KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

COLLEGE OF SCIENCE

DEPARTMENT OF ENVIRONMENTAL SCIENCE

EFFECT OF PESTICIDES USAGE ON WATER QUALITY OF THE TANO RIVER IN THE ASUNAFO SOUTH DISTRICT OF BRONG AHAFO REGION OF GHANA

BY

JOSEPH ANAB LUGUSHIE

OCTOBER, 2012

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A Thesis Submitted to the Department of Theoretical and Applied Biology in partial fulfillment of the requirement for the award of the Master of Science Degree in Environmental Science

BY

JOSEPH ANAB LUGUSHIE

OCTOBER, 2012

STATEMENT OF ORIGINALITY

"I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the qualification of any other degree or diploma of a university or other institution of higher learning, except where due acknowledgement is made"

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DEDICATION

I dedicate this very work to the entire families of Lugushie for all their moral support as well as their deep love for my vision

ABSTRACT

In order to increase crop yields and ensure food security, farmers have resorted to the use of assorted pesticides on their crops. Overuse and misapplication of these pesticides can have negative effects on the environment, especially on water bodies. In this study, the levels of pesticide residues in water samples from the Tano River in two vegetable growing communities of Dantano and Siana in the Asunafo South District in Ghana were assessed. Water samples were collected from the Tano river in January and February 2012 for physico-chemical and pesticide residue analysis. The extraction of the pesticide residues was done by liquid –liquid extraction method and analysed by GC-Electronic Capture Detector. Determination of physico-chemical parameters was by standard methods. The results from the pesticide analysis showed the presence of some pesticide residues. Aldrin, dieldrin, endrin, chlordane, heptachlor and cis-heptachlor epoxide levels were above the WHO permissible limits for drinking, while residues such as isomers of HCH, chlordane, and DDT and its metabolites were below the limits. Most of the physico-chemical parameters measured at the two sampling locations were fairly similar over the sampling period, and did not appear to have been impacted negatively by the farming activities. However, the presence of the residues can be directly attributed to the farming activites.

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LIST OF ABBREVIATIONS

COND	=	Conductivity
DDD	=	Dichloro Diphenyl
DDE	=	Dichloro Diphenyl Ethylene
DDT	=	Dichloro Diphenyl Trichloroethane
EPA	=	Environmental Protection Agency
FAO	=	Food Agriculture Organization
GAEC	=	Ghana Atomic Energy Commission
GC	=	Gas Chromatography
GWC	=	Ghana Water Company
HCH	=	Hexachlorocyclohenxane
II	=	Moderately hazardous
III	=	Slightly hazardous
ND	=	Not detected
O	=	Obsolete as pesticide; not classified (WHO, 2009)
OC	=	Organochlorine
OP	=	Organophosphate
PCB	=	Polychlorinated Biphenyls
PO_4	=	Phosphate
S1	=	Sampling Point One
S2	=	Sampling Point Two
S3	=	Sampling Point Three
S/N	=	Serial Number
TDS	=	Total Dissolved Solid
TSS	=	Total Suspended Solids
U	=	Unlikely to Present Acute hazard in Normal Use as Pesticides
WHO	=	World Health Organization

CHAPTER ONE

INTRODUCTION

1.1 Background

The need to protect water bodies to ensure water quality is a top environmental priority as the turn of the century approaches. This is because water resources such as rivers, lakes and streams are deemed dependable resources in support of a nation's surge in manufacturing, construction and more importantly agriculture. Indeed, the necessity to ensure water quality is not only critical to economic viability but also human health as well as environmental quality. The use of pesticides to boost agricultural production whiles maintaining water quality is a major challenge we face today both in our communities and nationwide.

This has become increasingly significant as a result of the use of pesticides to increase food production and production of industrial raw materials. Pesticides are used to control insects, weeds, and plant diseases that interfere with maximum plant growth, development, yields and marketability of crops, thereby ensuring sustainability of food production and availability of food all year round. Tijani (2006b) noted that the use of pesticides in rice and cocoa production has increased yields significantly such that about 45 per cent of the total production is lost to pests and diseases without the use of pesticides. In Ghana, pesticides usage have shown to be an important input for combating crop damage and yields reduction from pest and diseases to ensure sustainable food production with improved yields and greater availability of food crops.

Notwithstanding these benefits, we must recognize that pesticides use can affect water quality. Water contamination by pesticides is one of the problems associated with agricultural activities. According to Calamari and Naeve (1994), the coastal waters, sediments and biota are generally less contaminated with pesticides than inland water environmental compartments with the exception of few hotspots. The United States Environmental Protection Agency (USEPA) (1994), identifies agriculture as the leading cause of water quality impairment of rivers and lakes in the United States and third in importance for pollution of estuarines. During the 1990s, the herbicides, Atrazine and Endosulphan were found most often in surface waters in the USA and Australia due to their widespread use. Other pesticides detected included Pronofos, Dimethoate, Chlordane, Diuron, Prometryn and Fluometuron (Cooper, 1996). High levels of pesticides chlordecone were detected in coastline, rivers, sediments and groundwater in the Caribbean island of Martinique due to its massive application on banana plantations (Bocquene and Franco, 2005).

Most recent studies also report the presence of pesticides in the surface waters close to agriculture lands all over the world (Woudneh *et al*., 2009; Anasco *et al*., 2010). Pesticides can get into water through drift during pesticides spraying, by runoff from treated area and leaching via the soil. Water contamination depends mainly on the nature of pesticides, soil properties, weather conditions, landscape and also on the distance from an application site to water source.

The methods of safe storage, handling and application of pesticides are not widely used in most developing countries (Williamson *et al*., 2008). Kishi (2005) observed that pesticides pose potential hazards to human health and the environment when inappropriately handled. Poorly regulated and unsafe use of pesticides coupled with absence of education has led to increasing pesticides impact on public health and, in particular on the health of farm workers (Tijani, 2006a). It is in the light of this that the FAO (1990) recommends that appropriate steps must be taken to ensure that agricultural activities do not adversely affect water quality so that subsequent uses of water for different purposes are not impaired. Indeed, sufficient amount of knowledge is required about pesticide use and practice, contamination on water quality and socio-economic effects. Increasing unsprayed buffer zones around crops is critical to the success of any new strategy to prevent the harmful impact of pesticides (de Jong *et al*., 2008). Therefore, this study seeks to investigate pesticides contamination and its effects on the water quality of the Tano River in the Asunafo South District.

1.2 Problem Statement

There is an increasing concern about overuse and misuse of pesticides in developing countries (Tijani, 2006b), where over 3 million people have suffered severe acute pesticides poisonings (Larsen, 2003). The indirect effects of pesticides misuse include negative impact on human health, degradation of the environment, loss of biodiversity and irreversible changes to ecosystems (Ajayi, 2000; Gurler *et al*., 2006; Jansch *et al* 2006).

In Ghana, pesticides use has increased over time and is particularly elevated in the production of high value cash crops and vegetables (Gerken *et al*., 2001). According to Ntow (2008), Ghanaian vegetable farmers often spray hazardous insecticides like organophosphates and organochlorines up to five times or more in a cropping season when perhaps two or three applications may be sufficient.

Often, many of these vegetable farming are carried out along the banks of stream and river bodies for easy access to irrigation water during the dry season, making these water bodies highly susceptible to pesticides contamination through runoff water from the farms. When this happens, the quality of the water is affected, and this could threaten the integrity of the aquatic systems, and the health and wellbeing of the water users. This happens to be the case in Dantano and Siana, two communities in the Asunafo South District of the Brong Ahafo Region, where farmers produce the bulk of vegetables in the District. The farmers rely heavily on the use of pesticides and depend on Tano river as a source of irrigation water especially during the dry season. The intensive cultivation of vegetables along the banks of the river by these farmers poses potential threat of pesticide runoff into the river, and hence affecting its quality. This research was therefore, to study the effects of pesticides use on the water quality of the Tano River in the two farming communities.

1.3 Justification of the Study

Pesticides constitute an integral part in the development and expansion of modern agriculture. Several studies have proven that the use of pesticide has brought increases in crop yield. According to Kuniuki (2001) not using pesticides reduced crops yields by about 10%. In this case, farmers can benefit immensely from all year agricultural production where irrigation facilities are available. However, there is a growing concern about pesticide poisoning of rural folks and the general public through food and water contamination. Death cases and pesticide poisoning have been reported around the world particularly in developing countries (Tariq *et al*., 2007). Coupled with this concern is frequent use of banned and restricted chemical pesticides by some farmers in the rural communities.

The economic activity which is pre-dominating in the Asunafo South District is Agriculture. As a result, the Tano river basin does not only serve as reliable source of irrigation water but also offers fish for human consumption. It also serves as good drinking water for both human and livestock. Therefore, any research study that seeks to unearth farming practices along the banks of Tano basin that has potential to contaminate the river is justified, hence the current study.

1.4 Objectives of the Study

The main objective of this work was to assess the effects of pesticides usage on the water quality of the Tano river within the farming communities of Dantano and Siana in the Asunafo South District of the Brong Ahafo Region.

The specific objectives of the study were to:

(i) assess the different types of pesticides commonly used by farmers at Dantano and Siana;

(ii) determine the levels of the pesticide residues in water samples from the Tano river at Dantano and Siana; and

(iii) determine the following parameters in water samples taken from the Tano river: turbidity, pH, water temperature, water colour, total suspended solids (TSS), conductivity, total dissolved solids (TDS), nitrates and phosphates.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

There are several million tonnes of pesticides scattered all over the world. In 2006 and 2008, the world used approximately 5.2 billion pounds of pesticides with herbicides constituting the majority of the world pesticides use at 40% followed by insecticides and fungicides at 17% and 10%, respectively (USEPA, 2007). In Ghana, pesticides are used on regular basis for agricultural purposes for the protection of crop plants from harmful organisms and to control the growth of certain weeds. The use of each of these pesticides could be a potential source of entry into the air, soil and water bodies in the rural communities. The rural communities cannot hope to develop and prosper if they suffer from illness caused by pesticides poisoning.

According to FAO and WHO, each year around 30% of the US$900 million pesticides marketed in developing countries do not meet internationally accepted quality standards, and they are posing a serious threat to human health and the environment. This chapter, therefore, looks into the relevant literature on pesticides contamination of water bodies and their effects on water quality.

2.2 Definition of Pesticides

A pesticide is defined by the Ghana Pesticides Control and Management Act (Act 528, 1996) as any substance, mixture of substances or other agents used to control, destroy or prevent damage by or protect something from a pest. It also includes chemical substances that are used to attract and repel pests as well as those used to regulate plant growth or remove coat or leaves. Pesticides are substances or mixture of substances intended to preventing, destroying, repelling or mitigating any pest (USEPA, 2007).

According to FAO (2002), a pesticide is any substance or mixture of substances intended for preventing, destroying or controlling any pest including vectors of human or animal disease, unwanted species of plants or animals causing harm during or otherwise interfering with production, processing, storage, transport or marketing of food, agricultural commodities, wood and wood products or animal feedstuffs, or substances which may be administered to animals for the control of insects, arachnids or other pests in or on their bodies. The term includes substances intended for use as a plant growth regulator, defoliant, desiccant or agent for thinning fruit or preventing the premature fall of fruit. Also, it is used as substances applied to crops either before or after harvest to protect the commodity from deterioration during storage and transport. It can be deduced from the definition that pesticides are not mainly used for agriculture but also for public health such as controlling vectors of diseases.

2.3 Brief History of Pesticides Application

Humans have utilized pesticides to protect their crops before 2000 BC. The first known pesticide was elemental sulphur dusting used in ancient Sumer about 4,500 years ago in ancient Mesopotamia. The Rig Veda which is about 5000 years old mentions the use of poisonous plants for pest control (Rao *et al.,* 2007). By the 15th century, toxic chemicals such as arsenic, mercury and lead were being applied to crops to kill pests. In the 17th century, nicotine sulphate was extracted from tobacco leaves for use as an insecticide.

The 19th century saw the introduction of two more natural pesticides, pyrethrum which is derived from chrysanthermuons and rotenone which is derived from the roots of tropical vegetables (Miller, 2002).

Until the 1950s, arsenic based pesticides were dominant (Ritter, 2001). Organochlorines were replaced in the U.S. by organophosphates and carbamates by 1975. Herbicides became common in the 1960s led by "atriazine and other nitrogen-based compounds carboxylic acids such as 2, 14 dichlorophenoxyacetic acids and glyphostate (Ritter, 2009). Some sources consider the 1940s and 1950s to have been the start of the "pesticides era" (Graeme, 2005). Pesticide use has increased 50-fold since 1950 and 2.3 million tonnes of industrial pesticides are now used each year (Miller, 2002). Seventy-five percent of all pesticides in the world are used in developed countries, but use in developing countries is increasing (Miller, 2004).

