KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

KUMASI

COLLEGE OF SCIENCE

DEPARTMENT OF THEORETICAL AND APPLIED BIOLOGY

ORGANOPHOSPHATE AND PYRETHROID INSECTICIDE RESIDUE LEVELS IN WATER BODIES IN COTTON GROWING AREAS IN SAVELUGU/NANTON DISTRICT, NORTHERN REGION, GHANA

BY

ABDULAHI ALIYU

NOVEMBER, 2014

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THESIS SUBMITTED TO THE DEPARTMENT OF THEORETICAL AND APPLIED BIOLOGY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MSC. DEGREE IN ENVIRONMENTAL SCIENCE

BY

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NOVEMBER, 2013

DECLARATION

I hereby declare that this submission is my own work towards the MSc. Degree and to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the Kwame Nkrumah University of Science and Technology or any other university, except where due acknowledgement has been made in the text.

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(Head of Department) Signature Date

DEDICATION

I dedicate this thesis to my parents, Mr and Mrs Abdulahi, my wife Ibrahim Mariama, my daughter, Aliyu Ahlaam and to all my friends for their support and encouragement.

ACKNOWLEDGEMENT

Glory, honuor and praise to Almighty God the most high who granted me protection, guidance and direction throughout my period of study. My profound and heartfelt gratitude goes to my supervisor, Professor Kwasi Obiri-Danso for guiding me to carry out this research. Prof, I would forever remain grateful to you for your kindness and may the Good Lord guide and protect you and your family throughout your lives. I am also grateful to Mr. Sadick Moammed for your assistance and encouragements during the compilation of this document. I will also like to express my sincere appreciation to Mr. Malik Adongo, a staff of the Ghana Standard Authority for assisting me with the laboratory analysis in their laboratory. I would also like to extend my gratitude to my family, friends especially my wife, Mrs Aliyu Mariama and every Individual who in one way or the other contributed to the success of this work. To all and sundry whose names have not been mentioned I say thank you and may the Good Lord bless you all.

ABSTRACT

Organophosphate and pyrethroid insecticide residue levels in water bodies in cotton growing areas in Savelugu/Nanton District in the northern region of Ghana were investigated. Water samples were collected from twelve boreholes and four hand-dug-out wells from sixteen communities in the district and analyzed using the US EPA Method 3510 for aqueous matrix for the analysis of semi-volatile and non-volatile organics. In total, eight different insecticides were detected. Concentrations of Cyhalothrin, Chlorpyriphos and Flubendiamide in the water samples were 0.910, 0.870 and 0.621 µg/L, respectively, and were higher than the maximum residue limit of 0.5 µg/L set by the Ghana Standard Authority and the acceptable limit of the European Economic Commission standard for drinking water (0.1 µg/L) . Concentration of cypermethrin, acetamiprid, Flubendiamide, profenos and imidacloprid were below the detection limit by 12, 43, 37, 25 and 44%, respectively in the water samples analyzed. The results of this study provide information on levels of various insecticide residues in the water bodies in the cotton growing areas in the district and the potential health risks to users and farmers. The further also revealed that insecticide handling among cotton farmers in the District is inadequate.

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LIST OF ACRONYMS

ANOVA	Analysis of Variance
CEPS	Customs Excise and Preventive Service
CSIR	Council for Scientific and Industrial Research
DDT	Dichloro-diphenyl-trichloroethane
EPA	Environmental Protection Agency
EEC	European Economic Commission
EJF	Environmental Justice Foundation
FAO	Food and Agricultural Organization
GSA	Ghana Standards Authority
GTZ	German Technical Cooperation
HCH	Hexa-chlorocyclohexane
IPM	Integrated Pest Management
ICAC	International Cotton Advisory Committee
ISSER	Institute of Statistical, Social and Economic Research
MOFA	Ministry of Food and Agriculture
MSc	Master of Science
NPASP	Northern Presbyterian Agricultural Services and Partners
PPRSD	Plant Protection and Regulatory Services Directorate
PAN	Pesticide Action Network
POP	Persistent Organic Pollutants
SARI	Savannah Agricultural Research Institute
SPSS	Statistical Package for Social Scientists
SNDA	Savelugu/Nanton District Assembly

UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
USEPA	United States Environmental Protection Agency
WHO	World Health Organization

CHAPTER ONE

INTRODUCTION

1.1Background

Worldwide, it is estimated that approximately 1.8 billion people are engaged in agricultural activities as the primary source of livelihood and therefore use insecticides to protect the food and commercial products they produce (Alavanja, 2009). In Ghana, agriculture forms an important component of the country's economy, providing employment to about 60% of the population while contributing as much as 40% to gross domestic product (Gerken *et al.,* 2001). Crop damage from pest and disease infestations often results in serious consequences, warranting the need to use insecticides. World history contains numerous episodes of mass destruction of crops and people by diseases and insects. For instance, in 1845-1851 the potato famine of Ireland occurred as a result of widespread infection of potatoes by the fungus, *Phytophthora infestans*, now referred to as late blight. In the 1930s, 30 percent of the U. S. wheat crop was lost to stem rust. The same organism destroyed 3 million tons of wheat in Western Canada in 1954. Construction of the Panama Canal was abandoned by the French in the 19th Century after 30,000 labourers died from yellow fever. It is estimated that the number of deaths resulting from all wars are small when compared to the toll taken by diseases transmitted by arthropod vectors (Grodner, 1996).

However, pest and disease infestation is one of the major constraints that impede development of the agricultural sector. It is estimated that each year pests destroy about 30-48% of the world's food production (Zacharia, 2011). For example, in 1987 it was reported that, one third of the potential world crop harvest was lost to pests. In India, during 1973-74 the estimated loss was Rs.6000 million and this increased to Rs.1,84,000 million in 1989-90 (Dhaliwal and Pathak, 1993). Crop loss from pests declines substantially when Insecticides are used (Pimentel, 1997; Liu and Liu, 1999). India, a former country of famine, has quadrupled grain production since 1951 (Jha and Chand, 1999) and now not only feeds itself but exports produce. Similarly, average national wheat yields in the United Kingdom rose from 2.5 t/ha in 1948 to 7.5 t/ha in 1997 (Austin, 1999). Corn yields in the USA went from 75 bushels per hectare to over two hundred per hectacre over the period from 1920 to 1980 (Kucharik and Ramankutty, 2005). Warren (1998) also drew attention to the spectacular increases in crop yields in the United States. Webster *et al*. (1999) stated that considerable economic losses would be suffered without pesticide use and estimated 50% yield and gross margin increase resulting from pesticide use in British wheat production. Webster and Bowles (1996) concluded that without insecticides, apple production would not be commercially viable and farmers would have to use their land for other purposes. The economic value of apple has increased to 1,223 million dollars by using fungicides (Guo *et al.,* 2007). In Russia, Petrusheva (1975) attributed orchard yield increases of 1.5–2 times to the use of insecticides. Gianessi and Leonard (1999) also attributed all year round availability of inexpensive and good quality fresh fruits and vegetables largely to the use of insecticides. Baquedano *et al.*, (2010) reported increased cotton yields in West Africa from an average of roughly 200 kg/ha in 1963 to highs of 1400 kg/ha in the middle part of the 1980s to the use of insecticides, herbicides and chemical fertilizers.

Notwithstanding the major impact insecticides make on agricultural productivity, vast differences exist among different agricultural regions in terms of insecticide production and consumption. Approximately, 5.6 billion pounds of insecticides are used worldwide with over 1 billion pounds of insecticides used in the United State each year (Alavanja, 2009). China is the world's biggest user, producer, and exporter of Insecticides (Yang, 2007). China produces about

300 types of insecticides and an additional 800 types of pesticide mixtures. In 2005, China produced 1,039,000 tons of insecticides and exported 428,000 tons (Yang, 2007). According to Xinhua (China's main state news agency), the annual pesticide use in China is about 1.2 million tons, on approximately 300 million hectares of farmlands and forests. Currently, South Africa is one of the four largest importers of insecticides in sub-Saharan Africa (Osbanjo *et al.*, 2002) and has more than 500 registered insecticides to her name (Pesticide Action Network (PAN), 2010). The distribution of insecticide consumption by individual crops also differs globally. For example, in Brazil the top four crops for pesticide consumption by value were soybean (45%), cotton (10%), sugar cane (8%) and maize (8%). In the USA, cotton was the third largest crop for total pesticide use by value (8%) after maize (23%) and soybean (19%). Worldwide sales of Insecticides used in cotton production between 2004-2007 consistently represented ca. 8% of total sales, with pesticide sales for cereals (maize and rice), fruits, vegetables, and soybean being higher (SEEP, 2006).

Cotton, although a non-food crop with the least insecticide consumption when compared to food crops such as soybean and maize, is responsible for the release of US$ 2 billion of chemical insecticides each year, within which at least US$ 819 million are considered toxic enough to be classified as hazardous by the World Health Organization. Cotton accounts for 16% of global insecticide releases, more than any other single crop. It is estimated that almost one kilogram of hazardous insecticides is applied for every hectare under cotton (EJF, 2007).

The use of insecticides in agriculture may lead to contamination of surface and ground water by drift, runoff, drainage and leaching. Surface water contamination has potential ecotoxicological effects on aquatic, natural flora and fauna and human health if the water sources are used for public consumption (Foney *et al.*, 1981). Surface water contamination usually depends on the agricultural season and does not last long while ground water contamination has a strong inertia, which may cause a continuous human exposure through drinking water supplies (Funari and Vighi, 1995). Before the 1970s, attention was primarily focused on contamination by organochlorine insecticides, such as DDT and Dieldrin. Since that time however, a broad array of modern, medium to polar insecticides have been released for use in agriculture, with less persistence, partly to reduce the potential for residue contamination of surface waters (Berry *et al.*, 1979).

1.2 Problem Statement

According to the Ministry of Food and Agriculture of Ghana (MOFA, 2011), out of the total land area of 23,853,900 hectares, only 57.1% (13,620,576.9 hectares) is suitable for agriculture. However, 7,876,820 hectares of the arable land are cultivated because the soils are infertile and only productive with proper management and good agricultural practices. In the light of this and the need to increase food supply, the use of crop protection chemicals, organic fertilizers, improved water and soil management as well as increased area of agriculture land seems the simplest way to obtain better yields (Fianko *et al.*, 2011).

In the past, agricultural production was done on a more organic basis, making use of natural sources of pest and disease control mechanisms and organic fertilizer. However with increasing population, thus increased demand for food and other agricultural products to satisfy human needs, larger acres of land are now put under agricultural production. In Ghana, the increase in urban population and food demand has catalyzed the use of chemical insecticides for food production (Amoah *et al.*, 2006). The importation and use of modern technology and crop varieties which demand high use of inputs (insecticides, fertilizer, etc.) to achieve optimum yields have also resulted in increased pesticide use (NPAS, 2012).

According to Rao (1980) unless production inputs were matched with protection measures, yield increases are not possible. Slightly more than 50 per cent of all yield increases in agriculturally advanced countries of the world today are the result of agro-chemicals. Fungicides are used on 80% of fruits and vegetable crops in the United States. The economic value of apple has increased to 1,223 million dollars by using fungicides (Guo *et al.*, 2007). Knutson *et al.*, (1990) stated that if the consumption of insecticides is prohibited, the food production in the USA would drop sharply and food prices would soar. Hence, export of cotton, wheat and soybean in the United States would decline by 27%, and 132,000 jobs would be lost (Zhang *et al.*, 2011).

Though pesticide use is said to have contributed significantly to food security by way of increase in crop production and reduction of post harvest losses, there is growing concern over the ill-effects of insecticides on human health, environment, natural resources and sustainability of agricultural production as their use is usually accompanied with deleterious environmental and public health effects (Zacharia, 2011). Indiscriminate use of insecticides reduces biodiversity and aggravates soil, water and air pollution (Nagendra, 2009). In Ghana, insecticide contamination has been detected in water, sediment, crops and human fluids in areas of highly intensive vegetable production (Ntow, 2001). Chemical Insecticides are used improperly or in dangerous combinations (Obeng-Ofori *et al.*, 2002), a phenomenon which could lead to these residual effects.

