PESTICIDES: OCCUPATIONAL EXPOSURE AND POTENTIAL IMPACTS ON ECOSYSTEM AND HUMAN HEALTH IN MERU COUNTY, KENYA.

GABRIEL MUTHEE MARETE

B.Sc. (UoN); Mphil (Assiniboine, Canada); M.Sc. (KEMU)

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DECLARATION

This thesis is my original work and has not been submitted in any other institution for a degree award or other qualifications.

Gabriel Muthee Marete

REG. NO. SSEY 06722P/2012

Signature: ________________________________ Date: ________________________________

This thesis has been submitted for examination with our approval as university supervisors.

Signature: __________________________ Date: _______________________________

PROF. JOSEPH O. LALAH
THE TECHNICAL UNIVERSITY OF KENYA

Signature: ____________________________ Date: _________________________________

DR. JANE MPUTHIA

THE TECHNICAL UNIVERSITY OF KENYA

Signature: ___________________________ Date: _________________________________

DR. VITALIS W. WEKESA

THE TECHNICAL UNIVERSITY OF KENYA

DEDICATION

This thesis is dedicated to God Almighty who is the Author and finisher of our faith, my understanding and caring wife Grace, my parents the late Mr. and Mrs. Muriithi, my Brother, Sisters and Sons Mutethia and late Kimathi.

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I am indebted to the ALMIGHTY GOD who gave me the strength and wisdom to complete this work through His Son Jesus Christ, my Lord and Savior. O Eternal One, teach me how to worship, to serve and to reflect on You.

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LIST OF ABBREVIATIONS

ADI	Acceptable Daily Intake
BDL	Below Detection Limit
DDT	Dichloro diphenyl-trichloro ethane
EPA	Environmental Protection Agency
EPZ	Export Processing Zone
FAO	Food Agricultural Organization
GC	Gas Chromatography
GC-MS	Gas Chromatography Mass Spectrometry
GPS	Global Positioning System
GDP	Gross Domestic Product
HCH	Hexachlorocyclohexane
HPLC	High Performance Liquid Chromatography
KALRO	Kenya Agricultural and Livestock Research Organization
MRL	Maximum Residue Levels
OC	Organochlorine
OECD	Organisation for Economic Co-operation and Development

OP	Organophosphate
OPPs	Organophosphate pesticides
POPs	Persistent Organic Pollutants
PCPB	Pest Control and Products Board
RSD	Relative Standard Deviation
SPSS	Statistical Programme for Social Scientists
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
UNEP	United Nations Environmental Programme
USEPA	United States Environmental Protection Agency
WHO	World Health Organization

DEFINITION OF TERMS

Ecosystems A community of living organisms in conjunction of the non living components of their environment, interacting as a system (Wildlife Conservation Society, 2018).

Pesticides A chemical or substance used to kill harmful insects, small animals, wild plants and their unwanted organisms (Maroni, 2006).

Occupational Pesticides Exposure

It’s any exposure to pesticides during manufacturing, transport, storage, preparations and spreading by the user but also during re-entry to the treated fields, harvest and equipment cleaning (Maroni, 2006)

Human Health A state of complete physical, mental and social well being and not merely absence of disease or infirmity (Ebi, 2005)

ABSTRACT

This study assessed the usage of pesticides and its impacts on ecosystems and human health through occupational exposure in selected farming communities in Imenti North, Imenti South and Buuri Sub-counties in Meru, Kenya, where horticultural crops including French beans, kales and tomatoes are grown intensively for export and local consumption. The study was done through use of questionnaire distributed to farmers, agricultural extension and health care workers in selected farms in the three Sub-counties. In addition, analysis of pesticide residues by GC-MS in samples of farm soil, French beans, kales and tomatoes, from randomly selected sites in the three Sub-counties was done.

The survey established that various pesticides in the classes of organochlorines, organophosphates, carbamates, pyrethroids and fungicides, were used in the three Sub-counties, with the most frequently used ones (>60 respondents out of 173) being parathion, diazinon, permethrin, pirimiphos methyl, carbaryl, deltamethrin, dieldrin, methoxychlor, cypermethrin, propoxur and carbofuran. Some of these including dieldrin, parathion and carbofuran were used illegally because they have been banned. Although most farmers had general information on pesticide usage through various social groups and contact with agricultural extension workers, only 32–43 % of the farmers had received training on pesticide handling and use. Most farmers (65%) had knowledge of safe pesticide handling procedures including reading labels on packages and wearing protective clothing; but many farmers (44% in Buuri, 57% in Imenti South and 60% in Imenti North) did not wear the requisite protective clothing when applying pesticides. Agricultural extension workers (52%) and health care workers (59%) were trained in their work and had at least a certificate level qualification from a tertiary institution. Most agricultural extension workers (95%) and health care workers (71%) had experience of dealing with pesticides and knew how to administer 1st AID against pesticide poisoning, respectively. Farmers (26%) reported experiencing health effects after using pesticides, with most effects being felt after using dimethoate, malathion, carbofuran, carbaryl and heptachlor. There was a statistically significant ($p < 0.05$) association between various factors (availability of protective clothing, hiring of labourers, farm land size, expenditure on pesticides and expenditure on treatment, respectively) on intoxication from pesticide exposure.

Analysis of organochlorine pesticide residues in soil, French beans, Kales and tomatoes sampled randomly from the selected sites found widespread contamination of soils with organochlorine pesticide residues, with total (Σall OCs analysed, in μg/Kg dry weight) ranging from 15.78 – 307.70 in Imenti North, 1.25 – 159.88 μg/Kg in Imenti South, and 14.96 – 106.13 μg/Kg in Buuri. However, organochlorine pesticide residues were not detected in any of the vegetables. Other pesticides, including chlorpyrifos, carbendazine, imidacloprid, acetaprimid, metalaxyl, diazinon, azoxystribin, triadimefon, acephate, thiamethoxim and diuron were found in farm soils, French beans, kales and tomatoes, with concentrations (in μg/Kg dry weight) in soil samples ranging from BDL (metalaxyl and azoxystrobin) – 13,030 (carbendazin). In French beans, kales and tomatoes, the concentrations (in μg/Kg wet weight) ranged from BDL – 290, with the highest being imidacloprid in tomatoes. The pesticide residue levels generally were very low and met the Maximum Residue Limits set by European Union and other countries, and posed no concern to human health. Risk assessment of the residues in terms of estimated daily intakes (mg/Kg BW/day) also confirmed no health risk in the population. However, it is recommended that preharvest intervals for the pesticides should be observed in the three Sub-counties to avoid long term exposure to consumers.

CHAPTER ONE: INTRODUCTION

1.0 Study Background

1.1 The Potential of Agriculture in Kenya

Kenya's physical features are marvelously varied, while much of north eastern Kenya is a flat plain, the remainder of the country encompasses the Great Rift Valley and the magnificent Mount Kenya. The land altitude rises from the sea level on the western Indian oceans shores to 5500m on snow-capped Mt. Kenya at the equator. The total area of the country is 580 370 km², including 11 230 km² of inland water bodies (KNBS, 2019). It is estimated that 27.4 million ha is cultivable, of which 6.1 million ha is cultivated and 21.3 million ha are permanent pastures. The agricultural sector is based predominantly on smallholder farmers producing around 75 percent of the agricultural production and 50 percent of the marketed one, on farms averaging 0.2-0.3 ha each. Large-scale farming mainly produces industrial crops such as tea, coffee, maize and wheat on farms of 50 ha in average, as well as livestock on farms up to 30 000 ha. Agriculture is mainly rainfed and maize, wheat, beans, tea, coffee and potatoes are the main crops (KNBS, 2019)

This has resulted in an acute competition between land use for social economic activities such as agriculture and forestry and impact on water hydrologic circle. The results of this competition are devastating changes on the environment and in the hydrological regime (Ogallo & Mwangi, 1996). Flash floods, soil erosion, reduced ground water recharge and declimated River flows are some of the consequences.

The primary source of fresh water in Kenya is rainfall, which is unevenly distributed in the country. Reliability of its occurrence even in areas of high rainfall is low and most of the country suffers from drought. According to Kenya Meteorological Department (2020), Rainfall activities increased slightly both in intensity and spatial distribution between years 2017, 2018 and 2019. Day-time (maximum) temperatures and Minimum temperatures were still on an increasing trend. Western region received the highest rainfall amount of 73.9 mm at Kakamega station; compared to 49.2mm reported at Thika station in Central region. Maximum and Minimum temperatures were still on an increasing trend in most stations. The highest Maximum temperature of 39.0 0C was recorded at Mandera station in North - Eastern region just as in the previous dekad. Nyahururu station in Central region continued to record the lowest Minimum temperature of 8.3 ^{0}C.

Agriculture remains the most important economic activity in Kenya, although less than 80% of the arable land is used for crop and food production (Government of Kenya, 1994). Arable land (% of land area) in Kenya was reported at 10.2% (FAO, 2020). About 80% of the workforce engages in agriculture or food processing (Government of Kenya, 1994). Brazil is the world leader in horticulture product export while Kenya while Kenya is third producer and exporter of tea (FAO, 2020). Small farms grow most of the corn and also produce potatoes, bananas, beans and peas (Jones, 1995). White and red sweat potatoes are the most common varieties grown by Kenyan farmers. There has been a steady increase in the area planted with sweat potatoes from about 55000 hectares in 1988 to about 65000 hectares in 1996 (FAO, 1997).

Average yield of coffee is about 10 tons per hectare. Coffee in Kenya has been grown over century now, since 1893. The total area under coffee is estimated at 160,000 hectares, about one third of which is the large scale and the rest under small holders with an average of 7,000,000 growers (Nyandiko, 2001). The total annual production has been fluctuating widely due to climate as well as social- economic factors that include market fluctuations, and general farmer apathy. At the moment production stands at about one million bags (approximately 100kg each) per year. Tea was introduced into Kenya from India by a European settler G.W.L Caine in 1903 (Nyandiko, 2001). Over the years Kenya has grown into a formidable world tea producer, with annual production of about 300 million kilograms and is rated as the fourth largest tea producer and the second biggest exports in the world. This formidable growth has seen the tea industry grow into the most important agricultural sub-sector and the leading foreign exchange earner in Kenya (Nyandiko, 2001).

There are different types of livestock farming practiced in Kenya such as beef farming sheep farming, goat keeping, pig farming and poultry farming. The market for livestock supplies is increasingly expanding both locally and regionally. Nearly all the cattle from Moyale and some of the cattles and goats from Mandera market originate from the Boran and Somali regions of Ethiopia (Leete, 2001). Kenya's livestock population is estimated at 12milllion herds, close to 20 million are goats and a million camels (Leete, 2001).

The use of pesticides in these various agricultural therefore plays a major role in maintaining high level of agricultural production in Kenya (Mwaisaka, 1999). Pesticides are defined as any agent intended for preventing destroying, repelling, or mitigating any pest (U.S EPA, 2007). They are classified into groups, such as insecticides acaricides, Nematicides, herbicides, avicides, rodenticides and molluscicides depending upon the species of the pest (Farrely *et al.*, 1984).

1.2 Importation and Regulation of pesticides in Kenya

According to Ministry of Agriculture (2018), Kenya imported 15, 600 tonnes valued at 128 Mill $ in year 2018. It's remarkable that the volume of imported insecticides, herbicides and fungicides has more than doubled within four years from 6,400 tonnes in 2015 to 15,600 tonnes in 2018, with a growth rate of 144%These pesticides are an assortment of insecticides, fungicides, herbicides, fumigants, rodenticides, growth regulators, defoliators, proteins, surfactants and wetting agents. Of the total pesticide imports, insecticides, fungicides and herbicides account for about 87% in terms of volume and 88% of the total cost of pesticide imports. It's remarkable that the volume of imported insecticides, herbicides and fungicides has more than doubled within four years from 6,400 tonnes in 2015 to 15,600 tonnes in 2018, with a growth rate of 144%

The Pest Control Products Act which came into law on 19 May 1983 regulates manufacture, distribution and use pesticides in Kenya (PCPB, 2005). By mid-2010, the Pest Control Products Board (PCPB) had registered over 1000 pest control products for use in agriculture, animal health and public health (PCPB, 2010). In order to ensure that the only registered pesticides are brought into the country and in the right quantities the Board has been controlling importation and exportation of pesticides through processing and issuing of import licenses (PCPB, 2010).

In Kenya the PCPB is a statutory body of the government, charged with the task of regulating the importation and exportation, manufacture, distribution, transportation, sale, disposal and safe use of pest control products and to mitigate potential harmful effects to the environment. It was established under the act of parliament, the Pest Control Products Act, Cap 346 of the Laws of Kenya of 1982. Through its pesticides registration process the Board ensures that only products that have been assessed for safety, quality efficacy and economic value are authorized for use in the country. PCPB is also charged with the responsibility of informing the industry, agricultural extension agencies and the Ministry of Agriculture on the authorized use of crop protection products (PCPB, 2008).

Kenya being predominantly an agricultural country, its demand for pesticides is relatively high. To further the development of the industry, based on the locally available pyrethrum and the imported products, the pesticide industry is likely to continue to get government encouragement as a means of increasing food production and tackling public health concerns. A major issue with the pesticide industry which has in the past affected investment in this area is the duty paid on raw materials used in various pesticides formulation industries, even though most of the finished products are imported duty free (Wandiga, 2001). According to PCPB statistics, a total of 119 applications were considered for registration in the year, 2007/2008. Seventy one pest control products were registered which were lower compared with 177 products granted registration in 2006/2007 (PCPB, 2008). The high figure in 2006/2007 was attributed to mass promotion of products under provisional registration to full registration status (PCPB, 2008). Approximately 12,983 metric tons of pesticides valued at ksh 10.7 billion were imported into the country in 2011/2012 (PCPB, 2012 in that year, more insecticides were imported in comparison to the other pesticides groups. The approximate quantities in tones and value in millions Kenya shillings of the various categories of pest control products imported between 2003/2004 and 2011/2012 are shown in Figure 1.1 below and Table 1.1 respectively.

Table 1.1: Amount of pesticides (in metric tonnes) imported between 2003/2004-2011/2012 financial years.

Categories/Year	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Insecticides	2165	2881	2844	2475	2887	2995	3181	3913	2897
Fungicides	1657	2031	2361	3190	2651	2340	2415	2940	4827
Herbicides	1396	1538	1311	1859	2289	2933	1840	2000	1537
Others	723	597	1192	1225	1330	1413	1396	3913	1482
Totals	**5941**	**7047**	**7708**	**8749**	**9157**	**9681**	**588832**	**12766**	**10743**

Note: Others include acaricides, fumigants, plant growth regulators, mitigants, and other biocontrol agents.

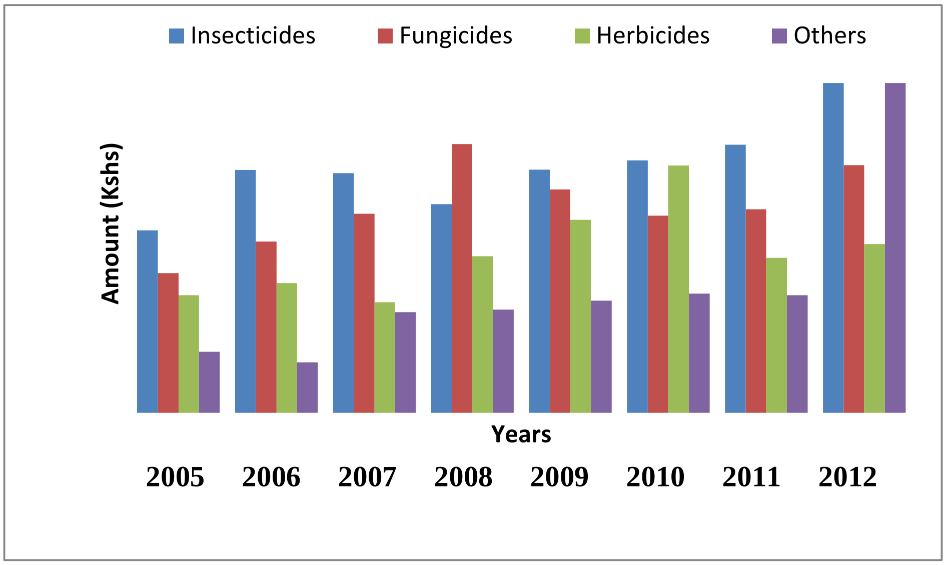


Figure 1.1: Amount (KSh.) spent on pesticide importation into Kenya between 2003/04-2011/2012 financial years.

The pesticides industries in Kenya consist mainly of firms formulating pesticides materials. The only raw materials available locally are pyrethrum extracts from pyrethrum flowers used to make pyrethroids. There are more than eleven firms manufacturing and selling various pesticides products in the country (PCPB, 2008). Other types include herbicides, plants growth regulators and insect repellents (PCPB, 2008) as well as biological control agents.

1.2 Pesticides usage in Kenya

There are different types of synthetic pesticides, which include organochlorines (OCs), organophosphates (OPs), carbamates (CBs) and pyrethroids. As in most tropical countries in Africa, pesticides are extensively used in the public health sector in Kenya to control vector such as trypanosomiasis (IPEP, 2006). Before DDT was banned in Kenya in 1985, about 70 tonnes were used annually for agriculture pest control on maize and cotton. Despite the official ban of these pesticides they are still illegally available in the market and in the environment. For instance, DDT is known to reduce malaria drastically, a disease that kills approximately 700 Kenyans a day and is therefore still being used for in door spraying against mosquitoes (WHO, 1989). DDT is the common name approved by the International Standards Organization for the technical product mixture which consist s of 70% of p, p'-DDT and 30% mixture of other isomers formed during manufacture (Shafer & Meyer, 2004).

Other organochlorines such as aldrin and dieldrin which were banned in Kenya in 1992, were initially used for seed dressing. The organochrlorine pesticides which are still officially in use in Kenya are endosulfan, alpha- and gamma-BHC, and alachlor (International POPs Elimination Project, 2006). Herbicides can be used to kill invasive weeds that may cause environmental damage. Herbicides are also commonly applied in ponds and lakes to control algae and plants such as water glasses that can interfere with activities such as swimming and fishing. They can cause water to smell or taste unpleasant (Helfrich *et al.,* 1996). In Kenya most herbicides are used to control weeds in agriculture. There has been concern on possible effects on water ecosystems (Getenga *et a*l., 2004).

The situation in Kenya is aggravated when cases of pesticides misuse occur due to farmers' ignorance and illiteracy (Odada, Ochola, Olago, 2009). Kenyan farmers, especially those from pastoral communities have lost herds of cattle after spraying with insecticides instead of acaricides. Sales of fake, expired or banned pesticides are also common (PCPB, 2005).

The effect of pesticides depend on several factors such climate (temperature and rainfall), soil type of the vegetative growth, biotic activity, light intensity, agricultural practices, and mode of introduction of the pesticides into particular environmental compartments; these factors determine the persistence of a pesticides in a specific environment (Pal *et al.*, 2006).

1.3 Institutions involved in the horticulture sector

The horticulture industry is governed by various public and private institutions with legal and institutional mandates. Public institutions established under various statutes in Kenya have a national mandate on various aspects of horticulture with a view to improving productivity and service delivery. These institutions include:

1.3.1 Horticultural Crop Development Authority (HCDA)

Recognizing the importance of the horticultural sub-sector, the government established the Horticultural Crop Development Authority (HCDA) in 1967 to develop the sector. The HCDA has been able to help farmers in an advisory and regulatory capacity over the years.

1.3.2 The Kenya Agricultural and Livestock Research Organization (KALRO)

KALRO is a premier national institution bringing together research programmes in food crops, horticultural and industrial crops, livestock and range management, land and water management, and socio-economics. KALRO promotes sound agricultural research, technology generation and dissemination to ensure food security through improved productivity and environmental conservation. It is mandated to undertake research in production, crop management, pre-and post-harvest and value addition of horticultural crops. The outputs from research activities implemented are to support the national horticultural industry.

1.3.3 Kenya Industrial Research and Development Institute (KIRDI)

This is a parastatal established under the Science and Technology Act (Cap 250). It is mandated to undertake research and development in industrial and allied technologies. KIRDI collaborates with Ministry of Agriculture and other stakeholders in technology development and transfer in processing of horticultural produce.

1.3.4 Universities

Among the universities offering courses in agriculture in Kenya include University of Nairobi, Jomo Kenyatta University of Agriculture and Technology, Moi University and Egerton University. These universities offer both degree and diploma courses.

1.3.5 Fresh Produce Exporters Association of Kenya (FPEAK)

FPEAK was established in 1975 as an association for horticultural produce exporters. Its functions include: representation and liaison with relevant public and private sector, local and international organizations, and trade associations; promoting exports through overseas exhibitions, trade missions and buyers' missions to Kenya; providing market information on export products and their destinations; training members and their out-growers on production, post harvest handling, packaging and export marketing techniques; and ensuring high quality, environmentally sound and safe products through adherence to an established Code of Practice.

1.3.6 Kenya Plant Health Inspectorate Services (KEPHIS)

KEPHIS is a state corporation that provides regulatory oversight for the government, business sector, scientists and farmers on matters of plant health and quality control of agricultural inputs and produce. Further, it is tasked with the responsibility of establishing linkages with various local and international government and non-government organizations so as to execute its mandate more professionally (HCDA, 2013). In partnership with private institutions it inspects Kenya's horticultural exports to the EU hence ensuring that they conform to the export market requirements, especially with respect to pesticide residue limits.

1.3.7 Ministry of Agriculture, Livestock and Fisheries (MoA)

The Ministry of Agriculture coordinates the implementation of agricultural, cooperative and rural development policies. The specific functions which are pursued by the Ministry include: rural development policy; agricultural policy; crop production and marketing; land use policy; pests and disease control; agricultural research; phytosanitary services; information management for the agricultural sector; cooperatives and regional development authorities among others.

1.4 Policy That Guides the Horticulture Sector in Kenya

Currently in Kenya, there is no horticultural policy that guides the horticultural sector. However, various pieces of legislation are in place and guide different aspects of the horticultural production. The Agricultural Act, Cap 318 governs the agricultural sector and includes conditions under which fruits and vegetables are grown. The Agricultural Produce (Export) Act Cap 319 provides for the grading and inspection of agricultural produce to be exported and generally for the better regulation of the preparation and manufacturing of agricultural produce for export. The regulations of this Act include Agricultural Produce (Export) (Horticultural Produce Inspection) and the Agricultural Produce (Grading of fruits and vegetables for export). Inspection and standards: - Regulations and standards for fresh horticultural produce are done at the port of exit by KEPHIS. This status is no longer feasible due to serious emerging challenges both locally and internationally and a National Horticulture Policy is being developed to provide sustainability and further spur growth in the industry.

1.5 Policy That Guides the Pesticide Use in Kenya

The pest control products registration (Amendment) regulation, 2006 requires that the use of genetic modified organisms and living modified organisms as microbial or microbial bio-pesticides shall comply with any other existing laws governing such organisms before an application is made to the board (Hunter, Salzman, & Zaelke, 2007). Bio-safety measures are also put in place to mitigate or protect human health and environment from possible adverse effects of the products of modern bio-technology. The protocol on bio-safety provides comprehensive and holistic regime designed to ensure that the development, handling, transport and use of products of modern bio-technology are undertaken in manner that maximize benefits while preventing or reducing risks to the environment and human health. The protocol is subsidiary agreement to the UN convection on biological diversity (CBD) Kenya signed the bio-safety protocol in 2000 and fulfilled the ratification requirement in 2003. One of the key obligations expected from the parties to the protocol is promotion and facilitation of public awareness education and participation in bio-safety activities as stipulated in article 23.

Bio-safety issues under the mandate of PCPB are:

i) Micro-organisms for use directly or as active agents in pest control products including genetically modified organisms

ii) Macro-bials for use directly or as active agents in pest control products including genetically modified organisms

iii) Bio-chemicals derived from genetically modified organisms, used directly or as active ingredients or in pest control products

In food safety assessment, all pest control products meant for use on edible crops or domestic animals are subjected to health and environmental risk assessment

All pest control products are expected to undergo local biological efficacy trials before registration. Monitoring is also carried out at the time of testing. Some special conditions may be attached to products with high risks

Premises where pest control products are manufactured, packaged and sold are monitored through inspection. For products released and post environmental release monitoring is carried out in collaboration with relevant agencies.

1.6 Overview of horticultural production in Kenya

In 2016, of the total value of horticultural produce, vegetables account for 44.6 percent, fruits 29.6 percent, flowers 20.3 percent, and nuts, medicinal and aromatic plants account for the rest. About 95 percent of horticultural production goes to the domestic market and 5 percent to the export market (KNBS, 2020). KES 235.1 Billion. The domestic value of horticulture production in 2018 was estimated at Kshs. 248.5 Billion compared to Kshs. 207.5 Billion in 2017 equivalent to an increase of 19.7 per cent. Export earnings for the year 2020 stood at Ksh.151Bn. Flowers earned the country Ksh 108B, Fruits Ksh 18B while Vegetables earned Ksh 24B (The domestic value of horticulture production in 2018 was estimated at Kshs. 248.5 Billion compared to Kshs. 207.5 Billion in 2017 equivalent to an increase of 19.7 per cent. Over the same period, cultivated area increased by 3.6 per cent from 402,796 ha to 417,367 ha while total production increased by 7.7 per cent from 6.2 million tons to 6.7 million tonnes in 2018 compared to 5.9 million tonnes in 2017.

In 2018, floriculture registered a 13 per cent increase in value at Kshs. 113 Billion from Kshs. 82 Billion realized in the year 2017, accounting for 45.5 per cent of the domestic value of horticulture. Fruits production showed mixed reaction during the period under review. The area increased in 2017 by 4.6 percent but the production and value decreased by 7.8 and 3.8 percent respectively. This was attributed to drought in 2017 because most of the fruits in Kenya are grown under rain fed conditions. In 2018, the area increased by 6.2 percent from 175,617ha to 186,494 ha while production and value increased from 2.9 to 3.1 Million tons while the value increased from 53.4 Billion to 59.4 Billion representing 7.4 and 11.1 percent increase respectively (KNBS, 2020).

The horticultural sector offers opportunities for economic growth both in the medium and high potential as well as the Arid and Semi Arid Lands (ASALs). Over the last two decades, however, Kenya's horticultural sub sector has substantially grown in terms of area under production, commodity and quantities produced. The national production of all horticultural crops in 2007 was estimated to be 7.1 million tones with a wholesale value of at least Ksh120 billion ($1.85 billion) (HCDA, 2008).