In the 1960s, it was discovered that DDT was preventing many fish-eating birds from reproducing, which was a serious threat to biodiversity. Rachel Carson wrote the best-selling book "Silent Spring" about biological magnification of pesticides. According to Lobe (2006), even though the agricultural use of DDT is now banned under the Stockholm convention on persistent organic pollutants, it is still used in some developing nations to prevent malaria and other tropical diseases by spraying on interior walls to kill or repel mosquitoes.

2.4 Benefits of Pesticides Use or Application

Pesticides are used to control organisms that are considered to be harmful. They are used to kill mosquitoes that can transmit potentially deadly diseases like West Nile, yellow fever, and malaria. Also, sicknesses that could be caused by mouldy food are prevented by pesticide applications. Uncontrolled pests such as termites and mould can damage farm structures.

Generally speaking, farmers benefit from having an increase crop yield and from being able to grow a variety of crops throughout the year. One study found that not using pesticides reduced crop yields by about 10% (Kuniuki, 2001). Consumers of agricultural products also benefit from being able to afford the vast quantities of produce available year round (Cooper *et al.*, 2007). The general public also benefits from the use of pesticides for the control of insect-borne diseases and illnesses, such as malaria. According to Helfrich *et al.*, (1996), herbicides are commonly applied in ponds and lakes to control algae and plants such as water grasses that can interfere with activities like swimming and fishing and cause the water to look or smell unpleasant. The use of pesticides creates a large job market, which provides jobs for all of the people who work within the industry.

2.5 Environmental Effects of Pesticide

Pesticide use raises a number of environmental concerns. Over 98% of sprayed insecticides and 95% of herbicides reach a destination other than their target species, including non-target species, air, water and soil (Miller, 2004). Though there can be benefits using pesticides, inappropriate use can counterproductively increase pest resistance and kill the natural enemies of pests. Many users are inadequately informed about potential short and long-term risks, and the necessary precautions in the correct application of such toxic chemicals are not always made (Damalas *et al.,* 2011). Pesticides can contaminate unintended land and water when they are sprayed aerially or allowed to run off fields, or when they escape from production sites and storage tanks or are inappropriately discarded (Tashkent, 1998).

The amount of pesticide that migrates from the intended application area is influenced by the particular chemical's properties: its propensity for binding to soil, its vapour pressure, its water solubility, and its resistance to being broken down over time (Kellogg *et al.*, 2000). Soil factors such as texture, its ability to retain water, and the amount of organic matter contained in it, also affect the amount of pesticide that will leave the area (Kellogg *et al.,* 2000).

2.5.1 Effect on Water

In the United States, pesticides were found to pollute every stream and over 90% of wells sampled in a study by the US Geological Survey (Gilliom *et al.,* 2007). Pesticide residues have also been found in rain and groundwater (Kellogg *et al.,* 2000). Studies by the UK government showed that pesticide concentrations exceeded those allowable for drinking water in some samples of river water and groundwater (Bingham, 2007).

Pesticide impacts on aquatic systems are often studied using a hydrology transport model to study movement and fate of chemicals in rivers and streams. As early as the 1970s quantitative analysis of pesticide runoff was conducted in order to predict amounts of pesticide that would reach surface waters (Hogan *et al.*, 1973).

There are four major routes through which pesticides reach the water: it may drift outside of the intended area when it is sprayed, it may percolate, or leach through the soil, it may be carried to the water as runoff, or it may be spilled, for example accidentally or through neglect (States of Jersey, 2007). They may also be carried to water by eroding soil (Papendick *et al.*, 1986). Factors that affect a pesticide's ability to contaminate water include its water solubility, the distance from an application site to a body of water, weather, soil type, presence of a growing crop, and the method used to apply the chemical (Pedersen,1997).

Maximum limits of allowable concentrations for individual pesticides in public bodies of water are set by the Environmental Protection Agency in the US (Kellogg *et al.*, 2000). Similarly, the government of the United Kingdom sets Environmental Quality Standards (EQS), or maximum allowable concentrations of some pesticides in bodies of water above which toxicity may occur (Bingham, 2007).

2.6 Health Effects of Pesticides

Pesticides may cause acute and delayed health effects in those who are exposed to them (USEPA, 2007). Pesticide exposure can cause a variety of adverse health effects. These effects can range from simple irritation of the skin and eyes to more severe effects such as affecting the nervous system, mimicking hormones causing reproductive problems, and also causing cancer (www.epa.gov/pesticides). Bassil *et al.* (2007) found that "most studies on non-Hodgkin lymphoma and leukemia showed positive associations with pesticide exposure" and thus concluded that cosmetic use of pesticides should be decreased. Strong evidence also exists for other negative outcomes from pesticide exposure including neurological, birth defects, fetal death (Sanborn *et al.*, 2007) and neurodevelopment disorder (Jurewiez and Hanke, 2008).

The World Health Organization and the UN Environment Programme estimate that each year, 3 million workers in agriculture in the developing world experience severe poisoning from pesticides, about 18,000 of whom die (Miller, 2004). According to one study, as many as 25 million workers in developing countries may suffer mild pesticide poisoning yearly (Jeyaratnam, 1990). Another study found pesticide self-poisoning the method of choice in one third of suicides worldwide, and recommended, among other things, more restrictions on the types of pesticides that are most harmful to humans (Gunnell *et al.*, 2007).

Pesticides can enter the human body through inhalation of aerosols, dust and vapour that contain pesticides; through oral exposure by consuming food and water; and through dermal exposure by direct contact of pesticides with skin (Department of Pesticide Regulation, 2008). Pesticides are sprayed onto food, especially fruits and vegetables, they secrete into soils and groundwater which can end up in drinking water and pesticide spray can drift and pollute the air.

The effects of pesticides on human health are more harmful based on the toxicity of the chemical and the length and magnitude of exposure (Lorenz , 2009). Farm workers and their families experience the greatest exposure to agricultural pesticides through direct contact with the chemicals. But every human contains a percentage of pesticides found in fat samples in their body. Children are more susceptible and sensitive to pesticides (Department of Pesticide Regulation, 2008) because they are still developing and have a weaker immune system than do adults. Children may be exposed due to their closer proximity to the floor and natural tendency to put contaminated objects in their mouth, and also because children tend to spend more time at home in a potentially contaminated environment. Pesticides tracked into the home from family members increase the risk of toxic pesticide exposure which is normally area specific. Also, toxic residue in food may contribute to a child's exposure to a certain pesticide (Eskenazi *et al.,* 1999). The chemicals can bioaccumulate in the body over time.

Exposure to pesticides can range from mild skin irritation to birth defects, tumors, genetic changes, blood and nerve disorders, endocrine disruption, and even coma or death. (Lorenz , 2009). Developmental effects have been associated with pesticides. Recent increases in childhood cancers in throughout North America, such as leukemia, may be a result of genotoxic and nongenotoxic pesticides due to somatic cell mutations (Daniels *et al.,* 1997). Exposure to pesticides may occur in postnatal early stages of development, in uterus, and even if either parent was exposed before conception took place. Reproductive disruption has the potential to occur by chemical reactivity and through structural changes to a system (Hodgson *et al.,* 1996).

2.7 Pesticide Residue Accumulation

Pesticide accumulation refers to the buildup of pesticides resulting from repeated use. It may occur in the soil, groundwater, plants, lakes, ponds, and animal tissues.

Organochlorines insecticides are characterized by high persistence, low polarity, low aqueous solubility and high lipid solubility (lipophilicity) and as a result they have a potential to bioaccumulate in the food chain posing a great threat to human health and the environment globally (Lars, 2000). Although the production and use of many types of OCs and organophosphorus (OPs) have been banned in many countries including Ghana, they are, nevertheless, still being used unofficially in large quantities in many parts of Ghana, and in other developing countries because of their effectiveness as insectides and their relatively low cost. Farmers often spray hazardous insecticides like organophosphates and organochlorines up to five or more times in a cropping season when perhaps two or three applications may be sufficient (Ntow, 2008). Runoff of these pesticides from the agricultural fields may contaminate water sources. The pesticides are transported to aquatic bodies by rain runoff, rivers and streams and associate with biotic and abiotic macroparticles. Non-target flora and fauna concentrate these chemicals in their tissues and pass them on along the food chain, which may lead to biomagnifications in humans on the top of the food chain. This allows for fish contamination through ingestion, dermal absorption and respiration. The accumulation of such pollutants in the food chain may restrict the consumption of valuable food resource like fish.

2.8 Effects of Pesticide Residues Accumulation

The production and use of pesticides is an important source of economic welfare in Ghana. Generally, agriculture in Ghana, particularly vegetable farming is fraught with misuse and overuse of pesticides. Pests and diseases pose big problems in vegetable production and these have led many farmers to use chemical pesticides even if they have received no training in application techniques. As a result, residues of these pesticides enter the environment which causes pollution. There have also been reports of some health related problems in the country and the world at large. Organochlorine pesticides have been used in Ghana for more than 40 years, for agriculture and public health purposes with their residues having been found in water, sediments and crops and in humans (Ntow, 2001). According to Garabrant *et al*. (1992), organochlorines have been implicated in a broad range of adverse human health effects including reproductive failures and birth defects, immune system malfunction, endocrine disruptions, and cancers. Studies have shown that dichlorodiphenyltrichloroethane (DDT), dieldrin and polychlorinated biphenyls (PCBs) have endocrine disrupting capacities (Mckinnney and Waller, 1994). Similarly, epidemiological studies have suggested an etiological relationship between exposure to organochlorines and Parkinson's diseases (Fleming *et al*., 1994).

2.9 Pesticide Use in Agriculture

Agrochemicals are integral part of current agriculture production systems around the world. Accordingly, the use of agrochemicals viz fertilizers and pesticides remain a common practice particularly in many nations in the tropical world (Carvalho, 2006). Despite the ban on the production and use of OCPs in accordance with Stockholm convention in 2001 (Ennacer *et al*., 2008) and replacement with less persistent organophosphates and carbamates, some developing countries have resumed the use of OCPs such as DDT. It is also worth noting that dieldrin, aldrin and other OCPs are still used for the control of pest of cotton, cocoa, fruits, cereals and vegetable (Ize-Iyamu *et al*., 2007).

In Ghana, according to Ntow *et al.* (2006), most of the agrochemicals used by the farmers include banned and restricted products such as aldrin, dieldrin chlordane and dichlorodiphenyltrichloroethane. Ntow (2001), reported that many of the agrochemicals meant for crops such as cocoa and coffee were misapplied for tomato cultivation. Many pressure groups, example, Consumer Associations, Non-governmental Organizations and International bodies are against the presence of these persistent pesticides in the environment. They perceive the presence of pesticide residues in the environment as detrimental to human health and water quality (Fianko *et al*., 2011).

The contamination of the environment and exposure of the public to pesticide residues in food could lead to high health risk. Results of scientific research reveal that even in low concentrations, the combined effect of persistent synthetic chemicals such as pesticides causes suppression of immune response and hypersensitivity to chemical agents. Causes of breast cancer, reduced sperm count, male sterility etc are well documented as a result of pesticide ingestion (Carvalho, 2006). In Ghana, agrochemicals used in farming dates back to the colonial era and have been inherent component in agricultural practices in the nation. The objective of this study is to summarize the agro-chemical monitoring studies in Ghana and gives the true picture of their detrimental effects to the environment. It will also determine the current state of knowledge in agrochemicals in Ghana to set the future plan of action in agrochemical research in Ghana (Fianko *et al*., 2011).

2.10 General Agrochemical Use in Crop Production in Ghana

Agriculture is the most important sector in Ghana's economy, forming nearly 41% of total Gross Domestic Product (GDP) (FAO, 2005). Out of the total area of 238.854 square kilometers of Ghana only 57% (13 628 000 hectares) is suitable for agriculture. However, 6 331 000 hectares of the arable land are cultivated because the soils are infertile and only productive with proper management and good agricultural practice (MOFA, 2003; FAO, 2004). In the light of these 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 yield. Instead, the current trend has been the decrease of agriculture land (hectares per inhabitant) in all regions of the globe as a result of population growth, net loss of agricultural land due to erosion, reduction of fertility, salinization and desertification of soils (Carvalho, 2006). Therefore the best response to the need for increasing food production is more intensive use of agrochemicals (Fianko *et al*., 2011).

As farms have become massive in size, the challenges in keeping the crop free of damage have increased. Hand-tilling weeds have become impractical, as one example. Thus the whole world has known a continuous growth of agrochemical usage both in numbers and quantities. The use of agrochemicals has been critically important in increasing the yield of agricultural crops. However, some uses of agrochemicals cause environmental and ecological damage, which detracts significantly from the benefits gained by the use of these materials (Fianko *et al*., 2011).