Ghana is among the countries that use the least amount of insecticides in the world, however, insecticide use and misuse is increasingly becoming popular. The misuse of chemical insecticides is of so much concern that promotion of safe use of insecticides on vegetables has been placed on the agenda of Ghana's Food and Agriculture Sector Development Policy (Ministry of Food and Agriculture, 2002). The ministry collaborates with the Environmental

Protection Agency of Ghana (EPA) to implement various activities aimed at reducing environmental damage caused by the use of insecticides. However, despite this effort, there seem to be no compliance by insecticide users as current research suggests Cotton is the world's most important non-food agricultural commodity, yet it is responsible for the release of numerous chemical insecticides each year, of which more than 50% are considered toxic and hazardous by the World Health Organization. Cotton is seen as one crop that can be used to fight poverty in resource poor communities in developing countries. Predominantly, members of the rural poor, cultivate cotton on plots of less than one-half hectare, or on part of their farms, as a means of supplementing their income. The majority (99%) of these resource poor farmers live and work in the developing world where there are low levels of safety awareness, lack of access to personal protective equipment, illiteracy, poor labeling of insecticides, inadequate safeguards, and chronic poverty. All these are factors that can exacerbate the damage caused by cotton insecticides (EJF, 2007).

Generally, determination of the environmental impact of Insecticides depends on several factors such as pesticide active ingredient, dose rate, application frequency and method, environmental conditions (weather, soil type and geological formation), and site characteristics (available surface water resources and presence of biological species) (Reus et al., 1999).

Agricultural workers, consumers of agricultural produce and beneficial living organisms (both plant and animal species) in the environment are often the obvious victims of insecticides toxicity and hazards. The extent to which the environment in which the resource poor rural cotton farmers who lack protective clothes are affected by insecticide use toxicity and hazards over the years seemed to have been largely neglected by researchers, in poor producing areas such as Northern Ghana. Policy makers also seemed to have largely ignored this issue and regulations protecting farmers who earn their income through cotton production tend to be either weak or poorly enforced.

In Ghana, the major challenge facing cotton companies and farmers for expanded cotton cultivation is limited expertise on good agricultural practices on the part of both company extension officers and the farmers contracted by cotton companies to produce cotton. Extension service is not readily available to cotton farmers, leaving them with no choice but to rely on traditional forms of farming practice, which may not be sustainable. Insecticide handling practices among these cotton farmers is not monitored and it seems probable that there is significant contamination of ground and surface waters which pose potential health risks to communities. Surface and ground water are the main source of drinking water in most farming communities and so this risk should be taken seriously. The present study therefore aimed at assessing the presence and levels of organophosphate and pyrethroid insecticide residues in water bodies close to cotton farms and the health implications in one of the highest cotton growing districts in Northern Ghana, the Savelugu–Nanton District of the Northern region.

The study was conducted in a savanna zone noted for its production of cotton and so may not necessarily be representative of the country as a whole, Nevertheless, in the absence of evidence confirming the levels of pesticide residue in water bodies close to cotton farms and the health implications, the results will provide information about potential health risks to farmers and other users of Insecticides, due to exposure to insecticides for consideration by policymakers and the government. Means to mitigate the potential health hazards faced by farmers due to use of insecticides will be considered.

Main Objective:

The aim of this study was to assess the presence and levels of organophospate and pyrethroid insecticide residues in water bodies in cotton growing areas and the health implications to farmers in the District.

Specific Objectives:

The specific objectives were to:

1. Determine the insect pests that attack cotton crops in the Savelugu-Nanton district.
2. Determine the insecticides available and in use by cotton farmers in the district.
3. To evaluate Insecticides handling practices by cotton farmers in the district.
4. To establish the presence and levels of organophosphate and pyrethroid insecticide residues in water bodies of cotton growing areas in the District

CHAPTER TWO

LITERATURE REVIEW

2.1: Definition of Pesticides

The FAO (1989) defined a pesticide as any substance or mixture of substances intended for preventing, destroying, or controlling any pest including vectors of human or animal diseases, unwanted species of plants or animals causing harm during, or otherwise interfering with, the production, processing, storage, or marketing of food, agricultural commodities, wood and wood products, or animal feedstuffs, or which may be administered to animals for the control of insects, arachnids or other pests in or on their bodies. The term includes chemicals used as growth regulators, defoliants, desiccants, fruit thinning agents, or agents for preventing the premature fall of fruits, and substances applied to crops either before or after harvest to prevent deterioration during storage or transport. The term, however excludes such chemicals used as fertilizers, plant and animal nutrients, food additives and animal drugs. The term pesticide is also defined by WHO in collaboration with UNEP (1990) as chemicals designed to combat the attacks of various pests and vectors on agricultural crops, domestic animals and human beings. The definitions above imply that, Insecticides are toxic chemical agents (mainly organic compounds) that are deliberately released into the environment to combat crop pests and disease vectors.

2.2: Classification of pesticides

Pesticide is a general term which encompasses all chemicals, irrespective of their physical, chemical and biological properties that are used to control pests. Hence to make their identification and study easier, it`s important to classify them according to these properties under their respective groups. Two broad categories of pesticides, thus synthetic and botanical are identified. Synthetic pesticides are classified based on various ways depending on the needs. However, there are three most popular ways of classifying pesticides which are; classification based on the mode of action, classification based on the targeted pest species and classification based on the chemical composition of the pesticide (Drum, 1980).

2.2.1 Classification of Insecticides based on the mode of action

Under this type of classification, insecticides are classified based on the way in which they act to bring about the desired effect. In this way insecticides are classified as contact (non systemic) and systemic insecticides (Zacharia, 2011). The non-systemic insecticides are those that do not appreciably penetrate insect tissues and consequently not transported within the insect vascular system. These insecticides will only bring about the desired effect when they come in contact with the targeted pest, hence the name contact insecticides. Examples of contact insecticides are paraquat and diquat dibromide. On the other hand, the systemic insecticides are those which effectively penetrate the insect tissues and move through the insect vascular system in order to bring about the desired effect. Examples of systemic insecticides include 2, 4-D and glyphosate (Buchel,1983). Under this classification also are stomach poisons that bring about the desired effect after being eaten, example Rodenticides.

2.2.2: Classification of Insecticides based on the targeted pest species

Insecticides are also classified based on the pests they are supposed to control. Thus, herbicides are used to control crop pests, fungicides to control fungi, rodenticides to control rodents, insecticides to control insects, wood preservatives to protect wood, virucides to control viruses, bactericides to control bacteria, garden chemicals, household disinfectants etc.

2.2.3: Classification of Insecticides based on the chemical composition

Under chemical classification, Insecticides are categorized according to the chemical nature of the active ingredients. The chemical classification of Insecticides is by far the most useful classification to researchers in the field of Insecticides and environment and to those who search for details. This is because, it is from this kind of classification that gives the clue of the efficacy, physical and chemical properties of the respective Insecticides, the knowledge of which is very important in the mode of application, precautions that need to be taken during application and the application rates. Based on chemical classification, Insecticides are classified into four main groups namely; organochlorines, organophosphorous, carbamates and pyrethrin and pyrethroids (Buchel, 1983).

Organochlorine Insecticides are organic compounds with five or more chlorine atoms. They were the first synthetic organic Insecticides to be used in agriculture and in public health. Most of them were widely used as insecticides for the control of a wide range of insects, and they have a long-term residual effect in the environment due to their resistance to most chemical and microbial degradations. Organochlorine insecticides act as nervous system disruptors leading to convulsions and paralysis of the insect and its eventual death. They have since been banned in most developed and developing countries including Ghana. Some of the commonly used organochlorine Insecticides are DDT, lindane, endosulfan, aldrin, dieldrin and chlordane (Zacharia, 2011).

Organophosphorous Insecticides on the other hand contain a phosphate group as their basic structural framework. Organophosphorous insecticides are generally more toxic to vertebrates and invertebrates as cholinesterase inhibitors leading to a permanent overlay of acetylcholine neurotransmitter across a synapse. Unlike organochlorines, organophosphorous insecticides are easily decomposed in the environment by various chemical and biological reactions, thus organophosphorous insecticides are not persistent in the environment (Martin, 1968). Some of the widely used organophosphorous insecticides include parathion, malathion and diaznon. **Carbamates** are organic Insecticides derived from carbamic acid. The cholinesterase inhibitions of carbamates differ from that of organophosphorous in that, it is species specific and it is reversible (Drum, 1980). Some of the widely used insecticides under this group include carbaryl, carbofuran and aminocarb.

Pyrethroids are synthetic analogues of the naturally occurring pyrethrins; a product of flowers from pyrethrum plant. Pyrethroids are acknowledged for their fast knocking down effect against insect pests, low mammalian toxicity and facile biodegradation. Although the naturally occurring pyrethrins are effective insecticides, their photochemical degradation is so rapid that their uses as agricultural insecticides become impractical. The most widely used synthetic pyrethroids include permethrin, cypermethrin and deltamethrin (Zacharia, 2011).

2.2.4: Other minor classes of Insecticides

2.2.4.1: Activity spectrum of the pesticide

In this system of classification, Insecticides are classified into two groups as broad spectrum Insecticides and selective Insecticides (Zacharia, 2011). Broad spectrum Insecticides are those Insecticides that are designed to kill a wide range of pests and other non target organisms. They are nonselective and are often lethal to reptiles, fish, pets and birds. Some examples of broad spectrum Insecticides are chlorpyrifos and chlordane. Selective Insecticides on the other hand are those Insecticides which kill only a specific group of pests leaving other organisms with a little or no effect at all. A good example in this case is a herbicide 2,4-D which affects broad-leaved plants leaving the grassy crops unaffected.

2.2.4.2: Mode of formulation

Insecticides are also classified based on how they are formulated. Thus emulcifiable concentrates, wettable powders, granules, baits, dusts and fumigants.

2.2.5: Toxicity level

Toxicity of Insecticides according to their potential risks and hazards to human health caused by accidental contact is used by the World Health Organization (WHO, 2005) to group Insecticides into the following classes;

Class Ia = extremely hazardous

Class Ib = highly hazardous

Class II = moderately hazardous

Class III = slightly hazardous

Class IV = products unlikely to present acute hazard in normal use

2.3: Advantages and disadvantages of using Insecticides

Most of the good attributes of Insecticides use are only realized when they are properly applied by following recommended practices. Thus Insecticides use has the following advantages;

- Insecticides kill only target pest organisms and have no short- or long-term health effects on non-target organisms, including humans.
- They are broken down into harmless chemicals in a fairly short time.
- Insecticides use saves money and time compared to other pest control mechanisms, thus increase profits for farmers.
- Insecticides save human lives threatened by insect-borne diseases, such as malaria (mosquitoes) and sleeping sickness (tsetse flies)

- Insecticides increase human food supplies and lower food costs because they reduce losses of crops to pests.

On the other hand when Insecticides are misused, it could lead to some debilitating effects including;

- Insecticides promote development of tolerant ecotypes in pest populations.
- They kill natural pest enemies and convert minor pests into major ones.
- Many Insecticides are mobile or are biomagnified in natural ecosystems.
- Many Insecticides are persistent and lead to long-term environmental contamination
- Insecticide applications often kill not only the intended pest, but also the predators and parasites that naturally kept the pest in check. The result is that the pest may achieve even higher abundance than it did before the application
- Many of the major Insecticides, including chlorinated insecticides are broad-spectrum, so they affect more than the intended target organisms hence Insecticides present a threat to natural non-target plants and animals

2.4 Global pesticide production and consumption

The history of Insecticides can be divided into three phases (Zhang *et al.*, 2011): (1) in the first phase (the period before 1870s) natural Insecticides, for instance sulfur in ancient Greece, were used to control pests; (2) the second phase was the era of inorganic synthetic Insecticides (the period 1870s-1945). Natural materials and inorganic compounds were mainly used during this period; (3) the third phase (since 1945) is the era of organic synthetic Insecticides. Since 1945, the man-made organic Insecticides, e.g., DDT, 2,4-D, and later HCH, dieldrin, have terminated the era of inorganic and natural Insecticides. Since then most Insecticides have been synthesized by humans, and they were named chemical Insecticides. The application of chemical

Insecticides, in particular the organic synthesized Insecticides has been a significant mark of human civilization, which greatly protects and facilitates agricultural productivity. In the earlier period of organic synthesized Insecticides, there were mainly three kinds of insecticides, carbamated insecticides, organophosphorus insecticides and organochlorined insecticides (Zhang *et al*, 2011). The exact date of the introduction of synthetic Insecticides into Africa is not known with exactitude. They are said to been brought into the continent by colonial powers at around the turn of the first or second decade of the last century (Wandiga, 2001). Since then the use of Insecticides has remain in Africa to date with various trends of usage across different parts of the continent.