The area under pineapple production has been decreasing since 2001 whereas that of mangoes has steadily increased. The decrease in the area under production for pineapples could be due to the increased influx of imported pineapples from regional markets mainly Uganda and rapid changes in weather patterns (GOK, 2010). The rapid increase in area allocated for mangoes could be attributed to increased availability of improved varieties of mangoes that attract better prices and product diversification (e.g. juices and dried mangoes). For the vegetables, tomatoes have shown a steady increase in the area allocated and the increase can perhaps be explained by the increased green house tomato production.

Horticultural production in terms of the quantities produced show mixed trends for various crops. Some crops, particularly onions, chillies and pineapples have shown a decline in production while some like French beans, mangoes and bananas show a general increasing trend after 2001. There has been a marked increase for both cabbage and tomatoes this could be explained by the reduced field losses caused by pests and diseases as a result of more farmers adopting green house production (the case of tomatoes) as well as the use of improved cabbage varieties. (Dawson *et al.,* 2005).

The mixed trends in horticultural production could be attributed to a number of factors that include area expansion or contraction, climatic, technological and price changes. While it is in fact true that climatic factors such as drought are important in explaining the horticultural performance, the major culprits are policy related (Minot & Ngigi, 2002). Although some commodities like bananas show a general increasing trend in production, this increase is actually in hectare rather than an increase in productivity or yields (Minot & Ngigi, 2002).

Kenya's horticultural exports mainly fruit and vegetables grew by 9% per year in the first decade after independence, then 17% per year from 1974-1983 (Minot & Ngigi, 2002). The quantities of horticultural produce exported between 2001 and 2007 show mixed trends, in terms of export volumes, with pronounced periodical fluctuations and this also mirrors the area under production and quantities produced. While over 90% of smallholder farmers in all but the arid regions of Kenya produce horticultural products, fewer than 2% do so directly for export (Bawden *et al.*, 2002). The limited horticultural produce for export has been attributable to the stringent sanitary and phytosanitary (SPS) requirements that developing countries have to meet before penetrating the export markets (Wasilwa, 2008). Meru County is well known for agriculture, in particular, horticultural production. It produces various horticultural produce including tomatoes, beans, green grams, onions, kales and French peas, among others, for local markets like Nairobi and for export. The use of pesticides is therefore critical and various types of pesticides are applied through large scale and small scale farming ventures. Meru County is part of the Mount Kenya region that consumes up to 70% of all pesticides sold for agriculture in Kenya (PCPB, 2018)..

1.7 Constraints and challenges to horticultural production in Kenya

Smallholder farmers in Kenya are faced with a number of challenges in their horticultural production activities. These include but are not limited to: misallocation and under investment in agriculture, poor infrastructure, high cost of inputs, limited access to extension services, unreliable weather, and low produce prices (Wasilwa, 2008). The impact of high cost of inputs has been aggravated by declining soil fertility (Ngowa, Mbise1, Ijani, London, & Ajayi, 2007). There is also a limited access to extension services in most parts of the country with the national extension staff to farmer ratio standing at 1:1,500. The low/uneconomic prices are mostly attributed to weak farmer bargaining power and market cartels. The sector is also subject to lags in policy and legal framework, which are not in line with a liberalized economy (Wasilwa, 2008). This situation has hindered most farmers from keeping pace with changing technological advances (Wasilwa, 2008) and therefore there is still lack adherence to recommended safe methods of pesticide handling and use practices by farmers.

1.8 Problem Statement

A large variety of pesticides are used both in agriculture and public health in Kenya and imported in large quantities. Due to lack of relevant data, equipment and qualified personnel, these pesticides are normally applied following specifications set in the countries of manufacture (Lalah, 1993) and there is lack of adherence to recommended safe methods of handling and use of pesticides.

Farming intensification in Meru County has contributed to increased application of pesticides to improve crop yields. Unfortunately, some of these pesticides are known to stay longer in the environment and their residues may contaminate water, soil and plants posing threat to non-target organism such as human and wildlife (Osoro *et al.*, 2016; Madadi, 2010; Aucha *et al.*, 2017). As a consequence, toxic effects may manifest on humans as a result of consumption of food with pesticide residues. While pesticide manufacturers provide strict guidelines in application and handling there have been cases of serious issues concerning human health risks as a result of consuming food with pesticide residues above the recommended limits (Damalas & Eleftherohorinos, 2011; Benson, 2011). Parent chemical compounds as well as pesticide metabolites have been found left in sediments, soil, air, vegetables, weeds and water (Rudel, 1997; Osoro *et al.*, 2016; Madadi, 2010; Aucha *et al.*, 2017; Okworo, 2018) and both of these contaminants have detrimental impacts on water quality and human life.

These cases have varied from acute to serious and others build up in the body leading to sub-lethal health effects. Studies have shown that Pesticide exposure among farmers applying pesticides in their small scale farms can arise through lack of knowledge and mishandling of pesticides (Ohayo-Mitoko, 1997; Moturi *et al.,* 2015). The agricultural extension workers have also been reportedly exposed to organophosphate and carbamates through acetylcholinestase inhibition assay tests, in Kenya (Ohayo-Mitoko *et al.*, 2000). However information on the status of pesticide use, health effects and their impacts on ecosystems in small scale farms are lacking.

Most of the persistent pesticides along with their metabolites are absorbed byplants or remain in the soil and water hence their residues are found in the food chain (Spanoghe *et al.*, 2009, Okworo, 2018). Water sources get polluted by pesticides used in farms. In many cases diffuse pollution of water sources is the most common form of water contamination by pesticides used on crops (Konstantinou, 2006).

There has been a significantly high amount of pesticide residues reported in vegetables, French beans, fruits and cereals such as rice and wheat in other studies (Kingola, 2015; Miyata *et al.*, 1994). Pesticides residues have also been detected in tomatoes, onions and potatoes (Miyata *et al.*, 1994) as well as oranges and apples in amounts exceeding the maximum residue levels in other countries (Roy *et al.,* 1997). Bio-accumulation of persistent pesticides has been reported to occur in living organisms from bacteria and algae to higher plants and animals including human (Roy *et al*., 1997).

Pesticide residue concentration in organisms increases as the position of that organism increases upwards in the food chain (Jolanta *et al.,* 2011). The current study investigated the levels of pesticide contamination in kales, French beans, tomatoes and soil samples obtained from Imenti North, Imenti South and Buuri Sub counties in Meru County.

1.9 Objectives

1.9.1 General Objective

The general objective of this research project was to establish the status of pesticide usage and effects on ecosystems and human health in small scale horticultural farming in selected communities in Meru in Mount Kenya region of Kenya.

1.9.2 The Specific Objectives

i. To establish the status of pesticide types and their usage in selected small scale horticultural farms in Meru.

ii. To evaluate and document actual patterns of pesticides mixing, storage and applications as well as the use of personal protective devices.

iii. To assess the knowledge, perceptions and reported practices of agricultural extension workers as well as health care workers in Meru with respect to the diagnosis, treatment and prevention of pesticides poisoning.

iv. To determine the levels of pesticide residues in farm soil, kales, tomatoes and French beans in the selected farms in Meru.

1.10 Justification

Meru County is located in the Mount Kenya region in central Kenya where most pesticides are used in various agricultural activities. More than 70% of pesticides imported in Kenya are used in the Mount Kenya region (PCPB, 2018). However the status of pesticide usage and their impacts on farmers who apply them in the farms as well as their residues on farm soil and horticultural produce have not been established. The horticultural produce, which includes tomatoes, kales, cabbages, potatoes, French beans, onions and fruits, from Meru County feeds both the the local as well as the international market; and therefore residue limit requirements must be adhered to in order to conform to residue limit requirements for export and to prevent negative impacts of residues on human health. Research on pesticide residues and their persistence in soil and vegetable crops is on going and a lot need to be done in Kenya (Damalas & Khan, 2017). This research is important because it will be a source of information to farmers around Imenti North, Imenti South and Buuri Sub counties in Meru County and all other parts of the country to support decision making regarding pesticides application to crops.

Secondly, the findings of this study could be important to consumers and policy makers since it will provide information on the levels of pesticide contamination in soil, tomatoes, kales and French beans from Imenti North, Imenti South and Buuri Sub counties in Meru County. Agriculture is the major foreign exchange earner in Kenya therefore it must be practiced in the safest manner possible to ensure that the products meet international standards more so pesticides should be less than the maximum recommended level.

This study is important to environmental scientists and other scientists in the area of research since it will contribute to the understanding of the role they can play in promoting knowledge on best agricultural practices in order to reduce pesticides residues in the environment and crop produce.

CHAPTER TWO: LITERATURE REVIEW

2.0 LITERATURE REVIEW

2.1 Persistent Organic Pollutants

The Stockholm convention on persistent organic pollutants (POPs) seeks to eliminate pesticides and unintentionally produced POPs. The 22 chemicals listed as POPs under the Stockholm Convention are namely; aldrin, chlordane, Dichloro-diphenyl-trichloroethan (DDT), dieldrin, endrin, heptachlor, hexachlorobenzene, mirex, toxaphane, polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), alpha hexachlorocyclohexane, beta hexachlorocyclohexane, chlordecone, hexabromidiphenyl, hexabromidiphenyl ether and heptabromodiphenyl ether, Lindane, pentachlorobenzane, perfluorooctane sulfonic acid and salts and perfluoroactane sulfonyl fluoride, technical endosulfan and its related isomers, tetrabromodiphenyl ether and pentabromidiphenylether. According to the national implementation plan, Kenya does not produce any intentional POPs and other organochlorine pesticides but they are present in the Kenyan environment and some such as DDT are restricted to disease vector control (Government of Kenya, 2006). The government national implementation plan, therefore, addressed the presence of several POPs, either as obsolete waste awaiting disposal or as environmental contaminants. According to Ministry of Agriculture (2018), Kenya imported 17,803 tonnes valued at 128 Mill $ in year 2018. The national implementation plan outlines the activities to be undertaken to manage POPs, such as building the capacity of the Ministry of Environment and Natural Resources to drive the implementation process, disposing of waste containing POPs that are tested in the POPs inventory, mobilizing financial resources for projects to build the capacity of laboratories (Government of Kenya, 2006). Specifically, the plan intends to: – Establishment of coordinating mechanism and process organization; Establishment of POPs inventories and assessment of national infrastructure and capacity; Facilitate coordination and integration with national sustainable development, chemicals management and pollution control policies

In promoting proper disposal of waste, and identifying alternatives to dichlorodiphenyltrichlororethane, better known as DDT, the national implementation plan has also identified specific sites with accumulated waste that need to be disposed of including obsolete pesticides at sites in Wajir, Kitengela, Dandora dumpsite and Nakuru (UNEP, 2017). These obsolete pesticides include mainly the organochlorines e.g. DDT, which have now been banned. Table 2.1 shows the list of banned pesticides in Kenya.

Table 2.1: Banned Pesticides in Kenya

Common Name	Use	Year banned
2,4,5 T (2,4,5 – Trichloro-phenoxybutyric acid)	Herbicide	1986
Chlordane	Insecticide	1986
Chlordimeform	Insecticide	1986
DDT (Dichlorodiphenyl Trichloroethane)	Agriculture	1986
Dibromochloropropane	Soil Fumigant	1986
Endrin	Insecticide	1986
Ethylene dibromide	Soil Fumigant	1986
Heptachlor	Insecticide	1986
Toxaphene (Camphechlor)	Insecticide	1986
5 Isomers of Hexachlorocyclo-hexane (HCH)	Fungicide	1986
Ethyl Parathion	Insecticide All formulations banned except for capsule suspensions	1988
Methyl Parathion	Insecticide All formulations banned except for capsule suspensions	1988
Captafol	Fungicide	1989
Aldrin	Insecticide	2004
Benomyl, Carbofuran, Thiram combinations	Dustable powder formulations containing a combination of Benomyl above 7%, Carbofuran above 10% and Thiram above 15%	2004
Binapacryl	Miticide/Fumigant	2004
Chlorobenzilate	Miticide	2004
Dieldrin	Insecticide	2004
Dinoseb and Dinoseb salts	Herbicide	2004
DNOC and its salts (such as Ammonium Salt, Potassium salt & Sodium Salt)	Insecticide, Fungicide, Herbicide	2004
Ethylene Dichloride	Fumigant	2004
Ethylene Oxide	Fumigant	2004
Fluoroacetamide	Rodenticide	2004
Hexachlorobenzene (HCB)	Fungicide	2004
Mercury Compounds	Fungicides, seed treatment	2004

Source: The Pest Control Products Board of Kenya (PCPB,2010).

2.2 Pesticides

Pesticides are, worldwide, used for the prevention and control of pest, diseases, weeds, fungi and nematodes (WHO, 2002), in an effort to reduce crop losses due to pests. FAO estimates that annually between 20 to 40 percent of global crop production are lost to pests (FAO, 2019). Each year, plant diseases cost the global economy around $220 billion, and invasive insects around US$70 billion (FAO, 2019). One of the pests responsible for the greatest losses was the locust.

Petsts attack food crops while in the farm and in store and this agravtes the situation. An increase in number of pesticides and in the amounts used in the last decades have led to growing attention to possible adverse effects on human health, caused not only by the active ingredients and associated impurities but also by solvents, carriers ,emulsifiers, and other constituents of the formulated products (Bhanti, Shukla, & Taneja, 2004). These chemicals however cause significant occupational and environmental health risks (Moses *et al.,* 1993). Farmers are routinely exposed to high levels of pesticides, usually much greater than those of consumers. Farmers' exposure mainly occurs during the preparation and application of the pesticide spray solutions and during the cleaning-up of spraying equipment (Damalas, 2011). Estimates by WHO indicates that, worldwide, 3 million severe pesticides poisoning cases occur annually (WHO/UNEP, 1990). In addition, 25 million symptomatic occupational pesticides poisoning occur among agricultural workers in developing countries (Jeyratnam, 1990).

Long term risks have been poorly described while it is known that some of these pesticides are mutagenic, carcinogenic, teratogenic and immunosuppressive in humans (Moses *et al.,* 1993; Davis, 1990). Epidemiological research to evaluate occupational exposure to pesticides of a population of farmers is complex, since it typically concerns exposure to a mixture of agents. Furthermore, contribution to uptake through the different exposure routes (skin, respiratory and gastro intestinal tract) depends on physicochemical properties of the pesticides, personal human factors, environmental and occupational conditions (De cock *et al*., 1995)

In the early years of pesticide use, research on adverse health effects, most often, focused on acute effects and fatal intoxications. Knowledge of adverse effects was mainly based on toxicological data from animal studies and human case reports (Lesmes-Fabian, 2012). More recently, epidiemological studies are carried out on a larger scale and cover a diversity of health end points, such as neurotoxic, immunotoxic, carcinogenic, reprotoxic, and developmental effects (Ohayo-Mitoko *et al.*, 2000). Chronic effects of long term exposure are usually focused on these studies. Chronic health effects in humans are most likely to result from excessive pesticides exposure that might occur in occupational settings (Ohayo-Mitoko *et al.,* 2000).

The pesticides currently in use involve a wide variety of chemicals, with great differences in their mode of action, in uptake by body, metabolism, and elimination from the body and toxicity to humans (Oates, & Cohen, 2011). Acute toxic effects are easily recognized, whereas effects that result from long term exposure to low doses are often difficult to distinguish (Anon, 2005). It should be recognized that for most pesticides, a dose effect relationship has been defined, and the effects of pesticide may be detected by measuring minor biochemical changes before the onset of severe clinical health effects. There may be a thresh-hold below which no effects can be observed (no-observed effect level (WHO/UNEP, 2012). However, malnutrition, dehydration and high climatic temperatures which are common in developing countries, are likely to increase sensitivity to pesticides (Via & Mechanick, 2013).

2.3 Classification of pesticides

Pesticides are divided into organic and inorganic. Inorganic pesticides are naturally occurring non-carbon elements, they are generally stable, non volatile and soluble in water. Most inorganic pesticides contain arsenic, cyanide, mercury and thallium, but the presence of such metals make pesticides persistent and bioaccumulative (Hassall, 1990). Organic pesticides are mainly synthetic compounds containing either aliphatic or aromatic hydrocarbon chains. They are classified into organochlorines, organophosphorus, organosulfur, carbamates and pyrethroids depending on the element bonded to the hydrocarbon system (Wasswa, 2008).

2.3.1 Organochlorine Pesticides (OCs) and their Mode of Action

Organochlorine pesticides are a large class of multipurpose chlorinated hydrocarbon chemicals (Briggs, 1992). The chemical structures of common organochlorines are shown in Appendix section. They break down slowly in the environment and accumulate in fatty tissues of animals. Thus, they stay in the environment and food web long after being used. DDT now banned in United States because of its harm to health of wildlife and people, is a notable example of an organochlorine pesticide (Damalas & Eleftherohorinos, 2011). DDT, lindane and dieldrin are also banned in Kenya. Many organochlorine pesticides are endocrine disrupting chemicals, meaning they have subtle toxic effects on the body's hormonal systems (Lemaire *et al.,* 2004).

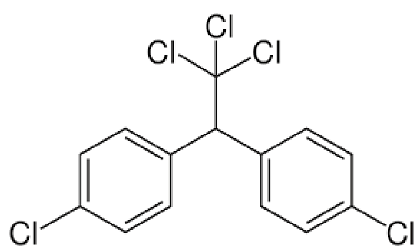


Figure 2.2: General Structure of DDT

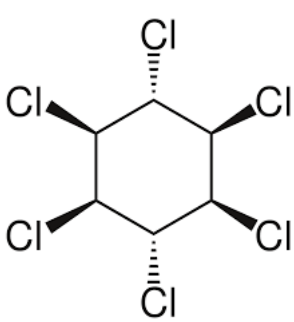


Figure 2.3: General Structure of Lindane

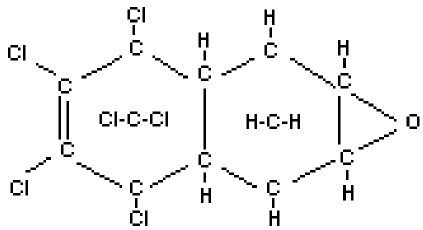


Figure 2.4: General Structure of Dieldrin

Endocrine disrupting chemicals often mimic the body's natural hormones, disrupting normal functions and contributing to adverse health effects. They are very toxic organic compounds, which persist in the environment and have the potential for long range transport, posing a serious threat to the environment and its habitats at remote places (Vesna *et al.,* 2001). They also recycle within the ecosystem, partitioning in aerosols, water, soil, plants and animal tissues, respectively (Vesna & Darinka, 2001). Organochlorine Pesticides (OCs) include dieldrin, heptachlor, chlordane, aldrin, endrin, dichlorodiphenyltrichloroethane (DDT), hexachlorobenzene (HCB), mirex, and toxaphene. OCPs were used widely to protect crops, livestock, buildings and households against a variety of pests such as ticks, locust, termites and mosquitoes. Currently, most of these pesticides have been banned, except a few which are under restricted use. Following the ban, large stocks of obsolete OCPs are still in the environment especially with individual farmers, households and Government agencies (Dixon, Gibbon, & Gulliver, 2001). Some still find their way back into the country illegally. The probability of these chemicals being released into the environment is very high posing a high risk to animals and human health.

Organichlorine pesticides control pests by disrupting nerves impulses transmission through interference with Na^+/K^+ ions flow at the axon /synapse level. They are generally persistent in soil, food, human and animal bodies and can thus accumulate in fatty tissues. Traditionally, they are used for insect and mite control, but many are no longer used due to their ability to remain in their environment for a long time. Examples of orgachlorines include: aldrin, dieldrin, chlordane, endrin and lindane (Freedman, 1995).

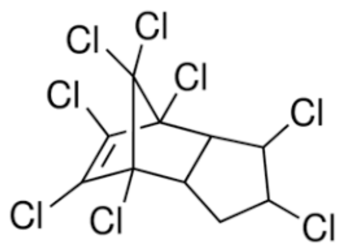


Figure 2.5: General Strucuture of chlordane

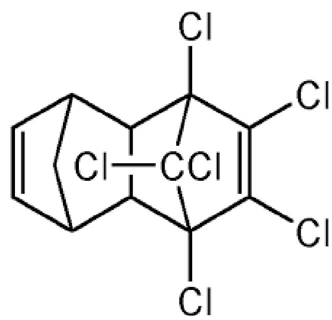


Figure 2.6 General Strucutre of aldrin

2.3.1.1 Health Effects of Organchlorines

In varying degrees, organochlorides are absorbed by the gut and also by the lungs and across the skin. The efficiency of dernomal absorption is variable, with lindane having documented 9.3% dermal absorption rate (Clarke, Cordery, Morgan, Knowles, Guy, 2018), and is absorbed even more efficiently in abraded skin. Many organochlorides pesticides are endocrine disrupting chemicals meaning they have subtle toxic effects on body's growth and development system (Lemaire e*t al.,* 2004a). Endocrime disrupting chemicals often mimic the body's natural hormones, disrupting the normal functions and contributing to the adverse health effects (Lemaire e*t al.*, 2004b).

2.3.1.2 Ecological Effects of Organochlorines

The presence of high concentrations of organochlorines and PCBs, and their residues, in marine mammals have been suggested as the cause of the pathological and reproduction failures in whales (Sherpa, 2019). To achieve snail control in flowing waters, such as irrigations canals, a concentration of niclosamide at 0.3 to mg/l for 24 hours is recommended, this concentration would be toxic to fish in the same waters. DDT and trifenmorph can accumulate in fish tissues which can cause crisis to human beings who consume the fish. This is one reason the use of these pesticides at Mwea irrigation Scheme was discontinued (National Irrigation Board, 2014). Benthic organism samples from the Kenyan coast were analysed for PCBs and cyclic pesticides, and the PCBs congeners and cyclic pesticides concentrations were found to be higher amount in Sabaki River than in Tana River (Gitari, 2011). In the same study, they also found both bivalve molluscs and gastropod molluscs from the mouth of the Sabaki River and Kiwaya bay to have the highest level of PCBs (30 and 60 mg/g) and p, p'-DDE, a metabolite of p, p'-DDT, was at levels ranging from BDL to 48ng/g of lipid. The above study observed the presence of some groups of POPs compounds including organochlorines (p, p'-DDE) and PCBs (Everaarts *et al.*, 1997), implying that the organochlorine compounds such as p, p'-DDT could still be in use in Kenya regardless of their ban.

2.3.2 Organophosphorus Pesticides (OPs)

Organophosphate pesticides are composed of an ester structure and break down fairly easily on the surfaces and inner parts of plants as well as in the soil (Cairns & Sherma, 1992). The toxicity of these compounds is through the inhibition of the function of enzymes that control the activities of the nervous system, majorly, acetylcholinesterase (AChE) (Akan *et al.*, 2013). OPs bind to the enzyme's hydroxyl group in a reversible but fairly permanent way thus preventing decomposition of acetylcholinesterase (Jolanta *et al.,* 2011). The blockage of cholinesterase activity by binding to the AChE leads to an increase in the quantity of acetylcholine at the synapses, ending up to hyper arousal; this is followed by paralysis of the muscles and the major respiratory centres (Akan *et al.,* 2013). Figure 2.1 shows the general structure of organophosphates.

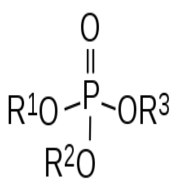
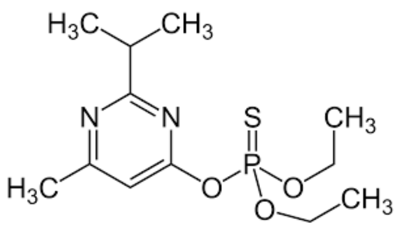


Figure 2.7: General structure of organophosphates.

The chemical structures of OPs can be found in the Appendix section. The OPs include Malathion, parathion, chlorpyrifos, diazinon, dimethoate among others (see Table 2.2). The OPs act as insecticides, acaricides and herbicides and are widely used in agriculture, veterinary and public health vector control (PCPB, 2018). Some very common examples of OPs include diazinon and chlorpyrifos which are described in the following sections.

2.3.2.1 Diazinon

Diazinon is an insecticide classified under the organophosphate group and is mainly used to protect most crops against various insects (Abass *et al.*, 2011). Trade names for diazinon include Knockout, Alfatox, Basudin, AG 500, Dazzel, and Gardentox (ATSDR, 2008). Some of its agricultural uses include controlling insects, soil pests as well as insect pests in foliage on field crops, nuts, fruits as well as vegetables. Prior to its cancellation on home uses in the USA in 2004, diazinon was applied on gardens as well lawns to control fleas, ticks and flies (USEPA, 2004).



Figur 2.8: General Strucutre of Diazinon

Diazinon kills by inhibiting the enzyme acetylcholinesterase whose function is to hydrolyse acetylcholine neurotransmitter in the cholinergic synapses and in the neuromuscular junctions. This results in an abnormal build-up of the neurotransmitter in the nervous system (Timchalk, 2001). Table 2.2 shows the physicochemical properties of diazinon and chlorpyrifos

Table 2.2: Physicochemical Properties of Diazinon and Chlorpyrifos pesticides

Physicochemical properties	Diazinon	Chlorpyrifos
Physical form	Liquid	solid
Density	1.116 g/cm^3	1.398 g/cm^3 (43.5 °C)
Water solubility	0.06 g/L (20 °C)	0.73 mg/L (20 ^{o}C)
Vapour pressure	8.4 × 10 $^{-5}$ mmHg (20 °C)	1.87 x 10^{-5} mmHg at 25 °C
Log Kow	3.3	4.7

Source: USEPA (2011).

Diazinon is degraded by biotic and abiotic processes when given adequate time, hence there is no parent compound persistency. Diazoxon and 2-isopropyl-6-methyl-4-hydroxypyimidine are the degradation products of diazinon. While the toxicity of diazoxon is high, 2-isopropyl-6-methyl-4-hydroxypyimidine is less toxic but persists in the environment (USEPA, 2004). Oxypyrimidine is the major diazinon degradation product in soil and water (USEPA, 2004). In the atmosphere, conversion of diazinon to diazoxon takes place via ultraviolet (UV) radiation (Timchalk, 2001). The approximate half-life for the reaction of the hydroxyl radicals together with the vapour phase of diazinon is estimated to be four hours (ATSDR, 2008).