2.11 Pesticide Use in Ghana

Ghana as a developing country is experiencing high economic growth rate in the West African Sub-region (FAO, 2005). As an agriculture-based nation, the use of pesticides contributes much to the national development and public health programmes. Ever since the inception of pesticides, its use to protect crops from pests has significantly reduced losses and improved the yield of crops such as cereals, vegetables, fruits and other crops. Ghana thus, has known a continuous growth of pesticide usage, both in number of chemicals and quantities because of the expansion of area under cultivation for food, vegetables and cash crops (MOFA, 2003).

Pesticide application in Ghana is more concentrated in cocoa, oil palm, cereals, vegetables and fruits sectors (FAO, 2004). Although purchased physical inputs (agrochemicals, seeds and tools) represent less than 30% of the total cost of crop production, the use of pesticides is becoming more widespread. For instance, between 1995 and 2000, about 21 different kinds of pesticides were imported into the country for agricultural purposes (FAO, 2004). Pesticide use has been embraced by local communities that are making a living from sale of vegetables and other cash crops. There is ample evidence that food crops, especially tomatoes are always sprayed and sold immediately after maturity for consumption. This inevitably puts a high risk on consumers who always get their supply directly from the farmers. In Ghana, it is estimated that 87% of farmers who use pesticides, apply any of the following or a combination of pyrethroids, organophosphates, carbamates, organochlorines on vegetables (Ntow, 2001).

Among the different types of pesticides known, organochlorine pesticides are the most popular and extensively used by farmers due to their cost effectiveness and broad spectrum activity. Lindane was widely used in Ghana on cocoa plantations, vegetable farms, and for the control of stem borers in maize (MOFA, 1998). Endosulfan is popularly applied in cotton growing areas, vegetables farms, and coffee plantations (FAO, 2004) in some parts of Ghana. Pesticides particularly DDT and lindane which are no longer registered for any use in the country were once employed to control ectoparasites of farm animals and pets in Ghana (Ntow *et al*., 2006).

Pesticides mostly used to control foliar pests in Ghana include chlorpyrifos, dimethoate, diazinon, cymethoate and fenitrothion while the fungicides maneb, carbendazim, imazil, copper hydroxide are used for post-harvest treatment (Kyofa-Boamah and Blay, 2000; Cudjoe *et al*., 2002). Lambda-cyhalothrin, cypermethrin, dimethoate and endosulfan are also used by vegetable growers in tomato, pepper, okra, egg-plant, cabbage and lettuce farms (Cudjoe *et al*., 2002). Glyphosate, fluazifop-butyl, ametryne, diuron or bromacil are normally employed in land clearing (Aboagye, 2002). Nonetheless, the most extensively used pesticides in the pepper, tomato, groundnut and beans cultivation are karate, cymbush, thiodine, diathane, lubillite and kocide (Yeboah *et al*, 2004).

Dinham (2003) estimates that 87% of farmers in Ghana use chemical pesticides to control pests and diseases on vegetables and fruits. Ntow *et al*. (2006) gave the proportions of pesticides used popularly on vegetable farms as herbicides (44%), fungicides (23%) and insecticides (33%). In a study encompassing 30 organized farms and 110 kraals distributed throughout the 10 regions of Ghana, Awumbila and Bokuma (1994) found that 20 different pesticides were in use with the organochlorine lindane being the most widely distributed and used pesticides, accounting for 35% of those applied on farms. Of the 20 pesticides, 45% were organophosphorous, 30% were pyrethroids, 15% were carbamates and 10% were organochlorines (Awumbila and Bokuma, 1994).

In the public health sector, pesticides, primarily temephos have been used by the Onchocerciasis Programme in the Volta Basin for the control of black flies (Simulium spp. Diptera: Simulidae), which transmit onchocerciasis (African river blindness, a disease caused by the pathogenic nematode, *Onchocerca volvulus*) to humans and for the control of diseases (Awumbila, 1996) and domestic pests, such as cockroaches, various flies, mosquitoes, ecto-parasites including ticks and other insects (Clarke *et al.*, 1997). Pesticides have also been used to control black flies along the banks of the Tano and Pra rivers (Ntow, 2005).

Analysis of pesticide trade flow patterns, recorded by Ghana's Statistical Service, in 1993 indicated that a total of 3,854,126 kg of pesticides were imported with the following distribution and use as per Figure 1 (Boateng, 1993).

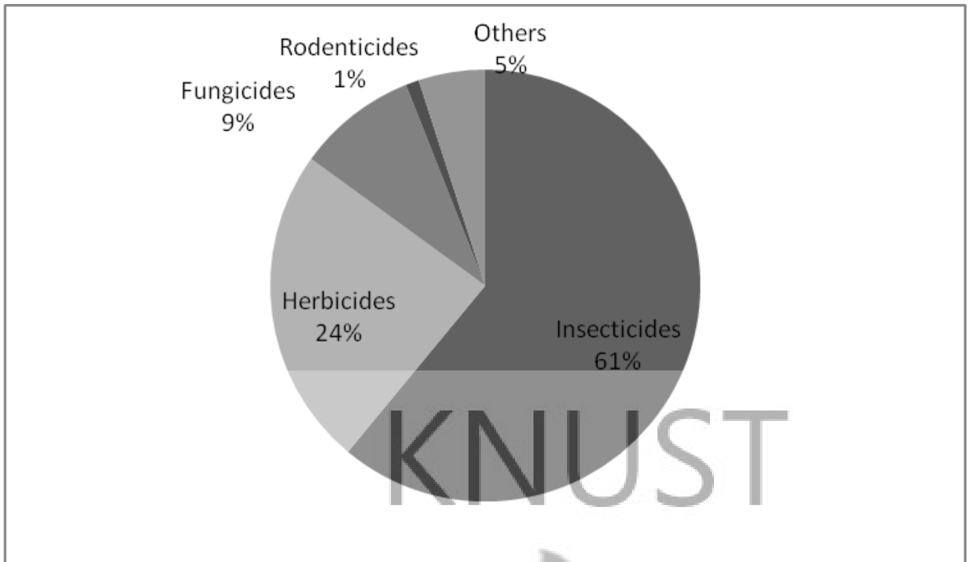

Fig.1 Distribution of pesticides imported into Ghana (Source: (Fianko *et al*., (2011)).

Besides, a survey conducted between 1992 and 1994 in the Ashanti, Brong Ahafo, Eastern and Western Regions of Ghana revealed that the most broadly used pesticides by farmers were: copper (II) hydroxide (29.0%), mancozeb (11.0%), fenitrothion (6.0%), dimethoate (11.0%), pirimiphos methyl (11.0%), λ-cyhalothrin (22.0%), and endosulfan (10.0%) (Acquaah and Frempong, 1995). Moreover, it was established that insecticides constituted about 67% of pesticides employed by farmers while fungicides were about 30% and herbicides and other pesticides types form 3% of the total use. On the other hand, it is on record that between 1995 and 2000, an average of 814 tonnes of pesticide was imported into the country annually, the greatest quantity being insecticides, 70% (FAO, 2004). The amount of pesticides imported into the country from 2002 to 2006 increased from 7763 metric tonnes to 27,886 metric tonnes, (Table 1). Updated register of pesticides from the Environmental Protection Agency in Ghana in 2008 indicated that about 141 different types of pesticide products have been registered in the country under the Part II of the Environmental Protection Agency Act, 1994 (Act 490). These consists of insecticides (41.84%), fungicides (16.31%), herbicides (31.83%) and others (10.01%) (Ghana, EPA, 2008).

Table 1 Annual imported pesticide into Ghana from 2002 to 2006 (Ghana,EPA, 2008).

Class of Pesticide (Mt)	YEAR				
	2002	**2003**	**2004**	**2005**	**2006**
Insecticides	4130	5974	8418	10,006	12728
Herbicides	2186	2939	4578	8566	10718
Fungicides	1079	1249	2402	2205	3195
Others	368	496	544	707	1224
Total	**7763**	**10658**	**15942**	**21484**	**27886**

2.12 Pesticide Use and Residues in Vegetable Farming

A study by Ntow (2008) found a total of 43 pesticides in use in vegetable farming in Ghana. This figure was obtained as a direct summation of pesticides applied on farms, but it could be lower than the actual number of pesticides in use. The pesticides comprised insecticides, fungicides and herbicides. Herbicides (44%) were the class of pesticides mostly used in vegetable farming in the areas surveyed, followed by insecticides (33%) and fungicides (23%). The classification of these pesticides by the type of pests they control, active ingredient, chemical group and WHO Hazard Category is presented in table 2. The herbicides and fungicides used are mostly under WHO

Hazard Category III, with a few under Hazard Category II. All the insecticides used are under Hazard Category II, which WHO classifies as moderately hazardous. This category includes organochlorines (OCs), organophosphates (OPs) and pyrethroids. Endosulfan was the only OC mentioned in use in the survey.

Table 2 Types of pesticides applied in vegetable production in Ghana

Pesticide type (% of total number in use)	Active ingredient (AI)	Chemical group	Chemical AI Hazard Category (WHO)	Registered for use on
Herbicide	Pendimethalin	Dinitroaniline	III	Tomatoes, onions
(44%)	2,4-D	Aryloxyalkanoic acid	II	Rice, sugarcane
	propanil	Anilide	III	Rice
	MCPA-thioethyl	Aryloxyalkanoic acid	III	Not registered
	Oxadiazon	Oxadiazole	III	Not registered
	Oxyfluorfen	Diphenyl ether	III	Not registered
	Bensulfuron-methyl	Sulfonylurea	III	Rice
	Glyphosate	Glycine derivative	III	Various crops
	Paraquat dichloride	Bipyridylium	II	Various crops
	Acifluorfen	Diphenyl ether	III	Not registered
	Metolachlor	Chloroacetamide	III	Not registered
	Phenmedipham	Carbamate	III	Not registered
	Mancozeb	Carbamate	III	Mangoes, vegetables
Fungicide	Metalaxyl-M	Acylalanine	II	Not registered
(23%)	Thiophanate-methyl	Benzimidazole	III	Various crops
	Carbendazim	Benzimidazole	III	Not registered
	Benomyl	Benzimidazole	III	Not registered
	Lambda-cyhalothrin	Pyrethroid	II	Vegetables
	Chlorpyrifos	Organophosphorus	II	Citrus, public health
Insecticide	Endosulan	Organochlorine	II	Cotton
(33%)	Dimethoate	Organophosphorus	II	Not registered
	Cypermethrin	Pyrethroid	II	Not registered
	Deltamethrin	Pyrethroid	II	Various crops

Source (Ntow, 2008)

2.13 Pesticide Residues in Surface and Ground Water

A fundamental contributor to the "Green Revolution" has been the development and application of pesticides for the control of a wide variety of pests that would otherwise diminish the quantity and quality of food produce (Tariq *et al*., 2007). Notwithstanding the increased food production, massive use of pesticides has caused serious contamination of aquifers and surface water bodies, decreasing the quality of water for human consumption (Carvalho, 2006). Pesticide residues have been a catch cry of environmental and consumer groups since the mid-1960's when Rachel Carson drew the public's attention to the deleterious ecological effects of organochlorine pesticides especially Dichloro-Dichlorophenyl-Trichloroethane (DDT), which were in widespread use at that time.

Water samples from rivers in the intensive cocoa growing areas in the Ashanti and Eastern Regions of Ghana have been found to contain lindane and endosulfan (Acquaah, 1997). Water samples from Akumadan, a vegetable farming community in the Ashanti Region and different areas of Ghana revealed the presence of significant levels of pesticide residues. The Volta Lake was also found to be mildly contaminated with lindane, DDT, DDE and endosulfan (Ntow, 2005). In another study by Acquaah (1997), lindane and endosulfan were found at significant oncentrations in water samples from Oda, Kowire and Atwetwe rivers in Ghana.

2.14 Some Physicochemical Parameters of Water

The quality of surface water is of serious concern to both the general public and the nation at large. As result, there is the need to ensure that anthropogenic influence on the surface water quality is minimal. Natural processes such as erosion, runoff, leaching coupled with anthropogenic activities determine the water quality of surface water .The physicochemical characteristics also determines the usefulness of surface water for domestic and recreational purposes

According to WHO (2010), the stipulated pH range of 6.5-8.5 is good for drinking and domestic purposes. The EU has also set protection limit of pH from 6-9 for fishes and aquatic life. Based on these background levels, river with pH within this range values will not affect aquatic organisms or water for domestic uses.