2.5 Trend in Insecticide Usage for Cotton Production in Ghana

According to the Northern Presbyterian Agricultural Services and Partners (2012), estimates of the proportion of Ghanaian farmers using chemical insecticides to control insects and diseases on their food and cash crops vary widely, but generally it is considered to be the majority, with some estimates as high as 80-90 percent. Most insecticides in Ghana are used in the forest zones in the Ashanti, Brong Ahafo, Western and Eastern regions. However, insecticides used are also wide spread among resource-poor cotton farmers in the northern part of Ghana.

Farmers used insecticides from different chemical classes to control insect pests on cotton. Some products have the same active ingredients but are marketed under different trade names (Abudulai *et al.,* 2006). The type of insecticide used is dependent on the region, organochlorine insecticides such us Callisufan and Endosulfan are those commonly used in the Northern and Upper East Regions whereas farmers in the Upper West Region generally use Organophosphates such as Dursban (Chlorpyrifos) and Pyrethroids such as karate (Lamda-Cyhalothrin) as well as insecticide mixtures such as Novabol (profenofos+cypermethrin). These insecticides are used either as emulsifiable concentrates (EC) or ultra low volume (ULV) concentrations (Abudulai et.al, 2006). Majority of farmers in the Northern and Upper West regions applied five (5) sprays while those in the Upper East region applied four (4) sprays during a season. Control practices generally start at the vegetative stage and squaring (Abudulai *et.al*, 2006).

2.6 Category of Insecticide Used by Cotton Farmers

Soon after the Second World War, global cotton production changed dramatically when a number of newly discovered neurotoxic chemicals such as DDT were first introduced as an alternative means of pest control. Perceiving these chemicals to be cheaper alternative to the use of labour and machinery, cotton farmers began to use these and former methods of pest control were largely abandoned (EJF, 2007). However, for many developing world cotton farmers, the switch to toxic insecticides is a comparatively recent phenomenon. Environmental Justice Foundation (2007) reported that the world cotton farmers spend a total of US$ 2 billion on agricultural insecticides each year, of which over US$ 819 million worth are toxic enough to be classified as hazardous by the World Health Organization.

Organochlorined Insecticides (OCPs) are parts of persistent organic pollutants (POPs), which include HCH, DDT, aldrin, dieldrin, endrin, chlordane, heptachlor, toxaphene, HCB, etc. POPs are much different from other insecticides in these aspects: they are environmentally persistent, semi-volatile, high-bioaccumulative and highly toxic (Yu *et al.*, 2005). According to the "Stockholm Convention on Persistent Organic Pollutants", nine in twelve POPs are organochlorined insecticides.

2.7 Effects of Insecticides on Human Health

Sanfilippo and Perschau (2008) reported that while hazardous insecticides are applied to cotton grown worldwide, their negative impact on human health is visited disproportionately upon those living and working in developing countries. They further indicated that low levels of safety awareness together with lack of access to and/or money for protective clothing, poor labelling of insecticides, unsafe storage and misuse of used containers, illiteracy and chronic poverty each exacerbate the damage caused by cotton insecticides among these low income communities. Increasing pesticide use as the main method of pest control in areas with intensive agriculture can bring adverse effects as growers may use excessive amounts without adequate protective measures (Palis *et al*., 2006). Even farmers who are aware of the harmful effects of insecticides are sometimes unable to translate this awareness into their practices (Damalas *et al.*, 2006; Isin and Yildirim, 2007). It is reported that between 1 and 3% of agricultural workers worldwide suffer from acute pesticide poisoning with at least 1 million requiring hospitalization each year according to a report prepared jointly for the FAO, UNEP and WHO. These figures equate to between 25 million and 77 million agricultural workers worldwide (EJF, 2007). According to a report of WHO and UNEP, worldwide there are more than 26 million human pesticide poisonings with about 220,000 deaths per year (Richter, 2002). In the United States, there are 67 thousand human pesticide poisonings per year. In China, there are 0.5 million human pesticide poisonings with 0.1 million deaths per year. Insecticides can not only cause death but also induce various diseases. It is estimated that cancer patients resulting from pesticide poisoning account for nearly 10% of the total cancer patients (Gu and Tian, 2005). Chen (2004) found that the incidence of breast cancer was linearly correlated with the frequency of pesticide usage, and organochlorine pesticide, DDT, and its derivative, DDE, are likely responsible for breast cancer.

Perhaps the largest regional example of pesticide contamination and human health is that of the Aral Sea region. UNEP (1993) linked the effects of insecticides to “the level of oncological (cancer), pulmonary and haematological morbidity, as well as on inborn deformities and immune system deficiencies”. Human health effects are caused by 1) Skin contact: handling of pesticide products, 2) Inhalation: breathing of dust or spray and 3) Ingestion: Insecticides consumed as a contaminant on/in food or in water. Farm workers have special risks associated with inhalation and skin contact during preparation and application of insecticides to crops. However, for the majority of the population, a principal source is through ingestion of food which is contaminated by insecticides. Degradation of water quality by pesticide runoff has two principal human health impacts. The first is the consumption of fish and shellfish that are contaminated by Insecticides; this can be a particular problem for subsistence fish economies that lie downstream of major agricultural areas. The second is the direct consumption of pesticide-contaminated water. WHO (1993) has established drinking water guidelines for 33 insecticides. Many health and environmental protection agencies have established “acceptable daily intake” (ADI) values that indicate the maximum allowable pesticide daily ingestion over a person’s lifetime without appreciable risk to the individual. For example, Wang and Lin (1995) studying substituted phenols, tetrachlorohydroquinone, a toxic metabolite of the biocide pentachlorophenol, was found to produce significant and dose-dependent DNA damage. The harmful effects of insecticides are 1) Death of the organism, 2) Cancers, tumours and lesions on fish and animals, 3) Reproductive inhibition or failure, 4) Suppression of immune system, 5) Disruption of endocrine (hormonal) system, 6) Cellular and DNA damage, 7) Teratogenic effects (physical deformities such as hooked beaks on birds), 8) Poor fish health marked by low red to white blood cell ratio, excessive slime on fish scales and gills, etc., 9) Intergenerational effects (effects are not apparent until subsequent generations of the organism) and 10) Other physiological effects such as egg shell thinning. These effects are not necessarily caused solely by exposure to Insecticides or other organic contaminants, but may be associated with a combination of environmental stresses such as eutrophication and pathogens (Baker, 1990).

Insecticides are commonly found in water. The ground-water from some US and Canadian provinces has been reported to contain the residues of 39 insecticides and their metabolites (Hallberg, 1989). The calculation of level of allowable pesticide for water is made depending on the exposure of children and adults; the children being 4 times more vulnerable to the pesticide toxicity than adults (McConnell *et al.,* 1993). Residues of Insecticides that are "severely restricted" because of their serious effects on human health were also found in significant quantities in the water sources. The pesticide residues exerting serious effects on human health enter the water supply through leaching from soil into ground water (Agrawa *et al.,* 2010).

2.8 Pesticide Residues in Water Bodies

Pesticide contamination of surface water, which has emerged as an important environmental problem in the past few decades, caused serious concerns with respect to the long-term and low-dose effects of insecticides on public health as well as non-target species of aquatic life (Sudo, *et al.,* 2002). Zahedeh *et al.,* (2010) noted that the detection and permanence of insecticides in water depends on parameters such as, the pesticide halftime and solubility in water, the spread and the amount of insecticide applications, and the soil type to leach insecticides into ground waters. They also indicated that the wide spread and huge amount of insecticide applications are the main reasons for detecting organophosphorous insecticide residues especially in the rainy season.

The consumer risks from pesticide residues and other contaminants in drinking water should be viewed in the context of setting minimum residual limits to minimize the overall risk. Regulations encourage ozone treatment of raw water to reduce pesticide residue levels below a maximum level for drinking water. The treatment, where it is only removing low levels of pesticide residues, would apparently increase consumer risk (Hamilton *et al*., 2003). In developed countries, water intended for human consumption must meet minimum specified requirements, including for insecticides a maximum level for each pesticide of 0.1µg/l and a maximum of 0.5µg/l for total insecticides, except for alderin, dieldrin, heptachlor and heptachlor epoxide which are each limited to maximum levels of 0.03µg/l (European Union, 1997).

Numerous studies undertaken in major cotton producing countries such as USA, India, Parkistan, Uzbekistan, Brazil, Australia, Greece and in West Africa have documented detectable levels of hazardous insecticides commonly applied to cotton in local water resources (United States Geological Survey, 1998). While this type of contamination undoubtedly occurs regardless of the economic status of the countries involved, it is likely to pose a greater threat to communities living in the developing world, where drinking water is less often treated and quality monitoring facilities are often lacking.

US scientists tested water samples taken from the Mississippi Embayment (Arkansas, Kentucky, Louisiana, Mississippi, Missouri and Tennessee), a major area for cotton production in the United States (United States Geological Survey, 1998). Dicrotophos (WHO Ib), an organophosphate used extensively in the cotton growing areas was the most frequently detected (35% of samples) (Pesticide Action Network, 2006). Methyl parathion (WHO Ia), the most used insecticide in the cotton growing areas was the second most frequent contaminant (18%). The researchers also found traces of profenofos (12%), malathion (12%), cyanazine (46%), fluometuron (57%), and norflurazon (49%) as insecticides applied to cotton growing in the region (US department of Agriculture, 2004).

In Brazil, the world's 4th largest consumer of agrochemicals, researchers analysed samples of water taken from streams, rivers and surface water in the Pantanal basin, southern Mato Grosso state. Among other insecticides the scientists detected traces of alachlor (WHO III), chlorpyrifos (WHO II), endosulfan (WHO II), metolachlor (WHO III), monocrotophos (WHO Ib) and profenofos (WHO II): as insecticides applied to cotton within the study area (Laabs et al, 2006). The scientists also analysed rain water collected from sites in the same region finding traces of 19 different Insecticides – 12 of which were applied to cotton. Almost 80% of samples taken from the planalto region – the major region of cotton production within the study area – contained endosulfan.

Ntow (2005) analysed samples of water taken from 6 locations in Lake Volta: the most important inland water resource in Ghana. The lake is fed by the river Volta which originates from Burkina Faso, Cote d'Ivoire and Togo, and flows through farming regions in these countries, before reaching Ghana Ntow, 2005). These farming regions are noted for their production of cotton, among other crops. Lindane was detected in 22.7% of the samples, while endosulfan showed up in up to 18%. Endosulfan is commonly applied to cotton growing in Cote d'Ivoire, while in Togo, lindane is applied to cotton in response to various diseases of cotton (International Cotton Advisory Committee, 2005).

2.9 Forms of Insecticide Abuse or Misuse by Farmers

Damalas and Hashemi (2010) reported that a common case of pesticide misuse by many cotton growers in Greece was the use of unregistered pesticide products (i.e. the application of pesticide products to crops that are not indicated on the product label). They attributed this to the growers believe that surplus products can be used for other crops without paying attention to the label and that whether a pesticide is registered or not for a specific use, is more effective than other products. They further observed that experienced farmers take greater risk during pesticide handling due to familiarity of usage because they feel that after many years in farming new efforts to protect their health are unnecessary.

In Ghana, the chances of misuse of agrochemicals are relatively high due to low awareness of the safe use of agrochemicals especially Insecticides and illiteracy. There are various means by which humans become exposed to agrochemicals and other toxic chemicals, notable among which are exposure via diet, drinking water, soil and air. Persistent Insecticides move through air, soil, and water finding their way into living tissues where they can bio-accumulate up the food chain (Fianko *et al*, 2011). They also reported that public health risks of insecticides depend not only on how toxic various compounds are, but also on how many people are exposed, their risk related, demographic, socioeconomic and health profile, the kinds of contaminants they are exposed to, and the extent and routes of exposure. The general population can be exposed to low levels of insecticides in three general ways: vector control for public health and other non-agricultural purposes; environmental residues; and food residues.

Health and safety issues are exacerbated by a general lack of hazard awareness; the lack of protective clothing, or difficulty of wearing protective clothing in tropical climates; shortage of facilities for washing after use, or in case of accidents; the value of containers for re-use in storing food and drink; illiteracy; labeling difficulties relating either to language, complexity or misleading information; lack of regulatory authorities; and lack of enforcement (Fianko et al, 2011). Poisoning surveillance systems are usually maintained only at large urban hospitals. Village health centers may be completely excluded from monitoring reports (Clarke et al, 1997).