After the release of diazinon into the soil or surface waters, it may be volatilized or hydrolysed, undergo photolysis or in some cases biodegradation. In the aerobic environment, biodegradation is the main process that takes place for diazinon in relation to soil and water. It can also undergo anaerobic biodegradation (De Vlaming *et al.,* 2000). Diazinon can also undergo hydrolysis in water and soil, especially at low pH (USEPA, 2006). Some of the factors that influence diazinon's half-life in soil comprise of the soil type and pH (USEPA, 2004).

Diazinon's release into the environment is mainly attributed to its widespread use particularly as an insecticide in the control of garden pests as well as household related lawn. Its use indoors and as a pest control agent in agriculture has also contributed to its release to the environment. About four million tones of diazinon's active ingredients are used yearly on agricultural sites (USEPA, 2004).

Through a number of monitoring studies, diazinon together with its metabolite diazoxon have been detected in surface water (De Vlaming *et al.*, 2000). According to USEPA (2004) diazinon exposure can occur through inhalation, skin penetration and ingestion. Serious additive toxicity can occur through multiple route exposure. Just like any other organophosphate insecticide, diazinon's symptoms of acute poisoning comprise of sweating, tearing, dizziness, agitation as well as drowsiness. Other symptoms include headache, nausea, and anxiety together with salivation (De Vlaming *et al.*, 2000).

Diazinon is usually harmful to important insects as well as mites which are very helpful in agriculture. Mengistu ZM, Beyene JT (2014) for example, found out that Diazinon is harmfull to honey bees and affetcts the lifespan of worker honey bees. According to Currie *et al.* (1990), diazinon was in the highest toxicity category in a screening program that was carried out internationally for useful insects and mites (Currie *et al.,* 1990). Diazinon's effects are similar on predators and parasites of the pecan aphids (USEPA, 1990).

2.3.2.2 Chlorpyrifos

Chlopyrifos is an organophosphate insecticide used to kill a variety of insects. It was introduced in Kenya in 1965and marketed by Dow Company under the trade names Dursban emulsifiable concentrate, dust, flowable pillets spray, granules, and wettable powder formulations (Meinster, 1992). Which originally were used primary to kill mosquitos in the immature, larval stage of development. Chlopyrifos is no longer registered for this use (PCPB, 2018). Chlopyrifos is used to control various species of fever ticks (*Boophilus sp*), ear ticks, lice and horn flies on beef cattle and non-lactating dairy cattle by use of emulsifiable liquids formulation in water with concentration varying from 0.025 to 0.125% applied as a spray or dip (Meinster,1992).

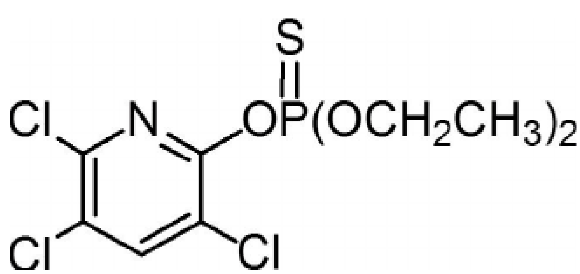


Figure 2.9: General Strucutre of Chlorpyrifos

Chlopyrifos is also used in industries and factories during the construction of the building to prevent termite infestation. This is done by applying it under the slap treatment combined with circum-foundation soil barrier treatment during construction (Meister, 1992).Treatment for all ear ticks is limited to six applications at 21 intervals, and not within two weeks of slaughter. Sheep dipped or sprayed with wet table powder or emulsifiable formulation of chlopyrifos is protected from blow fly, ticks, body lice and sheep sheds (Meister, 1992). A minimum of seven days is required between treatment and slaughter (USEPA, 1991). Chlopyrifos is also effective in controlling cutworms, corn rootworms, cockroaches, grubs flea bettles, flies, termites, and fire ants (USEPA, 1988). It is used as an insectides on grain, cotton, fruit field nut and vegetable crops, as well as on lawns and ornamented plants (USEPA, 1988).

It is also registered in U.S for direct use of sheep's and turkeys, for horse site treatment, dog kennel, domestic dwellings, farm building and storage bins, and in industries as termicides and insecticides and in domestic dwelling as termicide (Lee *et al.*, 2011). Considerable work on the analysis of cattle tissue for residues of chlopyrifos as well as its oxygen analogue and pyridinol metabolite has been documented (USEPA, 2003). Cattle dipped in 0.025 chlorpyrifos emulsification at an interval of 21 days showed in the first phase half-life of chlorpyrifos to be 22 days (USEPA, 2004).

Amjad and coworkers analyzed chlorpyrifos in wild plant (*Melilotus indica*), in Lahore area, Pakistan, using (Amjad et al., 2010). They found that chlopyrifos residue level in the wood plant ranged between 20 and 710 ug/kg. Maximum limits of chlopyrifos residue in this plant established by a European Union (EU) are 50 and 500 mg/kg, respectively (Amjad *et al.*, 2010). The highest level of 70mg/ kg was therefore above the limit set out by the two bodies, while the lowest level of 500 mg/kg was below them.

2.3.3 Organosulphurs

Organosulfurs have sulfur in their structure as the central atom. Their mode of action is by disrupting the target organism's metabolism. They have low toxicity to insects and mammals and as a result are used for selective purposes. They are characterized by their toxicity to young and adult insects which is a valuable property. They also cause irritation to the eyes, ears and nose. The common examples are aramite, propargite, tetradifon, and tetrasul.

2.3.4 Pyrethroids

Pyrethrin is a natural insecticide extracted from *Chrysanthemum cineraria folium* (pyrethrum)- the crude flower dust. The synthetic pyrethroids are derivative of pyrethrins which was designed to improve the biological activity of the active principal of the natural pesticide (Kegley, 2007). Pyrethroids synthesized before 1970 were very sensitive to sunlight, as their molecules easily split under UV light making them unsuitable for agricultural use but effective for indoor insect pest control (Kegley, 2007). Since 1970s, synthetic pyrethroids with a better photo-stability and low volatility have been produced to suit both agricultural and indoor uses. This class of pesticides poisons the target by contact and causing paralysis. These compounds have low mammalian toxicity, but are highly toxic to insects and aquatic organisms. The common pyrethroids are permethrin, cypermethrin, lambda-cyhalothrin, deltmethrin, fenvalerate and tetramethrin, esfenvalerate, tefluthrin, cyfluthrin, imiprothrin, acrinathrin.

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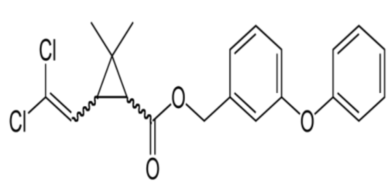

Figure 2.10: General chemical structure of pyrethroids

Pyrethrum is a safe insecticide (oral LD_{50} 1,500 mg/kg in rat) and very fast acting on insects, causing immediate paralysis. It is commonly formulated with synergists as house hold sprays and aerosols because insects may recover from pyrethrum alone. It is not useful in agriculture due to costs and instability in sunlight. Synthetic pyrethroids which are analogues of pyrethrum are divided into two classes depending on their mode of toxicity, i.e. types I and II. Distinct chemical structures convey selectivity towards certain insect species and to mammals.

Current synthetic pyrethroids are slightly soluble in water and have low vapour pressures 10^{-6}-10^{-7} mmHg (therefore not so volatile). Minimal volatility, high photostability properties, both cause them to have extended residual effectiveness (up to 10 days). They are effective against most agricultural pests at low rates, especially for Type II compounds. They have low mammalian toxicity, e.g. Type I pyrethroids belong to WHO Category III pesticides (oral LD_{50} (rats) of 500-5,000 mg/kg range). Type II pyrethroids belong to WHO Category II pesticides (oral LD_{50} (rats) of 50-500 mg/kg range, according to the WHO rating based on LD_{50}'s. WHO Category I have an LD_{50} range: <50 mg/kg (oral, rats) (WHO, 2002).

The mode of toxicity of pyrethroids is through binding to the sodium channels and interfering with nerve impulse. Type I pyrethroids, which includes permethrin , resmethrin, tetramethrin, and allemethrin, bifenthrin and metofluthrin, affect the sodium channels in nerve membranes, causing repetitive neural discharge and prolonged negative after-potential (similar to DDT effect), i.e. by causing delay in sodium channel closing. Type II pyrethroids, which includes cypermethrin, fenvalerate, deltamethrin, tralomethrin, esfenvalerate, fenpropathrin, lambda-cyhalothrin, tefluthrin, cyfluthrin, acrinathrin and imiprothrin, produce an even a longer delay in sodium channels closing/ inactivation, leading to persistent depolarization of nerve membranes, without repetitive discharge and eventual blockage of impulses. Type II are more effective as insecticides and more popular. Other sites of action have been noted for pyrethroids e.g. inhibition Ca^{2+} and Mg^{2+}-ATPase, which results in increased intracellular calcium levels and binding to γ (gamma)-amino butyric acid (GABA)- receptor chlorine channel complex, impending chloride ion transport .

2.3.5 Carbamates

They are organic compounds derived from carbamic acid (NH_2COOH). A carbamate group, carbamate ester (ethyl carbamate), and carbamic acid are functional groups that are inter-related structurally and are often inter-converted chemically. Carbamates have groups attached to the central carbonyl carbon (see Figure 2.2). R_2 is always an aromatic or aliphatic moiety. The major difference among the carbamate pesticides is in the functional group attached at R_1. For instance, carbamate insecticides have R_1 as an ethyl group, herbicides have R_1 is an aromatic group, whereas fungicides have R_1 as a benzimidazole moiety. Some of the known carbamates are carbaryl, carbofurans and aldicarbs. Biologically, carbamates resemble the organophosphates in their activity (Obulakondiah, Screenivasulu, & Venkateswarlu, 1993). They inhibit the cholinesterase enzyme required for nerve function in animals.

The mechanism of toxicity is by inhibition of AChE activity, involving carbamylation (not phosphorylation as in OPs) of the ester in AChE, resulting in similar accumulation of acetyl choline at nerve impulses. The inhibition with CBs is more labile and the effects shorter (and therefore referred to as reversible binding/inhibition). Some carbamates are also suspected carcinogens (USEPA, 2009). Carbamates are hydrolyzed slowly in neutral and mildly acidic aqueous surroundings, but in the presence of alkali, they decompose rapidly. The half- life of carbaryl, for example, is about 10 days in neutral aqueous suspension (pH 7) but only a few minutes at pH 11 (Briggs, 1992).

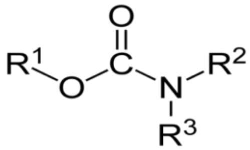

Figure 2.11: General structure of carbamates

The chemical structures of some of the common carbamates are given in Appendix 3. The carbamates include carbaryl, aldicarb, methomyl, propoxur, carbofuran, oxamyl, pirimicarb, bendicarb, methiocarb, thiodicarb and trimethacarb among others. The table on commonly available carbamates is attached in Appendix section.

2.3.6 Biopesticides

Biopesticides include botanical insecticides, insect growth regulators and microbial insecticides which are beginning to become more popular due to their non persistent nature in the environment and on food crops (Amjad et al., 2010, 2015). The botanical pesticides include nicotin, rotenone, azadirachnin, sabadilla and ryania. Although botanical insecticides were used in the past, their attribute mainly lies in them being natural products and degradable unlike most synthetic pesticides (Amjad e al., 2015; Birech et al., 2006). Insect growth regulators such as the juvenoids, triazines and thiodiazines which have low mammalian toxicity are also used in public vector, for example methoprene and hydroprene larvicides with LD_{50} (oral, rat) values >34,000 mg/kg body weight which are used against mosquitoe larvae in water surfaces. Microbial insecticides e.g. bascillus thuringiensis have been developed as sprayable products although their use is still limited due to high costs and limited persistence for residual effectiveness. Another popular microbial pesticide which is used as an insecticide and acaricide in Kenya is Abamectin, an insecticide and acaricide. It contains toxins derived from actinomycete i.e. streptomyces avaermittili, a soil microorganism. These products are often developed as natural pesticides by companies such as the flower companies in Naivasha (Birech *et al.*, 2006).

2.4 Health effects of pesticides

The occupational health of agricultural workers has been studied in the past (Ohayo-Mitoko, 1997; Tsimbiri *et al*., 2015) which showed a consistent pattern of adverse effects of pesticides on farmers's and the impairment of farmer health, reducing their productivity (Pingali, Prabhu & Roger, Pierre, 2013). Occupational exposure of humans to agrochemicals, especially pesticides is common and can result in both acute and chronic health effects including acute neurotoxicity, lung damage and respiratory failure, male infertility. A variety of cancers have also been linked to exposure to various pesticides, particularly haematopoietic cancers (Ezra, Aiwerasia, Ngowi, Stephen, & Mamuya, 2017).

Pesticide exposure is linked with various diseases including cancer, hormone disruption, asthma, allergies, and hypersensitivity (Van Maele-Fabry et al., 2010). A line of evidence also exists for the negative impacts of pesticide exposure leading to birth defects, reduced birth weight, fetal death, etc. (Baldi et al., 2010; Meenakshi et al., 2012; Wickerham et al., 2012). On the basis of scientific evidence, the real, predicted, and perceived risks that pesticides pose to human health (occupational and consumer exposure) and the environment are fully justified. In light of the environmental significance of pesticide pollution and its impact, this review has been organized to describe the general aspects of pesticides with respect to classification, the status of pollution, the transfer route, and the impacts on human health. The objective of this review is to conduct a systematic review of published studies (since 1999 to 2016) with respect to the use of pesticides and their detrimental impacts on human health and ecological systems.

Training to planters, weeders, harvesters who are mainly women (61.6%) was recommended (Tsimbiri *et al.,* 2015). In their study concerning pesticide use Tsimbiri *et al.* (2015) recommended training of sprayers first and foremost; and second, longer reentry times between the last spraying of pesticide and time of reentry of the workers, particularly in greenhouses. In this regard, re-entry times for greenhouses and farm fields established for specific pesticides in Europe, North America, Japan or Australia were recommended to be adapted by Kenya, and the guidelines to be enforced by the Government of Kenya to reduce exposure to pesticides within this vulnerable group of workers. They also recommended that these workers should also use protective clothing including gloves and masks at all times while handling chemicals or recently sprayed plants or flowers. It would also be prudent for flower farm owners to introduce an integrated pest management regime to reduce pesticide use and worker exposures. Further research is required both to identify validated biomarkers that can reliably be used to identify pesticide exposure prior to the occurrence of acute toxicity; and to follow up individual cases of known exposures for chronic health effects as some of the biomarkers such as assessment of acetyl choline esterase levels are not very specific (Tsimbiri *et al.*, 2015).

2.5 Risk Classification

International Programme on Chemical Safety, World Health Organization, & Inter-Organization Programme for the Sound Management of Chemicals (2009) has grouped formulated pesticides by degree of hazard and the hazard classes. In their classifications, any of the organophosphorus insecticides were considered to be very hazardous. Certain countries have moved some pesticides between categories on the basis of problems peculiar to them, for example, in Malaysia, paraquat has been moved from hazard class to 1b, because it is highly hazardous under the conditions of use in Malaysia and other developing countries. When two or more pesticides are used simultaneously, they may interact and become either more toxic (Synergism or potentiation as with lindane and heptachlor) or less toxic (antagonism). Interactions of dietary nitrite with pesticides that contain a secondary amine group can result in the formation of nitrosamines, which may be more toxic, mutagenic or carcinogenic (Zenser et al., 2009). Effects that result from the interaction of pesticides, although hazardous to quantify, are probably of more importance than is generally recognized. However the WHO classification which is based on oral rat LD_{50} ranges is still recommended for use to assess their mammalian risks. According to this WHO classification, Class I pesticides have LD_{50} range: <50 mg/kg (oral, rats), Class II pesticides have oral LD_{50} (rats) ranging from 50-500 mg/kg, and Class III pesticides have oral LD_{50} (rats) ranging from 500-5,000 mg/kg (WHO, 2002).

2.6 Populations at risk: Exposure in different agriculture systems

For several reasons, the use of pesticides and thus the possible health effects, differ between regions and farming systems. In developing countries, most of the subsistence farmers cater for local needs only. There may be many pest problems in this type of agriculture, but usually, the losses are "accepted or controlled in traditional ways as the use of pesticides are limited, and the farmers may not be aware of their existence, value and / or cannot afford them.

In developing countries where commercial agriculture is practised, like Kenya, some pesticides may find their way into the hands of subsistence farmers, who are unfamiliar with the potential risks and necessary safety measures. The use of pesticides in agriculture in developing countries is thus very much connected with production for the regional, national or international markets. However, it is also connected with misuse and mishandling by farmers. The most intensive use of pesticides is in the production of horticultural crops such as soya beans, flowers, kales, tomatoes, carrots, cabbages and onions others includes tobacco, cotton, rice, corn and wheat (Issa et al. 2010).

Issa *et al*. (2010) categorized farming systems in developing countries in three groups; plantation farming which is usually monocultural and requiring intensive pest control, cash cropping which is diverse in both types of crops grown and size of the holdings and subsistence farming, respectively. The smaller the holding and the more the crops is for subsistence, the lower is the likelihood that pesticides will be used. Infact, the crop itself also has an influence. The three crops most vulnerable to insect attack being cotton, rice, and horticultural crops (Issa *et a*l. 2010). Herbicides tend to be less widely used in all types of agriculture in developing countries since weeds can be controlled by human effort (Nguyen & Dang, 1999). In Kenya, the importation data for pesticides in classes as insecticides, herbicides and fungicides, show a similar trend in which more insecticides are imported and used than herbicides (PCPB, 2018).

In plantations pesticide use may be high but the amount of exposure depends on the quality of management, as pesticides tend to be used in a large scale and applied by employers using air craft, tractor, driven equipment or sometimes knapsack sprayers (Hanke & Jurewicz, 2004). In contrast, the cash crop farmers use smaller quantities of pesticides than the plantation farmers, either because of lack of access or because of high costs (Baker & Benbrook, 2002). In this case pesticides are usually applied using knapsack sprayers and usually by the farmer himself or member of his family. For subsistence farmers, there is much less exposure to pesticides because they cannot often afford the products. They must suffer the crop losses caused by pests and probably represent the group least exposed to pesticides (Buiatti *et al.*, 2013).

2.7 Factors influencing exposure

Pesticide hazards appear to be more serious in developing countries where pesticide use is widespread, and where pesticides banned elsewhere because of carcinogenic or other adverse characteristics may still be in use. It is also in developing countries where workers and health professionals may not be adequately informed or trained in the recognition and prevention of pesticide poisoning and where means of reducing exposure such as personal protective devices, may not be easily available (WHO/UNEP, 2001).

The application equipments used in developing countries are poorly maintained and supplies are usually inadequate. Pesticides are often applied with efficient hand sprayers, ox -drawn sprayers, or dusting equipments, and inadequate protective clothing is used (WHO/UNEP, 2001). In addition many pesticides are applied by people wearing inadequate or unsuitable clothing, which are frequently worn for extensive periods after being contaminated by pesticides. Besides, workers are also exposed as a result of re-entry into sprayed areas. This increases the overall exposure of the individual. Moreover, in hot climates, protective clothing can seldom be used, because the temperature inside the clothing gets so high that the workers are not comfortable. Infact, in many developing countries, the hot climate and the general lack of education make pesticides use dangerous to the operator (Forget, 1991; Ojo, 2016).

In developing countries, pesticides are generally applied by farmers and farm workers (agricultural workers), many of whom have insufficient education and training in different methods of application. The farmers often lack awareness of the potential hazards and do not take elementary precautions. For this reason, an effective network of extension and advisory services, which provide technical advice on the safe use of pesticides, can be of great value in preventing health effects. Many developing countries have inadequate or no extension service and advice mainly come from representatives of pesticide manufacturers and traders. Furthermore, pesticides are often applied at too frequent intervals, particularly when they are first used in a country at a time when yields increase dramatically (WHO/UNEP, 2001).

The labeling and packaging of pesticides in developing countries are often inadequate and inappropriate for the area where they are used (WHO/UNEP, 2001). The advice is often written in a language that the user does not understand and the toxicity is either explained poorly or not at all. In addition, the appropriate uses of the pesticide are usually not stated clearly and the dosages not specified (Kimani & Mwathi, 1995). Although guidelines on good labeling practices have been published by FAO these technical details are of no use when presented to illiterate farmers or if entrusted to agricultural extension workers who may not understand them (FAO, 2015).

In most developing countries, there is bewildering range of formulation of the same chemicals often prepared locally. Unscrupulous formulators add diluents or use expired ineffective chemicals. In this connection, it may be noted that the World Bank, in its guidelines for use of pesticides in projects financed by the Bank, recommended that materials that are likely to become widely distributed should be made available only in relatively low toxicity formulations (Mont, 2007; WHO/UNEP, 2001). The recommendation is based on the concept that complete protection of workers cannot be expected under other conditions (Mont, 2007). Water soluble packages and free flowing granular and micro-encapsulated formulations are safe to use (WHO/UNEP, 2001). Although the last two are at present, very expensive, especially for the small scale farmers.

2.8 Cholinesterase inhibition as an indicator of organophosphate and carbamate pesticide exposure

Organophosphates and carbamatess are the most common pesticides used in Kenya and other developing countries and are responsible for most of pesticides poisoning reported (Macharia, 2015). Organophosphates and N-methyl carbamate pesticides inhibit cholinesterase causing first excitation and then depression of the parasympathetic nervous system. Recovery from organoposphate induced cholinesterase inhibition is more prolonged than recovery from carbamate induced inhibition which is rapidly reversed usually within 24 hours (Miyata *et al.*, 1994). The enzyme, cholinesterase, hydrolyses the neuro transmitter of acetyl choline at the cholinergic nerve synapses and its inhibition effects on the nervous system is the most meaningful index of the risk of poisoning. Cholinesterase monitoring usually involves measuring the cholinesterase activity of the red blood cells (RBC) or plasma from blood samples (i.e. the enzyme levels) and this provides fairly sensitive method for detecting exposure to organophosphate or carbamate pesticides (Jansen, 2004).

Although baseline blood cholinesterase is subject to considerable intra and inter person variability, cholinesterase activity is often used in reports of organophosphate and carbamate pesticide exposure. Because the range of normal cholinesterase level is wide, optimal cholinesterase monitoring requires the periodic comparison of blood cholinesterase activity values with an individual's cholinesterase baseline value established prior to cholinesterase inhibiting pesticides (Hayes, 1992; Chu and Yuting, 2018; Ratner *et al.*, 1989; Ritter and Franklin, 1989). Inhibition of cholinesterase to levels ranging from 60% to 25% of an individual's baseline value (a depression of 40% to 75% below baseline) may result in respiratory difficulty, leading to unconsciousness, pulmonary oedema and death due to respiratory arrest may result necessitating the removal of the individual from exposure until his or her cholinesterase level reverts to at least 80% of baseline (Ames *et al.*, 1989). Resting of workers is normally recommended when acetylcholinestrase inhibition is 70% of baseline, which is also the WHO recommended level for removal of workers from exposure.

2.9 Contamination of the environment and effects on biodiversity

Residues from pesticides may spread to the soil and aquatic compartments causing harm to both terrestrial and aquatic organisms. Contamination of surface water in agricultural areas is often the case, affecting both the fish and general aquatic life (Subashiny & Thiruchelvam, 2008). Effects of birds' populations and other beneficial arthropods are often indirectly attributed to pesticides, as an effect operating through ecological web (South & Henderson, 2000). It was found that reduction in number of birds during the breeding season due to reduced number of host plants forming a habitat for invertebrates' preys due to herbicides cause a reduction of weeds and seeds as food sources in winter (Subashiny & Thiruchelvam, 2008). This loss of biodiversity extends in all directions including wildlife. Residues of pesticides also find their way into domestic and drinking water (Subashiny & Thiruchelvam, 2008).

2.11 Sustainable Use of Pesticides

The 1987 report of the World Commission on Environment and Development (Brundtl & Report, year) stressed on sustainable development through human activity to progress the entire planet into a distance future (Feola, 2010). Hence sustainable development is "development", which meets the needs of the present without compromising the ability of the future generations to meet their own needs (WHO, 2007). This means that sustainable development must maintain overall quality of life, continuity, access to natural resources and avoid lasting environmental damage. In view of these, efforts including those of research and development (R&D) institutes like the Tropical Pesticides Research (TPR) directed towards identifying the best practices in the use of pesticides are recommended (Audenhaege, 2009). Sustainable use of pesticides included effective use of pesticides in a catchment following good agricultural practices which include keeping records of pesticides, application rates, monitoring the environment for species diversity changes, risk assessment as well as adopting an Integrated Pest Management (IPM) techniques. Lalah *et al*. (2018) have described an integrated assessment approach for effective use of agrochemicals in an agricultural catchment and their potential risk assessment in a case study conducted in Nzoia Nucleus Estate sugarcane farms in western Kenya where herbicides were intensively used. The current research aimed at identifying potential risks of pesticides on ecosystem and human health based on farmers'health and residue levels in farm soil and horticultural produce for purpose of informing policy for sustainable development.

2.10 Parameters of effective, efficient and safe application of pesticides

It has been observed that limited knowledge results in serious environmental and health problems to users and non targeted organisms. In previous studies, field visits in monitoring and control of pesticides use revealed that farmers have inadequate knowledge in pesticides applications (Harari *et al.,* 997). Knowledge about appropriate, safe, effective and efficient pesticides applications is vital for that use pesticides. This knowledge is seldom offered as it should be at the university level including East Africa. The topic is often neglected and is never considered in detail in college curricula especially in developing countries (FAO, 2001). To be cost effective, safe, efficient and good biological efficiencyis necessary while protecting the environment and biodiversity. Pesticides application requires knowledge of behavior and biology of the target species in order to understand where and when the treatment will be effective.

Knowledge of pesticides formulations suitable for particular treatment and pesticides application technology and equipment is needed. Knowledge of how to use it, and monitoring of target species to evaluate the efficacy of the treatment is also necessary (Wilson, 1986). The ignorance of farmers concerning hazards of pesticides may cause them to mishandle these chemicals. The second issue is poverty. Inadequate funds both for the farmers and governments in the developing world has forced many farmers to use poor and leaking equipments, improper or no protective clothing, wrong or no antidotes and inadequate and poor handling of utensils and equipments. Another aspect is the issue of misleading advertisements and marketing practices. Due to present marketing competition, many pesticide companies are inclined to label and advertise the products misleadingly (AK'habuhaya, 1988).