Generally, the conductivity of a river is lowest at the source of its catchments and as it flows along the course of the river, it leaches ions from the soil and also picks up organic materials from the biota and its detritus (Ferrar, 1989).The average conductivity value of typical, unpolluted rivers is approximately 350 µS/cm (Koning and Roos, 1999). In another study, Antwi and Ofori-Danson (1993) recorded conductivity value ranged 62.0-77.5 µS/cm

Total suspended solids are a common indicator of polluted waters. The WHO (2006) stipulates a guideline value of TDS as 1000 mg/L. McCutheon *et al*. (1983), have reported that the palatability of water with TDS levels less than 600 mg/L is generally considered to be good whereas TDS greater than 1200 mg/L becomes increasingly unpalatable. Akoto *et al.* (2010), have recorded the following ranges for physicochemical parameters of the surface water in the Owabi watershed in Ashanti region of Ghana: pH (6.75-7.40), TDS (28-197 mg/L) and nitrate (0.01-0.017 mg/L).

CHAPTER THREE

METHODOLOGY

3.1 Study Area

The study was conducted in the farming communities of Dantano and Siana in the Asunafo South District of the Brong Ahafo Region. The area is a forest zone noted for its cultivation of cocoa and horticultural crops such as tomato, garden egg, pepper and okro. The vegetable productions in the two communities are notably carried out along the banks of the Tano River for easy access to the River for irrigation purposes. These two communities were selected based on intense agricultural activities and heavy pesticide usage in the areas.

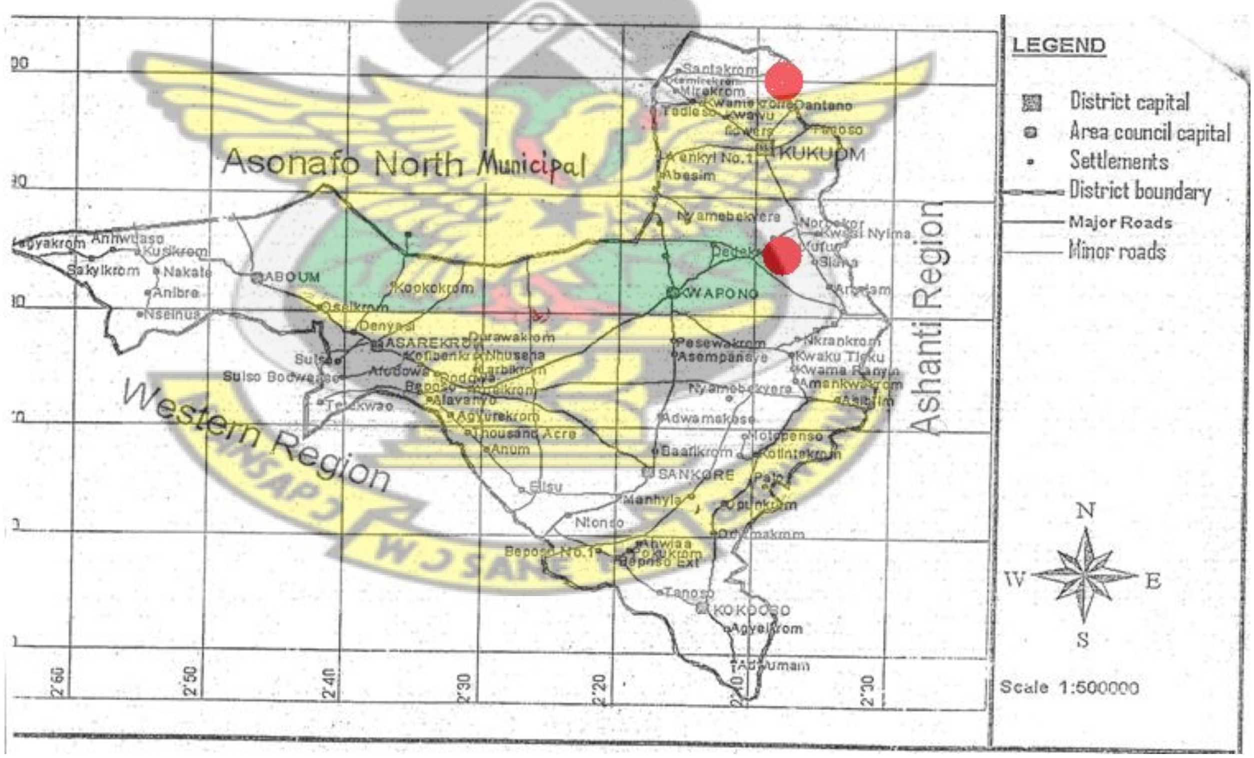

Fig. 2 Map of the Asunafo South District showing the two sampling stations

Plate 1 A section of the Tano River at Siana

Plate 2 Pipes carrying irrigation water from the Tano river to a farm at Dantano

Plate 3 A Tomato farm close to the Tano river at Dantano

Plate 4 A pepper farm close to the Tano river at Siana

3.2 Sample Collection

Water samples were collected in duplicates from January to March, 2012 at Dantano and Siana. At each community, three designated points namely, upstream (S1), midstream (S2) and downstream (S3) were selected. The points were at intervals of approximately 300 m. Prior to the collection of the water samples; a volume of water was allowed to enter the bottle by immersing in the river and rinsed. This was done twice and the water content was discarded in a way not to disturb sampling area. Two water samples were collected at each sampling point into a pre-washed 1 L bottle and were wrapped with aluminium foil. After collection, the water samples were placed in coolbox and transported to the Nuclear Chemistry and Environmental Research Laboratory of the Ghana Atomic energy Commission for pesticides residual analysis.

Plate 5 Collection of water samples from the Tano river

3.3 Digestion of Water Samples

3.3.1 Sample Extraction

The extraction of the collected samples was done by liquid-liquid extraction based on method suggested by Ahad *et al*. (2005) with slight modification. Fifty (50) ml of ethyl acetate was introduced into a separating funnel containing 50 ml of each of the water sample and shaken vigorously for 10 minutes so that the solvents could mix well. This was allowed to stand for 10 minutes for complete separation using tripod stand. After separation, the bottom aqueous layer was drained into round bottom flask while the organic layer was filtered into round flask containing 2 g of sodium sulphate as drying agent to remove any water. The extracts of each sample was then concentrated to 5 ml using a rotary evaporator at 68°C and low pressure equipped with water chiller.

Plate 6 Concentration of extracted samples using the rotary evaporator

3.3.2 Extract Clean-Up

The clean-up of the concentrated extract was realized by injecting through a clean-up material (micro column) containing 2g of sodium sulphate and 1.5g of silica gel. The clean up material was first conditioned with 5ml of ethyl acetate before injecting the concentrated extract. An internal standard of 50 ng/ml was added to each extract to correct any variability due to injection conditions. The extracts were transferred into glass vials for GC analysis.

3.4 Field Survey

Two sets of structured questionnaires were designed and used to solicit information from agro-chemical sellers and farmers in the study area. The interview was done throughout the month of March, 2012. Prior to the actual field interviews, a pre-testing of the questionnaires was carried out over a two week period spanning from 15^{th} – 29^{th} February 2012. A total of 11 agrochemical sellers and 35 farmers were interviewed during the survey.

Plate 7 interviewing an agrochemical seller at Siana

3.5 Determination of Physico-chemical Parameters

Temperature, pH, conductivity, salinity and TDS were determined in-situ using Hanna (H19828) multi-parameter probe (Plate 8) while colour, turbidity, phosphate and nitrate were analyzed using Wagtech Photometer 7100 (Plate 8).

Alkalinity of the water samples was determined when about 100 mL of the water samples was titrated against 0.02 NH_2SO_4 using Bromocresol green as indicator method.

Plate 8 The Hanna Multi-parameter probe model H19828

Plate 9 The Wagtech Photometer

Determination of Total Suspended Solids (TSS)

The TSS was determined by the gravimetric method.

Procedure

A fifty (50) ml of a well-mixed sample was filtered through a weighed standard glass-fiber paper. The residue retained on the filter was then dried in an oven at 103 to 105˚C for 1 hour. It was then cooled in a dessicator and weighed. The increase in weight of the filter represents the total suspended solids.

Calculation

The TSS was computed by using the formula below:

The TSS was computed for using the formula below:

$$\text{mg total suspended solids/L} = \frac{(A - B) \times 1000}{\text{sample volume, mL}}$$

A = weight of filter + dried residue, mg, and

B = weight of filter, mg.

Determination of Alkalinity:

This was done with reference to (APHA, 2005).

Procedure:

A volume of 100 ml of the sample was measured into volumetric flask. Three drops of phenolphthalein indicator were added. The Sample was titrated with 0.1N acid until a red colour appeared indicating the endpoint and the volume was recorded. The alkalinity was calculated as follows:

$$\text{Alkalinity as mg/L } CaCO_3 = \frac{(V \times N) \times 1000 \times 100}{\text{Sample volume (ml)} \times 2}$$

V= titration volume in mL

N= normality of the acid solution

100= molecular mass of $CaCO_3$

3.6 Statistical Analysis

The Kruskall-Wallis non-parametric test was used to test for significant differences ($p<0.05$) in the pesticide concentrations of the upstream, middle and downstream portions of the Tano River. The Mann-Whitney non-parametric test was also used to test for the spatial variations in the concentration of the pesticide at the two sampling locations. All statistical analysis and graphs were executed using the GraphPad Prism 5 Statistical Software.

CHAPTER FOUR

RESULTS

4.1 Demographic Characteristics of the Agrochemical Shop Owners

All the 11 agrochemical sellers interviewed had undergone at least some level of formal education. Five (5) of them, representing 45% of the total respondents had completed Middle School or Junior High School (JHS) level, while the remaining six (6), representing 55% had undergone formal education at least up to the secondary level (Table 3). Most of the agrochemical shops (64%) had been certified and registered by The Ghana Environmental Protection Agency (EPA).

The survey tested the knowledge of the agrochemical sellers on potential effects of pesticides on the environment as well as their knowledge on banned pesticides in the country. Six (6) of them had knowledge of banned pesticides in the country and mentioned some of them as Funguran, Gammalin 20, Kocide, Cabamot and Cocosta (Table 3). None of them indicated they had any of the banned pesticide in stock. Most of the 'banned' chemicals are for controlling pests on cocoa farms.

On the potential effects on the environment, 7 were aware of some harmful effects of their products to the environment, and demonstrated this by mentioning some as killing of non-target organisms, contamination of food crops, especially vegetables, contamination of soils and air and more importantly rivers and other water bodies.

Table 3 Demographic characteristics of the Agrochemical Sellers in the study areas

Variable	Number of Respondents	% of Respondents
Age (years		
20-25	1	9
26-30	3	27
31-35	4	37
36-40	2	18
40 or older	1	9
Total	11	100
Level of Education		
Middle School / JSS	5	45
Senior High School	5	46
Tertiary	1	9
Total	11	100
Years in Agro-Business		
1	2	18
2	4	37
3	2	18
4	1	9
5	1	9
Over 5 years	1	9
Total	11	100
Registration Status of agrochemical shops		

YES	7	64
NO	4	36
Total	11	100
Knowledge of banned pesticides		
YES	6	55
NO	5	45
Total	11	100

4.2 Major Types of Pesticides Used in the Asunafo South District

The major types of pesticides most commonly sold in the agrochemical shops in the two communities are presented in Table 4. A total of 55 different pesticides were named by the dealers. They comprised herbicides, insecticides and fungicides. In Table 4, the classification of these pesticides by their active ingredients and WHO Hazard Category are also presented. Most of the herbicides and fungicides mentioned were under WHO Hazard Category III (slightly hazardous), with a few under Hazard Category II (moderately hazardous).