A study by Yeboah et al.(2004) and Mensah et al.(2004) revealed that about 82% of farmers in Ghana are illiterates and do not always use any form of standard protective clothing. They also indicated that most of the farmers are not aware of long term chemical and physiological effect associated with improper agrochemical handling. About 41.5% of farmers claim they change their cloths before and after pesticide use, however, less than 5% washed these clothing before using them again. These contaminated clothing can enhance dermal exposure which can result in systemic poisoning. They further revealed that some of the farmers were involved in unhealthy practices that put them at high risk of being affected by the Insecticides. They drink from water bodies near their farms and eat without washing their hand with any detergent.

Malnutrition could bring about an increased susceptibility to pesticide intoxication, especially in women and children. Malnourishment, infectious diseases, and toxic chemicals interact with each other and with the immune system. Consequently, Insecticides immunosuppressive effects which have more pronounced health consequences in developing countries, could significantly affect immune responses at very low doses. Humans ingesting food preparations contaminated with pesticide, workers in pesticide manufacturing and packing units, and agricultural workers who prepare, mix, and apply Insecticides in the fields are all potentially exposed to more than one pesticide on the same or on successive days. Such expo-sure may induce a wide array of health effect, ranging from myelotoxicity to cytogenetic changes and carcinogenic effects (Fianko *et al*,1997).

Human exposure is on more sporadic basis through a hodgepodge of human activities, farmers and farm workers, workers and laborers in pesticide factories, populations that live in areas of intensive pesticide use or production, and populations exposed to persistent Insecticides that bioaccumulate in food are potentially exposed to pesticide hazards (Yeboah *et al*, 2004). Those that can be exposed to high levels of bioaccumulated Insecticides include: consumers of fish, livestock, and dairy products; foetus and nursing infants whose mother's bodies have accumulated substantial levels of persistent agrochemicals; and sick people who metabolize Insecticides bioaccumulated fatty tissues while ill (Mensah *et al.,* 2004). Soil can be a key source of exposure in young children who show significant hand-to- mouth activity. Although modern Insecticides are readily degraded in the environment by soil micro-organisms, residues on treated crops such as fruit or vegetables often do not dissipate quickly. Most Insecticides lack systemic action and therefore residues are mainly on the exterior surfaces where they are amenable to removal in operations such as trimming, washing or peeling that most crops undergo before consumption.

2.10 Regulatory Frameworks of Insecticides Usage in Ghana

Ghana's primary legislation regulating the use of Insecticides is the Environmental Protection Act of 1994 while the two main bodies responsible for Insecticides surveillance and monitoring are the Environmental Protection Agency (EPA) and the Plant Protection and Regulatory Services Directorate (PPRSD). The EPA's Chemicals Control and Management Centre is directed by the Insecticides Registrar whereas the PPRSD Pesticide Management Division supervises and trains inspectors and extension officers. The Customs, Excise and Preventive Service (CEPS) Management Law of 1993 regulates all imports into Ghana including chemicals and gives CEPS officers the power to search people and seize prohibited chemicals. Although the Environmental Protection Act was enacted in 1994, subsidiary legislation is needed (that is the regulations) to implement it. However, the regulations have been in draft form since 2000, have not yet been passed and remained under consideration by parliament. Until these regulations are in place, there is little hope that the Act will be effectively implemented.

Evidence suggests that the Ghanaian government is spending only around GHC 300,000 a year on pesticide surveillance and training in the EPA and PPRSD. The EPA has one pesticide inspector in each of the ten regions plus another five in Accra totaling 15 across the whole country. The PPRSD has about 46 inspectors around the country but they do not focus just on Insecticides but also on seeds and plants, among other areas. The EPA lacks the capacity to work in the rural areas, a major problem when unregistered dealers sell directly to farmers by visiting villages (NPASP, 2012).

On the international front, the main international legal instruments relating to chemical Insecticides of which Ghana is signatory to are; the International Code of Conduct on the Distribution and Use of Insecticides (also known as the FAO Code of Conduct, since it has been led by FAO), which is a voluntary international mechanism for countries to regulate the availability, distribution and use of Insecticides in their countries. It was revised in 2002. The Rotterdam Convention on Prior Informed Consent, which provides a process for sharing information between countries and for countries to prevent exports and imports of banned or severely restricted Insecticides. It also encourages identification of Insecticides that cause problems to health or the environment. Ghana signed the Rotterdam Convention in 1998 and ratified it in 2003 (Mensa-Bonsu, 2006 and NPASP, 2012). The Stockholm Convention on Persistent Organic Pollutants, which aims to protect human health and the environment from persistent organic pollutants (POPs). Countries are required to prepare National Implementation Plans which define the commitments and actions that they plan to undertake in the field of POPs management. Ghana signed this Convention in 2001 and ratified it in 2003 (NPASP, 2012). Ghana seemed to have enough Insecticides regulations in her books but either lacks the capacity or the willpower to implement them to protect Insecticides users.

2.11 Integrated Pest Management (IPM)

It is a system of pest management in which populations of any pest(s) are maintained at levels below that which causes economic damage or loss, and which minimizes adverse impacts on society and environment as a whole. Integrated pest management is a very effective and environmentally sensitive approach to pest management. It combines natural predators, pest-resistant plants, and other methods to preserve a healthy environment in an effort to decrease reliance on harmful Insecticides (Lydia, 2011).

IPM is a systematic approach to pest management that focuses first on preventing problems. It involves monitoring pest populations, identifying pests and choosing a combination of strategies to keep pest populations at an acceptable level. These strategies may include cultural, mechanical/physical, biological and chemical methods of pest management. IPM programs use current, comprehensive information on the life cycles of pests and their interaction with the environment. Hence identification of pest species and their life stages are at the core of any IPM programme.

Cultural Control

Pest problems can be reduced through the many recommended practices used in producing crops. These practices are aimed at not only ensuring farm hygiene but also serves as pest control mechanisms. They include proper tillage practices, burning of crop residues, use of resistant varieties, crop rotation, altering planting or harvest dates, controlling alternative hosts of pest, farm hygiene, use of trap crops and sound agronomic practices that promote vigorous crop growth reduce risk of injury and increase the crop's ability to withstand pests.

Biological Control

Another method of controlling pests is to use the pest's natural enemies to keep the pest population at levels that do not lead to economic injury. In general, there are four types of natural enemies: predators, parasitoids, diseases, and herbivores. Strategies of using biological control include creating a welcoming environment for natural enemies and subsequently releasing them into the environment.

.Mechanical and Physical Control

Mechanical control of pests involves the use of devices and machines that can control pests or alter their physical environment. These mechanisms directly affect the life of the pest and include the use of traps; light to attract or repel pests; sound to kill, attract or repel pests; barriers such as screens in homes and livestock shelters; radiation to sterilize or kill pests; cold or heat to kill pests and hand picking large, clearly visible or slow-moving insects.

Chemical Control

Despite concerns over their use, Insecticides are still important in many IPM programs. Problems arise when people rely too much on Insecticides. IPM seeks to restore balance so that Insecticides are used only when they are really needed. They are mostly preferred to other control measures due to their least cost and easy applicability.

2.11.1: Advantages of IPM

A well planned and implemented IPM programme has numerous benefits including;

- Decreasing the use of chemical application which will in turn reduce risks to the health of humans and the environment
- Decreasing use of chemical application may result in financial savings.
- IPM may be the only solution to some long-term pest problems where chemical

application has not worked.

- IPM ultimately allows for greater knowledge and control of pest activity in the environment.

2.11.2: Disadvantages of IPM

- IPM requires more human resource and time than traditional pest management
- IPM may initially be more expensive than traditional pest management.

2.12: Integrated Pest Management in Ghana

It is reported that the first systematic attempts to integrate non-chemical control measures in Ghana's agricultural sector started in the sixties with trials to control the cocoa swollen shoot virus disease through management of the vector with formicid ants (Gerken *et al,* 2001). Attempts were also made in the nineties to introduce biological control methods for the larger grain borer, water hyacinth, mango mealy bug and cereal stem borer (DIXON 1999). However, these were not formally integrated into government programs for the management of pests and diseases as little was done to develop Integrated Pest Management (IPM) programs as a crop protection strategy. It was until 1992 that Ghana adopted IPM as her strategy for pest and disease control (National Plant Protection and Pesticide Regulatory Committee 1992).

In 1995, MoFA and FAO jointly started a project to implement IPM programs for rice production (Gerken *et al,* 2001). The results of the pilot project and follow-up phases led to a reduction in the use of pesticides, especially for rice. Insecticide usage among participating farmers reduced by about 90% compared to the beginning of the project, with about 30% increased incomes.

Following this in 1997, the German Agency for Technical Co-operation (GTZ) supported the Plant Protection and Regulatory Services Directorate (PPRSD) to start the Integrated Crop

Protection Project (ICP) (Gerken *et al,* 2001). The project developed cost-effective and participatory extension for IPM using the Farmer Field School approach in the Brong Ahafo Region as well as policy, technical and framework conditions for IPM at the PPRSD.

The government has been supporting the development of locally produced formulations as substitutes for chemical insecticides. The initial efforts included estimates on the market potential of neem extracts (GTZ 1998). Pilot projects were initiated to test the effectiveness of neem extracts and other plant products such as Jatropha as alternatives for chemical pest control (Foerster and Larbi 1999).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

The study area is the Savelugu-Nanton district in the Northern region of Ghana**.** It shares boundaries with Tolon/Kumbugu District to the west, Tamale Metropolis to the south and Yendi Municipal to the south-east. The District has a total land area of 1,790.70 sq. Km. The predominant occupation is farming with about 97% of the district's economically active population (18-54 years) involved in farming staple food crops and cash crops. Less than fifty percent (50%) of the population in the district has access to safe drinking water namely treated water, boreholes and hand dug wells (www.ghanadistrics.com).

The area receives an annual rainfall averaging approximately 600mm, enough for a single farming season. The annual rainfall pattern is erratic at the beginning of the raining season, starting in April, intensifying as the season advances raising the average from 600mm to 1000mm.Temperatures are usually high, averaging 34^{o}C. The maximum temperature could rise as high as 42^{o}C and the minimum as low as 16^{o}C. The low temperatures are experienced from December to late February, during which the hot and dry North-East Trade winds (harmattan) greatly influence the district's weather. The generally high temperatures as well as the low humidity favour high rates of evapotranspiration, leading to net water deficiencies.

The District is in the interior (Guinea) Savanna woodland which can sustain large scale livestock farming, as well as the cultivation of staples like rice, groundnuts, yams, cassava, maize, cowpea and sorghum. The trees found in the area tend to be drought resistant and hardly shed their leaves completely during the long dry season. Most of these are of economic value and serve as important means of livelihood especially for women. Notable among these are shea trees, (the nuts which are used for making shea butter) and dawadawa (*Parkia biglobosa*) that provides seeds used for condimental purpose. The sparsely populated north of the district has denser vegetation mostly with secondary forest. The populous south on the other hand, is depleted by human activities such as farming, bush burning and tree felling among others.