Direct observation of pesticides handling, spray operations and disposal, have been made and confirms occupational exposure. Observation of household practices in pesticides storage and disposal, proximate to pesticides application and washing and food preparation establish that rural household members can be exposed through various routes. These observations are confirmed by measurement of pesticides residues in body tissues as well as acetylcholinesterase depletion. A larger body of experimental evidence based on vitro and in vivo models suggest that pesticide contamination and pollution damage the immune systems (Robert, 2005).

Most lapses in safety precautions occur in the developing world, where inadequate safety and hygiene practices are the norm while applying, formulating, storing, transporting and manufacturing of pesticides. Most farm workers are not trained in safe pesticides use and the few existing regulations that address farm workers safety are unrealistic or un-enforced. Pesticide warning labels do not ensure safe use often, they are printed incorrectly or in the wrong language and many users are illiterate. A survey by the Thai Division of the toxic substances found that 44% of the randomly selected pesticides formulations had the active ingredients incorrectly labeled (Tayaputch & Lichtenberg, 2001).

The major health problem arising from the use of pesticides is the acute and sub acute poisoning which results from repeated exposures during pesticides application. Studies from Sir Lanka have shown that approximately 1000 fatalities occur each year due to unsafe handling of pesticide. Extrapolating these figures to developing countries has, as a whole, suggested that about 220,000 fatalities are likely to occur annually. Estimates indicate that over 350,000 cases of pesticides poisoning occur in Kenya each year (Subashiny & Thiruchelvam, 2008). However pesticides and other agricultural chemicals can result in serious cases of poisoning through contaminated food and water (Choudhry, 2009).

2.11 Benefits of Pesticides

In the 1960's researchers began developing a different approach to pest control called "integrated pest management" IPM which is at aimed to keeping pests at economically insignificant levels by using crop production methods that discourage pests such as use of beneficial predators or parasites that attack pests and timing of pesticides applications to coincide with the most susceptible period of the pests life cycle (Hodgson *et al*, 2019). Eradication is not necessarily a goal or even desirable in some cases, because elimination of a pest may also cause the loss of the beneficial predators or parasites that need the pest in order to survive. IPM rarely is a substitute for using pesticides, rather it is more often used to improve the effectiveness or reduce the overall use of pesticides (Hodgson *et al*, 2019). The suggestion that a ban on pesticide use would help the environment may not be true because under the pesticide ban, the number of farmed acres would have to be increased to make up for the reduced per acre yields, which would in turn cause wide spread loss of wild life habitat. Without herbicides, farmers would probably have to cultivate fields more frequently to control weeds, which would lead to increased soil loss from erosion (Jefferson, 1997).

2.12 Perceived versus real risks of pesticides

Like many technological developments that improve the quality of our lives, pesticides can pose risks if they are not used judiciously. Few people would deny that medicines can reduce diseases and preserve life, but if they are not used without care they can be extremely hazardous. Berry (1991) and Bell (2005) pointed out that they will accept the risks associated with selling the analgesic drug, Paracetamol, over the counter in packets of five lethal doses, due to the benefits of easy access to pain relief and improvement in life quality that it brings. These examples provide parallel with pesticides, being technologies that make our lives better, provided they are regulated and used in such a way that the benefits significantly outweigh the risks. The potential benefits are particularly important in developing countries, where pesticides cost billions of dollars in national income and where horticultural and other food crop production has become very critical. On-farm, pre-harvest and post -harvest losses contribute to hunger and malnutrition, which kills between 12 million and 15 million children annually (Annan, 2005). According to United Nations Children's Fund (UNICEF) malnutrition is largely a silent and invisible emergency, exerting a terrible toll on children and their families (Bellart, 2005).

Weighting the risks against the benefits of pesticide use is not only hampered by the paucity of information on benefits, but also by the fact that most people are poor judges of the relative hazard that pesticides present. Based on earlier US data ranking 30 hazards on criterion of number of deaths per year, with number one being the largest number of deaths (Upton , 2000; Hibbett, 2009), pesticides were ranked very low at number 28 behind food preservatives which (ranked 27), home appliances ranked 15, swimming ranked seven and smoking and alcohol ranked 1 and 2, respectively. But public perceptions were very different, women voters thought that pesticides ranked number 9 in the list, and college students put them at number 4. Both groups performed poorly at estimating the relative risks posed by a list of hazards and their life cycle. Perhaps due to the predominantly negative publicity that pesticides receive, and lack of data on hazards caused by pesticides (Upton, 1982; Hibbett, 2009), there is irrational fear of pesticides as poisons regardless of the tremendous contribution they make in agricultural production. Information on pesticide benefits, regulation and effective use in agriculture is therefore very critical in developing countires. Moreover, food safety and health concerns among the general public have increased in Europe following serious incidents such as salmonella poisoning, *Bovine spongiform Encephalopathy* (BSE), foot and mouth disease in cattle and *Escherichia* coli infections (Hibbett, 2009). Pesticides residues in food detected at lower levels due to increasingly sensitive laboratory equipment are perceived to be associated with these issues and are lumped together with them as another of the evils of agricultural intensification (Ebi, 2005). However, the evidence does not support the popular view that pesticides residues represent a significant health risk in Europe and the U.S (Secoy, 2007).

Statutory maximum residues levels (MRLs) are the highest concentration of pesticides (expressed in mg/kg) legally permitted in or on food commodities and animal feed (Secoy, 2007). They are set by measuring the residue levels on harvested produce after it has been grown using good agricultural practice and in accordance with pesticides label instructions, provided this level does not constitute a hazard to consumers. In fact, contrary to public perception, MRLs are far below any level that would be hazardous to consumers, they are usually not approved unless they are factor of at least 100 below the no observable adverse effect level (NOAEL). The UK pesticides residue committee annual report of 2002 found that over 70% of the food in the UK contained no detectable pesticide residues and only 1.09% contained residues above the statutory MRLs. It concluded that "none of these residues caused concern for people's healths".

This backed by Brown (2004) and Bell (2005) of the UK food standards Agency, who said "there are no safety concerns or we would take action immediately". Controlling pests in pasture can also bring significant livestock productivity benefits. By using a single carefully timed insecticidal spray costing us 10 /ha to control red legged earth mite in clover, Australian sheep farmers have increased the value of their wool yield by 50% (Ridsill -Smith *et al*., 2000).

Herbicides are the most widely used types of pesticides since weeds are the major constraint that limit yield in many crops. Herbicides represent around 50% of all crop protection chemicals used throughout the world, compared with insecticides and fungicides that are around 17% each (Crop-life, 2004).There are knock-on benefits of these primary benefits. If marketable yields and quality are increasing, farm revenues are likely to increase. A higher yield means less pressure to cultivate un-cropped land, a wider benefit to biodiversity and the environment as highlighted by Mc Neely and Scherr (2008). In turn, regional and national agricultural economics become more buoyant and revenues from exports of high quality produce bring in much needed foreign exchange. The last factor is particularly important in some developing countries that export fruits and vegetables to the US and Europe, where the unintended presence of certain flora and fauna in the produce can be a major barrier to international trade (IPPC, 1997). Consumers in developed countries gain too from the wider range of imported crops that are available for communities also allows better nutrition, which carries over into healthier levels; healthier people are by and large also happier people, who are more productive and able to contribute better to their society. This contrasts with the situation where poor nutrition resulting from limited food suppliers increases, reducing people's energy and productivity in a vicious circle of deprivation pesticides can help break this circle that threatens security of personal livelihoods and quality of life (Annan, 2005).

Reliability of production is economically important to any producers and, to the resource poor communities with no financial or food reserves, it is critically important. It is no good having adequate harvest for 3years if there are large losses in the fourth year. By reducing risk of catastrophic loss to pests and diseases, pesticides are a tool to help deliver food security and dependable livelihoods from farming (Aspelin, 2003). Many people now expect and enjoy a healthier and longer life than in the past. Average life expectancy, affordability and overall consumption of fruits and vegetables are vital protection against cancer (Lewis & Rund, 2004).The nutritional properties of apples and blue berries in the US diet had concluded that their high concentrations of antioxidants act as protection against cancer, heart diseases and other chronic diseases associated with oxidative stress ad ageing.

Lewis attributed doubling in wild blue berry production and subsequent increase in consumption chiefly to herbicide use that improved weed control and attributed the all year round availability of inexpensive and good quality fresh fruits and vegetables largely to the use of pesticides. Herbicides replace the back breaking work of manual weeding and reduce fossil fuel requirements for mechanical cultivation (Gianessi & Janet, 2000). The reduction in the need for manual weeding is particularly significant in sub-saharan Africa where HIV/ AIDS has resulted in shortages of labour and many adults being too ill to work (Hainsworth *et al.,* 2000). When herbicides are used, the available labour can be reserved for other productive activities. Improved nutrition clearly improves the quality of life of rural communities, and it is surely what most people are seeking to improve, whether it is through money, work satisfaction, home, life or more time for recreation. An improved quality of rural life can contribute to a slowing down of dramatic rural to urban exodus, as people try to escape the poverty and suffering of agricultural communities (Baron *et al*, 2007), only to find themselves in deeper poverty in town with no viable opportunities afforded by herbicides to reduce mechanical cultivation in larger scale agriculture clearly have wider national and international benefits in reduced production of greenhouse gases, as well as slowing down soil erosion on sloping lands and reducing moisture loss from soil surfaces (Bates & Denton, 2007). Pesticides can also improve the quality of the produce (Kolbe *et al*., 1982) including its safety because when stressed or attacked by diseases, many plants or the pathogenic organisms causing the diseases produce chemicals that are toxic.

An extreme example is the cereal disease *Claviceps purpurea* that produces highly toxic sometimes lethal alkaloids in the grain under certain conditions unless protected by a fungicide. The use of fungicides can reduce the incidence of such fungal contaminants (Joshi, 2018). Joshi (2018) studied the influence of 10 commercial fungicides and insecticides on growth and formulation of afflatoxin B, by aspergillus parasiticus. Four of the five fungicides investigated in concentrations corresponding to commercial practice inhibited growth and toxin production in the laboratory media. Pesticides used in stored products can prolong the viable life of the produce and prevent huge post-harvest losses from pest and diseases (Dales & Galob, 1997). Dales and Galob (1997) reported that the insecticides can protect stored grain in bags or bins from insect spoilage. Their trails in Tanzania showed that larger grain borer *Prostephanus truncates* and S*itophilus* species can be controlled for at least 9 months by applications of insecticide-mixtures used in small quantities as protectants of shelled maize also reported on chemical control of stored product insecticides with fumigants and residual treatments and wrote that pesticides are often the cheapest and most efficient strategy available (Zettles & Arthur, 2000).

Different types of pesticides are used in Kenya for the control of various pests and diseases. About 80% of pesticides registered for use in Kenya fall under agricultural use while the remaining fall under public health and veterinary use. Pesticides users in Kenya are mainly pest controllers and small scale farmers. These groups encounter health risks while handling pesticides in different ways, in particular when safety precautions are not adhered to. The risks of being poisoned depend on the extent of exposure to the pesticides (Nguyen & Dang, 1999). All pesticide users should read the label and follow the instructions accordingly. Other protective measures while handling pesticides include; physical body protection by wearing full protective gear, and following good management of pesticides in storage premises. Field visit monitoring pesticide usage revealed that handlers including farmers do not follow safety precautions, while handling pesticides (Fenske, 2002). Therefore, there is need to follow known pesticide use safety procedures as well those indicated on the lables while handling pesticides as this will help reduce the risk to pesticide handlers and safeguard the environment (Murphy *et al.*, 1999)

2.13 Pesticides and Ecosystem Health

Fresh water system are created by water that enters the terrestrial environment as precipitation and flows both above and the below towards the sea (Chapman, 1998). These systems encompass a wide range of habitat including rivers, lakes, and wetlands and then riparian zones associated with them. Their boundaries are constantly changing with the seasonality of the hydrochloric cycle. Their environmental benefits and cost are distributed widely across time and space, through the complex interactions between climate, surface and ground water, and coastal marine areas (Chapman, 1998).

Fresh water ecosystem in rivers, lakes, and wetlands contain only small fraction 0.01% earth water and occupy less than one percent of the earth’s surface (Chapman, 1998; Waterhouse, 2009). The different types of pesticides used globally could potentially leach to these ground water resources. Although, the application of pesticides has decreased within last decade this does not necessarily indicate a decrease in environmental impact as new pesticides continues to be released into the market (Damalas & Eleftherohorinos, 2011).

Munga, 1985 conducted a study in Hola irrigation scheme, which demonstrated a strong correlation between DDT and emulsification tissue residue and the level of fat in fish study that involved four species had highest DDT residue level of 423 mg/kg (Munga, 1985). Sediments serve as the habitat for benthic biota such as insects which are commonly consumed by fish). They also serve as both source and a removal mechanism for some contaminants to and from the stream, and as the vehicle for contaminant transport downstream (McCready, Slee, & Taylor, 2000). Aquatic biota is also important in the food web of terrestrial animals such as wildlife. Analyzing contaminants in sediments and aquatic biota provides an efficient way to test the presence of hydrophobic contaminants and their implication for the ecosystem health examined organochlorides and organophosphorus compounds levels in water, soil and fish samples from lakes Victoria. In general, the residues levels ranges from BDL-0.44mg/kg in water, BDL- 481.8 mg/kg in fish samples and BDL-65.48mg/kg in fish samples Diedrin *P,P'*-DDT, Heptachlor, endosulfan sulfate and Lindane (which are all organochrorides) had the highest concentration (Abhik, 2008; Madadi, 2005). In a related study done in the Mount Kenya region, Kithure (2013) determined the impacts of rainfall patterns and location of agricultural activities on water quality of Tana River. Kithure (2013) looked at the distribution of various organochlorines including lindane and its isomers, heptachlor, aldrin, heptachlor epoxide, endosulfan I and II, endosulfan sulphate, dieldrin, endrin, p,p'-DDD, p,p'-DDT, endrin aldehyde, methoxychlor and chlorpyrifos, an organophosphate, in water, sediment and weeds along a transect of River Tana starting from upstream, midstream and up to downstream, respectively, i.e. by taking samples in the river at Makuyu, Sagana, Muranga, Kirinyaga, Tetu, Karatina, Marua, Kiganjo, Hombe and

Ndathi. She found a clear trend of total mean concentrations of organochlorine residue levels in water, sediment and weeds samples taken from the river which corresponded clearly with agricultural activities, season and location of the sampling sites, respectively. Kithure (2013) found the highest total mean concentrations of all the organochlorines in samples of sediment, water and weeds taken in the midstream part of the river which was adjacent to areas with highest history of agricultural activities compared with samples taken in the upstream and downstream, respectively. The totals of mean concentrations of OCs in water, sediment and weeds showed clear trends of sediment>water> weeds as well as dry season>short rains >long rains, respectively, which indicated that the OCs were just recycling in the water, with concentrations getting diluted in the wet season leading to their lower concentrations during the wet season. For chlorpyrifos, Kithure (2013) found that the concentrations were recent and therefore were getting washed off into the river from the catchment, with concentrations in water, sediment and weeds, respectively, highest during the wets season and in the midstream part of the river (at Karatina, Tetu and Marua), which is adjacent to major agricultural activities. The residue concentrations in water, sediment and weeds, followed the pattern: long rains>short rains> dry season. However, the concentration levels of both OCs and chlorpyrifos in the water and weeds were lower than the WHO lilmits for drinking water and vegetation of 40 μg/L and 50 μg/kg, respectively. Although this study showed the distribution of pesticide residues in the river and impacts of agriculture and rainfall changes on the health of the ecosystem, it did not indicate in particular where the pesticide residues could be originating from because no pesticide use survey was done to establish the types of pesticides being applied in the farms and their potential impacts on human and ecosystem health (Otieno, Schramm, Pfister, Lalah & Ojwach, 2013). The study also did not analyse the residues in soils in the farms adjacent to the river to determine whether the argicultural activities were in deed their sources in the water during rainfall (Kithure, 2013). In my project, these two aspects are covered because a pesticide use survey was done and residues were analysed in farm soils and horticultural produce to determine potential impacts on ecosystem and human health. Other researchers have recently found pesticide residues in water resources following pesticide application in farming, demonstrating pesticide usage impact on agricultural soils and surrounding water bodies. Muendo *et al*. (2012) conducted a survey to determine pesticide usage in Nzoia sugarcane subcatchment in western part of Kenya and analysed samples of farm soils and water in River Kuywa to determine the impact of pesticide application on ecosystem health of the river that is receiving wash off during rainfall. Organochlorines aldrin, dieldrin, endosulfan, p, p'-DDT, endrine and lindane were found to be present in farm soil, river water and sediment, with water concentrations ranging from 0.17 to 0.71 µg/L, despite the fact there was no current use of organocholines in the farms during the study (Muendo *et al*., 2012). In the same study the presence of herbicides atrazine, alachlor, hexazinone and diuron were recorded in river water at concentrations ranging from 0.74 to 1.98 µg/L (Muendo *et al.,* 2012). The herbicide residues detected in farm soil, river water and sediment were as a result of their extensive usage in the sugarcane farms, which was conbfirmed by recorded data by Nzoia sugarcane company (Muendo *et al*., 2012). Otieno *et al*. (2010) found carbofuran residue contamination in agricultural farm soils in Nanyuki, in the central part of Kenya where furadan was used in maize farming. In another study, Otieno *et al.* (2013) found residues of carbofuran, diazinon and chlorpyrifos in water and sediment of Lake Naivasha following contamination after their application in horticultural farming.

2.14 Analysis of PCB, OCs and OPs

Polychlorinated biphenyls (PCBs) organochlorine pesticides OCs are some of the persistence Organic pollutant (POPs) in the environment. The analytical methods for the analysis of polychlorinated biphenyis (PCBs) and organochloride pesticides (OCs) are available which are as results of vast amount of environmental analytical methods development and research on persistence organic pollutants (pops) over the past 30-40 years (UNEP, 2001). Critical to the successful application of this methodology is the collection, prepation and storage of samples as well as specific quality control and reporting criteria. The current trend to use isotope labeled analytical standards and high resolution mass spectrometry for routine POPs analysis is particular expensive (UNEP, 2001). The costs limit participation of scientists in developing countries and this is clear from the relative lack of publications and information on POPs from countries in Africa, South Africa and south Central America to modern capillary gas chromatography (GC) equipment with electron capture detector and low resolutions mass spectrometry (MS) detection to separate and quantity OCPs/PCBs is essential. PCBs and OCs can be considered together because they are extracted and analyzed together in most cases (Steve, Warwick, Marie, Joshua, & Douglas, 2005). In practice most laboratories determine about 30 or more individuals PCBs congeners, and 10-20 regardless of the sample matrix. Ongoing pops monitoring programmes vary in their analytic lists. For example, the integrated atmospheric deposition network (IADN) in the great lakes of north America includes over 100 PBC congeners (IADM, 1994), while the UNEP worlds bank GEF projection persistence organic pollutants , food security and indigenous peoples in Arcratic Russia included 15 PCB congeners (GEF, 2013). Organophosphate and organochlorides have similar methods of analysis because they are both hydrophobic organic compounds which can be extracted from their media only by use of organic solvents (Maroni, 2006; Maštovká, & Lehotay, 2004). However due to differences in chemical structure, organphosphate and carbamate pesticides and their metabolites are extracted more from soil and plant matrix by different methods, the most accepted method currently being Quetcher's method for multiresidue analysis (GEF, 2013).

2.15 Environmental impact of pesticides

The environmental impact of pesticides consists of the effects of pesticides on non-target species. Over 98% of sprayed insecticides and 95% of herbicides reach a destination other than their target species, because they are sprayed or spread across entire agricultural fields (Miller, 2004). Run off can carry pesticides into aquatic environments while wind can carry them to other fields, grazing areas, human settlements and undeveloped areas, potentially affecting other species. Other problems emerge from poor production, transport and storage practices (Tashkent, 1998). Over time related repeated application increases pest resistance while its effects on other species can facilitate the pests's resurgence (Damalas & Eleftherohorinos, 2011).

Each pesticide class comes with a specific set of environmental concerns. Such undesirable effects have led many pesticides to be banned, which regulations have limited and or reduced the use of others (Damalas & Eleftherohorinos, 2011). Over time pesticides have generally become less persistent and more species specific, reducing their environmental footprint. In addition the amounts pesticides applied per hectare have declined, in some cases by 99%. However, the global spread of pesticides use, including the use of older/ obsolete pesticides that have been banned in some jurisdictions has increased overall (Lamberth *et al.,* 2013).

While concern in ecotoxicology began with acute poisoning events in the late 19th century, public concern over the undesirable environmental effects of chemicals arose in the early 1960s with the publication of Rachel Carson's book, silent spring. Shortly thereafter, DDT, originally used to combat malaria effectively, and its metabolites were shown to cause population- level effects on raptorial birds and fish (Kohler & Triebskorn, 2013). Since the 70's therefore there has been increased concern and care just as new compound discoveries and production of pesticides for agriculture and veterinary purposes have continued to grow. Data on pesticides usage remains scattered and/ or not publicly available. The common practice of registration of poisoning incidents is inadequate for understanding the entirely of pesticide effects (Kohler & Triebskorn, 2013).

Since 1990, research interest has shifted from documenting incident and quantifying chemical exposure to studies aimed at linking laboratory, Mesocosm and field experiments. The proportion of effect related publications has increased. Animal studies mostly focus on fish, insects, birds, amphibians and arachnids. Since 1993, the United States and the European Union have updated pesticide risk assessments ending the use of acutely toxic organophasphosphate and carbamate insecticides (Kohler & Triebskorn, 2013). Newer pesticides aim al efficiency in target and minimum side effect in non-target organisms. The phylogenetic proximity of beneficial and pest species complicates the project. One of the major challenges is to link the results from cellular studies through many levels of increasing complexity to ecosystem.

2.15.1 Pesticide effects on soil

Many of the active ingredients in pesticide formulations are persistent soil contaminants, whose impact may endure for decades and adversely affect soil conservation (USEPA, 2007).The use of pesticides decreases the general biodiversity in the soil and therefore, not using the chemicals results in higher soil quality (Johnson, 2000). With the additional effect that most organic matters in the soil allow for higher water retention (Kellog, 2000). This helps increase yields for farms in drought years and, when organic farms have had yields 20-40% higher than their conventional counterpart farms with lower organic matter content (Lotters *et al.,* 2014). A smaller content of organic matter in the soil increases the amount that will leave the area of application, because organic matter binds to and helps break down pesticides (Kellog, 2000).

Degradation and sorption are both factors which influence the persistence of pesticides in soil, depending on the chemical nature of the pesticide (Baker & Benbrook, 2002). Such processes control directly the transportation from soil to water and in turn to air and into our food (WHO/UNEP, 1990). Breaking down organic substances, degradation involves interaction among micro-organisms in the soil. Sorption affects bioaccumulation of pesticides and is dependent on organic matter in the soil (WHO/UNEP, 1990). Weak organic acids have been shown to be weakly sorbed by soil, because of pH and mostly acidic nature of the soil. Sorbed chemicals have been shown to be less accessible to microorganisms. Aging mechanisms are poorly understand but as residence times in soil increase , pesticide residues become more resistant to degradation and extraction as they lose biological a activity (Areas-Estevez *et al.,* 2008).

2.15.2 Pesticide effects on plants

Nitrogen fixation ,which is required for the growth of higher plants, is hindered by pesticides in soil (Rockets, 2007).The insecticides DDT, methyl parathion and especially pentachlorophenol have been shown to intensify with legume-rhizobium chemical signaling (Rockets, 2007). Reduction of this symbiotic chemical signaling results in reduced crop yields (Rockets, 2007). Root nodule formation in these plants saves the world economy and 10 billion in synthetic nitrogen fertilizer every year (Fox *et al.,* 2007).

Pesticides can kill bees and are strongly implicated in pollinator decline and loss of species that pollinate plants, including through the mechanism of colony collapse disorder (Zettle & Arthur, 2002). In which worker bees from a beehive colony abruptly disappears. Application of pesticides to crops that are in bloom can kill honey bees which act as pollinators. The USDA and USFWS estimate that US farmers lose at least 200 million a year from reduced crop pollination because the pesticides applied to fields eliminate fifth of honey bee colonies in the US and harm an addition of 15% of the others side. Pesticides have some direct harmful effect on plants including poor root hair development, shoot yellowing and reduced plant growth (Walley *et al.*, 2006). Pesticide residues in soil in agricultural farmlands can also accumulate in plants and seeds up to toxic levels and have negative health effects on wildlife and human consumers (Otieno *et al.*, 2010).

2.15.3 Pesticide effects on animals

A pesticide harms many kinds of animals, resulting in many countries regulating pesticide usage through biodiversity Action plans. Animals including humans may be exposed to pesticide residues that remain on food, for example when wild animals enter sprayed fields or nearby areas shortly after spraying (Palmer, 2007). Residues can travel up the food chain for example birds can be harmed when they eat insects and worms that have consumed pesticides (Cornel University Education Program, 2007). Earthworms digest organic matter and increase nutrient content in the top layer of soil. They protect human health by ingesting decomposing litters and serving as bio indicators of soil activity. Pesticides have had harmful effects on groth and reproduction of earthworms (Yasmin & Souza, 2010). Some pesticides can bioaccumulate and build up to toxic levels in the bodies of organisms that consume them over time, a phenomenon that impact species higher on the food chain especially human (Du Toit, 1996).

2.15.4 Pesticide effects on Aquatic life

Fish and other aquatic biota may be harmed by pesticide- contaminated water Pesticide surface runoff into rivers and streams can be higly lethal to aquatic life sometimes killing all the fish in a particular stream (Helfrich *et al., 2014;* Riise, Lundekvam, Wu, Haugen, & Mulder, 2004). Application of herbicides to bodies of water can cause fish kills when the dead plants decay and consume the water oxygen, suffocating the fish. Herbicides such as copper sulfate that are applied to water to kill plants are toxic to fish and other water animals at concentrations similar to those used to kill the plants (Toughill, 1999). Repeated exposure to sublethal doses of some pesticides can cause physiological and behavioral changes that reduce fish populations, such as abandonment of nests and broods, decreased immunity to disease and decreased predator avoidance (Lorenz *et al.*, 2009).