Table 4 Types of pesticides found in agrochemical shops in Dantano and Siana

S/N	Brand	Category	Active Ingredient (AI)	Chemical Hazard Category (WHO)
1	Actara	Insecticide		
2	Adwuma Wura	Herbicide	Isopropylamine salt	
3	Agil	Herbicide	Propaquizafop	U
4	Akate Suro	Insecticide	Diazinon	II
5	Atraz 80 WP	Herbicide	Atrazine	II
6	Atrazine	Herbicide	Atrazine	II
7	Attack	Insecticide	Emamectin Benzoate	
8	Champion	Insecticide	Cyhalothrin	II
9	Chemosate	Herbicide	Glysophate	III
10	Confidor	Insecticide		
11	Conti-Halothrin	Insecticide	Cyhalothrin	II
12	Cotzeb	Fungicide		
13	Cyperdem	Insecticide	Cypermethrin	II
14	Fruitmaster	Fungicide		
15	Funguran	Fungicide		
16	Glycel	Herbicide	Glysophate	III
17	Glyphosate	Herbicide	Glysophate	III
18	Glysate	Herbicide	Glysophate	III
19	Gramoquick	Herbicide	Paraquat dichloride	II
20	Kabazeb	Fungicide	Mancozeb	II
21	Kadmaneb	Fungicide	Maneb	II
22	Kalach	Insecticide		
23	Kocide	Fungicide		
24	Kombat	Insecticide	Cyhalothrin	II
25	Kondem	Insecticide		
26	Kurasate	Herbicide	Glysophate	III
27	Lambda	Insecticide	Cyhalothrin	II
28	Limaneb	Fungicide	Maneb	II
29	Mancozeb	Fungicide	Maneb	II
30	Maneb	Fungicide	Maneb	II
31	Manzeb	Fungicide	Dithiocarbamate	O
32	Nnoboa	Herbicide	Glysophate	III
33	Nordox	Fungicide	Cuprous Oxide	II
34	Nwura Suro	Herbicide	Glysophate	III
35	Odeneho	Herbicide	Glysophate	III
36	Perfect 2.5EC	Insecticide	Cyhalothrin	II
37	Polythrine C	Insecticide	Cypermethrin	II
38	Power	Herbicide	Glysophate	III

39	Pronil plus	Herbicide	Propanil	II
40	Propacal Plus	Herbicide	Propanil	II
41	Rambo	Insecticide	Cyhalothrin	II
42	Rondo	Herbicide	Glysophate	III
43	Round Up	Herbicide	Glysophate	III
44	Sarosate	Herbicide	Isopropylamine salt	
45	Sharp	Herbicide	Isopropylamine salt	
46	Sidalsate	Herbicide	Glysophate	III
47	Sumitox	Insecticide	Fenvalerate	II
48	Sun-2-40-Amine	Herbicide	Dichlorophenoxy	II
49	Sunphosate	Herbicide	Glysophate	III
50	Sunpyrifos	Insecticide	Chlorpyrifos ethyl	II
51	Super Tiger	Insecticide	Cyhalothrin	II
52	Termex	Insecticide	Chlorpyrifos	II
53	Thiopsin	Fungicide	Methylthiopanate	III
54	Top Cop	Fungicide	Copper Sulphate	
55	Topsin	Fungicide	Methylthiopanate	III

Fungicide: Kills fungi including blight, mildew, moulds and rust

Herbicide: Kills weeds and other plants that grow where they are not wanted

Insecticide: Kills insects and other arthropods

II = Moderately hazardous; III = slightly hazardous; U = Unlikely to present acute hazard in normal use;

O = Obsolete as pesticide; not classified (WHO, 2009)

4.3 Demographic Characteristics of the Farmers

The demographic information of the 35 farmers interviewed at the two farming communities are presented as pie charts below. It was observed from the survey that the farmers were predominantly males (86%) as shown in Fig. 3. Of the 35 respondents, only five were females. More than half of those interviewed (54%) were found to be above 40 years of age with only 3% falling within the 20-25 age range (Fig. 4). The 26-30 and 31-35 age ranges accounted for 23% and 14% of the respondents respectively. The general age distribution reflected a trend of older people engaging in farming at the two sampling locations.

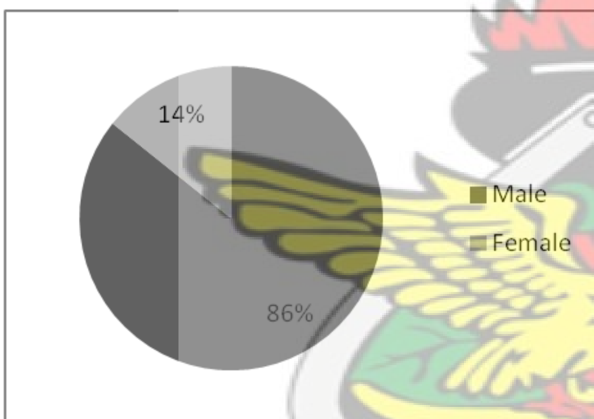

Fig 3. Gender distribution of the interviewed farmers at the two communities

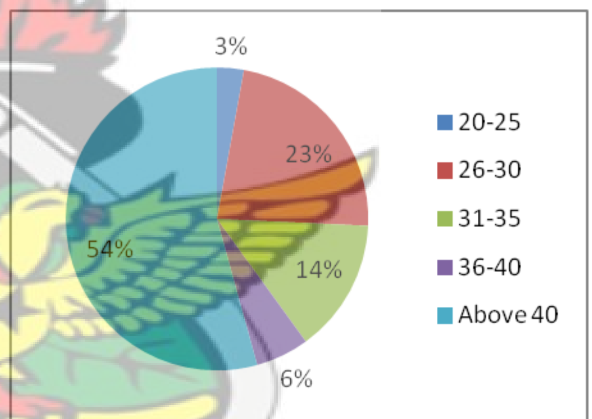

Fig. 4 Age distribution of the interviewed farmers at the two communities

4.4 Types of Pesticides and their Application

All respondents in the present survey sprayed their crops with various pesticides to control pests and diseases. The proportion by class of the pesticides used by farmers in the survey is shown in Fig. 5. The most widely applied pesticide groups on the farms were herbicides, which comprised 55%. Insecticides and fungicides formed 37% and 8%, respectively.

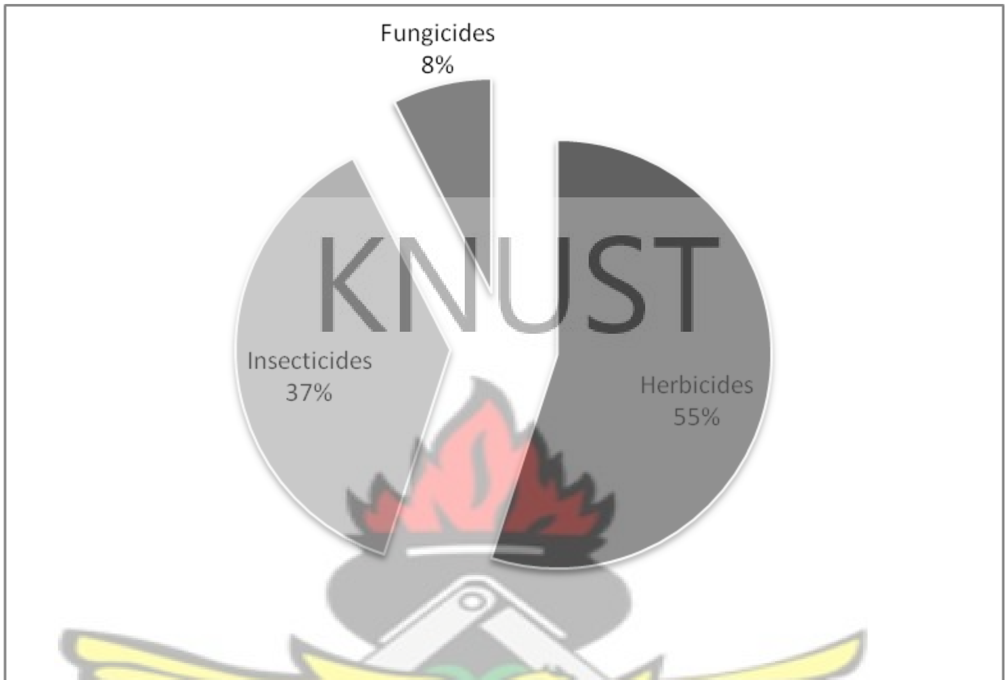

Fig. 5 Proportion by class of various pesticides used in vegetable production in the study area

The different pesticides identified as being in use on the farms are shown in Table 5. A total of 40 different pesticides were identified and these were among the 55 identified in the agrochemical shops in the area. Sunphosate was identified to be the commonest herbicide used in the area. The survey revealed that it was used on 13 out of the 35 farms. The next most common herbicide was "*Adwuma Wura*". It was found to be used in 11 out of the 35 farms visited.

Table 5 Types of pesticides applied in vegetable production at Dantano and Siana

1	Adwuma Wura	Herbicide	10
2	Agil	Herbicide	1
3	Agua	Herbicide	2
4	Akate Master	Insecticide	11
5	Akate Suro	Insecticide	1
6	Actala	Insecticide	3
7	Atrazine	Herbicide	3
8	Attack	Insecticide	5
9	Centidol	Herbicide	1
10	Champion	Insecticide	1
11	Confidor	Insecticide	6
12	Cyperthrin	Insecticide	1
13	Destroyer	Herbicide	2
14	Difin	Herbicide	2
15	D-Lion	Insecticide	2
16	Dursban	Herbicide	1
17	Enforce	Fungicide	1
18	Foko	Herbicide	1
19	Frankosate	Herbicide	1
20	Funguran	Fungicide	1
21	Glycel	Herbicide	5
22	Glyphosate	Herbicide	1
23	Gramoquick	Herbicide	9
24	Gramoxone	Insecticide	4
25	Harvest More	Insecticide	1
26	Kalach	Insecticide	2
27	Kondem	Insecticide	6
28	Lambda	Insecticide	8
29	Macho	Herbicide	1
30	Nnoboa	Herbicide	3
31	Ogyatanaa	Herbicide	1
32	Polythrine C	Insecticide	4
33	Power	Herbicide	2
34	Sunphosate	Herbicide	13
35	Round Up	Herbicide	3
36	Sidalco	Herbicide	1
37	Sulphosate	Herbicide	1
38	Sumitox	Fungicide	5
39	Sunpyrifos	Insecticide	7
40	Sylote	Herbicide	1

The most common insecticides used in the area were those used to control insect pests on cocoa farms. "*Akate Master*" was the most employed insecticide in the two farming communities.

Table 6 Pesticide use and management among the farmers of the study areas

Variable	Number	Percentage
Disposal of Used Pesticide Containers		
Left on Farm	21	60
Disposed off at the refuse dump	2	6
Buried in the Soil	6	17
Burnt on the Farm	4	11
Kept for Collection by Company	2	6
Total	35	100
Are Pesticides Harmful to the Environment?		
Yes	15	43
No	20	57
Do not know	0	0
Total	35	100
[b] **Do you wear full protective clothing during spraying**		
Yes	11	31
No	24	69
Total	35	100
N) Do you experience illnesses due to Exposure to pesticides		
Yes	21	69
No	14	31
Total	35	100
[c] **Pesticide poisoning cases among farmers**		
Dizziness, weakness	6	21
Headache	5	17
Rashes, skin irritation	12	40
Eye Irritation	2	7
Catarrh and sneezing	3	10
Others	2	7
Total	30	100

[b] *Full protection: Gloves, face mask, goggle, long boots, trousers, long-sleeved shirts*

[c] *Multiple responses: total responses per item over total responses*

Carrying Out Application Instructions		
Yes	15	43
No	20	57
Total	35	100
Training on Pesticide Application		
Yes	10	29
No	25	71
Total	35	100
Average Frequency of Pesticide		
Application in a production cycle		
1-3 Times	9	26
4-6 Times	11	31
7-9 Times	6	17
10 Times+	9	26
Total	35	100

From the survey, it was realized that the commonest way of disposal of the used pesticide containers was leaving them on the farms. About 60% of the respondents disposed their used pesticide containers in this way (Table 6). Six (or 17%) buried the used pesticide containers in the soil while about 11% burnt the containers.

About 43% of the farmers were aware of the potential harm pesticides pose to the environment. The respondents cited pollution of water bodies as the main harm that pesticides pose to the environment. About 69% of the farmers surveyed had become ill before due to pesticide exposure. The most frequent symptoms were reported as weakness, headache, dizziness, skin and eye irritation (Table 6).

It was also realized that farmers used very little personal protection during spraying. Some of the farmers (31%) did use some protective clothing. This included rubber boots, a overall with long sleeves, gloves and a piece of cloth to cover the mouth. The majority wore just trousers and a long-sleeved shirt. However, some wore a short-sleeved shirt and short trousers, with no gloves, and barefooted farmers (they wore slippers which exposed a greater part of their feet) even used their bare hands to mix pesticides in a container. These farmers who do not wear any protective clothing constituted about 69% of the respondents. As a consequence, their legs, feet and hands came into contact with pesticides.

Plate 10 A farmer with incomplete protective clothing applying pesticide to his crops

4.5 Physicochemical Parameters of the Tano River

Table 7 Mean and standard deviations of physicochemical parameter at Dantano

PARAMETER	S1	S2	S3	GWC STANDARD
pH	7.69	7.73	7.68	6.5-8.5
Temp (°C)	26.00±2.00	26.00±2.0	26.00±2.0	-
Salinity (PSU)	0.06±0.02	0.07±0.012	0.07±0.01	-
Cond (µS/cm)	0.14±0.03	0.15±0.03	0.15±0.06	250
TDS (gL^{-1})	0.07±0.02	0.07±0.01	0.07±0.01	1000
TSS (mgL^{-1})	28.33±6.81	32.00±11.14	37.00±17.00	-
Nitrate (mgL^{-1})	0.017±0.00	0.013±0.004	0.015±0.003	3.0
PO_4 (mgL^{-1})	0.39±0.24	0.34±0.19	0.47±0.09	3.0
Colour (CU)	237.33±90.	240.33±55.23	233.00±58.02	15
Turbidity (NTU)	25.33±8.08	23.00±7.55	22.33±11.59	5

Temperature recorded a mean of 26.00±2.00°C at all the sampling points.