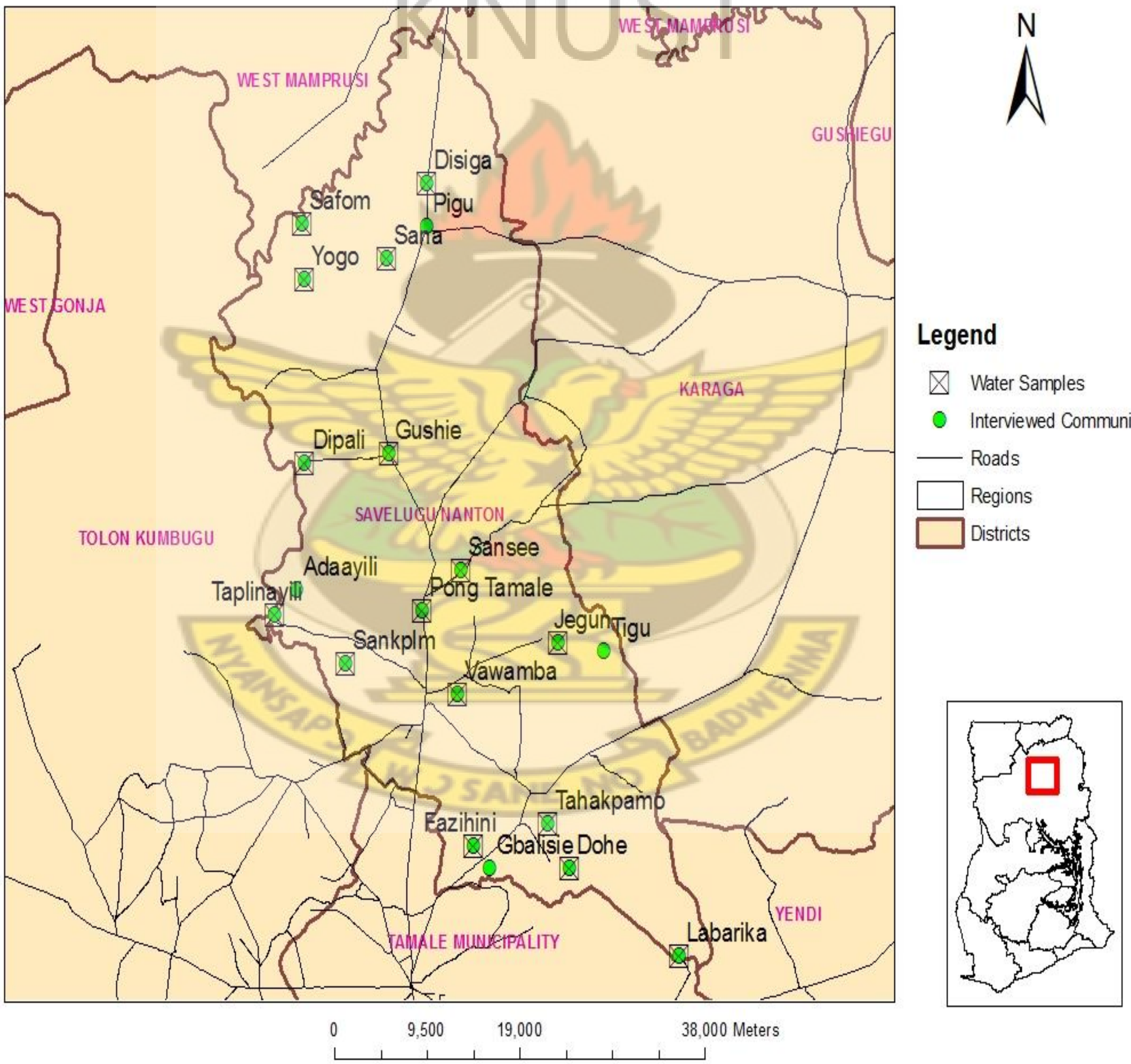

Figure 3.1: A map showing Savelugu/Nanton district in Northern Region of Ghana

3.2 Source of Data

The study collected primary and secondary data from cotton farmers and from relevant institutions such as Savanna Agricultural Research Institute (SARI) and the cotton companies. The primary data was generated by administering both structured and semi-structured questionnaires to selected cotton farmers in the study area. Whiles the secondary data was collected from institutional websites, data bases and journal publications and published reports. Water samples were also collected from boreholes and hand dug wells for laboratory analysis.

3.3 Sample Size and Sampling Procedure

In all hundred (100) cotton farmers were interviewed from twenty (20) communities. The district was divided into four (4) zones namely; the Northern zone, Southern zone, Eastern and the Western zones. Five (5) communities were selected from each zone and five (5) farmers were interviewed from each of these communities. Also, sixteen (16) communities were selected from the district, four (4) communities from each zone, water samples were taking from twelve (12) boreholes and four (4) hand-dug-out wells from these communities. The farmers and the communities were selected using simple random sampling method.

3.4 Types of insect pests of cotton in the district

Types of insect pests that attack cotton crops in the area were obtained from farmers and cotton companies using a questionnaire. Insect pests were then arranged according to the orther of importance as was indicated by farmers. A bar graph was developed to show types of insect pest attacking cotton crops in the area.

3.4.1 Types of Insecticides available and in use by the Cotton farmers in the District

Types of insecticides available and in use by cotton farmers in the district were obtained from farmers and cotton companies using a questionnaire. All insecticides were grouped appropriately as weedicides, herbicides and insecticides. The active ingredient, the target organism and the trade name of each pesticide used were recorded. An album of common Insecticides used by the cotton farmers in the Northern region was compiled to facilitate the identification process.

3.4.2 Evaluating pesticide handling practices by cotton farmers

Information on pesticide handling practices was obtained from farmers using a questionnaire and personal observations. These include: attitude to pesticide labels, storage of Insecticides, sources of Insecticides commonly used by famers, protective materials, mixture and quantities, application methods, disposal of empty pesticide containers and dosages used by farmers. Recommended practices for various Insecticides were obtained from pesticide labels and cross-referenced with those conventionally used by farmers.

3.4.3 Assessing the presence of organophospate and pyrethroid insecticide residues in water bodies of cotton growing areas in the district.

A preliminary field survey was conducted to have a general view of the variations in the study area. The preliminary field survey was conducted over a one month period during the main cotton season (August -September, 2012) with additional data collected towards the end of the season (November 2012- January, 2013). Identified water bodies which were close to cotton farms and served as sources of drinking water for residents were selected for the study. Sixteen (16) water samples were collected in 500ml sterile plastic bottles from twelve (12) bore holes and four (4) hand dug wells for laboratory analysis. Triplicate water samples were collected from each of the 16 waterholes. Water samples were transported to the laboratories of the Ghana

Standards Authority in a cool box with ice packs for analysis on the presence and concentrations of organophosphates and pyrethroids Insecticides residues in the water samples.

3.4.3.1 Extraction of Insecticides from water samples

The extraction technique employed in this work was the US EPA Method 3510 for aqueous matrix for the analysis of semi-volatile and non-volatile organics. The extracts were cleaned up by using the US EPA Method 3620B. Five hundred millilitres of the aqueous sample was measured and transferred into a 1000 mL separatory funnel. The aqueous sample was extracted three times with portions 100 mL of 1:1 (v/v) ethyl acetate/dichloromethane mixture. The separatory funnel was clapped for 30 min to allow phase separation. The combined organic phases were collected into a 500 mL beaker with the aqueous phase discarded. The combined organic layer was then dried of any aqueous substance with 20 g of anhydrous sodium sulfate and allowed to settle. The organic content was then decanted into a 300 mL round bottom flask and the content evaporated to dryness using the rotary evaporator at 40°C. The pesticide in the rotary flask was then dissolved and collected with 2 mL of ethyl acetate and transferred into a 2 mL vial ready for a clean-up.

3.5 Data analysis

Socio-economic and pesticide data were analyzed using Statistical Package for Social Sciences (SPSS (Version 17, 2008). The completed questionnaires were individually checked to ensure that they had been filled correctly. The questionnaires retrieved from the field were counted to ensure that they were up to 100. The closed-ended questions were then coded. All the responses given to the coded closed-ended questions were typed onto the Statistical Package for Social Sciences (SPSS) worksheet. The SPSS was then used in analyzing the coded closed-ended responses to generate frequency tables, percentages and bar graphs to characterize farmers' biodata, types of Insecticides used, pesticide spraying pattern and the challenges of pesticide usage.

Content analysis was used in analysing the qualitative data generated from the field. Each transcript was systematically worked through to identify specific characteristics within the text (Jorgensen, 1989). One Way ANOVA was also used to compare mean concentrations of insecticide residues from four (4) different clusters.

CHAPTER FOUR

RESULTS

4.1 Socio-economic Background of Respondents

In all hundred (100) farmers were interviewed in the Savelugu/Nanton district. Majority of the respondents (96%) were males and 4% females. Most of them (78%) were household heads and 22% were dependants of households. Farming was the main occupation (86%) of the people and 14% were engaged as drivers, traders, or public servants.

4.1.1 Age Distribution of Respondents

Majority (78%) of cotton farmers in the district were between the ages of 19- 60 with 19% above 60 years. However, 3% were children below 18 years. The average age of a cotton farmer in the district was 35 years (Table 4.1).

Table 4.1: Age distribution of respondents

Age range	Frequency	Percentage (%)
0-18	3	3
19-60	78	78
60+	19	19
Total	**100**	**100**

Source: Field Survey Data, January, 2013

4.1.2 Level of Education

Majority, 79% of cotton farmers in the district had no formal education. Twelve percent (12%) either had obtained primary or junior high school education, while 3% had senior high school education and only 1% had tertiary education. Five percent had gone through vocational schools or the adult functional literacy program (Table 4.2).

Table 4.2: Educational level of respondents

Educational Level	**Number**	**Percentage (%)**
No education	79	79
Basic education	12	12
Secondary	3	3
Tertiary	1	1
Others	5	5
Total	**100**	**100**

Source: Field Survey Data, January, 2013

4.2 Insect pests of cotton

Cotton farmers in the district were of the view that cotton production was severely affected by insect pests; Bollworm complex 69%, *Dysdercus spp* 11%, Leaf rollers 9%, Aphids 8% and Leaf hoppers 3%.

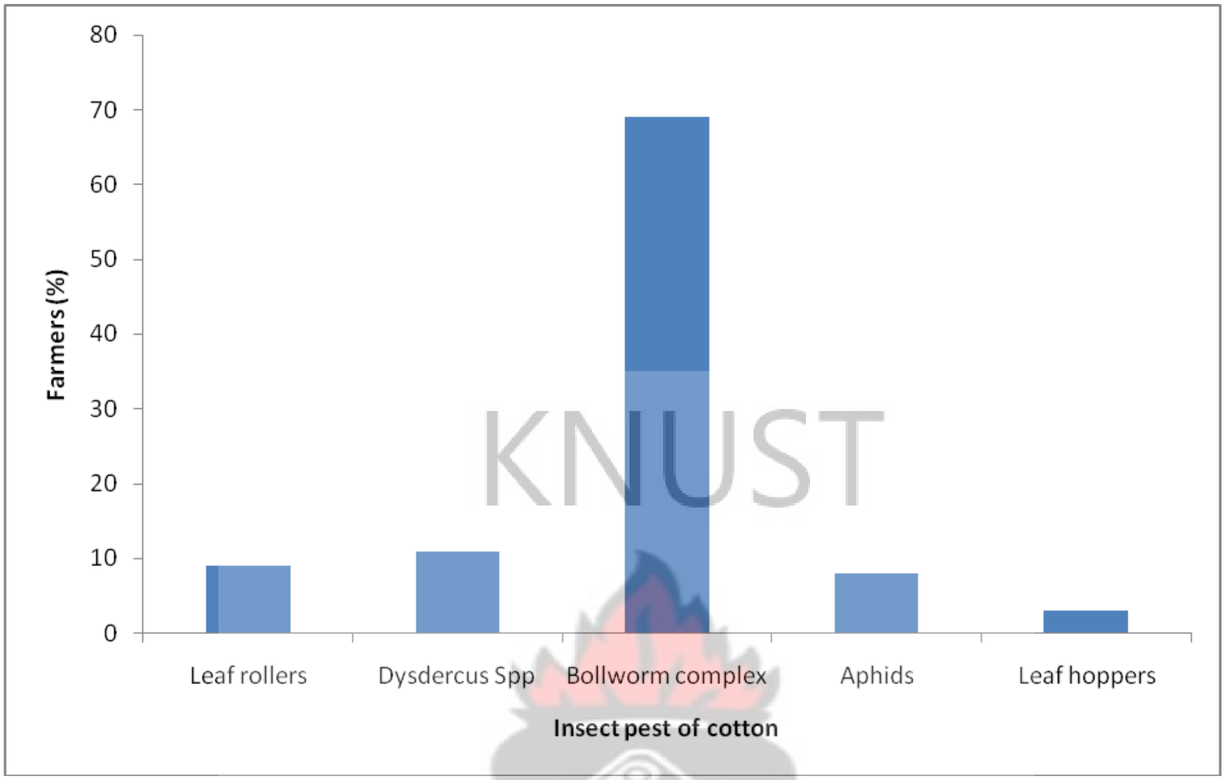

Figure 4.1: Insect pests of cotton reported by farmers

Source: Field Survey Data, January, 2013

4.3 Insecticides used by cotton farmers

Majority (93%) of farmers were not aware of other pest control practices apart from the use of Insecticides. However, 7% of farmers mentioned some physical, biological and cultural insect control methods. Practically all farmers applied Insecticides to manage insect pest on their cotton fields. A wide array of insecticides comprising pyrethroids and organophosporous were used by farmers. These include: Armada, Armaphos, KD 415, Chemaprid, Dursban, Pawa, Tihan, Polytrin C, Thunder and the unlabelled pesticide (Table 4.3). A cocktail (comprising Armaphos and chemaprid) was mostly used (33.2%) whiles Pawa was the least used as it recorded 0.88%. KD 415 recorded 19%, Dursban 17.1%, Armada 15.2%, thunder 5.7% with 4% each for polyterin C and tihan.