Application of herbicides to bodies of water can kill plants on which fish depend for their habitat (Guillette, 1998). Pesticides can accumulate in bodies of water to levels that kill of zooplanktons, the main source of food for young fish (Pesticide Action Network North America, 1999). Pesticides can also kill insects on which some fish feed, causing the fish to travel farther in search of food and exposing themselves to greater risk from predators (Helfrich *et al.*, 2014). The faster a given pesticide breaks down in the environment, the less threat it poses to aquatic life (Bingham, 2007).

2.15.5 Pesticide effects on Amphibians

In the past several decades, amphibians' populations have declined across the world, for unexplained reasons which are thought to be varied, but of which pesticides are considered to be part of. Pesticide mixtures appear to have a cumulative toxic effect on frogs. Tadpoles from ponds containing multiple pesticides take longer to metamorphose and are smaller when they do, decreasing their ability to catch prey and avoid predators (Vos *et al*., 2006).

Exposing tadpoles to organochlorines (endosulfan) at levels likely to be found in habitats near fields sprayed with the chemical kills the tadpoles and causes behavioral and growth abnormalites. The herbicide atrazine can turn male frog into hermaphrodites, decreasing their ability to reproduce (Vos *et al*., 2006).

Both reproductive and non-reproductive effects in aquatic reptiles and amphibians have been reported. Embryonic exposure in turtles to various PCBs and persistent organochlorines causes a sex reversal. Across the United States and Canada disorders such as decrease in hatching success, feminization, skin lesions, and other developmental abnormalities have been reported (Vos *et al.,* 2000).

2.15.6 Pesticide residue effects on Humans

Pesticides can enter the body through inhalation of aerosols, dust and vapour that contain pesticides; through oral exposure by consuming food/water and through skin exposure by direct contact (Lorenz *et al*., 2009). Pesticides when discharged into soil and ground water which can end up in drinking water. Pesticide sprays can drift and pollute the air and also enter into the aquatic environment and terrestrial food chain (Birch, Begg & Squire, 2011). The effects of pesticides on human health depend on the toxicity of the chemical and the length and magnitude of exposure. Farm workers and their families experience the greatest exposure to agricultural pesticides in their fat cells (Lorenz *et al.*, 2009).

Children are more susceptible and sensitive to pesticides because they are still developing and have a weaker immune system than adults. Children may be more exposed due to their closer proximity to the ground and tendency to put unfamiliar objects in their mouth (DU Toit, 1992). Hand to mouth contact depends on the child's age, much like lead exposure in children under the age of six months who are more apt to experience exposure from breast milk and, inhalation of small particles pesticides tracked into the home from family members increases the risk of exposure (Du Toit, 1992). Toxic residues in food may contribute to a child's exposure. The chemicals can then bioaccumulate in the body over time (Du Toit, 1992).

Human exposure effects can range from mild skin irritation to birth defects, tumors, genetic changes blood and nerve disorders, endocrine disruption, coma or death (Lorenz *et al*., 2009). Developmental effects have been associated with pesticides. Recent increases in childhood cancers such as leukemia in throughout North America, may be a result of somatic cell mutations (Crawford *et al.*, 1997). Insecticides targeted to disrupt insects can have harmful effects on mammalian nervous system (Hodgson *et al*., 2019). Both chronic and acute alterations have been observed in exposees. DDTand its breakdown product DDE disturb estrogenic activity and possibly lead to breast cancer. Fatal DDT exposure reduces male penis size in animals and can produce undescended testicles (Hodgson *et al*., 2019).

2.16 Pesticide Drift

Pesticides can contribute to air pollution. Pesticide drift occurs when pesticides suspended in the air as particles are carried by wind to other areas, potentially contaminating them (GoK, 2006). Pesticides that are applied to crops can volatilize and may be blown by wind into other areas, potentiality posing threat to wildlife, depending on weather conditions at the time of application as well as temperature and relative humidity change with spread of pesticide in the air. As wind velocity increases, so does the spray drift and exposure (GOK, 2006).

Low relative humility and high temperature result in more spray evaporating. The amount of inhalable pesticides in the outdoor, environment is therefore often dependent on the season. Droplets of sprayed pesticide or particles from pesticides applied as dusts may also travel by wind to other areas (USEPA, 2007). Pesticides may adhere to particles that blow in the wind, such as dust particles (USEPA, 2007).

Farmers farther can further employ a buffer zone around their crops, consisting of empty land or non-crop plants such as evergreen trees to serve as wind breaks and to absorb the pesticide, preventing drifts into other areas such as processes control directly the transportation from soil to water and in turn to air and our food. Breaking down organic substances, through degradation, involves interaction with micro-organisms in the soil. Sorption affects bioaccumulation of pesticides which are dependent on organic matter in the soil (Vos *et al*., 2000). Weak organic acids have been shown to be weakly sorbed by soil (Areas-Estevez et al., 2008). Sorbed chemicals have been shown to be less accessible to microorganisms. Aging mechanisms are poorly understood, but as residence times in soil increase, pesticide residues become more resistant to degradation and extraction as they lose biological activity (Areas-Estevez *et al.*, 2008).

2.17 Pest rebound and secondary pest out breaks

Non-target organisms can also be impacted by pesticides. In some cases, an insect pest that is controlled by beneficial predators or parasites can flourish should an insecticide application kill both pest and beneficial population (Gordeziani & Gordeziani, 2007). A study comparing biological pest control and pyrethroid insecticides for diamond back moths a major cabbage family insect due to loss of insect predator has been done (Gordeziani & Gordeziani, 2007). Likewise pesticides sprayed to control mosquitoes may temporarily depress mosquito populations; however, they may result in a large population upsurge in the long run by damaging natural control (Gordeziani & Gordeziani, 2007). The phenomenon, where the population of a pest species rebounds to equal or great number than it was before pesticide use,is called pest resurgence and can be linked to elimination of its predators and other natural enemies (Howell, 2000).

Loss of predator species can also lead to a related phenomenon called secondary pest outbreak,an increase in problem from species that were not originally a problem due to loss of their predators or parasites (Howell, 2000). An estimated third of the 300 most damaging insects in the US were originally secondary pest and became a major problem after the use of pesticides. In both pest resurgence and secondary outbreaks, their natural enemies were more susceptible to the pesticides than the pests themselves, in some cases causing the pest population to be higher than it was before the use of pesticide (Aktar et al., 2009).

2.18 Eliminating pesticides

Many alternative are available to reduce the effects of pesticides have on the environment. Alternatives include manual removal, applying heat, covering weeds with plastic, plcing traps and lures, removing healthy soil that breed healthy more resistant plants, cropping native species that are naturally more resistant to native pest and supporting biocontrol agents such as birds and other pest predators (Aktar et al., 2009).

Biological controls such as resistant plants varieties and the use of pheromones, have been successful and at times permanently resolve a pest problem. Integrated pest management (IPM) employs chemical use only when other alternatives are ineffective. IPM causes less harm to humans and the environment. The focus is broader than on a specific pest, considering a range of pest control alternatives. Biotechnology can also be an innovative way to control pests strains can be genetically modified (GM) to increase their resistance to pest (Lewis, 2003). However the same techniques can be used to increased pesticide resistance and was employed by Monsato to create glyphosate resistant strains of major crops. In 2010, 70% of all the corn that was planted was resistant to glyphosate, 78% of cotton and 93% of all soybeans (Issa *et al*., 2010).

2.19 Current Environmental Sustainability Policy in Kenya with Respect to Agriculture

To ensure sustainable agricultural development, problems relating to environmental and disaster management need to be addressed. In Kenya, higher human and animal populations have resulted in additional agricultural activities and higher wood-fuel consumption rates leading to increased soil erosion, deforestation soil and water contamination (Ondieki *et al.,* 2004). In response to these problems, the government has enacted a National Environmental Action Policy and National Environmental Action Plan (NEAP), which laid the foundation for coordinated, multi-sectoral actions to address environmental issues (Ondieki *et al.,* 2004).

Environmental concerns will remain a key consideration in the country in order to conserve the existing resource potential for future generations and to meet the needs of the current generation. Proper environmental management has been a top priority for the government since independence. The National Development Plan of 1979 states “Environmental considerations must prevail upon development decisions at every level (Ondieki *et al.,* 2004).

In an effort to conserve the environment the government established the National Environmental Management Authority (NEMA) through the Environmental Management and Co-ordination Act (EMCA) of 1999, to exercise general supervision and co-ordination over all matters relating to the environment (Ondieki *et al.,* 2004). EMCA entitles each and every one to a clean environment but also requires us to safeguard environmental quality. There are other concerted efforts by government ministries and parastatals to safeguard the environment. Kenya is a United Nations (UN) member country and has pledged to achieve the millennium development goals number 7 by ensuring environmental sustainability (Ondieki *et al.*, 2004). The Kenyan government also ratifies treaties on POPs and other dangerous chemical substances and this has seen a number of organochlorine pesticides banned in the country to comply with UNEP ban (see list of banned pesticides). For sustainable development, the country needs to increase agricultural productivity to produce food for export and local consumption. The use of pesticides is therefore foreseen to increase in the future. However, PCPB is expected to play a leading role in controlling pesticide importation, ensuring that pesticides whose toxicities have been highlited and their use banned in other countries are not allowed into the country. In addition, for sustainable development efficient use of imported pesticides which involves regular environmental monitoring, risk assessment and education and awareness campaigns to farmers and the general public on pesticide use and its impacts on human health and the environment is mandatory. This is also the basis of this PhD project.

2.20 Biological Monitoring and Determination of Pesticide Exposure

Biological monitoring provides the basis for estimating an internal chemical dose by measuring pesticide and or/ metabolite compound concentrations in selected tissues fluids or bodily wastes of faeces and or urine (Woolen, 1993). The data generated using this guideline will serve as the basis for regulating chemicals in various settings including agriculture, industry and the residential market. This regulation will be based on the exposure and risk assessment process using the data. Additionally this data can be used in conjunction with concurrently gathered ambient chemical dissipation data to establish total exposure transfer coefficients that can be used in the exposure and risk assessment process to predict exposures for specific activities using ambient concentration data in the absence of scenario-specific exposure data. Monitoring pesticide or metabolite levels associated with short biological half –lives e.g. blood levels may be an appropriate measure of current or very recent exposures; monitoring associated with long biological half –lives may be an appropriate measure of integrated exposure over an extended period of time (ACGIH, 1990). The most appropriate methods of biological monitoring should be chosen based on a thorough knowledge and understanding of the pharmacokinetics of the specific pesticide in humans, whether recent or long term exposures are to be captured by the monitoring technique (Woolen, 1993). In contrast to biological monitoring which measures the pesticide or its metabolites in human tissue, biological effects monitoring i.e. use of biomarkers has been used to detect evidence of chemical exposure by measuring a biochemical response, such as changes in enzyme activity (Woolen, 1993). In other words, pesticide exposure is estimated based on an indicator property rather than through direct quantification of the chemical itself. This type of monitoring does not provide an indication of the potential for adverse effects dose cannot be estimated unless the correlation between exposure and biochemical response is well understood.

Biological effects monitoring has a long history of use in occupational settings correlations between levels of exposure to various industrial chemicals and covalent addicts between the chemical or its metabolite and hemoglobin have been reported (Ritter & Franklin, 1989; Robert, 2002). Specific examples of industrial chemicals for which this approach has proved, useful include ethylene oxide (Cullman *et al.,* 1978), chloroform (Pereira & Chang, 1982) and aniline (Neumann, 1984).

One example of biological effects monitoring with regard to pesticides is the use of cholinesterase levels in the blood as an indicator of worker exposure to organophosphate pesticides (Ohayo-Mitoko, 1997; Ohayo-Mitoko *et al*., 2000). Attempts to correlate levels of cholinesterase inhibition with concentrations of pesticides and/ or their metabolite/analog compounds in blood have been generally unsuccessful because of the wide variability in cholinesterase levels among individuals. Because biological effects monitoring does not yet provide quantitative estimates of pesticide exposure, the focus has been on biological monitoring of pesticides and their metabolites in human body tissues or body fluids (Cairns & Sherma, 1992).

Analyses of blood and urine are the most frequently used types of pesticides biological monitoring. Blood analysis is used to measure current or recent exposures. However it is not as frequently used because of the invasive nature of the collection method. Urine analysis is used to measure the elimination of a pesticide and /or its metabolite/analog compounds as an indicator of exposure. The presence of the parent compound or known urinary metabolites has been used for almost four decades as an indicator of exposure to a number of pesticides including paraquat, arsenic (Wagner & Weswig, 1974), parathion, chlorobenzilate (Levy *et al.,* 1982), the phenoxy acid and organophosphate pesticides (Wagner, 1989). In recent studies Dong and coworkers (Dong *et al*., 1996) used urine monitoring with a pharmacokinetic model to stimulate doses of malathion in individuals exposed to trial sprays and evaluated urinary clearance of disodium octaborate tetra hydrate used for flea control on carpets and furniture (Dong *et al.,* 1996). Besides being used as an indicator of exposure, urinary metabolites have been used to confirm poisoning cases involving pesticides, including those involving organophosphates and carbamates (Davis *et al.,* 1982). Such studies have noted the relationship between pesticides and or metabolites analogue compounds in urine with exposure. However, more typically, no accurate quantification of exposure was able to be made from these data partly because of a lack of adequate understanding of the pharmacokinetics of the pesticides. Therefore it is emphasized that through knowledge of human metabolism and pharmacokinetics associated with that pesticide of interest is required for biological monitoring to be a useful technique for estimating doze. Pesticides /the metabolite/analog compounds may also be monitored through fecal analysis even through there is by comparison relatively little liberation on this approach. Analysis of sweating as a biological monitoring very recent exposure to volatile non poles pesticides, particularly some fumigants based on methodological considerations and ease of use, the main focus in biological monitoring of exposure will be the elimination of pesticides in urine. Urine is an ideal sampling matrix because its collection is relatively simple and non-invasive (Wilson, 1986).

Pesticides that are rapidly absorbed and are sequestered or metabolized to a greater extent are usually good candidates for biological monitoring. Also pesticides for which a quantitative relationship between exposure and urinary metabolites can be established are good candidates for biological monitoring (Ritter & Franklin, 1989). In contrast, pesticides may not be suitable for biological monitoring if they are excessively metabolized into a large number of metabolites) or if they are substantially retained in the skin. In addition, biological monitoring should not be considered if the pharmacokinetics in humans are not well characterized.

Potential pesticide exposure in human can also be assessed by analyzing farm produce such as fruits and vegetables in terms of pre-harvest and post-harvest residue levels. The horticultural sector in Kenya has become very successful, some the major exports including French beans, snow peas and flowers. The use of pesticides in this sector has also increased considerably. The assessment of the fate of pesticides in horticultural produce has recently attracted a number of researchers (Minot & Ngigi, 2004; Kingola, 2015; Macharia, 2015; Okworo, 2018). These studies have looked at residues in selected vegetables as well as the preharvest intervals in order to ensure that the residue limit requirements for European Uinion are met (Kingola, 2015; Okworo, 2018).

2.21 Surveys of Knowledge, perceptions and reported practices and observations

Forget (1991) reported that lack of information at all levels may be one of the most important causative factors of chemical intoxication in developing countries. He also recommended that further research should concentrate on behaviours leading to chemical intoxication. This should be done concurrently with proper prospective surveys. In addition, information should be sought relative to the decision processes of import, legislation and licensing. Research and Development efforts in appropriate technology and safety devices are also critically needed (Forget, 1991). Increased use of pesticides in farming can increase possibility of pesticide exposure and its associated risks to workers and residents in the surrounding farms. The importance of knowledge of recommended pesticide usage through education and awareness creation was reported by Tsimbiri *et al.* (2015), in a study where 801 respondents including farm workers and non-farm workers who were residents in Naivasha, the study area. They recommended training to planters, weeders and harvesters, apart from sprayers, because although sprayers might be trained and therefore more cautious when handling pesticides, weeders, planters and harvestors were found to have higher symptoms of pesticide exposure such as general malaise and headache than sprayers. In addition to having had proper training, sprayers also had state of the art equipment that protected them and decreased chances of exposure (Tsimbiri *et al.*, 2015). They went further to say that environmental contamination through air, soil, water, used containers, contaminated foods, drift, volatilization and home spraying are all potential sources of human exposure and therefore even those not working on farms such as flower farms need to be educated on pesticide usage and their impacts as they were also found to have similar symptoms of pesticide exposure though at comparatively lower incidence (Tsimbiri *et al*., 2015; WHO, 2001).

Ohayo-Mitoko (1997) described how knowledge and human behavior characteristics can lead to increased pesticide exposure in her PhD thesis dealing with occupational pesticide exposure among selected agricultural workers with respect to epidemiological and public health perspectives. The author describes lack of knowledge, pesticide handling, incorrect perceptions and dangerous practices among agricultural workers, such as failing to wear correct clothing and technical gear during spraying as well as knowledge, perceptions and practices of agricultural extension workers with respect to safe use of pesticides (Ohayo-Mitoko, 1997). Knowledge, perceptions, and practices of health care workers with respect to diagnosis, management and prevention of pesticide poisoning are also described. The author (Ohayo-Mitoko, 1997) used ‘preceed-proceed’ model for health promotion and evaluation to formulate recommendations for interventions in her study as well as blood acetyl cholinesterase levels to demonstrate human exposure. In the current study, knowledge and perceptions of farmers and healthcare workers are determined and the ‘preceedeproceed’ model is used. However potential ecosystem and human health impacts are demonstrated by analysis of pesticide residue levels in farm soil and horticultural produce.

CHAPTER THREE: MATERIALS AND METHODS

3. MATERIALS AND METHODS

3.1 Study area and Sampling

The study was conducted in Meru County. Meru County is found in the eastern region of Kenya, approximately 225 kilometers northeast of Nairobi. Meru County has a total area of 6,936 km^2 (Chiramba *et al.*, 2011) and lies within latitude 0.0515° N and longitude 37.6456° with an altitude of 5300 feet above the sea level. It has a population of 1,635,264 people (KNBS, 2019) and is among the fastest developing towns in Kenya (Jolicoeur, 2000). The growth is associated with rising vegetable and flower farming businesses in the areas selected for the study. Tourism and its related activities in the area together with relocations from rural to urban areas because of decreasing farming incomes from the conventional cash crops have also been contributing factors towards this growth (Jolicoeur, 2000). Meru County has a total of nine sub counties namely Igembe north, Igembe central, Igembe south, Tigania east, Tigania west, Buuri, Imenti central, Imenti south and Imenti north.

3.1.1 Sampling area

Sampling was done in 3 sub counties namely Buuri, Imenti north and Imenti South (Figure 3.1), where ten (10) farms were selected from each sub county for soil and tomato sampling and another ten sites were also chosen from each of the three subcounties for French beans and kales sampling. The 10 farms were selected for their ease of access, avalbalility of the interviewees (farmers), the horticulture crop being grown in the farm.

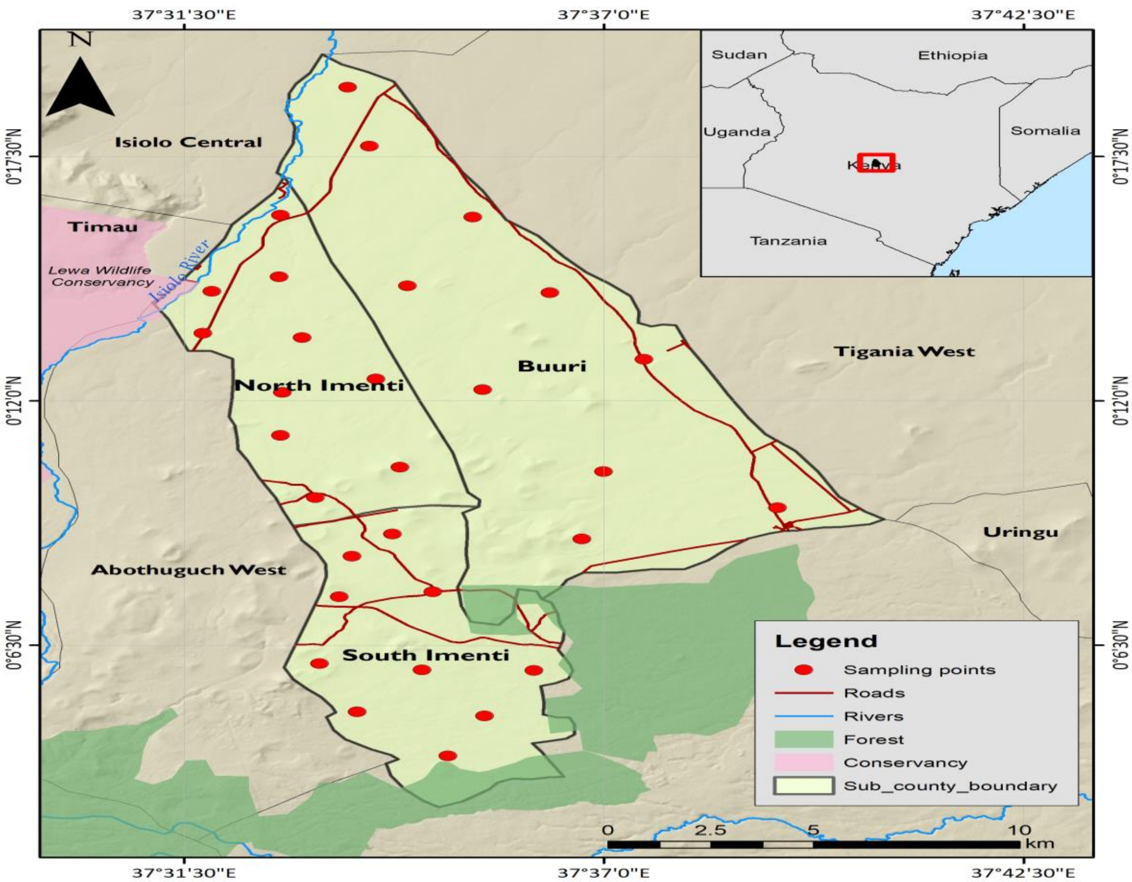

Figure 3.1: Map of Meru, Kenya showing the sampling sites

3.2 Pesticide use survey

Information on pesticides commonly used in Meru County was obtained through visits to the area Agriculture and Livestock extension officers, farmers and agrochemical dealers. The key places where the survey was conducted included North Imenti, Nouth Imenti and Buri. This was achieved using structured field questionnaires which were distributed to a total of 313 respondents chosen randomly (see Appendix 1 for questionnaire). The questionnaire consisted of both open and closed ended questions. Information was obtained on genders, age, main occupation, and level of education of the respondents.

The respondents were asked questions on pesticides used and safety information, training on the use and formulation of pesticides, pesticides related accidents and their frequencies, any known effects of pesticides to the users of any unlabelled pesticides and their source and any technical assistance from agricultural extension workers. Additional questions were designed to gather work information from the agro-veterinary dealers and the extension workers. The questions touched on awareness on safe handling of pesticides, stock pesticides within the area as well as emerging issues.

3.3 Household questionnaire

The study was conducted in three sub counties in Meru namely Imenti south, Imenti North and Buuri. The Area Ecological Zones (AEZ) for the sub-Counties were LM3, UM3 and LH2, for Imenti south, Imenti North and Buuri, respectively. Sample distribution by sub-county and AEZ. A total sample of 173 respondents was pickedand the formula used to pick the sample is provided below with Confidence interval of (90, 95, 99%).

The proportion of the sample was determined to be i.e. 80% of the total population. With a Margin of Error (ME) of this was used to determine the sample size.

$$ss = \frac{z^2 \text{x } p(1-p)}{c^2}$$

Where:

ss=sample size

z=z value (in this case 1.96 for 95% confidence interval level)

p=percentage of selecting respondents expressed as decimal, i.e. 80% (0.8)

c=confidence interval, expressed as decimal

Sample distribution by sub-county and area ecological zone is provided below.

Table 3.13: Sample distribution by sub-county and area ecological zone

Variable	Sub- county	No.	Percentage
	Not specified	5	3%
	Imenti South	49	28%
	Imenti North	65	38%
Sub-county	Buuri	54	31%
	Not specified	5	3%
	LM3	49	28%
	UM3	65	38%
Area Ecological Zone	LH2	54	31%

The health care workers were interviewed using the PRECEDE- PRECEEDE method.

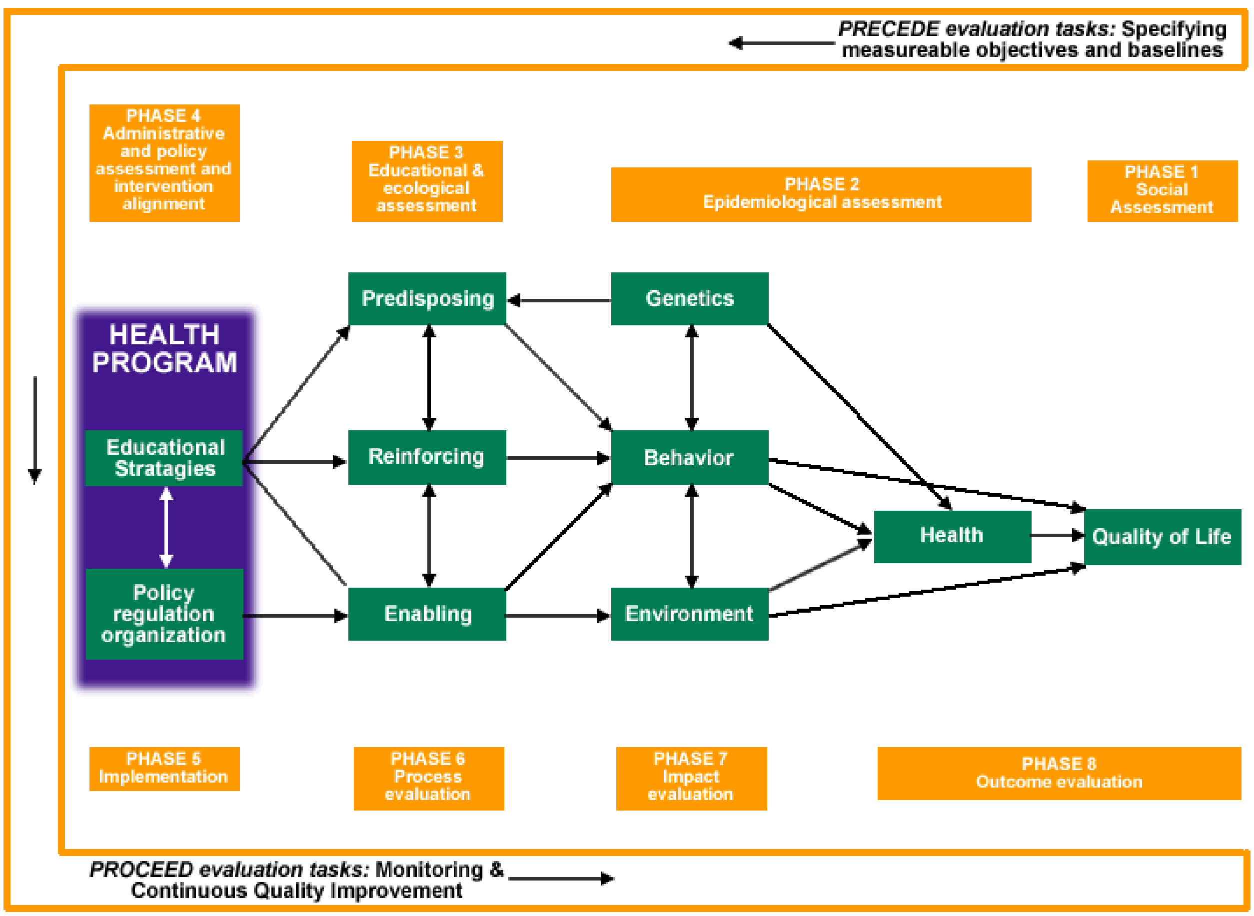

Figure 3.2: PRECEDE- PROCEED Model

3.4 Chemicals and reagents used

Dichloromethane, n-hexane and acetone (all general purpose) and HPLC grade iso-octane were bought from SCIELAB LTD, Nairobi. The general purpose grade solvents were triple distilled in the laboratory before use. Anhydrous sodium sulphate and aluminium oxide, both analytical grade, were also bought from SCIELAB LTD, Nairobi. High purity Nitrogen, used for reducing samples, was purchased from Gas labs LTD. Hydrogen that is of very high purity, white spot nitrogen together with helium used for gas chromatography were bought from BOC Kenya LTD, Nairobi. High purity pesticide standards and pesticide standard mixtures, which were of very high purity, were provided by the PCPB (Pest Control Products Board).