The mean pH ranged from 7.68 at the downstream sampling point (S3) to 7.73 at the midstream station (S2).

Mean salinity values were 0.06±0.02, 0.07±0.012 and 0.072±0.01 PSU for the S1, S2 and S3 respectively.

Conductivity values did not vary much from one sampling station to the other and they were 0.14±0.03, 0.15±0.03 and 0.15±0.06 µS/cm at S1, S2 and S3 respectively

Whereas, mean TDS values were the same at all the sampling points at 0.07 g/L, TSS increased from 28.33 mg/L at upstream (S1) to 37 mg/L at the downstream (S3).

Nitrates showed mean concentrations of between 0.013 and 0.017 mg/L while phosphate ions ranged from 0.34 - 0.47 mg/L.

Mean colour values ranged from 237.33 to 240.33 CU while those of turbidity were 22.33-25.33 NTU.

Table 8 Mean and standard deviations of physico-chemical parameters of water samples at Siana over the sampling period.

PARAMETER	**S1**	**S2**	**S3**	GWC STANDARD
pH	7.72	7.78	7.72	6.5-8.5
Temp (°C)	24.67±2.08	26.00±1.73	25.67±2.32	-
Salinity (PSU)	0.07±0.02	0.07±0.02	0.07±0.02	-
Cond (µS/cm)	0.13±0.06	0.14±0.04	0.13±0.06	250
TDS (g/L)	0.07±0.02	0.07±0.02	0.09±0.03	1000
TSS (mg/L)	27.00±4.36	26.00±8.71	21.33±4.16	-
Nitrate (mg/L)	0.02±0.005	0.014±0.004	0.015±0.005	3.0
PO_4 (mg/L)	0.46±0.19	0.43±0.18	0.38±0.21	3.0
Colour (CU)	209.67±30.50	215.33±34.42	220.00±45.82	15
Turbidity (NTU)	21.67±6.81	25.67±15.31	25.33±11.37	5

The mean and standard deviations of the physicochemical parameters recorded at Siana showed trends that were similar to those at Dantano.

Temperature values recorded had mean values of 24.67°C, 26.00°C and 25.67°C at S1, S2 and S3, respectively. Mean pH values ranged from 7.72 to 7.78. Mean salinity value was 0.07 PSU at all sampling points. Whereas the mean conductivity was the same at S1 and S3, it was slightly higher at S2. It was 0.13 µS/cm at S1 and S3, and 0.14 µS/cm.

TDS values ranged from 0.07-0.09 g/L. The TSS decreased from 27 mg/L at the upstream (S1) to 21.33 mg/L at the downstream (S3).

Nitrates showed mean concentrations of between 0.02 and 0.015 mg/L while phosphate ions ranged from 0.38 - 0.46 mg/L.

Mean colour values ranged from 209.67 to 220 CU while those of turbidity were 21.67-25.67 NTU.

4.6 Pesticide Residue Concentrations in the Water of the Tano River

Table 9 presents the results of the pesticide residues and their mean concentrations found in the water samples at Dantano. In all, seven different classes were found. They included HCH isomers, aldrin, deldrin, endrin, chlordane isomers, DDT and its metabolites, and heptachlor isomers.

The HCH isomers detected were α-HCH, β-HCH, δ-HCH and γ-HCH (lindane). The α-HCH had a mean concentration that ranged from 0.024 (midstream) to 0.080 (downstream) µg/L at all the sampling points for the two months. The highest mean concentrations of the β-HCH for the two sampling months were 0.594 and 0.577 µg/L and both were recorded at the downstream. δ-HCH was undetectable at all sampling points except the downstream points where values of 0.160 and 0.639 µg/L were recorded for January and February, respectively. The γ-HCH (lindane) concentrations ranged from 0.101 (downstream) to 0.680 (upstream) µg/L. It was, however, undetected in the midstream point in January.

Table 9 Mean and standard deviations of pesticide residues concentration at Dantano

	January			**February**		
Pesticide Residue (µg/L)	**Downstream**	**Midstream**	**Upstream**	**Downstream**	**Midstream**	**Upstream**
α-HCH	0.080±0.002	0.031±0.001	0.034±0.001	0.053±0.002	0.024±0.001	0.057±0.001
β-HCH	0.594±0.009	0.224±0.009	ND	0.577±0.005	0.179±0.001	0.008±0.000
δ-HCH	0.160±0.010	ND	ND	0.639±0.004	ND	ND
γ-HCH	0.101±0.013	ND	0.680±0.014	0.392±0.011	0.016±0.002	0.332±0.015
Aldrin	0.474±0.009	0.134±0.100	0.068±0.000	0.315±0.008	0.217±0.004	0.071±0.000
Dieldrin	ND	0.025±0.003	ND	ND	0.033±0.001	0.169±0.002
Endrin	0.842±0.030	ND	0.023±0.002	0.675±0.011	ND	0.024±0.002
***cis*- Chlordane**	0.154±0.017	0.118±0.006	ND	0.133±0.011	ND	ND
***trans*- Chlordane**	0.253±0.004	0.308±0.018	0.021±0.0009	0.474±0.11	0.606±0.020	0.030±0.0031
***o,p'*-DDD**	ND	0.194±0.008	ND	ND	0.268±0.031	ND
***p,p'*-DDD**	ND	ND	ND	ND	ND	0.020±0.001
***o,p'*-DDE**	0.073±0.004	ND	ND	0.049±0.004	ND	0.462±0.000
***p,p'*-DDE**	0.075±0.003	ND	0.033±0.002	0.092±0.003	ND	0.040±0.003
***o,p'*-DDT**	0.272±0.028	0.059±0.009	0.081±0.0004	0.208±0.004	0.034±0.002	0.053±0.0025
***P,p'*-DDT**	0.449±0.034	0.274±0.027	0.084±0.001	0.477±0.016	0.298±0.096	0.081±0.003
Heptachlor	ND	0.232±0.003	0.609±0.015	ND	ND	0.0225±0.016
***cis*- Heptachlor epoxide**	0.020±0.027	0.658±0.000	ND	ND	ND	ND
***trans*- Heptachlor epoxide**	ND	ND	ND	0.006±0.001	0.002±0.000	0.001±0.000

Mean concentrations of aldrin, deldrin and endrin ranged from 0.068-0.474, 0.025-0.169 and 0.023-0.842 µg/L, respectively. Highest aldrin and endrin concentrations were detected downstream in both months.

The concentrations of the two isomers of Chlordane, *cis*- and *trans*-Chlordane were detected in the study. The *trans*-chlordane recorded the highest mean concentrations of 0.308±0.018 µg/L and 0.606±0.020 µg/L for the months of January and February, respectively. The *cis*-chlordane had the highest mean concentration of 0.154±0.017 µg/L and 0.133 ±0.011 µg/L for January and February respectively.

The DDT and its metabolites (namely *o,p'*-, *p,p'*-DDD, *o,p'*-, *p,p'*-DDE, and *o,p'*-, *p,p'*-DDT) were also detected. The *o,p'*-DDD isomer ranged from 0.194±0.008 µg/L at mid stream in January to 0.268 ±0.031 µg/L at downstream in February while *p,p'*-DDD recorded 0.020±0.001 µg/L mean concentration at upstream in February. The highest mean concentration for *o,p'*-DDE and *p,p'*-DDE were 0.462±0.000 µg/L at upstream in February and 0.092±0.003 µg/L at downstream also in February respectively. The isomers *o,p'*-DDT and *p,p'*-DDT also recorded the highest mean concentration of 0.272 ±0.028 µg/L at downstream in January and 0.477±0.016 µg/L at downstream in February

Heptachlor, *cis*-heptachlor and *trans*-heptachlor had the following highest mean values: 0.609±0.015 µg/L (upstream in January), 658±0.000 µg/L (midstream in January) and 0.006±0.000 µg/L (downstream in February) respectively.

Table 10 Mean and standard deviation of pesticide residues concentration at Siana

	January			February		
Pesticide Residue (µg/L)	**Downstream**	**Midstream**	**Upstream**	**Downstream**	**Midstream**	**Upstream**
α-HCH	0.045±0.000	0.040±0.001	0.045±0.001	0.054±0.000	0.043±0.000	0.046±0.002
β-HCH	ND	ND	ND	ND	ND	ND
δ-HCH	0.228±0.006	0.870±0.002	0.958±0.077	0.303±0.010	0.944±0.011	0.906±0.007
γ-HCH	0.227±0.005	0.517±0.006	0.456±0.007	0.108±0.008	0.538±0.005	0.601±0.006
Aldrin	0.067±0.006	0.049±0.002	0.081±0.000	0.072±0.001	0.050±0.006	0.070±0.000
Dieldrin	0.147±0.006	ND	ND	ND	ND	ND
Endrin	0.144±0.004	0.082±0.011	0.052±0.002	0.086±0.100	0.053±0.005	0.039±0.007
***cis*- Chlordane**	ND	ND	ND	ND	ND	ND
***trans*- Chlordane**	0.144±0.001	ND	ND	0.153±0.002	ND	0.309±0.017
***o,p'*-DDD**	0.015±0.002	ND	ND	0.019±0.000	ND	ND
***p,p'*-DDD**	ND	0.008±0.001	0.228±0.004	0.028±0.001	0.005±0.001	0.253±0.010
***o,p'*-DDE**	ND	ND	ND	ND	0.449±0.020	ND
***p,p'*-DDE**	0.071±0.002	ND	0.085±0.009	0.071±0.002	ND	0.062±0.001
***o,p'*-DDT**	0.068±0.013	0.027±0.009	0.171±0.0053	0.043±0.001	0.030±0.005	0.157±0.006
***P,p'*-DDT**	0.196±0.022	ND	ND	0.160±0.001	ND	0.017±0.003
Heptachlor	0.431±0.014	1.667±0.018	0.814±0.009	1.931±0.013	0.692±0.013	1.539±0.022
***cis*- Heptachlor epoxide**	ND	ND	ND	ND	ND	ND
***trans*- Heptachlor epoxide**	ND	ND	ND	0.002±0.000	0.001±0.001	ND

Seven different classes of pesticide residues were detected in the water samples collected in the Siana community (Table 10). The pesticides detected in the water samples are the same as those found at Dantano.

All the HCH isomers were detected at all the sampling stations for the two months except the β-HCH, which was undetectable at all the points. The mean concentrations ranged from 0.040-0.054 µg/L, 0.228-0.958 µg/L and 0.108-0.601 µg/L, respectively for α-HCH, δ-HCH and γ-HCH.

The mean values for aldrin and endrin for the two months were 0.049-0.072 and 0.039-0.144 µg/L, respectively, while dieldrin was not detected in the samples except in January where it was detected at the downstream.

The *cis*-chlordane was not detected in all the samples in both months while the *trans*-chlordane was detected at downstream in January and also at downstream and upstream in February.

The highest mean concentrations of DDT and its metabolites are as follows: *o,p'*-DDD (0.019±0.000 µg/L), *p,p'*-DDD (0.253±0.010 µg/L), *o,p'*-DDE (0.449±0.020 µg/L), *p,p'*-DDE (0.085±0.009 µg/L), *o,p'*-DDT (0.171±0.0053 µg/L) and *p,p'*-DDT (0.196±0.022 µg/L). The mean concentration of Heptachlor ranged from 0.431±0.014 µg/L to 1.931±0.013 µg/L while the highest value for *trans*-heptachlor was 0.002 µg/L.

CHAPTER FIVE

DISCUSSION

5.1 Types of Pesticides Used by Farmers in the study Area

A total of 40 different types of pesticides were identified on the 35 farms visited in the two communities understudied and these pesticides were available in the 11 local agrochemical shops visited. The major categories were dominated by herbicides (55%), followed by insecticides (37%) and fungicides (8%) (Fig. 5). This is similar to that of earlier study by Ntow *et al*. (2006) that gave the proportion of pesticides used popularly on vegetable farms as herbicides (44%), insecticides (33%) and fungicides (23%). Sunphosate, Gramoquick and "*Adwuma Wura*" were the mostly used brands of herbicides. These brands were mostly purchased by farmers because of their perceived ability to effectively control weeds and the longer time it takes for the weeds to grow again. Twelve (12) or 52% identified herbicides were found to have Glysophate as their active ingredients. Glyphosate is a broad-spectrum systemic herbicide, patented and sold under the trade name *Roundup*. According to the Ghana EPA (2003), there was an increasing trend in herbicide importation relative to the other pesticides up to 2006. This trend is a possible indication that the vegetable farmers at Dantano and Siana perceived that herbicides use is able to suppress weeds for a longer time and over a wider area than manual or mechanical weeding and also significantly reduced weeding time and labour costs. As a result, the farmers at the two locations probably shifted to the use of herbicides even if they can weed manually.