Table 4.3: Insecticide Used by Cotton Farmers in the District

Trade name	Active ingredient	Category of pesticide
Armada	Lambda Cyhalothrin	Pyrethroids
Armaphos	Chlorpyriphos	Organophosphate
KD 14	Cyhalothrin	Pyrethroids
Chemaprid	Cypermethrin/Acetamiprid	Pyrethroids
Dursban	Chlorpyrifos	Organophosphate
Pawa	Cyhalothrin	Pyrethroids
Tihan	Flubendiamide/Spirotetramate	Class II
Polytheriyn C	Profenos/Cypermethrin	Organophosphate/Pyrethroids
Thunder	Beta-Cyfluthrin/Imidacloprid	Pyrethroids

Source: Field Survey Data, January, 2013

4.4 Insecticide usage pattern

The farmers often applied Insecticide frequently. The common practice was to spray Insecticides more than three (3) times on cotton farms in a season, a practice adopted by 88% of the farmers. Others even sprayed five (5) times in one season. All of the farmers were found mixing different brands of Insecticides to effectively control insect pest on their farms. Majority (83%) of the farmers indicate that first spraying was done at the vegetative stage (between 35-40 days) of the cotton plant whiles only 17% of farmers indicated that first round of spraying was done at the beginning of square formation (between 46-50 days). However, all farmers reported that the remaining rounds of spraying (Second to Fifth) were done at an interval of every two weeks (Table 4.4).

Table 4.4: Farmers' Insecticide spraying schedule

Type of insecticide	**Rounds of Spraying (%)**				
	1^{st}	**2^{nd}**	**3^{rd}**	**4^{th}**	**5^{th}**
Lambda Cyhalothrin	-	-	74	-	-
Chlorpyriphos+ cypermethrin+Acetamiprid	-	-	-	72	61
Cyhalothrin	4	92	-	-	-
Chlorpyrifos	83	-	-	-	-
Profenos + Cypermethrin	-	-	21	-	-
Flubendiamide + Spirotetramate	13	8	-	-	-
Beta-Cyfluthrin+Imidacloprid	-	-	-	16	9
Percentage of farmers in each round of spraying	**100**	**100**	**95**	**88**	**70**

Source: Field Survey Data, January, 2013

4.5 Farmers' perceived challenges to insecticide usage

Farmers interviewed in the district assigned different reasons for their inability to apply as much insecticides as needed to deal with insect pest on their cotton fields. These include cost of purchasing Insecticides 86%, Unavailability of insecticides or untimely delivery of insecticides 78% and Health concerns 46%. More than half (64%), of the famers indicated that storage of insecticides was not a challenge as Insecticides provided by cotton companies were stored by various lead farmers. Again, majority (54%), of the famers indicated that challenges in relation to pesticide use and know-how was not a challenge as they had been using Insecticides over the years and had acquired some experience (Table 4.5).

Table 4.5: Farmers' perceived challenges to insecticide usage

Challenges of pesticide Usage	**Farmers response (Perceptions) ranking**			
	Very challenging	**Low challenging**	**Not challenging**	**Total**
Unavailability/Untimely delivery	78	18	4	100
Health threat	46	12	42	100
Cost	86	14	0	100
Know-how	38	13	54	100
Storage	28	8	64	100

Source: Field Survey Data, January, 2013

4.6 Insecticides handling practices by cotton farmers

Best pesticide handling practices as spelt out by manufacturers of various insecticides were documented to compare with farmers practice on the field. Farmers whose practices were in accordance with manufacturers' advice were recorded as positive while those who were not in any way following instructions of the manufacturers were recorded as negative. Those who were partially following manufacturer's instructions were recorded under average. Majority (67%) of farmers interviewed did not follow best practices in selecting Insecticides for their farms while 16% followed best practices (Table 4.6).

Table 4.6: Farmers' attitude to insecticides handling

Pesticide handling practices	Farmers response	Frequency	Percentages (%)
Selection of Insecticides	Positive	16	16
	Negative	67	67
	Average	17	17
	Total	**100**	**100**
Storage of Insecticides	Positive	0	0
	Negative	90	90
	Average	4	4
	Not Applicable	6	6
	Total	**100**	**100**
Usage of Insecticides	Positive	4	4
	Negative	81	81
	Average	15	15
	Total	**100**	**100**
Disposal of Insecticides (Empty containers and tank washings)	Positive	0	0
	Negative	85	85
	Average	15	15
	Total	**100**	**100**

Source: Field Survey Data, January, 2013

However, 17% of farmers partially followed best practices in selecting insecticides for their farms. Most (90%) of farmers did not store insecticides using best practices spelt out by manufacturers. None of the farmers interviewed stored their insecticides according to the instructions of the manufacturer. However, 4% of farmers partially followed manufacturer's instruction on storage and 6% indicated that they did not store Insecticides.

Also, 81% of the farmers interviewed did not follow best practices as stated by manufacturers whilst 15% of farmers partially followed manufacturer's instructions with only (4%) following manufacturers instruction in terms of pesticide usage. Similarly, 85% of farmers were not following manufacturer's instructions on disposal of empty containers and insecticides were often left in spraying machines. However, 15% of the farmers partially followed manufacturer's instructions.

4.7 Organophosphate and Pyrethroid Insecticides residues in Water samples

The laboratory analysis showed that 79% of the water samples were positive for the presence of Organophosphates and pyrethroids. Cyhalothrin, Imidacloprid and Chlorpyriphos were the Insecticides detected in larger concentrations (0.001 to 0.910 µg/L), while Cymethrin, Acetamiprid, Flubendiamide, Profenos and Beta-Cyfluthrin were detected in lower concentrations (<0.431 µg/L).

Total mean concentration of Cyhalothrin was the highest (5.058 µg/L) and Beta-Cyhalothrin was the lowest (1.303 µg/L) (Table 4.7).

Table 4.7: Mean concentration of Organophosphates and Pyrethroids residues in water sampled from various locations

Sample code	Cyhalothrin	Cypermethrin	Acetameprid	Flubendiamide	Profenos	Beta cyfluthrin	Imidacloprid	Chlorpyrifos
NC1	0.049	0.035	0.037	0.417	0.006	0.032	0.006	0.184
NC2	0.369	0.005	0.038	0.287	ND	0.008	0.287	0.870
NC3	0.910	0.003	ND	ND	0.270	0.023	0.169	0.563
NC4	0.368	0.324	ND	ND	0.064	0.359	0.312	0.488
EC1	0.032	0.037	0.052	ND	0.050	ND	0.005	0.156
EC2	0.095	0.078	0.150	ND	0.431	ND	0.124	0.564
EC3	0.026	0.123	0.026	ND	0.477	ND	0.532	0.213
EC4	0.321	0.243	ND	0.621	0.125	ND	0.038	0.032
WC1	0.781	0.003	0.032	0.231	0.451	ND	0.102	0.077
WC2	0.083	0.431	ND	0.320	0.013	0.234	0.234	0.021
WC3	0.871	0.051	0.064	0.076	ND	ND	0.030	0.245
WC4	0.008	0.076	0.140	0.032	ND	0.067	0.035	0.087
SC1	0.015	0.051	ND	0.073	ND	0.213	0.435	0.254
SC2	0.780	ND	ND	0.215	0.534	0.354	0.312	0.521
SC3	0.347	ND	0.348	ND	0.358	ND	0.002	0.631
SC4	0.003	0.210	ND	0.210	0.212	0.013	0.023	0.261

Source: Laboratory analysis of water samples taken from field, January, 2013

ND; Non detectable, **NC1**; water sample from Safom, **NC2**; Yogo, **NC3**; Saha; **NC4**; Disiga, **EC1**; Dipali, **EC2**; Gushei, **EC3**; Taplinayili, **EC4**; Sankpim, **WC1**; Sansee, **WC2**; Jegun, **WC3**; Vawamba, **WC4**; Pong Tamale, **SC1**; Fazihini, **SC2**; Tahakpano, **SC3**; Dohe, **SC4**; Labarika

Detailed statistical analysis of mean concentrations of Organophosphate and pyrethroid residues can be found in appendix 2.

4.8: Comparisons of mean concentrations of Organophosphates and pyrethroids Insecticides residue in water samples from different clusters in the District

Pesticide residue concentrations in the Southern and Eastern clusters were high as compare to the Western and Northern clusters. Pesticide residue concentrations from all four (4) locations of both South and East were each statistically significant, only two (2) of the locations in the Western cluster recorded high concentrations of Insecticides residue and hence they were significant. Pesticide residue concentrations in the Northern cluster were low and as a result only one (1) of the sample locations was highly significant (Table 4.8).

Table 4.8: Comparison of mean concentration of Organophosphates and pyrethroids Insecticides residues in water from different clusters in Savelugu/Nanton District

Sample Location	T	Mean	Std. Deviation	Std.Error Mean	Level of sign.
NC1	2.203	.1068	.13705	.04845	0.063
NC2	2.300	.2663	.30632	.11578	0.061
NC3	2.245	.3230	.35245	.14389	0.075
NC4	5.594	.3192	.13976	.05706	0.003***
EC1	2.600	.0553	.05213	.02128	0.048**
EC2	2.871	.2403	.20508	.08372	0.035**
EC3	2.565	.2328	.22232	.09076	0.050**
EC4	2.528	.2300	.22290	.09100	0.053**
WC1	2.236	.2396	.28353	.10716	0.067
WC2	3.192	.1909	.15821	.05980	0.019**
WC3	1.670	.2228	.32684	.13343	0.156
WC4	3.849	.0636	.04370	.01652	0.008**
SC1	2.670	.1735	.15915	.06497	0.044**
SC2	5.483	.4527	.20221	.08255	0.003***
SC3	3.378	.3372	.22323	.09983	0.028**
SC4	3.092	.1331	.11393	.04306	0.021**

*****and ** means 1% and 5% significance respectively**

CHAPTER FIVE

DISCUSSION

5.1: Background of Respondents

The study shows that women participation in cotton production is low in the district as most (96%) of the farmers interviewed were males. This could be attributed to the fact that women do not own land and are rarely involved in making production decisions, which can be explained by cultural factors such as household leadership in such patriarchy society. When women do not own land, they cannot therefore make decisions on what the land should be used for. This is similar to that of the International Trade Center (2011) which reported that the percentage of women who owned land and participate in decision making in cotton production in Africa is usually low and nearly the same, with a maximum variation of 10%. However, the study found that women are mostly involved in field and support services in cotton production in the district such as sowing of cotton seeds, picking of seed cotton on the field, taking care of the household and other farm-related chores. Field and support services are the only area in cotton production in Africa where women are mostly involved in decision making (25% in the field and 30% in support services, especially catering to cotton workers and farmers) (International Trade Centre (2011).

Most (78%) of the farmers interviewed were household heads and as such major stakeholders in providing basic needs for their households, the remaining 22% percent were dependants of households. Cotton production in the district was a major source of income for household's heads in supporting their families basic needs. Some farmers also go into cotton production with the aim of getting agro inputs for their food crops. This means that the benefits from cotton production in the district are not only to the individual but rather to entire households.

5.1.1 Age distribution of respondents

Majority (78%) of the respondents were within the working class (19 -60 years) and therefore there was an active labour force to ensure all year round cotton production and the production of food crops for subsistence in the district. Cotton production by the farmers guaranteed constant cash flow from the sale of seed cotton to cotton companies. Most of the aged (60+) who constitute 19% of the respondents were often more interested in food crop production but participated in cotton production activities to access to agro inputs such as fertilizers, Insecticides and tractor plough services for their food crops.

5.1.2 Educational Level of Respondents

Illiteracy rate among cotton farmers in the district was high as (79%) of respondents have never received any form of formal education. This may explain farmers' inability to read, understand and follow label instructions of various insecticides they use. Consequently, farmers were engaged in unhealthy practices such as spraying of insecticides without adequate protective clothing, drinking from water bodies close to sprayed farms and eating without washing hands with any detergent immediately after spraying. This exposes farmers to pesticide poisoning (Fianko *et al.*, 2011; Yeboah *et al*., 2004; Mensah *et al*., 2004; Abudulai *et al*., 2006).