3.5 Equipment and apparatus used

The Soxhlet set up was used in extracting kales and soil samples. It is made upof a heating mantle, a condenser together with a Soxhlet extractor. Extraction from water samples was done using a 2 litre separating funnel. Clean up of the samples was done using a 25 cm long glass column with an internal diameter of 1.5 cm. The extracted samples were then concentrated using the Stuart rotary evaporator. A fractional distiller was used for distilling the solvents. BINDER E28♯04-71528 oven was used for drying the soil, kales, tomatoes and French beans samples so as to determine the moisture content. Glassware were dried in a Mammoth oven above 100 ^{o}C.

Weights for all the samples were taken using the analytical weighing balance (Fisher Scientific A-160). A lab-line explosion proof refrigerator was used to temporarily store the samples before extraction. A HP Agilent GC system equipment with ECD and a GC-MS (HP 6890 PLUS) combined with an auto sampler (Agilent 6890 series injector) were used for quantification of pesticides in the samples extracts.

3.6 Preparation of reagents

Drying of Aluminium oxide (Al_2O_3) was done overnight at 200 ºC in order for it to be 100% active. Deactivation of the Al_2O_3, so as to achieve Al_2O_3 (8% w/w), was done using water. This was done by adding 8 ml of HPLC water to 92 g of the Al_2O_3 that had been activated. The process was done in a 250 ml Erlenmeyer flask and it involved shaking the mixture by hand so that all the lumps could be eliminated. These chemicals were then left in the oven again at 200ºC to condition.

3.7 Sample Collection

3.7.1 Soil sampling

Soil samples were collected from thirty farms, ten from each sub county. Sampling sites were randomly selected within each farm. Soil cores were dug using a pre-cleaned hoe and scooped using a stainless steel shovel from a depth of 15- 25 cm from five different locations within each farm and approximately 200 g of the core scooped. The five (5) cores were combined and 500 g of the soil was then placed on clean aluminium foils, wrapped and put inside a black polythene bag labelled' packed in self-sealing bags, put inside cooler boxes and transported to the laboratory. They were then preserved at -20ºC in the refrigerator prior to extraction (UNEP, 2010).

3.7.2 Kales sampling

Kales samples were collected from thirty farms, ten from each sub county. Sampling sites were randomly selected within each farm. Fifty (50) g of the vegetables (kales) was collected in triplicate from each of the thirtysampling sites. The samples were packed in clean self-sealing bags, clearly labelled and transported to the laboratory for storage in a refrigerator at 4ºC, awaiting extraction

3.7.3 French beans *(Phaseolus vulgaris)* sampling

French Beans samples were collected from thirty farms, ten from each sub county. Sampling sites were randomly selected within each farm. Fifty (50) g of the French beans was collected in triplicate from each of the thirty sampling sites. The samples were packed in clean self-sealing bags, clearly labeled and transported to the laboratory for storage in a refrigerator at 4 ºC, awaiting extraction.

3.7.4 Tomatoes (*Solanum lycopersicum*) sampling

Tomatoes samples were collected from thirty farms, ten from each sub county. Sampling sites were randomly selected within each farm. One hundred (100) g of the tomatoes was collected in triplicate from each of the thirty sampling sites. The samples were packed in clean self-sealing bags, clearly labeled and transported to the laboratory for storage in a refrigerator at 4 ºC, awaiting extraction.

3.8 Sample extraction for OCPs analysis

3.8.1 Extraction of soil samples

Soxhlet extraction (EPA method 3540) was used in soil extraction (USEPA, 1996). Before extraction, the soil samples were taken from the freezer and left to thaw for 6 hours. Twenty (20) g of anhydrous sodium sulphate was used to dry 20g of the soil sample; this was done by grinding and mixing them thoroughly in a Pestle and Mortar. The mortar containing the dried soil sample was then covered with an aluminium foil and left to stand for about 12 hours. The process was done in triplicates for each of the samples. Extraction was then carried out for sixteen hours in the Soxhlet using a mixture of hexane together with acetone (200 ml) in the ratio of 3:1, respectively. After the sixteen hours, the Soxhlet extractor was turned off and the extracts allowed cooling. This was followed by an addition of 2ml of isooctane, which acts like a keeper and the extracts concentrated using a rotary evaporator to about 3ml. The concentrated extracts were thereafter transferred into vials using Pasteur pipettes and stored in a refrigerator at 4ºC pending clean-up.

3.8.2 Extraction of kale *(Brassica oleracea var. sabellica)* samples

Kales were extracted using USEPA method 3510 (USEPA, 1996), which involved using a mixture of hexane and acetone in the ratio of 3:1, respectively. This is a method used for the extraction of pesticide residues in non-fatty crops. Twenty (20) grams of the vegetable samples were dried overnight in an oven and mixed with anhydrous sodium sulphate in a Pestle and Mortar. This was done in triplicates for all the sites.

The kales were then extracted in a Soxhlet for sixteen hours using a 200 ml mixture of hexane and acetone in the ratio 3:1. The extracts were allowed to cool and 2 ml of iso-octane added to act as a keeper. Using a rotary evaporator, the extracts were then evaporated to 3ml at 35ºC. The concentrated extracts were then transferred into clean vials, tightly capped and stored in freezer at 4ºC pending clean up.

3.8.3 French beans samples extraction

French beans were extracted using USEPA method 3510 (USEPA, 1996), which involved using a mixture of hexane and acetone in the ratio of 3:1, respectively. This is a method used for the extraction of pesticide residues in non-fatty crops. Twenty grams of the vegetable samples were dried overnight using anhydrous sodium sulphate in a mortar. This was done in triplicates for all the sites.

The kales were then extracted in a Soxhlet for sixteen hours using a 200ml mixture of hexane and acetone in the ratio 3:1. The extracts were allowed to cool and 2 ml of iso-octane added to act as a keeper. Using a rotary evaporator, the extracts were then evaporated to 3ml at 35°C. The concentrated extracts were then transferred into clean vials, tightly capped and stored in freezer at 4°C pending clean up.

3.8.4 Tomatoes samples extraction:

Tomatoes were extracted using USEPA method 3510 (USEPA, 1996), which involved using a mixture of hexane and acetone in the ratio of 3:1, respectively. This is a method used for the extraction of pesticide residues in non-fatty crops. Twenty grams of the vegetable samples were dried overnight using anhydrous sodium sulphate in a mortar. This was done in triplicates for all the sites.

The kales were then extracted in a Soxhlet for sixteen hours using a 200ml mixture of hexane and acetone in the ratio 3:1. The extracts were allowed to cool and 2 ml of iso-octane added to act as a keeper. Using a rotary evaporator, the extracts were then evaporated to 3ml at 35°C. The concentrated extracts were then transferred into clean vials, tightly capped and stored in freezer at 4°C pending clean up.

3.9 Cleaning up of extracts

3.9.1 Cleaning up of kale, tomatoes and french beans extracts:

Cleaning up of the kale tomatoes and French beans samples was done as follows; a 25 cm long chromatographic column with an internal diameter of 1.5 cm was filled with 2 g of activated anhydrous Na_2SO_4 then with 15g of deactivated Al_2O_3 and topped up with 3 g of activated charcoal (decolourizer) and finally another 2 g of activated anhydrous sodium sulphate.

Preconditioning of the column was done using 15 ml of triple distilled n-hexane. The residue in 3 ml hexane: acetone mixture was poured into the column and the vial rinsed three times with 1 ml hexane. The analytes were then eluted by adding 175 ml of n-hexane into the column. Two (2) ml of iso-octane was then added to the cleaned extract which was then concentrated to around 3ml under vacuum evaporator. The same process was applied to all the samples. The last extract was reduced to 0.6 ml under a mild stream of nitrogen. At this point the samples were ready for GC analysis.

3.9.2 Soil samples extracts

Cleaning up of the soil samples was done using a chromatographic column filled with 2 g of activated anhydrous Na_2SO_4 followed by 15 g of deactivated Aluminium oxide and lastly by 2 g activated anhydrous sodium sulphate. The column was conditioned with 15 ml of n-hexane and the sample mixture poured into it then the vial rinsed three times with 1 ml hexane. The analytes were then eluted using 175 ml of n-hexane. Two (2) ml of iso-octane was then added to the cleaned extract which was then concentrated to around 3 ml under vacuum evaporator. The same procedure was applied to all the samples. The last extract was reduced to 0.6 ml using a mild nitrogen stream. At this point the samples were ready for GC analysis.

3.10 Removal of sulphur from soil samples

Approximately 1 g of copper powder that had just been activated was added to the already cleaned soil extracts in order to remove sulphur. All extracts containing Sulphur formed copper sulphide as indicated by the black colouration. Aglass funnel filled with glass wool together with 2g of activated anhydrous $Na_2SO_4$was used to filter the soil extracts. The anhydrous sodium sulphate was conditioned using 5ml of HPLC hexane and the samples introduced then 20 ml of HPLC hexane used to elute the analytes into a round bottomed flask. This was followed by an addition of 2 ml iso-octane before it was concentrated. The reduced extracts were transferred into clean auto vials and further reduced to 0.5 ml under a mild stream of nitrogen ready for GC analysis.

3.11 Determination of moisture content of kales, tomatoes, french beans and soil samples

Calculation of the moisture contents of the soil, kale, tomatoes and French beans samples was done using the difference between the wet and dry weight. This involved a 24 hour (at 105 ºC) heating of 5g of each of the soil and kales samples in pre-cleaned and pre-weighed watch glass in an oven (Model E 28♯ 04-71528). The moisture content was calculated using the formula below;

$$\text{Moisture content} = \frac{\text{Weight of wet sample} - \text{Weight of dry sample} \times 100}{\text{Weight of wet sample}}$$

3.12 Quechers Method for Multiresidue Analysis of Other Pesticides: Organophosphate, Carbamate and Other Pesticides.

For fresh samples of horticultural produce, tomatoes (22 samples), French beans (22 samples and Kales (20 samples), QuEChERS method was used. QuEChERS protocol was chosen as a method of extraction and clean-up step, which has been developed to be Quick, Easy, Cheap, Efficient, Rugged and Safe. The residues were extracted from the test portion following the addition of acidified acetonitrile. The mixture was centrifuged, filtered and directly analyzed by LC-MS/MS. Quantification was performed with the help of internal standard (tryphenyl phosphate), which wasadded directly to the test portion. The procedure details: samples were homogenized in a Stephan mixer and weighed into Polypropylene centrifuge tube size 50 ml. Extraction solution was added to the weighed sample, vortexed before adding salts and again vortex for one minute before centrifuging.

For clean up, after centrifugation the supernatant was transferred to a Polypropylene centrifuge tube size 50 ml and 150 mg $MgSO_4$, 50 mg PSA, 50 mg GCB were added to the extract and the contents well mixed by vortex for 30 seconds. After shaking and an additional centrifugation step the final extract was diluted to1:5 with 6.7Mm formic acid then final extract was analysed by LC-MS/MS. Agilent Technologies 1260 HPLC system with ESI source coupled with Agilent Technologies 6490 Triple quard LC/MS and masshunter software (B.06.00) was used for data acquisition and processing. The first step in developing the LC-MS/MS method was to determine the polarity of ionization to be used for detection of pesticide residues. The type of ionization used was based on which mode gave a higher ion count. Simultaneously, the ESI operating parameters were optimized during the infusion of a standard of mixed pesticides. Parameters were optimized to give high signal intensity of both molecular and fragments ions. This allowed the parameters for the MRM scan analysis to be determined concurrently for pesticides.

Product-ion scans were determined individually for each compound in order to determine the most representative or intense product ion that results after fragmenting the precursor ion. The specificity of the analytical method was vastly increased by monitoring a distinct fragmentation process for each compound in order to realize absolute quantitation (Hughes, 2006). All the residues were observed when positive ionization was chosen in the acquisition method during the Q1 scan analysis. The total ion chromatogram (TIC) that was generated depicts the signal intensity over the entire range of all m/z plotted against time. The extracted ion chromatogram for each corresponding compound was generated by extracting the ion of interest from the TIC. Ions of interest with the best precision of masses were chosen. Determination of the fragmentation pattern of the compounds was elucidated after consolidating the preferred instrumental parameters for ionizing the ions. Residues were detected in both mode of ionization.

During validation process spikes for qualifying residues were shown to have the retention time in the range + 0.5 min compared to standard solution and ion ratio of precursor ion and daughter ion in the range ± 25% compared to the ion ratio of standard. The pesticide residues were separated on a reversed-phase column, Zorbax Eclipse Plus column C18, size 2.1X100mm 3.5-Micron and detected by tandem mass spectrometry (MS/MS) by electrospray (ESI). Tryphenyl phosphate was used as internal standard for quantification. All pesticides were detected in the dynamic multiple reaction monitoring mode (DMRM). For each pesticide precursor ion and two product ions were determined. One product ion for quantification and one for qualification.

The calibration curve is determined by the analysis of each of the analytes at six calibration levels, i.e. 0.05, 1.0, 5, 10, 25 and 50, ppb. The calibration curves were in general best fitted to a linear curve. The majority of the correlation coefficients (R) were higher or equal to 0.995.

The method was validated for 375 pesticides in the vegetables. The validation was performed in 5 replicates for repeatability and five days for reproducibility on each sample with three spiking levels; 0.10 and 10 ppb.10 ppb is normally MRL for most vegetables and recoveries at this level gave good reproducibility results, thus was adopted as LOQ. Repeatability was calculated for all pesticides on all the spiking levels and is given as the relative standard deviation on the result from under same conditions while results due reproducibity was done under changed conditions.

The accuracy was determined by QC and recovery of spiked blank matrix at two concentration levels (0.1 and 10 ppb). For the pesticides to be accepted as validated the following criteria for precision and trueness must to be fulfilled: (i) the relative standard deviation of the repeatability should be ≤20%; (ii) the average relative recovery must be between 70 and 120%; (iii) the ion ratio shall be of ± 25% compared to the ion ration of standard. For preparation of the samples before analysis, solvents and reagents (LC-MS grade) were used in sample preparations and pesticides reference standards, purity >99.5% were all sourced from Sigma-Aldrich, stock solutions were prepared in acetonitrile by dissolving the standards in 1mg/ml. Mixed working standards solutions were prepared in a concentration range of 0.05 to 50 µg/ml.

The residues were extracted from honey samples using QuEchERS protocol (quick, easy, cheap, rugged and safe) by weighing 10g of the samples in to poly propylene disposable centrifuge tube-50 ml, and then 10 ml of acetonitrile with 0.1% acetic acid were added and shaken before adding QuEchERS salts to induce phase separations. The extracts were then cleaned and 5.0µL was injected in to high performance tandem mass spectrometry (LC-MS/MS). Quality control was performed by spiking targeted mixture of pesticide residues to blank samples at LOQ levels. Recoveries were evaluated and were shown to be within the acceptance range of 70-120%.

3.13 GC Analysis and quantification of the extracts

Kales, soil, French beans and tomatoes cleaned extracts were analysed for selected pesticides using gas chromatography–mass spectrometry (GC–MS) on a 6890N GC instrument (Agilent, USA) equipped with a thermo scientific trace GOLD GC column (TG 5SILMS 30m X 0.25mm X 0.25 µm) coupled to an Agilent 5973 MS (USA). The mass spectrometer (MS) was operated in EI + mode in the resolution of >5000. Injection was splitless with a volume of 1µL to 280^{o}C, with helium as carrier gas at 1 ml min^{-1}flowrate. The injection temperature program applied was as follows: 90˚C (3 min), 90 ºC to 200 ˚C (at 30 ˚C/ min and hold time of 15 min), 200 ˚C to 275 ˚C (at 30 ˚C/min and hold time of 5 min). Chemstation software was used in data processing.

3.14 Identification and quantification

Organochlorine pesticides and pyrethroids as well as chlorpyrifos, carbedazim, imidaclopid, acetamiprid, azoxytrobin, matalaxyl and diazinon standards were used at various points in the analysis (Miyoshi, Yamana, & Tonogai, 1994). The choice of these standards was based on the survey results which indicated the various organochlorine, organophosphate, carbamate and pyrethroid pesticides being used in the farms in the three Sub-counties selected for this study (Samoh, & Ibrahim, 2008). The choice of standards was alsolimited by availability of the reference standards. Reference standards ranging from 0.01 mg/L to 0.981 mg/L were individually prepared for each standard and quantification was based on calibration curve calculations. Each standard gave a calibration curve with a straight line and the line of best fit drawn from the plot of the response factor (peak area) against standard concentration.

All analyte regression lines gave a correlation factor (R^2) above 0.99 for calibration standards showing high correlation between analyte concentration and instrument response ratio and peak area. Standard concentrations were obtained by interpolation from the graphs which applied the equation

$$Y = mX + c$$

Where Y = Normalised peak area (instrument response)

X = Standard concentration (ppb)

m = Gradient, and

c = Constant

Concentrations of the sample analytes were also obtained in the same way and, working backwards, various concentrations of the analytes in soil, kale, tomatoes and French beans sample on a wet weight basis were obtained.

3.15 Statistical Data Analysis

All results were recorded in Microsoft excel and Statistical Programme for Social Scientists (SPSS) and ANOVA, for calibration standards, survey data and tests of significance for residue levels, respectively. Representation of the results was done by use of tables as concentration ± standard error, graphs and statistical tables.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.0 RESULTS AND DISCUSSION

The survey reports were divided into three categories based on questionnaire given to household, agricultural extension workers and health care workers, respectively, in the three study sites Buuri, Imenti North and Imenti South subcounties. The following results and reports covered the specific objectives (i), (ii) and (iii) of the thesis. Household questionnaire covered age, gender, marital status, education background, farming experience (number of years the respondent was involved in farming), off-farming activities (keeping and sale of animals, permanent employment, gross income and values of the animals), financial assets, credit facilities available, source of information on pesticides, prior training on pesticide usage, sickness from pesticide usage and the types of pesticides used at the time of sickness and which social groups the respondent belonged to, respectively. The same questions also applied to agricultural extension and health care workers, except that for each of these two groups, specific questions that targeted their specific experiences in their respective professions were also asked as presented in this section. For extension workers such questions also targeted information on pesticide handling procedures such as labeling, protective clothing, storage, mixing, application rates, specific pesticides and the corresponding diseases experienced from exposure, education and awareness on pesticides as well as disposal, among others (Settimi, Masina, Andrion, & Axelson, 2003). For health care workers, the questions also targeted responses such as pestide usage, types of pesticides, symptoms of pesticide poisoning and ability to offer first aid against poisoning, among others.

The results are summarized and discussed in the following sub sections in Sections 4.1 and 4.2. More data from the survey are included in the Appendices II and XXX upto XXXXIII in the Apendix Section. The fourth objective is covered in Section 4.3.

4.1 Household questionnaire

4.1.1 Age of the respondents

A total of 173 household questionnaires were administered in the three sub-counties. Table 4.1 shows that most respondents were over 30 years.

Table 4.1: Age range of the respondents

Total	**Percentage**
Up to 15yrs	1%
16-30yrs	8%
31-45yrs	32%
46-60yrs	39%
>60yrs	21%

4.1.2 Marital status of respondents

The study found that 87 per cent of the respondents were married. Others were divorced and separated (8%), single (3 %) and widowed (2%). The Pie Chart (Figure 4.1) shows the marital status of the respondents. Most respondents were married (87%).

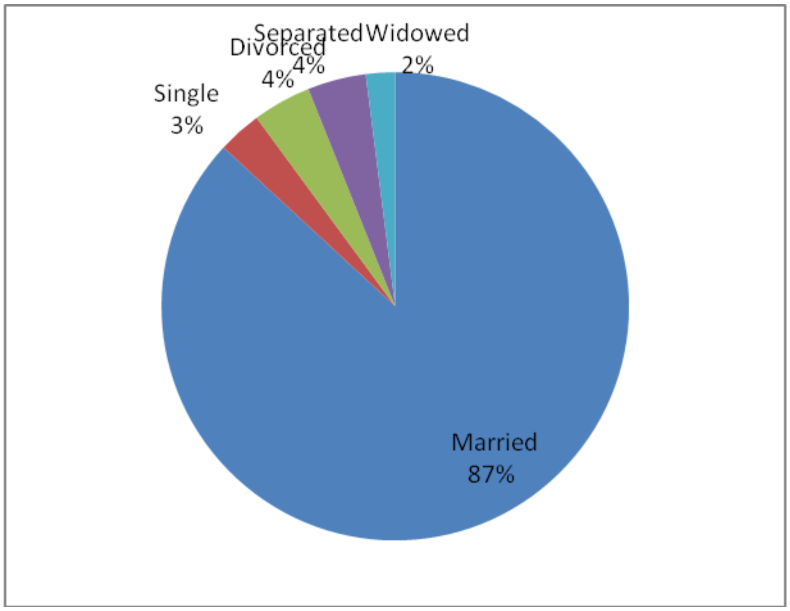

Figure 4.1: Marital status of the respondents

4.1.3 Education Background of the respondents

The study found out that most respondents (62%) had attained secondary or post-secondary education while 29% had primary education. Illiterate respondents were only 9%. More than half (56%) of the total respondents hired or employed farm workers. This varied by each sub-county i.e. 67% in Imenti North, 57% in Buuri and 46% in Imenti South. These workers were hired depending on the nature of work to be done either on a piece work, daily or monthly basis.

Table 4.2: Number of years in farming

No years	**Percentage**
Up to 5 yrs	10%
6-10 yrs	16%
11-15 yrs	13%
16-20 yrs	17%
21-25 yrs	7%
26-30 yrs	11%
>30 yrs	8%
Not specified	18%

About 52% of the respondents were involved in Food crops production while those involved in cash crop production and livestock were 29% and 12%, respectively. Others were casual labourers (3 %), Artisans (off-farm activities) (2%) and employed (1%).

Most respondents (74 %) had farming experience below 30 years (Table 4.2). There was nearly an equal distribution of respondents in terms of years of experience in farming. The study thus was not biased in terms of experience since both extremes i.e. the most experienced farmers and noviciates were all interviewed. Majority (60 %) relied on rain fed agriculture while 10% relied on irrigation. About 29% applied both irrigation and rain fed technology in the production system

4.1.4 Off-farm income and business activities

Some respondents (45%) compared to (55%) had worked or had had their household members work off the household land (away from the family farms) either on someone else's land or in some other gainful employment in order to be paid in cash or in kind. The proportion of members involved in farming in each household were 66% (1-2 people house hold), 19% (3-people household) while 14% did not specify how many were involved in the past 12 months.

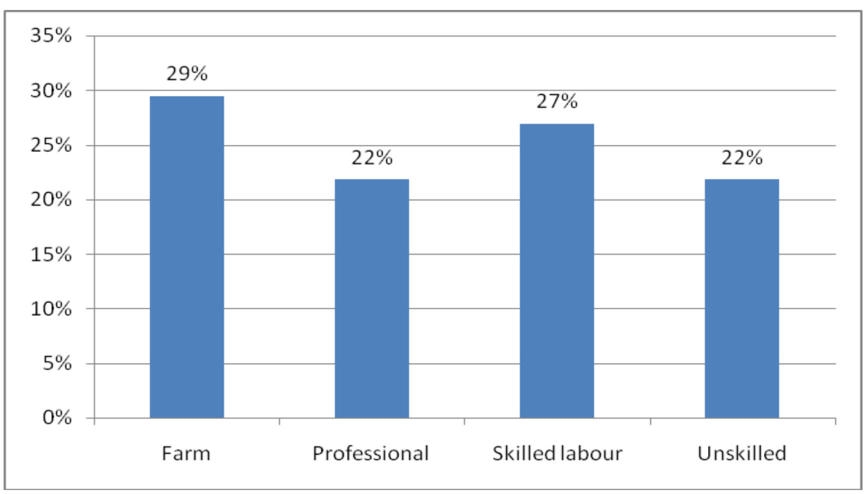

Figure 4.2: Employment of respondents

Among those involved in work of the household's land were split proportionally in farm (29%), professional (22%), skilled labour (27%) and unskilled labour (22%) (Figure 4.2). They were mainly engaged as contract workers (46%), permanent employees (31%) and daily workers (23%). Skilled labourers were mainly permanent employees while on farm workers were mainly engaged on a daily basis.

The main employers of off household farm workers were small scale farmers (46%), Government employees (14%) and commercial or large estates (12%). Urban dwellers and NGOs were 8% and 3%, respectively. Industrial crops such as coffee, tea, and cotton as well as horticulture were the main major enterprises for those employed in small scale farmers. Most respondents 54% have title deeds for their household lands. About 38% did not have while another 8% only had for some pieces of land.

