

52. How long do you wait from last spraying to selling of crops?

- ☐ I sell just after pesticide spraying
- ☐ 1-2days

☐ 3 - 6 days

☐ One week

☐ More than one week

☐ Depending on manufacturer's instructions

☐ Others ....

53. Do you use the crops you spray with pesticides as food in your family?

☐ Yes

☐ No

54. After application of pesticides to crops, have you ever experienced...

a) ...headache?

☐ Yes ☐ No

b)... burning sensations in eyes/face?

☐ Yes ☐ No

c)... weakness?

☐ Yes ☐ No

d)... fever?

☐ Yes ☐ No

e)... watering eyes?

☐ Yes ☐ No

f) ... skin rash?

☐ Yes ☐ No

g) ...itching and skin irritation?

☐ Yes ☐ No

h)... dizziness?

☐ Yes ☐ No

i)... chest pain?

☐ Yes ☐ No

j)...forgetfulness?

☐ Yes ☐ No

k)... vomiting?

☐ Yes ☐ No

i) ... diarrhoea?

☐ Yes ☐ No

55. What common diseases (health problems) do you get in your family?

………………………………………

………………………………………

………………………………………

56. What are the common medication you normally use?

………………………………………

……………………………………….

……………………………………….

57. Do you know any other methods of pests control apart from using pesticides?

☐ Yes

☐ No

58. If answered "Yes" on question 57, mention the alternative methods of pest control

i)…………………………………….

……………………………………….

ii)……………………………………

……………………………………….

iii)…………………………………

……………………………………….

……...

THANK YOU FOR YOUR COOPERATION

APPENDIX B

A COCOA PLANT WHICH HAS BEEN INFESTED WITH BLACK POD DISEASE.

APPENDIX C

A COCOA PLANT WHICH HAS BEEN CROSS POLLINATED BY HUMAN AND HAS BORE LOT OF FRUITS.

APPENDIX D

SOIL COLUMN LEACHING EXPERIMENTAL SETUP