Similarly, Sanfilippo and Perschau (2008) also attributed low level of safety awareness and precautions such as use of protective clothing, strict adherence to insecticides labels, unsafe storage and misuse of used containers in low income cotton growing communities to high illiteracy rate among farmers and chronic poverty.

5.2: Insect pests of cotton

The study has revealed that insect pests are a challenge to cotton production in the District. Several insect pests of cotton were identified by farmers in the area but the majority were bollworms (69%) which feeds on the cotton bolls making it impossible to open. Damage of bollworms on cotton plants have also been reported by Salifu, (1996); Martin *et al*., (2002); Torrres-Villa *et al*.,(2002); Abudulai *et al.*, (2006). Leafhoppers were also identified as the least (3%) damaging insect pest of cotton in the area.

5.3: Farmers perception of pest control methods

Majority (93%) of cotton farmers in the district were not aware of other methods of pest control aside the use of Insecticides, but all of the farmers interviewed used Insecticides as means of controlling insect pest. Some of the alternative pest management strategies mentioned by farmers include good sanitation on the farm, use of pepper with water and the use of botanicals such us neem extracts, tobacco extracts and wood ash, which were used to control pest on food crops. However, these alternatives were not used on cotton farms because of the supply of synthetic chemicals to famers by the contract cotton companies. This confirms Abudulai *et al.* (2006) report that only a few (28%) cotton farmers are aware of alternative pest control strategies and that none of them used those strategies in managing pest in their cotton farms.

5.3.1: Insecticides used by cotton farmers

Farmers used insecticides from different chemical classes to control insect pest on cotton. Some of the products had the same active ingredients but they were marketed under different trade names. The type of insesticide used was largely dependent on what was provided by the cotton company. However, there were instances where the cotton companies delayed in delivering insecticides to famers which often results in some farmers (9%) using insecticides recommended by neighbors and what was readily available on the market. Pyrethroids; Armada (55.6%) was often used by the farmers and organophosphates such as Dusbarn and insecticides mixtures Tihan (Flubendiamide+spirotetramate) was also often used. This disagrees with Abudulai *et al*.

(2006) work that, insecticide used by cotton farmers is dependent on the region and that Organochlorine insecticides such as Callisufan and Endosulfan are the most commonly used in the Northern and Upper East Regions. However, farmers in the Upper West Region generally used Organophosphates such as Dursban (Chlorpyrifos) and Pyrethroids such as karate (Lamda-Cyhalothrin) as well as insecticide mixtures such as Novabol (profenofos+cypermethrin). They however, added that variation in terms of the type of pesticide used by cotton farmers from time to time is largely due to the variation in companies that contract farmers to produce cotton for them, which the current study too confirmed.

Farmers also indicated that some of the Insecticides supplied to them by the cotton companies were ineffective against the insect pest on their field and as a result, insect pest were not killed several days after spraying. This could build resistance of insects under field conditions. Abudulai *et al.,* (2006) reported that applying ineffective and sub-lethal doses of Insecticides induce resistance in insect pest on the field. Vassal *et al.,* (1997) reported that the cotton bollworm, *H. armigera* acquired resistance to pyrethroid in field populations in Cote d'Ivoire due to application of ineffective and sub-lethal doses of Insecticides on cotton farms.

5.4: Insecticide usage pattern

Results from the field show that farmers in the area often apply Insecticides very frequently. It was quite common (88%) for farmers to spray Insecticides more than three (3) times on a cotton farms in a season. The spray frequency in the area was as high as five (5) times on cotton crop in one season, confirming Abudulai *et al.,* (2006) report that majority of cotton farmers in the Northern and Upper West Regions sprayed five (5) times in a season. Majority (83%) of farmers reported that the first round of spraying was done at the vegetative stage (between 35-40 days) of the cotton plant whiles only 17% of farmers indicated that the first round of spraying was done at the beginning of square formation (between 46-50 days). Though the farmers indicated that the first round of spraying was to control insect pest that will disturb flower bugs formation, this was contrary to findings by Greene *et al.* (2001) that applying Insecticides at the vegetative stage is generally unnecessary as damage at this stage often does not result in economic yield reduction. This practice by farmers in the District could unnecessarily build up cost of production and drastic reduction in the population of natural enemies of insect pest as observed by Salifu (1990); Javid *et al.* (1998) and Greene *et al.* (2001).

5.5: Farmers perception on challenges of insecticide usage

Interviews with cotton farmers in the district showed that there are different reasons for their inability to apply as much insecticide as they needed to properly manage insect pests on their cotton fields. Farmers (86%) were of the view that cost of purchasing insecticides was high and as a result leading to an increase in cost of production which affects the income levels of farmers and therefore was ranked highest by farmers. However, insecticide storage and farmers knowledge about various insecticides were not seen as challenges as was indicated by 64% and 54% of farmers respectively. This is because insecticides provided by cotton companies were stored by various lead farmers and were only released to farmers on the day of application. Farmers also claimed that having used the insecticides over the years, they had become experienced with the various insecticides over the years.

Seventy eight percent (78%) of farmers reported that untimely delivery of insecticide by cotton companies or insecticides unavailability was a major challenge and therefore was ranked as a second major challenge for farmers in the District. This resulted in high pest infestation of cotton fields thereby reducing the volume of cotton produced and famers overall income from cotton production. Under the current arrangement for cotton production in Ghana, neither do farmers have influence on the type of insecticides to apply nor the timely delivery of Insecticides. Insecticides are provided by cotton producing companies at cost to farmers.

Only 46% of farmers consider health risk of pesticide as very challenging and hence little or no attention was given to personal protection from pesticide contamination or poisoning during pesticide handling. Damalas and Hashemi (2010) reported that experienced farmers take greater risk during pesticide handling due to familiarity of usage because they feel that after many years in farming new efforts to protect their health were unnecessary. They also reported that a common case of pesticide misuse by many cotton growers in Greece was the use of unregistered pesticide products (i.e. the application of pesticide products to crops that are not indicated on the product label). They attributed this to the growers believe that surplus products can be used for other crops without paying attention to the label and that whether a pesticide is registered or not for a specific use, its efficacy was what was most important.

Increasing pesticide use as the main method of pest control in areas with intensive agriculture can bring adverse effects as growers may use excessive amounts without adequate protective measures (Palis *et al.*, 2006). Even farmers who are aware of the harmful effects of Insecticides are sometimes unable to translate this awareness into their practices (Damalas *et al.*, 2006; Isin and Yildirim, 2007).

5.6: Farmers attitude to insecticide handling

5.6.1: Insecticide selection

The most common source of farmer procurement of insecticides was through local agricultural supply dealers. They play an important role not only in the distribution of insecticides but as an important source of information about the products and their uses. Dealers, in performing their distribution functions, also influence the amounts and types of insecticides that are used by farmers in their production operations (Young, 1972). Majority (67%) of farmers in Savelugu/Nanton District placed priority on availability rather than the correct usage in their choice of Insecticides for their cotton fields. Hence, surplus products can be used for other crops without paying attention to the label in so far as it is effective. The perception of cotton farmers in the district on the choice of pesticide is also as a result of the fact that cotton companies supply insecticides to farmers on credit bases and therefore, dictating the types of Insecticides used by cotton farmers in the district.

5.6.2: Storage of Insecticides

Majority (90%) of farmers in Savelugu/Nanton District either stored their insecticides under their beds, kitchen or on top of trees on their farms without any warning signs or locked them away from children and innocent adults. This sometimes exposes the children to the harmful effects of the pesticides (Ngowi *et al*., 2001).

5.6.3: Usage of Insecticides

Best insecticide usage practices as spelt out by manufacturers of the various insecticides includes, wearing clean protective cloths, not eating, drinking or smoking whiles applying Insecticides, not to allow insecticides to contact your skin, wash hands with detergents before eating, wash clothes with soap after each spray, not to stir insecticides with hand and never spray directly into the wind. When compared with on-farm insecticides application practiced by farmers in the district, it revealed that majority (80%) of farmers in the district were spraying insecticides without any form of protection, not washing their hands and cloths with any detergents after spraying and sometimes smoking or chewing cola nuts whiles spraying. This exposes farmers to insecticides poisoning through inhalation, ingestion or skin contact of

Insecticides (Yeboah *et al*., 2004; Mensah *et al*., 2004; Ajayi and Akinnifesi, 2007; Mekonnen and Agonafir, 2002; Yassin *et al.*, 2002). Contrary to this finding, however, Schenker *et al*. (2002) reported that 93% of California farmers wore personal protective equipment when handling insecticides, which was considerably higher than for farmers in other areas of the USA. Similarly in Canada, Nicol and Kennedy (2008) reported that 63% of those who applied insecticides in fruit growing farms wore personal protective equipment, which was somewhat higher than in other Canadian studies, although the specific use patterns were similar in the same study, no association was found between frequency of protective equipment use and age.

The study also revealed that 41% of farmers claimed they changed their clothes before and after pesticide use, however, less than 5% washed these clothing before using them again. These contaminated clothing could enhance dermal exposure which could result in systemic poisoning.

5.6.4: Disposal of insecticide empty containers and other insecticide related waste

Majority (85%) of cotton farmers claimed knowledge of disposal of empty insecticides containers and other pesticide related waste, but what was described and practiced by farmers were not appropriate for disposal of empty pesticide containers and other pesticide related waste. These farmers were found using empty insecticides containers to fetch water, store salt and sugar. Others were found leaving empty containers on their fields and washing of spray equipments close to water bodies. This serves as source of pollution to both surface and underground water sources. This finding confirms a report by FAO (1999) that people often reuse empty plastic or metal pesticide containers as storage for fuel or even food and water, even though it is usually impossible to remove all traces of chemicals from these containers. The report further states that old products, unlabelled containers and leaking packages are often kept in misguided efforts to avoid waste just because people do not understand the hazards they pose.

The study further established from close examination of user manuals of some insecticides used by the farmers (Tihan and Thunder) indicating that, pesticide manufacturers recommend that after application, empty containers should be rinsed at least three times before disposal. Also the user manuals indicate that empty containers should not be thrown into ponds and or rivers but be destroyed and buried. This practice was contrary to the FAO (1999) guidelines on disposal of pesticide containers that empty pesticide containers should not be buried or burned. The FAO noted that safe, hazard-free burning techniques required a good understanding of pesticide chemistry while safe pesticide burial requires knowledge of local hydrology as well as of the environmental behavior of insecticides, which many end users do not have given their circumstances.

5.7: Organophosphate and pyrethroid insecticide residues in water samples

Organophosphorus and pyrethroids insecticide residues were detected at a higher concentration in some of the water samples analyzed. About 54% of water samples analyzed recorded mean concentration of insecticides higher than the European Community allowable residual limits in drinking water set at 0.1µg/L with about 12% of the water samples analyzed recorded mean concentrations higher than the Ghana standard Authority maximum residual limits of 0.5µg/L. The insecticide that recorded the highest concentration was cyhalothrin, detected at 0.910 µg/L,in water samples from Saha, which exceeded by 1.82 the maximum residual limit of 0.5µg/L set by the Ghana Standard Authority and 9.1 times the allowable limit of 0.1 µg/L of pesticide contamination set by European Economic Commission (EEC directive 98/83/EC).

Moreover, high levels of chlorpyriphos and flubendiamide insecticide residues of 0.87 µg/L and 0.621 µg/L were detected in the water samples collected from Yogo and Sankpim, which exceeded by 1.7 and 1.24 times the maximum residue limit set by the Ghana standard Authority and 8.7 and 6.2 times the allowable limit of 0.1 µg/L of pesticide contamination set by the EEC directive 98/83/EC.

Reasons could be that these Insecticides are marketed under different trade names and as a result, their usage could have been duplicated or triplicated at different stages of growth on the cotton farms. This partly disagrees with Zahedeh *et al*., (2010) report that pesticide with a higher application rate doesn't always result in a higher residue concentration, but mainly due to the chemical/physical characteristics of the Insecticides.

Secondly, most of the farmers in the study area did not have enough knowledge about the chemical properties of Insecticides that they used or the effects of the Insecticides on the environment and the subsequent exposure on public health, thus using them indiscriminately.

The study again found that the concentration of cypermethrin, acetamiprid, Flubendiamide, profenos and imidacloprid were below the detection limit in 12, 43, 37, 25 and 44% of the samples analyzed. This is largely due to the fact that those Insecticides were not usually provided by the cotton companies operating in the area and in instances where they were provided to farmers, they were only used for second round of spraying.