All the insecticides identified in the agrochemical shops had active ingredients that fell under Hazard Category II, which WHO (2009) classifies as moderately hazardous. The survey revealed that "*Akate Master*" and "*Akate Suro*" brands of insecticides were among the highest purchased. It was observed that insecticides such as "*Akate master", "Akate Suro"* and Funguran were used to control pests on vegetables although they were meant for cocoa production. This trend confirms earlier work by Ntow (2001) that many of the agrochemicals meant for crops such as cocoa and coffee were misapplied for tomato cultivation.

The overall number of pesticides identified at Siana and Dantano are possible indications that pests and diseases pose big problems in vegetable production in Ghana and most farmers resort to using pesticides to control diseases and pest on their farms. Vegetables tend to be more susceptible to biotic constraints than are other crops (Gerken *et al*., 2001). According to Gerken *et al*., (2001), pesticide use has increased over time in Ghana and is particularly used in the production of high-value cash crops and vegetables. Recent trends as reported by Fianko *et al*., (2011) indicate the importation of higher volumes of pesticides in recent years. With the trend towards increasing use of pesticides, observations of some of the practices revealed that some of the farmers at Siana and Dantano often mixed two or more pesticides together and apply it to crops. According to Obeng-Ofori *et al*., (2002), chemical pesticides are used improperly or in dangerous combinations by farmers in Ghana. According to Dinham (2003), an estimated 87% of farmers in Ghana use chemical pesticides to control pests and diseases on vegetables and the abuse of pesticides by some farmers have implications for the environment, especially the aquatic environment. This unsafe practice and the failure of some farmers to apply the right dosages of pesticides can be implicated in the concentrations of certain pesticide residues exceeding Guideline Values at certain portions of the Tano River.

Gerken *et al*., (2001) revealed that farmers in Ghana often spray pesticides on prophylactic basis due to lack of information. Handling of pesticides often does not take into consideration safety standards as was realized from this study. From the study, 57% did not carry out pesticide application instructions while 71% have never had any training on pesticide application (Table 6). It is thus very possible that most of the farmers in the two farming locations do not know the right application procedures and dosages of most of the pesticides they applied on their farms. Disposal of unwanted pesticide solutions was done indiscriminately, and empty containers were left in the field. These present potential pollution problems for aquatic systems, which are sources of livelihood for human communities and support varied animal and plant life. Non-target flora and fauna may concentrate these chemicals in their tissues and pass them along the food chain. The accumulation of such pollutants in the food chain may restrict the consumption of valuable food resources such as fish. Although this study did not actually collate such information, it was observed that the commonest place of disposing of the used pesticide containers was on the vegetable farms.

5.2 Pesticide Residues in Water Samples at Dantano and Siana

Although most of the analyzed pesticide residues were found to be below the WHO (2011) Guideline Values for Drinking Water, the highly measurable concentrations may be an indication of non-point pollution resulting from run-off from the surrounding vegetable farms. Non-point source agricultural pollution is regarded as the greatest threat to the quality of surface waters in rural areas. One of the most important routes leading to non-point source agricultural pollution of surface waters in rural areas is runoff (Neumann and Dudgeon, 2002). The impacts of such runoff are well documented (Cooper, 1993; Castillo *et al*., 1997; DeLorenzo *et al*., 2001).

5.2.1. *Hexachlorocyclohexane (HCH)*

Four of the five stable HCH isomers namely, α-HCH, β-HCH, γ-HCH and δ-HCH were detected in the water samples at both Dantano and Siana over the sampling period except β-HCH which was not detected at all at Siana sampling points for the two month period (Table 10). Although no particular trends were observed, the upstream (S1) and downstream (S3) portions of the river in the two locations generally recorded higher values for the HCH isomers. These could be attributed to the intense use of insecticides containing α-HCH, β-HCH, γ-HCH and δ-HCH in the area. According to MOFA (1998), γ-HCH (Lindane) was widely used in Ghana on cocoa plantations, vegetable farms, and for the control of stem borers in maize (MOFA, 1998).

Although the average levels of these residues were below the WHO guideline limit of 2 μg/L for drinking water, the highly measurable levels pose a threat to life since these chemicals are capable of bioaccumulation. The degradates from bioaccumulation can enter the food chain resulting in serious health effects. The presence of pesticide residues in the environment is detrimental to human health and water quality (Fianko *et al*., 2007).

The highly measurable concentrations of these pesticide residues in the water samples could also have resulted from the fact that the farmers at Siana and Dantano may have applied overdose of these pesticides on their farms to control pests which might have resulted in the presence of these pesticide residues in the Tano river. The farmers indicated in the survey that they applied the chemicals between 1 and 10 times per growing season. According to Ntow (2008), Ghanaian vegetable farmers often spray hazardous insecticides like organophosphates and organochlorines up to five or more times in a cropping season when perhaps two or three applications may be sufficient. According to Gerken *et al*., (2001), pesticide use has increased over time in Ghana and is particularly elevated in the production of high-value cash crops and vegetables.

5.2.2. *Aldrin, Dieldrin and Endrin*

Aldrin concentrations measured at the three sampling locations at Dantano varied over a wide range with the downstream portion recording the highest mean concentration of 0.474 µg/L during the January sampling period (Table 9). Highest aldrin concentration in February was 0.315 µg/L. The aldrin concentrations were all consistently higher than the WHO guideline value of 0.03 µg/L at the Dantano portion of the river over the sampling period (Table 9). The Siana portion also recorded aldrin concentrations higher than the WHO guideline value (Table 10). There were significant differences ($p<0.05$) in aldrin concentrations measured at the three sampling stations at Dantano, but no significant differences ($p>0.05$) existed among the aldrin concentrations at Siana.

Dieldrin was not detected at the downstream and upstream during January at Dantano. The value detected in midstream in January was slightly lower than the WHO guideline value. However, the values detected for midstream and upstream for February are higher than WHO guideline value of 0.03 µg/L for drinking water (Table 9).This might be explained by the fact that the crops were in their reproductive phase and attracted more pests necessitating pesticide use at this point.

The mean concentration of endrin was higher at the downstream than the WHO guideline value but was not detected at midstream and was slightly lower than the guideline value at upstream for the two months period. This observation may be explained by the fact farmers perceive certain chemicals as very effective, hence over reliance on it. According to Dinham (2003), an estimated 87% of farmers in Ghana use chemical pesticides to control pests and diseases on vegetables and the abuse of pesticides by some farmers have implications for the environment, especially the aquatic environment.

At Siana,the mean concentration of endrin was higher than the WHO guideline value of 0.03 µg/L (Table 10) for both January and February. The relatively high mean values recorded at Siana were possibly due to excessive runoff from the vegetable fields. Pesticides may be carried to water by eroding soil (Papendick *et al*., 1986). It may also be carried to water as runoff or spilled accidentally or through neglect (State of Jersey, 2007).

The mean values for both compounds were generally higher at Dantano than at Siana, even though no observable trends were found between upstream and downstream sampling points. Overall, there were significant differences ($p<0.05$) in dieldrin concentrations in the water samples of the two sampling locations.

Endrin concentrations showed significant differences ($p<0.05$) at the different sampling points at Dantano, but showed no significant differences ($p>0.05$) at Siana.

The three substances, aldrin, endrin and dieldrin are supposed to be banned in Ghana, and so its presence in the water samples means these chemicals are still being sold used in the country. This proves that banned and restricted agrochemicals are still being imported into the country. According to Ntow *et al*. (2006), most of the agrochemicals used by the farmers include banned and restricted products such as aldrin, dieldrin, chlordane and dichlorodiphenyltrichloroethane.

5.2.3 *DDD, DDE and DDT*

The two forms or isomers of DDT, DDE, and DDD (namely *o,p'*-, *p,p'*-DDD*, o,p'*-*, p,p'*-DDE, and *o,p'*-, *p,p'*-DDT) were detected, even though they were all the WHO guideline values of 2 µg/L. The *o,p'*-DDD forms of isomer were relatively absent and variable in most of the sampling locations of both the Dantano and Siana portions of the river (Tabe 9 and 10). The *o,p'*-DDD was not detected at the downstream and upstream during the two months of sampling at Dantano (Table 9) but was present at the midstream. At Siana, the *o,p'*-DDD was detected at downstream during January and February but was not detected at upstream and midstream (Table 10).

At Dantano, *p,p'*-DDD was not detected in all the sampling points except the upstream in February which was lower than the guideline value (Table 9). With the exception of the upstream, *p,p'*-DDD was detected at all the sampling points for both January and February at Siana (Table 10).

The downstream portion of Dantano recorded the highest mean concentrations of 0.272 µg/L and 0.208 µg/L of *o,p'*-DDT for the January and February, respectively. The *p,p'*-DDT recorded concentrations of 0.449 µg/L and 0.447 µg/L for January and February at the downstream.

In Siana, the highest mean *o,p'*-DDT concentrations of 0.171 μgL^{-1} and 0.157 µg/L were recorded at the upstream sampling station for January and February, respectively. Although, there was relatively lower *p,p'*-DDT concentration, the downstream recorded a measurable concentration of 0.196 µg/L in the month of January and 0.160 µg/L in February (Table 10).

The residue concentrations found were all below the WHO guideline values, yet their presence could be as a result of current application of the pesticide DDT by the farmers in the two communities and not from historical sources. Although, the use of DDT has been banned, the same cannot be said about a developing country like Ghana where there are a lot of unregistered chemical dealers and low monitoring. Ennacer *et al.* (2008) reported that despite the ban on the production and use of OCPs in accordance with Stockholm convention in (2001) and replacement with less persistent organophosphates and carbamates, some developing countries have resumed the use of OCPs such as DDT.

5.2.4. *Chlordane* and *Heptachlor*

The mean *trans*- chlordane concentrations at Dantano were generally higher than the WHO guideline values for drinking water of 0.2 µg/L at all the sampling stations except for that at upstream for both months (Table 9). This might be due to the effects of agriculture via pesticide use in the area. The mean concentrations of *trans*-chlordane recorded for Siana were mostly below the WHO guideline value of 0.2 µg/L for drinking water except for the upstream in February (Table 10). The mean concentrations of cis-chlordane were below the guideline values during the sampling period at Dantano but undetected in both January and February at Siana

Heptachlor concentrations were relatively very high at the two sampling locations. The midstream and downstream portions of the Dantano portion of the river, respectively recorded mean concentrations higher than the WHO guideline Value of 0.03µg/L. All the three sampling stations of the Siana portion recorded mean Heptachlor concentrations several folds higher than the WHO guideline value of 0.03µg/L (Table 10). The three sampling stations recorded values approximately 40-folds higher than the WHO guideline value indicating the adverse effect of pesticide applications to the farms located in the watershed of the river. Cis-Heptachlor epoxide concentrations were found to be higher than the WHO guideline value of 0.03µg/L at the midstream portion of the Dantano portion of the river (Table 9).

Heptachlor and its isomers in the water could well be due the fact that they do not dissolve easily in water. Heptachlor epoxide, however, dissolves more easily in water than heptachlor does and evaporates slowly from water. Like heptachlor, heptachlor epoxide sticks to soil (Lu & Wang, 2002) and may be released back into the water column possibly explaining the higher Heptachlor concentrations at some of the sampling stations. Although the concentrations of Heptachlor and Heptachlor epoxide in the Tano river were just a few folds higher than the WHO (2011) guideline values, bioconcentration of heptachlor may be significant in the water and biota in future. The present concentrations of these pesticide residues could well pose a threat to the humans who depend on the river as a source of drinking water and fish.

The intensive use of pesticides on the vegetable farm areas of Siana and Dantano poses a threat to the environment, especially the aquatic environment. According to Asante and Ntow (2009), pesticide usage in Ghana continues to increase as agricultural production intensifies. They, however, stated that associated with the increased use of pesticides are environmental and health problems which have arisen due to indiscriminate use and inappropriate handling of the chemicals.

5.3 Physico-chemical Parameters of Water Samples At Dantano and Siana

The physico-chemical parameters of the water samples from the Tano river at the two communities of Dantano and Siana were fairly similar during the study period. The pH of the river ranged 7.73 to 7.68 at Dantano(Table 7) whiles it ranged between 7.72 and 7.78 for Siana station (Table 8). The river was neutral to slightly alkaline and the values recorded were within the Ghana Water Company standard of 6.5-8.5 for drinking water. According to Chapman, (1996) the EU has set protection limits of pH from 6 to 9 for fisheries and aquatic life .The pH obtained in the river waters was within these ranges and as a result does not constitute problem for domestic, recreational and aquatic systems.