4.1.5a Livestock ownership of respondents

Gross income from the sale of animal products in the past 12 months is represented in Tables 4.3 and 4.4. The overall percentage of households with expenditure related to livestock such as labour for herding, purchase of feeds, veterinary services, medicines and vaccinations was 62%. This differed at sub-country level with Imenti South leading with 78% compared to 69% in Buuri and 45% in Imenti North. The finding seems to suggest that the larger part of Imenti south is in AEZ LM3, Buuri in LH2 and Imenti North in UM3. The average expenditure in livestock related expenses was distributed as follows is given in Figure 4.3.

Table 4.3: Current estimated value (KSh) of livestock

	Valid N	Maximum	Mean
Cows	116	1,500,000.00	126,962.93
Bulls	55	600,000.00	38,672.73
Oxen	34	75,000.00	4,602.94
Heifer	65	240,000.00	38,815.38
Dairy goats	58	120,000.00	17,206.90
Sheep	49	188,000.00	24,040.82
Goats	53	250,000.00	18,864.15
Donkeys	41	50,000.00	8,739.02
Chicken	110	260,000.00	13,459.09
Beehives	40	280,000.00	16,425.00

Table 4.4: Estimated revenues (KSh) from sales

	Maximum	Minimum	Mean	Median	Mode
Meat	35,000.00	7,500.00	25,642.86	30,000.00	30,000.00
Hides/skins	17,000.00	250.00	4,9967	5,600.00	6,000.00
Milk/cream	240,000.00	8.00	67,234.86	32,000.00	120,000.00
Chicken eggs	400,000.00	15.00	25,647.20	3,000.00	200.00
Honey	360,000.00	10.00	73,250.83	32,000.00	10.00
Live animals	480,000.00	5.00	69,618.08	40,000.00	40,000.00
Manure	150,000.00	1,000.00	25,000.00	15,000.00	15,000.00
Transport	36,000.00	1,000.00	6,637.27	3,000.00	1,000.00
Others	45,000.00	2,000.00	18,000.00	7,000.00	2,000.00

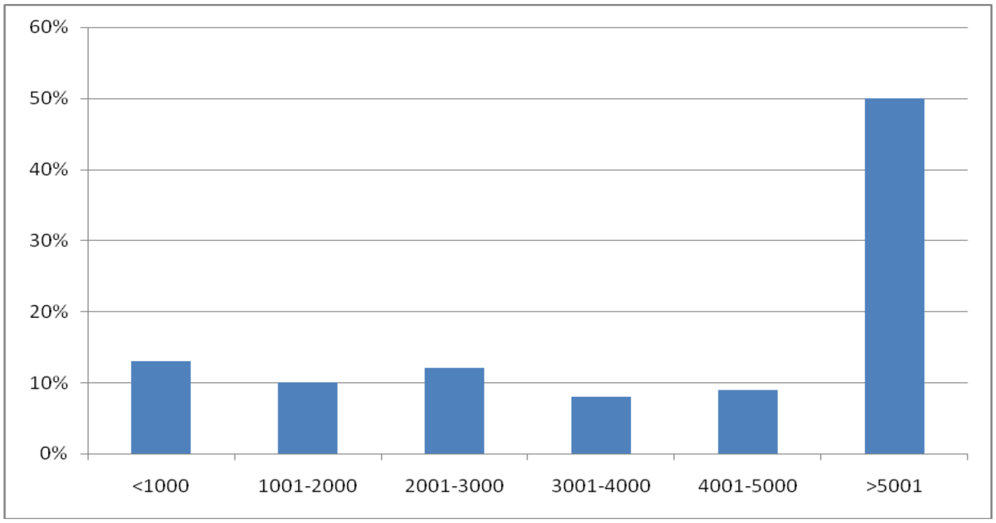

Figure 4.3: The average expenditure on livestock related expenses (Kshs.).

Various forms of livestock were kept including cattle (mostly), goats, sheep, donkeys, chicken and beehives (Table 4.3). Most respondents spent over 5,000 Ksh on livestock related expenses. The cost of expenses differed from each sub-county to another, the highest was KSh. 120,000 in Imenti South, while the least was KSh. 150 in Buuri while median expenditure was KSh. 12,000 in Imenti North, KSh. 5,000 in Imenti south and 4000 in Buuri. Most farmers in Imenti South spent the least up to KSh. 2,000, followed by Buuri Ksh. 3,000 and highest KSh. 12,000 in Imenti North. Therefore the cost of livestock maintainance is higher in Imenti North compared to other sub-counties. The median time it took farmers in Buuri was 23 minutes and 30 minutes each in Imenti north and south to deliver their production to market point. Overall, it took farmers a maximum of 150 minutes and a minimum of 1 minute to access the market point from the farm. The average walking time was 27 minutes in Buuri, 30 minutes in Imenti south and 38 minutes in Imenti North. Most farmers in Imenti south used an average of 15 minutes to access the nearby towns or markets.

4.1.5b. Contact with Agricultural Extension Officers

Figure below shows that most farmers had contacts with extension agents to get advice in the past 12 months.

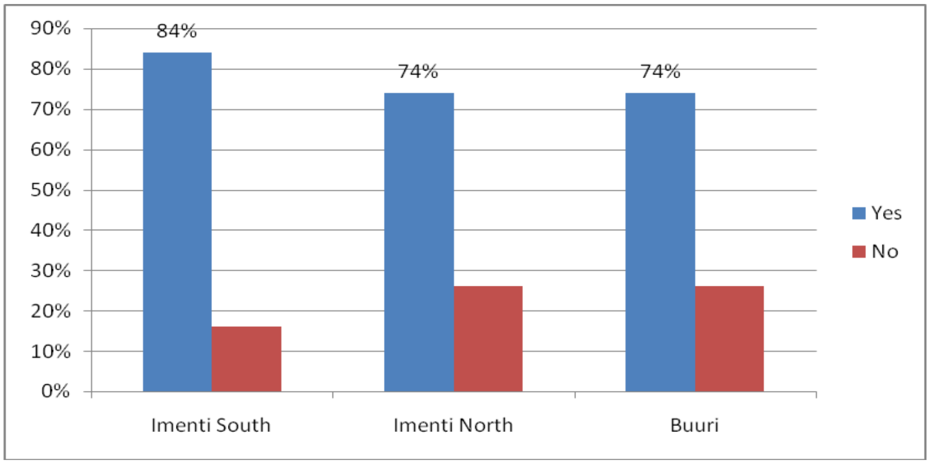

Figure 4.4: Farmers contacts with extension agents

Farmers in Imenti South had the most contacts with extension agents compared to both Imenti North and Buuri sub counties.

4.1.6 Social assets of respondents

Overall, nearly 60% of the interviewed farmers belonged to a group. However, only a paltry 38% belonged to groups in Imenti North compared to 78% in Imenti South and 61% in Buuri Sub-County. Most groups to which 50% of farmers belonged in Imenti south were barely 5 years and below, while most famers (44%) in Imenti north belonged to groups that have been into existence for between 6 to 10 years. Sixty (66) % of groups in Buuri have existed for less than 11 years. The oldest groups (16 and above years) were common in Buuri than in other sub counties.

Imenti North was leading with groups which are registered with the social services (92%) compared to 81% in Buuri and 79% in Imenti South.

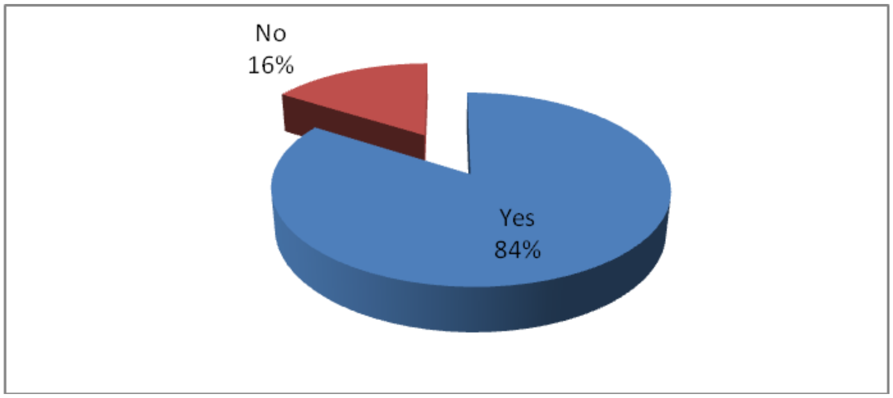

Figure 4.5: Groups registration status

The table (Table 4.5) below shows that most households belonged to farmers groups. Another significant proportion belonged to rotating savings and credit associations and water project groups.

Table 4.5: Kinds of a Social Groups Household belonged to.

What kind of a group	Imenti South	Imenti North	Buuri
Farmer group	45%	56%	44%
Rotating savings and credit associations	32%	20%	25%
Burial society	3%	0%	3%
Neighbourhood/village committees	5%	4%	0%
Clan family	0%	4%	3%
Trader or business associations	0%	0%	0%
Religious group	0%	0%	0%
Water project group	11%	12%	19%
Other	5%	4%	6%

Table 4.5 above shows that most households belonged to farmers groups. Another significant proportion belonged to rotating savings and credit associations and water project groups. Few respondents (32%) belonged to membership of agricultural organizations. Membership to agricultural association was least popular in all sub counties i.e. 28% in Imenti North, 35% each in both Imenti south and Buuri.

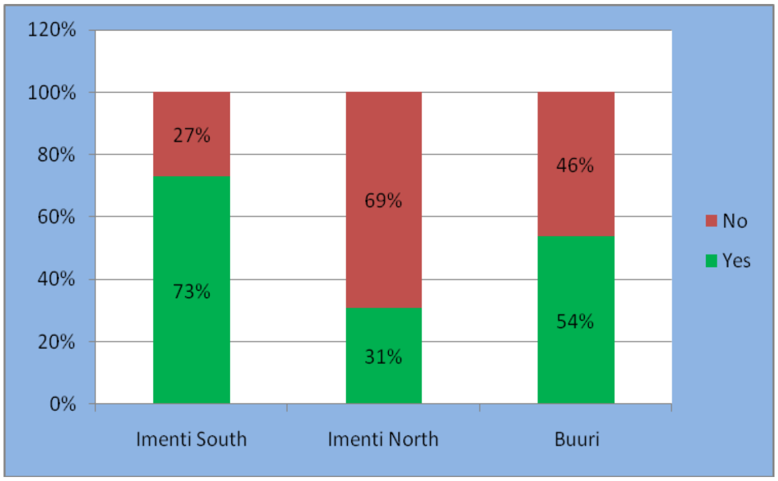

Figure 4.6: Financial Assets

More farmers in Imenti South and Buuri belonged to credit organizations (Table 4.6 and Figure 4.6). Farmers in Imenti North had least preference for Credit organizations. Approximately 49% of the total respondents had received credit services during the past 2 years. Majority did not have access to credit services.

Table 4.6: Credit Services to Farmers.

If Yes, from which organization?	Total	Imenti South	Imenti North	Buuri
1 SACCO	40%	38%	50%	38%
2 Commercial Bank	9%	13%	0%	10%
3 Micro finance	12%	22%	5%	7%
4 Group	38%	28%	45%	45%
5 Friends/relatives	1%	0%	0%	0%
6 AFC	0%	0%	0%	0%
7 Private leaders	0%	0%	0%	0%
8 Others [specify]	0%	0%	0%	0%

Credit services were mainly accessed through SACCOs (40%), Groups (38%) and Micro finance institutions (12%) (Table 4.6 and Figure 4.6). Commercial banks and Friends were least preferred or inaccessible.

4.1.7 Health effect of chemical use

About 36% of households had experienced some level of intoxication from pesticides in the past 3 years (Figure 4.7). Respondents from Imenti south were the least affected (8%) compared to Imenti North which had the highest level of intoxication at 57%.

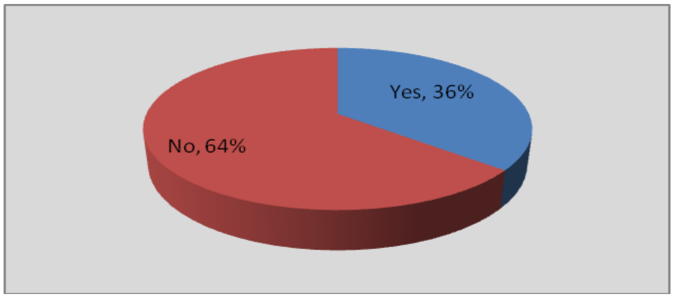

Figure 4.7: Level of intoxication from pesticides by Respondents

Table 4.7: Type of Pesticides applied when Respondents got sick

pesticides	Total	Imenti South	Imenti North	Buuri
1 Dimethoate	67%	33%	76%	63%
2 Karate	21%	33%	22%	16%
3 Decis	0%	0%	0%	0%
4 Fasta C	0%	0%	0%	0%
5 Bullock	0%	0%	0%	0%
6 Pencozeb	0%	0%	0%	0%
7 Plantvax 20EC	2%	0%	0%	5%
8 Dithane M45	2%	0%	0%	5%
9 Others [specify]	10%	33%	3%	11%

Table 4.7 above shows that Household heads and family members who used mainly Dimethoate and Karate experienced the highest level of side effects. Results above indicate that they experienced nearly the same level of symptoms arising mainly from usage of Dimethoate and Karate (Tables 4.7 and 4.8).

Table 4. 8: Percentage distribution in types and symptoms of pesticides poisoning

Types of symptoms	Total	Imenti South	Imenti North	Buuri
1 Headache	95%	88%	96%	98%
2 Sneezing	98%	92%	100%	98%
3 Vomiting	95%	88%	94%	98%
4 Stomach ache	97%	92%	96%	100%
5 Backache	95%	88%	94%	98%
6 Skin rash	96%	96%	96%	96%
7 Dizziness	96%	88%	98%	98%
8 Blurred vision	95%	88%	94%	98%
9 Diarrhoea	96%	88%	96%	100%
10 Eye irritation	98%	100%	98%	98%
11 other	91%	88%	89%	96%

4.1.8 Expenditure of Pesticides by Respondents

Expenditure on purchase of pesticides in the year 2015 is presented in Table 4.9.

Table 4.9: Expenditure on purchase of pesticides in the year 2015

Average household exependiture on pesticides	Total		Imenti South		Imenti North		Buuri	
1 Ksh.<2000	93	54%	36	73%	23	35%	31	57%
2 Ksh.2001-4500	28	16%	7	14%	13	20%	8	15%
3 Ksh.4501-9000	22	13%	3	6%	12	18%	7	13%
4 Ksh.9001-15000	16	9%	3	6%	7	11%	5	9%
5 Ksh.over 15,000	14	8%	0	0%	10	15%	3	6%

More than half (54%) of households spent less than KSh. 2,000 in the purchase of pesticides.

4.1.9 Training on Pesticide Use

Only 31% of the households had received training on application of pesticides. However the proportion of those who had received training was higher (45%) in Imenti South than any other sub-county.

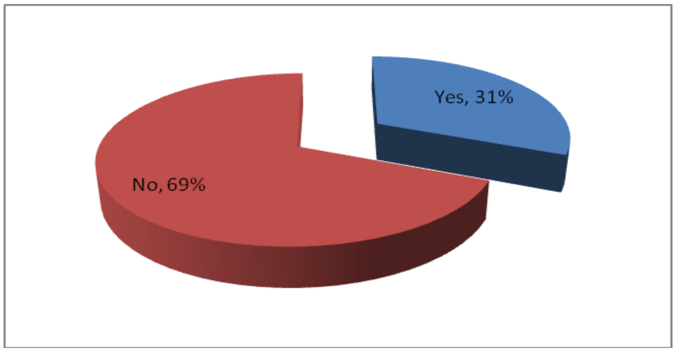

Figure 4.8: Training of the Respondents

In all households, it was the head of the household who made decisions about the use of pesticide at the household farm level. In most instances it was the field extension officers who provided information about the quality and quantity of pesticides as shown in table below (Table 4.10). A greater proportion in Imenti South relied on pesticides labels.

Table 4.10: Sources of Information by the Respondents

Source of Information on pesticides Usage	Total	Imenti South	Imenti North	Buuri
1 Extension service	59%	47%	72%	56%
2 Neighbours	24%	12%	28%	24%
3 Pesticide retailers	39%	45%	38%	37%
4 Salesmen from pesticides companies	24%	12%	35%	20%
5 Pesticide labels	38%	49%	37%	30%
6 TV/Radio	39%	22%	54%	41%
7 Experience	14%	14%	15%	11%
8 Other sources	1%	0%	3%	0%
9.Not specified	6%	6%	3%	9%

4.1.10 Frequency of accessing information

Households in Imenti south and Buuri received information more often compared to Imenti North which had limited access to information (Figure 4.9). All farmers using chemicals applied different crop protection practices in the dry and rainy seasons.

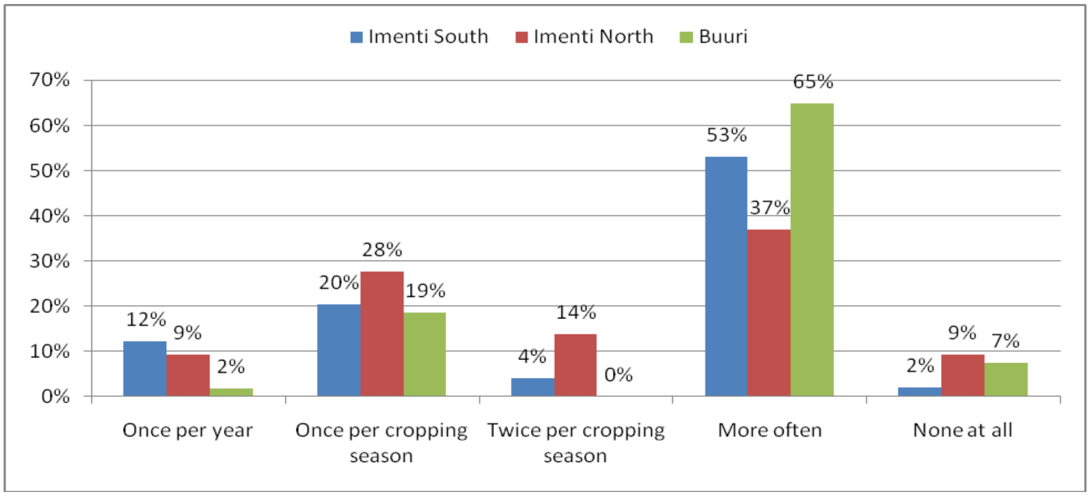

Figure 4.9: Frequency of accessing information

4.1.11 Information on other pesticides from Respondents

Approximately 86 households (49%) out of 173 interviewed used other methods other than chemicals, to protect their crops from pests and diseases (Table 4.11). The most commonly used method was physical killing and hand picking. Plant extract method was also popular in Buuri while those in Imenti South applied other methods as well while hand picking was least popular in the sub county.

Table 4.11: Other methods used by Farmers to protect Crops from Pesticides

Other methods	Total	Imenti South	Imenti North	Buuri
Total	86	20	39	23
Bio pesticide	12%	5%	13%	13%
Plant extract	22%	15%	15%	43%
Concoctions	6%	0%	5%	4%
Hand picking	60%	30%	90%	43%
Physical killing	64%	55%	79%	43%
More than one of these types	6%	10%	8%	0%
Others [specify]	24%	55%	8%	26%

Households mainly preferred other non chemical methods because of risk evasion and high cost of chemical methods (Figure 4.11). Lack of enough knowledge about chemical usage was also a contributing factor. Respondents did not take alcohol regularly. Only 20% of the respondents did take alcohol. The distribution of alcohol intake at sub-county level was 17% in Buuri, 18% in Imenti south and 23% in Imenti North. The average years of farmer drinking alcohol was 13 years in Imenti south, 5 years in Buuri and 3 years in Imenti North. Majority of respondents from Imenti south (71%) and Buuri (61%) had provision for separate storage for chemicals and the equipment. Only 68% in Imenti North kept chemicals and equipments in the same houses they lived in.

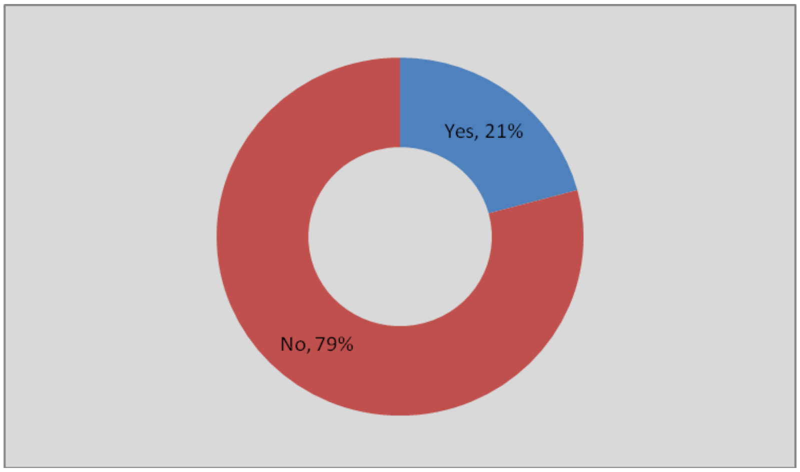

Figure 4.10: Percentage of smokers by respondents

About 21% of the total respondents smoked regularly (Figure 4.10). The average years of farmer smoking was 20 in Imenti south, 17 in Buuri and 8 in Imenti North. Farmers in Imenti North are less alcoholic and smokers compared to farmers from Imenti south and Buuri.

4.1.12 Separate Storage for Chemicals and the Equipment

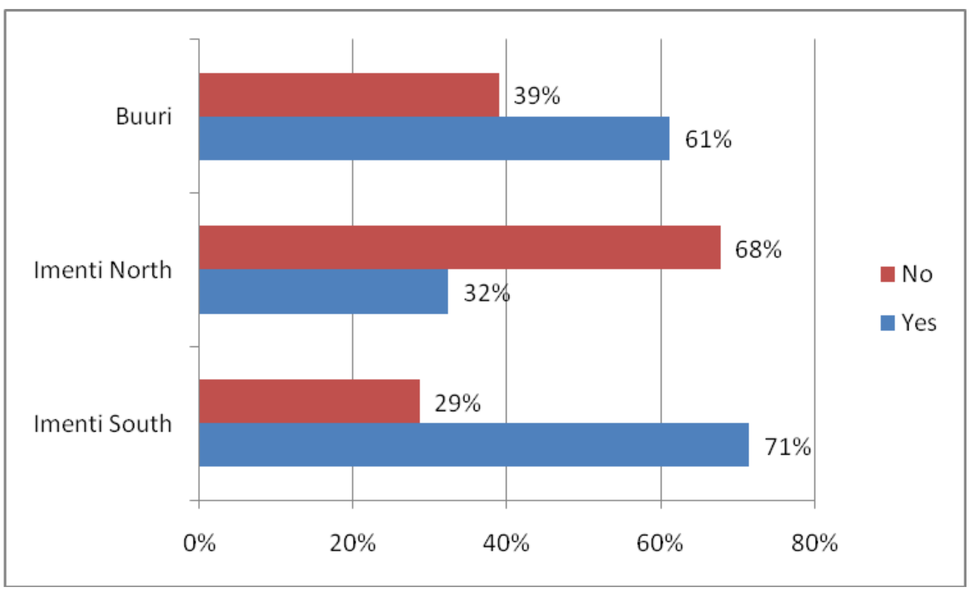

Figure 4.11: Separate storage for chemicals and the equipment

Compared to previous years, the expenditure on purchases of pesticides during the season 2015, had increased (83%) compared to previous years as shown in figure below (Figure 4.12).

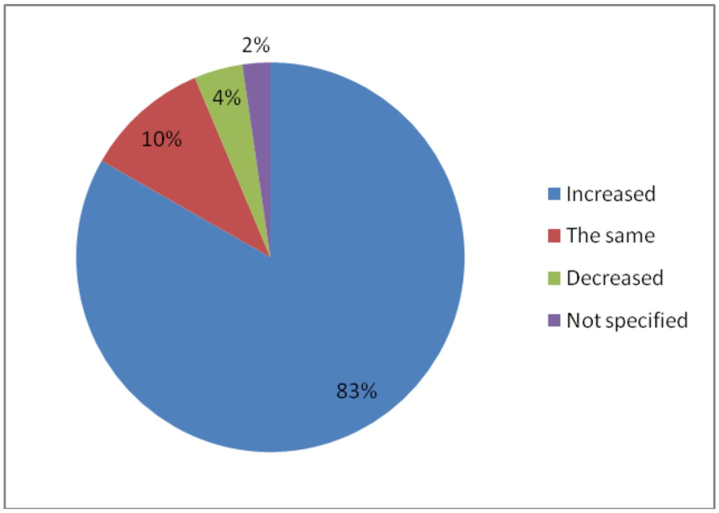

Figure 4.12: Expenditure on purchase of pesticides in 2015.

Majority of the farmers (65%) understood the labeling on the pesticides packages. Imenti south had the least farmers who did not understand labels on the pesticide packaging. Most workers (60%) were not equipped with suitable protective gears in accordance with label instructions when applying chemicals. However in terms of individual sub counties, 57% in Imenti south and 44% in Buuri were equipped with suitable protective gears (Table 4.12).

Table 4.12: Reason for non-usage of protective clothing

Reason for not using protective clothing	Total	Imenti South	Imenti North	Buuri
Total	104	21	48	30
1 No money to buy	40%	67%	23%	53%
2 Uncomfortable	38%	19%	56%	23%
3 Not suited for local condition	27%	0%	46%	17%
4 Unnecessary	20%	14%	27%	17%
5 Other reasons [specify]	14%	24%	8%	17%

About 99% of the total respondents had access to health services. Average distance to nearest health facility was 2.9 km in Imenti south, 3.3 km in Imenti North and 3.7 km in Buuri sub county. The furthest was 30 km in Buuri, 25 km in Imenti North and 18 Km in Imenti South.