However, pesticide residue concentrations found in this study, were relatively lower compare to findings of similar studies conducted by different authors. Alamgir *et al.*,(2012) found high concentrations of organophosphorous and carbamate Insecticides residues in samples originating from a paddy and vegetable fields of Savar and Dhamrai Upazila in Bangladish. Concentrations of Malathion and carbofuran in their study were detected at 105.2 and 198.7 µg/L respectively, which exceeded by 210.4 and 397.4 times the maximum residue level set by the Ghana Standard Authority and 1,502 and 1,987 times the allowable limit of 0.1 µg/L of pesticide contamination set by the EEC (directive 98/83/EC). Another study by Essumang *et al.*, (2007) found high concentrations of organophosphrous from four (4) Lagoons in Ghana. Total mean concentrations of 19.6, 14.8, 10.8 and 1,977 µg/L were detected from Etsii, Korle, Fosu and Chemu Lagoons respectively, which exceeded by 39.2, 29.6, 21.6 and 3,954 times the maximum residue limit set by the Ghana Standard Authority and 196, 148, 108 and 19,770 times the allowable limit of 0.1 µg/L of pesticide contamination set by the EEC (Directive 98/83/EC).

Lower pesticide residue concentration from the current study can be attributed to the fact that farmers in the District are mainly small scale farmers and therefore did not apply Insecticides at a larger scale compared to commercial farmers. Also, until about two years ago, cotton farmers were no longer having access to inputs credit which includes Insecticides from cotton companies and as a result, the rate of chemical application in the district went down.

5.8: Comparison of mean concentrations of pesticide residues from four (4) different clusters

Pesticide residue concentration deferred significantly (P=0.048, 0.035, 0.050 and 0.053) (P=0.044, 0.003, 0.028 and 0.021) in all sample locations from both Eastern and Southern clusters. This could be attributed to commercial mango production by Integrated Tamale Fruit Company (ITFC) in these parts of the district as Insecticides were used to control insect pest on the mango plantations. Mean concentration of Insecticides from two sample locations of the Western Cluster were significant (P=0.019 and 0.008), whiles only one location from the northern cluster was significant (P=0.003) for pesticide residue concentration. The sample location in the northern sector where pesticide residue concentration was highly significant was one of the communities where commercial mango production is on-going and the Insecticides used in controlling insect pest on the mango plantations could be contributing to the significance level of pesticide residue concentration in the area.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1: CONCLUSION

Some water bodies of cotton growing areas in the district were slightly polluted with insecticides residue, particularly with cyhalothrin. Other insecticides detected were cypermethrin, acetamiprid, flubendiamide, profenos, beta-cyfluthrin, imidacloprid and chlorpyriphos. In general, levels were lower than those reported from other countries and from the southern part of Ghana. Even though insecticide residues in some of the water samples were slightly higher than the maximum residue limits of the Ghana Standards Authority, they were not high enough as to be health risk to the people in the area.

Different types of insecticides were used by cotton farmers to control insect pest of cotton in the district but Pyrethroids and organophosphates were the most common. Some of the Insecticides have the same active ingredients but they are traded under different names leading to multiple applications of such Insecticides. However, the current pest management practices seem not to be effective. Among others, the use of expired chemicals and the application of sublethal doses of chemicals are largely responsible for the ineffectiveness of chemical pest management. Under the current arrangement for cotton production in Ghana, neither do farmers have influence on the type of Insecticides to apply nor the quantity to apply. Farmers rely so much on Insecticides because they believe they are more effective, cheaper and time saving. However, pesticide handling practices among farmers in the district is inadequate.

6.2: RECOMMENDATIONS

In order to ensure sustainable cotton production in the district, there is the need for increased education of farmers on best practices especially regarding the use of Insecticides. The education and training programme should not only include safe handling of these chemicals, but also include other important topics such as their effects on the farmers' health when misused. Other issues such as the need to use less toxic insecticides and economic threshold limits that warrant the use of insecticides are equally important to avoid direct or indirect exposure to insecticides. The use of Insecticides in cotton production cannot be stopped, however their use should be minimized in order to achieve the optimum benefits. Also extension officers of cotton companies and Ministry of Food and Agriculture should be given education on proper use of insecticides to address the problem of expired and inadequate doses of Insecticides in cotton pest management. Indigenous pest management strategies which are largely based on botanicals such as neem extracts have been found to be effective, less harmful to humans and economical in controlling major pest (Gahuka, 2000). Therefore, alternative pest management to insecticides in cotton should be developed around these botanicals. Government should give regulatory approval and promote the production of Bt cotton among famers to reduce the amount of Insecticides used by farmers to control insect pest of cotton. This will also cut down the cost of production for cotton farmers. Finally, further studies should be conducted to examine the health implications of pesticide handling by farmers in the District.

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Appendix 1: Questionnaire

A Questionnaire for Assessment of Pesticides Residues in Streams/Rivers close to Cotton farms and its Health Implications in Savelugu/Nanton District in the Northern Region of Ghana

*Name of Community*__________________ ______________________________

Part 1: Background to the Household & Farm

☑

Sex of the respondent? M / F		What is your age		Tribe	
Are you the head of the family Yes ☐ No ☐	Can you read and write: Yes ☐ No ☐		How much land do you farm:		Acres / Hectares

Marital status	Single ☐ Married ☐ Divorced ☐ Separated ☐ Widowed ☐
Highest level of education	None ☐ Primary ☐ Secondary ☐ More than secondary ☐
Occupation (all that apply)	Farmer ☐ Others (please specify)
Where is your farm located?	near river ☐ in hills ☐ low land ☐ others ☐ (specify)

What crops do you grow? *(Tick all that apply)*	Household use	Cash crops	Irrigated	Rainfed	Most important *(Tick two)*	Organic?
Maize						
Sorghum						
Millet						
Rice						
Beans						
Cotton						
Yam						
Groundnuts						

Fruit (specify)						
Others (specify)						

Do you use chemical pesticides on your crops	Yes Regularly ☐	Yes Occasionally ☐	No, I do not use them ☐

On your crops, do you also use: Artificial fertilizers ☐ Manure ☐ Biopesticides / natural enemies / IPM ☐

Part 2: Pesticide Use

If you use chemical pesticides, for what purpose do you use them? *(Tick any that apply)*	1. Control of weeds ☐ 2. Fungi/molds ☐ 3. Insect pests ☐ 4. Rodent control ☐ 5. Others (please specify):
Which type of chemical pesticide do you prefer?	Broad Spectrum ☐ or Pest Specific ☐ don't know ☐
Which Chemicals are you using? *Note: If the respondent does not know the name, or if it is a brand-name product that you do not recognize, you may need to ask if you can see the container.*	Brand name / Local name Purpose Chemical (if known)
Where do you buy these products? *(Tick any that apply)*	Cotton company ☐ local shop ☐ open market ☐ other ☐ (specify)

What do you consider before buying a pesticide? *(Tick any that apply)*	price ☐ availability ☐ toxicity ☐ recommended by neighbour ☐ other (please specify)
Which is the most important consideration? *(Tick only one)*	price ☐ availability ☐ toxicity ☐ recommended by neighbour ☐ other (please specify)
Who sprays / applies the pesticides? *(Tick any that apply)*	Father ☐ Mother ☐ Son ☐ Daughter ☐ Hired labour ☐ Others ☐ (specify)
How often do you apply the pesticide during a given year?	
Do you apply mixtures of pesticides? If so specify • which products, and • the reason for mixing	
Does your pesticide use solve your pest problem	Yes ☐ No ☐ don't know ☐
Does the amount of pesticide used on your farm increase or decrease each year?	Increase ☐ Decrease ☐ It varies ☐ don't know ☐
Where do you store your pesticides? My bedroom ☐ Community store ☐ Kitchen ☐ Others (Specify)	

Do you spray/apply pesticides yourself? Yes ☐ No ☐

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

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

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

If no, where do you get it from?

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

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

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

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

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

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

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

What do you do with empty pesticide containers?	Use for water and/or food storage ☐ Sell them ☐ Bury in the soil ☐ Other ☐ (specify)
Is there an expiry date on the container of pesticides that you use? Yes ☐ No ☐ don't know ☐	
Have you ever come across expired (old) chemicals in the market? Yes ☐ No ☐	
What do you do with expired pesticides?	Continue use it ☐ Ask Cotton company officer ☐ I dispose of it in the soil ☐ Other ☐ (specify)
Are you aware that some pesticides may now be obsolete and no longer suitable for use?	Yes ☐ No ☐

What type of pesticide formulation do you use? *(Tick all that apply)*	Dust or powder ☐ Bait ☐ Liquid Spray ☐ ULV ☐ Granules ☐ Dips ☐ other ☐ (specify)
How do you apply Dusts / Powder	with hands ☐ a powder sack ☐ a tin or plastic tub ☐ use a mechanical device ☐ other ☐ (specify)
How do you apply Granules?	With hands ☐ from a container (can/tub) ☐ use mechanical device ☐ other ☐ (specify)
How do you apply Liquids?	From a bottle ☐ backpack sprayer ☐ Knapsack sprayer ☐ Mist blower☐ other ☐ (specify)
Where do you prepare pesticides before	Near community water source ☐ near a river ☐ at home ☐

application?	in your field ☐ other ☐ (specify)

Do you follow instructions on the label to mix and prepare pesticides for application? Yes ☐ No ☐
Do you find the instructions: Easy to follow ☐ Difficult ☐ or, I need more equipment for this ☐

If you do not follow instructions on the label, or if there are no instructions, how do you decide on the correct dosage of to be used?	Advice from supplier ☐ Advice from Ag. Office ☐ Experience ☐ Other Farmers ☐ other ☐ (specify)

Do you consider wind direction when you spray pesticides? Yes ☐ No ☐
Are there any water bodies near where you spray pesticides? Yes ☐ No ☐ Don't know ☐
If yes please specify: Lakes / Dams ☐ Rivers ☐ other ☐ (specify)
If yes: Do you leave a distance between the water body and your farm? ( ) If yes specify ( )
Where is your main source of drinking water? Pipe borne water☐ Borehole ☐ Hand dug wells ☐ River/Stream ☐ Others (Specify)

Part 3: Health and Environmental Impacts of the Pesticides

Is the use of pesticides:	Always good ☐ Sometimes good ☐ Sometimes harmful ☐ Always harmful ☐ Not effective ☐ Don't know ☐ Other ☐ (please specify)
What are the benefits to you from pesticide use?	

Can chemical pesticides can be dangerous? Yes ☐ No ☐

If harmful, what is the damage?	To human health ☐ To animal health ☐ To wildlife ☐ To water bodies ☐ To All of these ☐ Others ☐ (please specify)

What can be done to minimize the negative effects of the chemical pesticides?

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

Reporting:

<table>
<tr><td colspan="2">Is there a channel for reporting any pesticide incidents that occur?</td><td>Yes ☐ No ☐ don't know ☐</td></tr>
<tr><td>To whom would you report any incidents to?
(Tick any that apply)</td><td colspan="2">Cotton company officer ☐ Health office ☐ Environmental Protection Agency ☐ Farmers group ☐ Others ☐ (specify)</td></tr>
</table>

Please record any additional comments relating to:

Part 1: Background to the Household & Farm

Part 2: Pesticide Use

Part 3: Health and Environmental Impacts of the Pesticides

Appendix 2: Detailed statistical analysis of table 4.7

Zonal Concentrations	t	Mean Concentrations	Std. Deviation	Std. Error Mean	Sign.
NC1	2.203	.1068	.13705	.04845	0.063
NC2	2.300	.2663	.30632	.11578	0.061
NC3	2.245	.3230	.35245	.14389	0.075
NC4	5.594	.3192	.13976	.05706	0.003***
EC1	2.600	.0553	.05213	.02128	0.048**
EC2	2.871	.2403	.20508	.08372	0.035**
EC3	2.565	.2328	.22232	.09076	0.050**
EC4	2.528	.2300	.22290	.09100	0.053**
WC1	2.236	.2396	.28353	.10716	0.067
WC2	3.192	.1909	.15821	.05980	0.019**
WC3	1.670	.2228	.32684	.13343	0.156
WC4	3.849	.0636	.04370	.01652	0.008**
SC1	2.670	.1735	.15915	.06497	0.044**
SC2	5.483	.4527	.20221	.08255	0.003***
SC3	3.378	.3372	.22323	.09983	0.028**
SC4	3.092	.1331	.11393	.04306	0.021**