The same temperature (26˚C) was recorded for the three sampling points at Dantano (Table 7) whiles that of Siana portion did not vary much, recording values 24.67°C, 26.00°C and 25.67°C, respectively, for S1, S2 and S3 (Table 8). There were no significant differences ($p>0.05$) between the temperature values recorded for the two study sites over the sampling period.

Salinity values recorded for the two communities were very similar (0.06-0.07) and revealed very little anthropogenic influence. All the sampling points of the Siana portions recorded a mean value of 0.07±0.02 PSU with slight variations of the Dantano portion recording 0.06, 0.07 and 0.07 PSU for S1, S2 and S3 respectively (Table 7). Statistically, no significant differences ($p>0.05$) existed among the salinity values for the different sampling points for the two sites over the sampling period.

The mean conductivity values at the two sites showed trends that were similar to most of the parameters. The values recorded were similar for the two farming communities (Table 7 and Table 8). All the conductivity values were less than that of the Ghana Water Company Standard of 250 µS/cm for drinking water.

Total dissolved solids (TDS) values for the samples at Siana were highly variable with the upstream, midstream and downstream portions recording mean values of 0.07, 0.07 and 0.09 g/L, respectively (Table 8) and that of the Dantano portions recorded the same value of 0.07 g/L (Table 7) and they were all below Ghana Water Company guideline of 1000 g/L. The TDS recorded at the two locations did not vary significantly ($p>0.05$) over the sampling period. The palatability of water with TDS less than 600 mg/L is considered to be good whereas water with TDS greater than 1200 mg/L becomes increasingly unpalatable (McCtheon et al., 1983)

The TSS trend for the Dantano portion was as follows; S3>S2>S1 with corresponding concentrations of 37.0 mg/L, 32.0 mg/L and 28.33 mg/L (Table 7). The trend at the three sampling stations of the Siana portion over the sampling period was S1>S2>S3 (Table 8).

The highest mean concentrations of nitrate recorded during the study period for Dantano and Siana were 0.17 mg/L at S1 and 0.15 mg/L at S3 (table 7) while that of phosphate for the same period was 0.47 mg/L at S3 and 0.46 mg/L at S1 for both Dantano and Siana (Table 7). These values were less than that of the Ghana Water Company standard of 3.0 mg/L for both nutrients. The presence of these ions could be due to anthropogenic sources such as agricultural runoffs from the fields. One of the most important routes leading to non-point source agricultural pollution of surface waters in rural areas is runoff (Neumann and Dudgeon, 2002). Although, the mean values recorded were well within the limits of 3.0 mg/L set by Ghana Water Company for drinking water, accumulation of these nutrients over a long period could cause eutrophication of the river.

The mean values for colour and turbidity recorded at both sampling locations over the period were above the permissible levels of 15 CU and 5 NTU set by Ghana Water Company, respectively. The turbid nature of the river at the various sampling points could be attributed to decay of leaf litter and vegetation, erosion and runoff from intense pumping of irrigation water on the field. This possibly impacted on the colour which also recorded higher mean values at all the sampling points.

Generally, the physico-chemical characteristics of the river in the areas studied indicated that anthropogenic activities have had very little negative influence on the water quality as far as the physico-chemical parameters are concerned.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

A total of 40 different types of pesticides were identified on the 35 farms visited in the two communities, and these pesticides were available in the 11 local agrochemical shops visited. This figure was, however, lower than the actual number of pesticides found in the agrochemical shops in the area. The pesticides comprised herbicides (55%), insecticides (37%) and fungicides (8%). Among the most patronized herbicide brands included Sunphosate, Gramoquick and "*Adwuma Wura*". The herbicides and fungicides used were mostly under WHO Hazard Category III (slightly hazardous), with a few under Hazard Category II (moderately hazardous).

The commonest way of disposal of the used pesticide containers was leaving them on the farm. The survey revealed that 60% of the respondents disposed their used pesticide bottles in this way. Where farms are close to waterways (which was the case in many farms visited), the disposal of unwanted pesticide solutions and empty containers in the field presents a potential pollution problem for aquatic systems.

The physico-chemical parameters of the water samples from the Tano River at the two sampling locations were fairly similar and were within the WHO guidelines for drinking water over the sampling period. However, the mean values of colour and turbidity were above the permissible limits.

Pesticide residues found in water samples in the two communities included isomers of HCH, aldrin, dieldrin, endrin, heptachlor and *cis*-heptachlor epoxide, chlordane (*cis* and *trans*), and DDT and its metabolites. Most of the studied pesticide residues were detected in measurable concentrations, although, they were generally below their respective WHO Guideline Values for drinking water. Aldrin, Dieldrin, Endrin and Heptachlor were, however, found to be above their respective WHO Guideline Values during the sampling period. High mean concentrations were recorded for aldrin and heptachlor, respectively, in the water samples.

The results of the study revealed that vegetable farms runoff had a relative effect on current- pesticides content of two sampling locations of the Tano River. This effect was evident from a comparison of upstream and downstream sites in the River. Runoff from the vegetable farms appears to have impacted the downstream sites possibly as a result of accumulation of these contaminants. Both sampling locations showed a relative downstream increase in concentration of pesticides after the runoff event. Vegetable fields dominated all of the downstream subcatchments of the two sampling location. Point-source discharge of pesticides was unlikely to have been a confounding factor as this was not evident within the study reaches.

6.2 Recommendations

The results of this research can serve as baseline data for further research on the Tano River as well as other freshwater bodies in Ghana. Further studies could also be carried out at the same study area to include other pesticide residues that were not covered in this research especially organophosphates and must cover a much longer period.

Measures should be put in place by the Ghana Environmental Protection Agency (EPA) and other stakeholders to ensure that farming activities are done at the right distances from rivers to prevent the run-off of excess pesticides into them.

Education on good environmental practices should also be intensified especially in the communities along the Tano River and there should be stricter enforcement of environmental laws by the District Assembly, the Environmental Protection Agency (EPA) and other concerned stakeholders.

There is the need to also establish national pesticide residues motoring programme for river and stream catchment areas due to intensification of pesticide use.

There should also be education of farmers through extension services on the right kinds of pesticides and the right amounts and frequency of administration of pesticides in a farming season to reduce the amounts of excess pesticides in the environments. This can be done by improving farmer field schools at the Ministry of Food and Agriculture

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APPENDICES

Questionnaire for the Determination of Commonly Used Pesticides by Farmers in Asunafo South Districts of the Brong Ahafo Region of Ghana and their Possible Effects on the Tano River

For Farmers

Please tick in the appropriate box or answer in the spaces provided

Part 1: Demographic Information

1. Sex of respondent Male [ ] Female [ ]

2. Age of respondent 20-25 [ ] 26-30 [ ] 31-35 [ ] 36-40 Above 40 [ ]

3. Marital status Single [ ] Married [ ] Divorced [ ] Separated[ ] Widowed [ ]

4. Highest level of education None [ ] Primary [ ] Secondary [ ] Tertiary [ ]

5. Occupation (s) (All that apply) Farmer [ ] Others (Please specify)
   ………………………………………………………………………………………………………
   ………………………………………………………………………………………

Part 2: Farm Information

6. What is the size of your farm? ....

7. What kinds of crops do you grow?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

….

8. How long have you been in crop production?

   0-5 years [ ]   6-10 years [ ]   11-15 years [ ]   Over 15 years [ ]

9. What is the source of your labour?   Self [ ]   Family [ ]   Hired [ ] Other [] (Please specify)…………………………………………………………….

10. Do you use pesticides on your farm? Yes [ ]   No [ ]

Part 3 Pesticide Acquisition, Application and Pest Control

11. What chemical pesticide(s) do you apply to control the insect pests?

Brand name/local name	**Purpose**	**Active ingredient(s)/ chemical**	**Broad spectrum/pest-specific**

12. How many years have you been using pesticides?..

13. Where do you buy these pesticides?

    Agricultural supplier [ ]   Local shop [ ]   Open market [ ]   Other [ ] (*Please specify*)

    ………………………………………………………………………………………………

    ………………………………………………………………………………………………

    ……

14. What do you consider before buying a pesticide? Price [ ]   Availability [ ]   Toxicity [ ]

    Recommended by someone [ ]

15. How often do you apply the same pesticide during a production cycle?

    ………………………………………………………………………………………………

    …

16. What type of pesticide formulation do you use?

    Liquid spray [ ]   Dust or powder [ ]   Other [ ]   (*Please specify*)

    ………………………………………………………………………………………………

    …

17. How do you apply the pesticides?

    From the bottle [ ]   Knapsack sprayer [ ]   Other [ ] (*Please specify*)

……………………………………………………………………………………………………

……………………………………………………………………………………………………

…………………………………………………………………………………………………..

18. Does the pesticide(s) solve your pest problem? Yes [ ] No [ ]

19. If NO, what do you think accounts for this?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

………

20. If YES, how effective is/are the pesticide(s) against the target organism?

Very effective [ ] Effective [ ] Moderately effective [ ]

21. Does the amount of pesticide used on your farm increase or decrease each year?

Yes [ ] No [ ] It varies [ ] Cannot tell [ ]

22. Do you usually read the labels on the pesticide containers? Yes [ ] No [ ]

23. Do you carry out the instructions for use? Yes [ ] No [ ]

24. Did you receive any training on pesticide application? Yes [ ] No [ ]

25. If YES, from who/where …………………………………………………………………….

26. How do you dispose of the pesticide container after use?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…….

27. What do you do with leftover pesticides

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

………

28. Do you think pesticides are harmful to the environment? Yes [ ] No [ ]

29. If YES, in what way?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………

Part 4 Additional Information

30. Do you wear protective clothing when applying pesticides?

Yes [ ] No [ ]

31. If NO, please pick one:

Too expensive [ ]

Not available [ ]

Uncomfortable [ ]

Other (Please specify)

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……

32. If YES, check one or more of the following:

Gloves [ ]

Overall [ ]

Goggles [ ]

Respirator [ ]

Face mask [ ]

Boots/shoes [ ]

Long-sleeved shirt [ ]

Trousers [ ]

Other (Please specify)

…………………………………………………………………………………………………

…………………………………………………………………………………………………

……

33. Have you or anyone experienced any illnesses due to exposure to pesticides?

Yes [ ]   No [ ]

34. If YES, what were the symptoms?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

………

Thank You

Questionnaire for the Determination of Commonly Used Pesticides by Farmers in Asunafo South Districts of the Brong Ahafo Region of Ghana and their Possible Effects on the Tano River

For Agrochemical Shop Owners

Please tick in the appropriate box or answer in the spaces provided

1. Sex of respondent Male [ ] Female [ ]
2. Age of respondent 20-25 [ ] 26-30 [ ] 31-35 [ ] 36-40 Above 40 [ ]
3. Marital status Single [ ] Married [ ] Divorced [ ] Separated[ ] Widowed [ ]
4. Highest level of education None [ ] Primary [ ] Secondary [ ] Tertiary [ ]

5. How long have you operated this agrochemical shop?

…………………………………………………………………………………………………

…………………………….

6. What brands of pesticides do you have in your shop?

Brand	**Active Ingredient(s)**	**Broad Spectrum/Pest Specific**	**Retail Price**

7. Which of the pesticides are mostly purchased by farmers?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…

8. Do you know the reason (s) why they mostly purchase these chemicals?

   Yes [ ]   No [ ]

9. If YES, can you state the reason (s)

   …………………………………………………………………………………………………

   …………………………………………………………………………………………………

   …………………………………………………………………………………………………

   …………………………………………………………………………………………………

   …

10. Are there other people aside the farmers who buy pesticides from your shop?

    Yes [ ]   No [ ]

11. If YES, can you name some of these people?

    …………………………………………………………………………………………………

    …………………………………………………………………………………………………

    …………………………………………………………………………………………………

    …………………………………………………………………………………………………

    …

12. Do you know about the right application of each pesticide? Yes [ ]   No [ ]

13. If YES, do you transfer this knowledge to the pesticide buyers? Yes [ ]   No [ ]

14. Do you think these pesticides are harmful to the environment? Yes [ ]   No [ ]   Don't know [ ]

15. If YES, in what way?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

…………………………………………

16. Do you know any pesticides which are banned by the government? Yes [ ] No [ ]

17. If YES can you name some of them?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

………

…………………………………………

18. Do you have some of these pesticides in your shop? Yes [ ] No [ ]

19. If YES, why do you still sell these banned pesticides?

………

………

………

………

…………………………………………………………………………….

20. Is your shop registered the Environmental Protection Agency (EPA,Ghana)?Yes ( ) NO ( )

Thank You