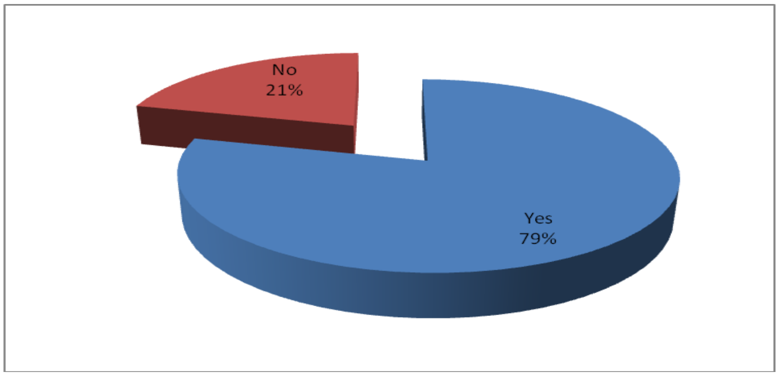

Figure 4.13: Percentage that visited health facility

Almost 79% of the total respondents had members who had visited health facilities for treatment of various ailments in the past season. The mean expenditure was 5,528 in Buuri, 7,041 in Imenti North and 7,770 in Imenti South while the highest expenditure was 120,000 Ksh in Imenti south, 40,000 Ksh in Buuri and 30,000 Ksh in Imenti North. Over 63% of the households lacked basic training in First Aids skills.

Table 4.13: Pesticide usage in the household

Household Members who applied chemicals	Total	Imenti South	Imenti North	Buuri
1 Household head	57%	45%	57%	67%
2 Spouse	26%	33%	26%	15%
3 Son	9%	9%	11%	8%
4 Daughter	1%	0%	0%	3%
5 Hired labour	0%	0%	0%	0%
6 Technician	9%	18%	4%	10%
7. Others	1%	0%	2%	0%

Chemicals were mainly applied by the household heads (57%) followed by spouse (26%) and male child (9%). Very few households sought the services of qualified technicians (9%) in the application of chemicals. However a significant proportion in Imenti South (18%) used technicians.

Table 4.14: Sources of Pesticides

Source of chemicals	Total	Imenti South	Imenti North	Buuri
1 Old stock	13%	9%	19%	10%
2 Friends	4%	0%	6%	5%
3 Open Market	10%	18%	7%	8%
4 Vet Shop	67%	76%	57%	69%
5 Others	10%	6%	11%	10%

Most farmers bought chemicals from the stockists, 76% in imenti south, 69% in Buuri and 57% in Imenti North. Another significant proportion recycled the old stock 13%. The incidences of leakages while spraying was rampant in Imenti North (52%) and lowest in Imenti South (9%) while usage of cocktail chemicals was high in Imenti south 80% and lowest in Imenti North 28%.

Chemicals were mainly applied during the morning 60%, 39% during lunch and 11% in the afternoon. Usage in the morning was rated very high in Imenti South compared to any other area.

Table 4.15: Application time

Weather after 1 hour of application	Total	Imenti South	Imenti North	Buuri
1 Raining	20%	36%	19%	10%
2 Sunny	58%	45%	63%	64%
3 Cloudy	28%	55%	13%	26%

Most farmers preferred to apply chemicals during sunny weather as shown in table above.

Table 4.16: Average number of protective clothing owned by farmer

Sub county	Maximum	Minimum	Mean	Mode
1 Imenti South	6	0	3	3
2 Imenti North	5	0	2	2
3 Buuri	7	1	3	4

In some households especially in Imenti South and North, farmers did not own even single protective clothing. The mean ownership of protective clothing was 2 in Imenti North and 3 each in Imenti south and Buuri. Maximum number of protective clothing in Buuri was high 7 compared to imenti south 5. All farmers in Buuri owned at least one protective clothing.

Table 4.17: Average cost of protective clothing

Sub-County	Maximum	Minimum	Mean	Median	Mode
1 Imenti South	15,000.00	500.00	3,733.93	3,500.00	1,500.00
2 Imenti North	30,000.00	-	5,064.71	3,000.00	5,000.00
3 Buuri	30,000.00	500.00	4,895.45	3,000.00	7,000.00

Table 4.18: Estimated number of family and hired labor involved in the application

Sub-County	Minimum	Mean	Maximum
1 Imenti South	1	2	5
2 Imenti North	1	2	12
3 Buuri	1	2	6

In all sub-counties, there was a minimum of one person each involved in the application. The maximum number of those involved was high 12 in Imenti north and lowest in Imenti south. The mean number of persons involved was 2 in all sub counties.

Table 4.19: Evaluation of rainfall from planting until harvesting

Evaluate	Total	Imenti South	Imenti North	Buuri
Excess	7%	10%	11%	0%
Good	23%	22%	22%	24%
Shortage	35%	35%	40%	30%
Average	35%	33%	28%	46%

Most respondents (40%) in Imenti North felt there was a shortage of rainfall while those in Buuri (46%) felt the rains were average. In all sub counties, rainfall was either average or less.

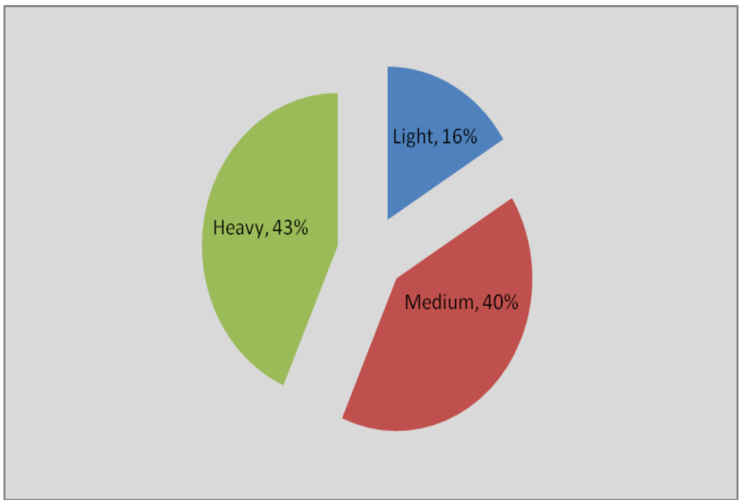

Figure 4.14: Degree of rainfall hazards

Table 4.20: Evaluation of degree of rainfall in Meru County

Evaluation of degree of rainfall hazards from planting to harvesting	Total	Imenti South	Imenti North	Buuri
Light	16%	21%	14%	15%
Medium	40%	50%	35%	42%
Heavy	43%	29%	51%	42%

Overall evaluation of degree of rainfall hazards from planting to harvesting was either heavy, 43% medium, 40% and light 16%. About 50% in Imenti south evaluated degree as medium while over half evaluated hazard degree as heavy in Imenti North.

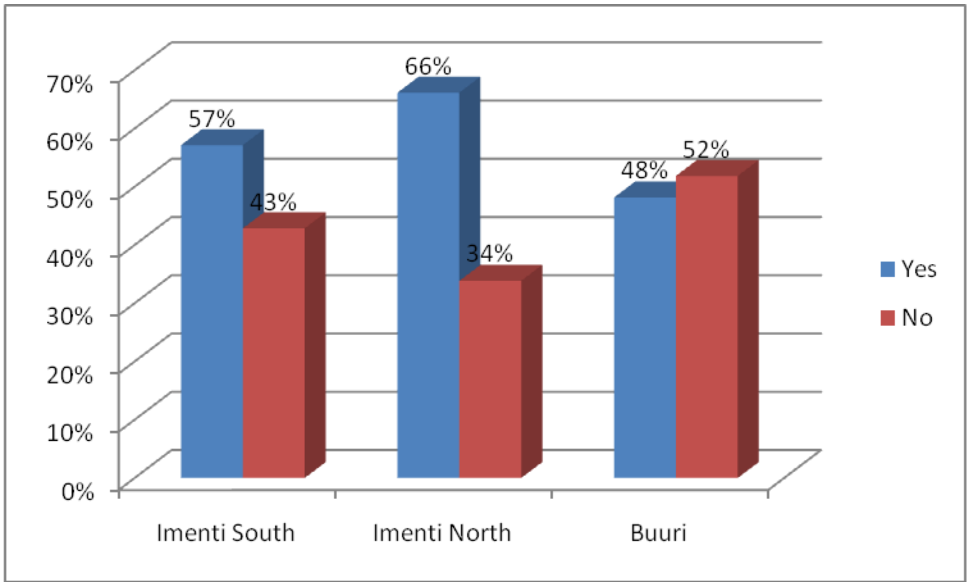

Figure 4.15: Experienced natural hazards.

Majority of respondents in Imenti South (57%) and North (66%) had experienced Natural hazards that damaged their crops more compared to 48% in Buuri.

Table 4.21: Health Effects of Pesticide use

Who in the HH has been Affected	Total	Imenti South	Imenti North	Buuri
1 You (HHH)	36%	100%	40%	20%
2 Wife	19%	100%	16%	20%
3. Son	44%	0%	44%	50%
4. Daughter	0%	0%	0%	0%
5. Other member	3%	0%	0%	10%

In most cases it is the son who has been intoxicated more compared to any other member of the household. These were manly evident in Imenti North and Buuri. Chemical application in imenti south was mainly done by The Head of the household and the spouse. All of them had been affected.

4.2 Health Care workers and Agriculture Extension officers questionnaire

4.2.1 Age and gender

The study interviewed 70 health care workers (HCW) in the three sub-counties to corroborate the information obtained from the household survey; 32 were female while 38 were male (Table 4.22). The mean age for all HCW was 44 (40 for female and 47 for male). The study interviewed 73 agricultural extension officers (AEO) in the three sub-counties to corroborate the information obtained from the household survey; 18 were female while 55 were male (Table 4.22).

Table 4.22: Gender of health care workers

Gender	Health Care Workers	Agricultural Extension Officers
Female	32	18
Male	38	55
Grand Total	70	73

The age of the health care workers had an average of 42 for female and 45 for male. The age of the agriculture extension officers had an average of 41 for female and 45 for male and age of the agriculture extension officers had an average of 41 for female and 45 for male (Table 4.23).

Table 4.23: Age of the respondents

	Health Care Workers			Agricultural Extension Officers		
Gender	Min	Average	Max	Min	Average	Max
Female	28	42	52	28	41	52
Male	29	45	59	29	45	59
Average		44				

4.2.2 Education Background

Most of the health care workers had diploma education level. The table below shows the level of education.

Table 4.24: Education of health care workers

Education status	No.
Adult Education	1
Certificate in Commutinity/Public Health	9
Degree	5
Diploma	17
Diploma in Community Devt	3
Diploma in Community Health	2
Diploma in Community Nursing	5
Diploma in Public Health and Sanitation	8
Form FOur	13
Form Two	1
Primary	6
Grand Total	70

Table 4.25a: Marital status of AEW

Marital	NO	%
Married	63	86
Single	10	14
Grand Total	73	100

Table 4.25b: Marital split by gender of AEW

Gender	No	%
Female	18	100
Married	9	50%
Single	9	50%
Male	**55**	**100**
Married	54	98%
Single	1	2%
Grand Total	73	100

Table 4.26a: Education Status for Agricultural Extension workers

Education Status	No.	%
Certificate	12	16
Degree	12	16
Diploma	28	38
Form Four	21	29
Grand Total	73	100

Table 4.26b: Education status for Agricultural Extension workers as per gender

Education Status	No.	%
Female	**18**	100%
Certificate	6	33%
Degree	1	6%
Diploma	6	33%
Form Four	5	28%
Male	**55**	100%
Certificate	6	11%
Degree	11	20%
Diploma	22	40%
Form Four	16	29%
Grand Total	73	100%

Table 4.27: Education Status of AEW by Specialization

Area of specialization	No
CERTIFICATE	12
Agriculture	12
DEGREE	12
Agriculture	4
Horticulture	3
(blank)	5
DIPLOMA	28
Agric.Education and Extension	1
Agriculture	5
Horticulture	2
(blank)	20
Form Four (without formal post edcuation)	21
Grand Total	73

Among the twenty one respondents with form four education, 16 were private animal health assistants while 4 were frontline extension workers. Eleven among the certificate holders whose main area of specialization was agriculture were employed as frontline agriculture extension officers. Twelve among the diploma holders were employed as assistants (Agriculture or Health Care Officers) and had a minimum of 4 years and a maximum of 26 years experiences. Majority had between 10 to 20 years in service. Among the twelve degree holders, 10 worked as (Extension officers, Agriculture assorted officers or crops officers), 1 was a division agricultural officers while the other headed the District/county. The average number of years in employment was 13 years for all AEW. Female extension workers were more experienced 17 years compared to Male 13 years.

Table 4.28: Do AEW deal with pesticide and their application?

	%
Deal in Animal Chemicals	1%
No	3%
Yes	95%
Yes-Advice	1%
Grand Total	100%

Among those interviewed, only 4% did not handle pesticides or chemicals, majority of the respondents 96% dealt with pesticides and chemicals.

Most of the agriculture extension officer had diploma education level. The table below shows the level of education. Among the twenty one respondents with form four education, 16 were private animal health assistants while 4 were frontline extension workers. Eleven among the certificate holders whose main area of specialization was agriculture were employed as frontline agriculture extension officers. Twelve among the diploma holders were employed as assistants (Agriculture or health officers) and had a minimum of 4 years and a maximum of 26 years experiences. Majority had between 10 to 20 years in service.

Among the twelve degree holders, 10 worked as (Extension officers, Agriculture assorted officers or crops officers), 1 was a division agricultural officers while the other headed the District/county. The average number of years in employment was 13 years for agricultural extension workers. Female extension workers were more experienced 17 years and above compared to Male 13 years and above.

Table 4.29: Age of agriculture extension officer

GENDER	Min	Average	Max
Female	28	41	52
Male	29	45	59
Average		44	

Among those extension workers interviewed, only 4% did not handle pesticides or chemicals, majority of the respondents 96% dealt with pesticides and chemicals and were able to provide a list of pesticides they dealt with which included acaricides, dewormers, insecticides, miticides, rodenticides, and herbicides (see Appendix XXX). The extension workers also explained their roles which included advice on handling of pesticides, application rates, wearing personal protective clothin, how to spray, preharvest intervals, where to buy the pesticides and how to store them. Deworming, pesticide labels, how to mix, banned pesticides specific pesticide and corresponding diseases as well as disposal.

From questionnaire given to farmers, farmers resonded to question where they got information of pesticide use with responses given being extension workers, other farmers, stockists, NGOs, media neighbours, pesticide retailers, health care workers, newspapers, radio, internet, as well as specific organizations such as KEPHIS, AAK and PCPB. Most farmers bought the pesticides from agrovet stores/dealers and a few bought them from open markets and factories. This indicates that some of the farmers buying the pesticides were knowledgeable on pesticides. Most were not keen (38%) on expiry dates, and some were keen (36%) on expiry dates on the labels. 61% of the small scale farmers knew when to apply pesticides and 57% responed that pesticide poisoning is a problem in the community. 71% of healthcare workers knew first aid procedures for pesticide poisoning. Most AEW advised the farmers on danger associated with pesticides (84%).

4.2.3 Pesticides used in Meru County: from the survey report

Table 4.30 below shows the list of pesticides sold in Meru County from the survey (generated from the survey results), their frequencies of use by respondents/farmer, as well as their active ingredients, mammalian toxicity, WHO toxicity rank and Log $_{Kow}$ data. Log K_{ow} indicates ability to partition into body fat and into the body. The chemical structure of the active ingredients for the pesticides is given in Appendices.

Table 4.30: List of pesticides used in Meru County as determined from the survey and their key properties

Formulation	Frequency of Use/ No. respondents	Active Ingredient	Pesticide Class	Mammalian Toxicity (a.i LD_{50}) mg/kg	WHO Toxicity Rank	Log K_{ow}
Chlorpyrifos	36	Chlorpyrifos	Organophosphate	96-270	WHO II	47-5
Parathion	62	Parathion	Organophosphate	3.6-10	WHO I	3.8
Malathion	31	Malathion	Organophosphate	900-5800	WHOIII	2.36-2.89
Diazinon	79	Diazinon	Organophosphate	150-220	WHO II	330-381
Dimethoate	67	Dimethoate	Organophosphate	235	WHO II	0.7-0.78
Permethrin	61	Permethrin	Pyrethroid	430-4000	WHO II	6.1
Actelic	54	Perimiphos Methyl	Organophosphate	2000	WHOIII	4.12
Actelic Super	23	Perimiphos Methyl	Organophosphate	2000	WHOIII	4.12
Ortho	54	bifenthrin	Pyrethroid	54-70	WHO II	6.0
Delta-Mectnin	57	Zeta-cypermethrin	Pyrethroid	160-300	WHO II	6.5
Agrinate	17	Methomyl	Carbamate	12-48	WHOI	0.6
Karate	11	lambda-cyhalothrin	Pyrethroid	56-700	WHO II	6.8-7.0
Cattle Dip	20	-	-	-	-	-
Sevin Dudu Dust	45	Cabaryl	Carbamate	500-700	WHO III	2.36
Heptachlor	25	heptachlor	Organochlorine	147-220	WHO II	6.1
Endosulfan	8	Endosulfan	Organochlorine	18-43	WHO I	3.66-3.62
Endrin	9	Endrin	Organochlorine	7-15	WHO I	5.4-5.2
Dieldrin	76	Dieldrin	Organochlorine	37-87	WHO I	5.40
Methoxychlor	48	Methoxychlor	Organochlorine	600	WHO I	5.08
Endrin Aldehyde	69	Endrin Aldehyde	Organochlorine	500	WHO II	4.8
Esfenvalerate	29	Esfenvalerate	Pyrethroid	458	WHO II	6.22
Cypermethrin	51	Cypermethrin	Pyrethroid	250-4123	WHO II	5.3-5.6

Permethrin	67	Permethrin	Pyrethroid	430-4000	WHO II	6.1
Deltamethrin	62	Deltamethrin	Pyrethroid	128-5000	WHO II	6.2
Heptachlor Epoxide	32	Heptachlor Epoxide	Organochlorine	40-162	WHOI	5.4
Propoxur	69	Propoxur	Carbamete	95-104	WHO II	1.52
Carbofuran	52	Carbofuran	Carbamate		WHO III	2.32
Endosulphan Sulphate	64	Endosulphan Sulphate	Organochlorine	18-220	WHO I	3.66
Source: Log K_{ow} and LD_{50} values obtained from Extoxnet (1995).						

There were other types of unspecified pesticides that were reported by farmers and agricultural externsion workers as being used in Meru County including biopesticides, dewormers for cattle, plant extracts as well as concoctions. The dewormers were reported by extension workers but not by farmers (Table 4.30) because the farmers targeted in the survey were horticultural farmers. From the list of pesticides used by farmers (Table 4.30), organochlorines (×8), pyrethroids (×8) and organophosphate (×7) pesticides were the main class of pesticides used, followed by carbamates (×4). The most frequently used pesticides (with more than 40 respondents) were parathion (62 respondents), diazinon (79), dimethoate (67), permethrin (67), actelic (a.i. = pirimiphos methyl) (54), ortho (a.i. bifenthrin) (54), deltamethrin (62), delta mectnin (a.i. zeta-cypermethrin) (57), Sevin dudu (a.i. carbaryl) (45), dieldrin (76), methoxychlor (48), cypermethrin (51), permethrin (67), propoxur (69), carbofuran (52) and endosulfan sulphate (64). The organochlorines reported here, some of them belonging to the most frequently used pesticides as reported by farmers have been banned (see Table 2.1). This implies that the organochlorines are still being sold or (resold/recycled as old stocks) to farmers and are being used illegally in the three sub counties of Meru. The authorities such as the Pest Control Products Board of Kenya should be informed if this is confirmed on the ground and the source of these banned pesticides therefore established and banned. The banned organochlorines which were reported by farmers included endrin, dieldrin and heptachlor. Parathion was also reported bny farmers in Meru county but was banned in the country because of its high mammalian toxicity (oral rat LD50: 3.6-10). Most of these organochlorines have been banned in developed countries because of their high mammalian toxicity (mainly belonging to WHO Class I and II) and endocrine disruptive effects. Carbofuran as a single a.i. formulation was removed from the shelves by the Kenyan Parliament in 2010 because of its high avian toxicity (LD50 in birds in the range of 1 mg/kg) and widespread poisoning of birds including vultures experienced between 2007 and 2010 in Kenya (Otieno et al., 2010). Carbofuran use (52 respondents) by farmers was found to be very frequent in Meru and this indicates possible illegal use, either from illegal exports or use of old stocks. The toxicity range for these pesticide shows that they are very toxic to mammals (Table 4.30) including man and therefore their use requires strict adherence to recommended handling procedures. Some of them such as dimethoate, parathion and diazinon were also reported in the survey in this study as being responsible for some of symptoms of poisoning that were recorded by respondents.

4.3 Organochlorine Pesticide Residue Levels in Agricultural Soils and Horticultural produce in Meru County.

The residue levels of organochlorines in farm soil, French beans, tomatoes and Kale samples taken from Buuri, Imenti North and Imenti South including the quality assurance taken into consideration, quantitation procedure and limits of detection in the 4 matrices are reported in the following sections. These results respond to the last specific objective (iv). The residue levels in farm soil samples from the three counties are presented in graphs shown in Section 4.3.5 which show their distributions with site, and the actual concentrations can be seen in Apendices Va, Vb upto VIIa and VIIb in the Appendix section.

4.3.1 Qualitative Characteristics

Reference standards of organochlorine pesticides obtained from Sigma Aldrich through their local agent Kobian ltd were used in various steps in the analysis. Working reference standard solutions in the range of 2 µg/L to 97.8µg/L were prepared for the seventeen organochlorines pesticides and concentration calculated on each standard, then calibration curve was drawn for each individual standard was a straight line and is best line fitdrawn from the plot of the response factor, that is, instrument response (peak area) against standard (analyte) concentration. All analyte lines gave a correlation factor (R^2) above 0.99 indicating a high correlation between instrument response ratio and analyte concentration. The quantification was based on calculations from calibration curves for each standard. The calibration curves are attached in Appendix 1. The standard (analytes) concentrations were obtained by interpolation from the graphs which applies the equation of the line i.e Y= mX+c; where; Y= Normalised peak area (Instrument response); X=Standard concentration ; m=Gradient ; and C= Constant.

4.3.2 Chromatograms

Standard calibration curves for the selected OCPs pesticides analysed in section 4.2 was obtained for the individual pesticide's retention time (for identification) and peak area (for quantification) and the procedure was repeated for the mixed standard solutions curves. Chromatograms for the standards is attached in Appendix 3. The chromatogram for field samples extract is attached in Appendix 3. The unidentified peaks indicate compounds that were present in the samples but not in the standard mixture. The chromatogram was obtained from a plot of instrument detector response (peak area) against the analyte retention time (minutes). The horizontal axis which shows the retention time of each analyte and is expected to coincide with that of the reference standard peak for a particular analyte for the peak to be identified.

4.3.3 Limits of Detection

The limit of detection (LOD) of a compound is the lowest concentration of the analytes that analytical process can reliably detect, but not necessarily quantitated as an exact value. It may be described as the concentration which gives a signal (Y) on the instrument which is different from the blank or background signal. It is calculated as the analyte concentration giving a signal equal to the blank signal Y_B plus two standard deviations of the blank, S_B (Miller and Miller, 1993). The relationship is expressed as $Y - Y_B = 3S_B$.The LOD of each of organochlorine pesticides was calculated based on the lowest concentration of the calibration standards injected and the corresponding noise signals using the relationship adapted from the equation below:

$$LOD = \frac{3 \times Noise peak area \times concentration of standard injected (ng)}{Analyte\ response\ in\ the\ lowest\ calibration\ point}$$

The limits of detection for OC Pesticides ranged from 0.0011 µg/L for α -HCH to 0.0036 µg/L for Aldrin. Any other values detected below the recorded ones were considered as noise and hence reported as below detection limit (BDL).

Table 4.31: Limit of Detection Values for Various Pesticides

Pesticides	LOD (µg/L)	Pesticides	LOD (µg/L)
α HCH	0.0011±0.00	Endosulfan sulfate	0.0021±0.00
β HCH	0.0016±0.00	Aldrin	0.0036±0.00
γ HCH	0.0016± 0.00	Dieldrin	0.0031±0.00
δ HCH	-	Endrin	0.0022±0.00
***p,p* DDT**	0.0017± 0.00	Endrin aldehyde	0.0022±0.00
***p,p* DDE**	0.0018± 0.00	Heptachlor	0.0011±0.00
***p,p* DDD**	0.0016±0.00	Heptachlor epoxide	0.0011± 0.00
α- endosulfan	0.0011±0.00	Methoxychlor	0.0016±0.00
β endosulfan	0.0015±0.00		

Mean ± S.D

4.3.4 Organochlorine Pesticide Recovery Levels

The average percentage recoveries of 17 pesticides ranged from 73.29±6.18% for endosulfan sulfate to 102.24±10.04% for dieldrin and the rest of the pesticides had values which have been summarized in Table 4.20. The pesticide residue levels detected in samples were not corrected since all recovery values (Table 4.20) were within the acceptable range of 70-120 % (Hill, 2000).

Table 4.32: Average Percentage Recovery data for selected Organochlorine pesticides

Pesticide	Recovery(%±S.D)	Pesticide	Recovery(%±S.D)
α HCH	93.67±1.34	Endosulfan sulfate	73.29±6.18
β HCH	82.41±2.18	Aldrin	91.61±5.08
γ HCH	94.89±5.33	Dieldrin	102.24±10.04
δ HCH	88.73±4.38	Endrin	76.31±8.32
p,p DDT	94.16±8.19	Endrin aldehyde	74.86±9.61
p,p DDE	84.31± 4.12	Heptachlor	92.45±4.56
p,p DDD	94.27±4.69	Heptachlor epoxide	92.36±3.62
α- endosulfan	98.54±1.87	Methoxychlor	91.26±4.17
β endosulfan	99.23±2.13		

Mean± S.D

4.3.5 Organochlorine Pesticide Residue Levels in horticultural farm soils in Meru County.

The widespread application of organochlorine pesticides in agriculture during the 19th century raised a serious concern due to their harmful effects on human and environment (Lemaire *et al.*, 2004). Although this resulted in the ban of most of these compounds, their residues are still detectable in environment due to persistence and bio-accumulative effects. In some cases, illegal application and emissions from obsolete stocks can introduce their residues in environment. Once released into the air pesticides are subjected to different degradation and transport pathways. The rates of degradation and dissipation vary greatly depending on the type of pesticide and the prevailing environmental condition such as temperature, wind, humidity, soil type and biotic factors. Consequently, the concentration, spatial and temporal trends in levels vary from one compound to the other. Organochlorine pesticides have been detected in water, soil and sediment samples around the world including Kenya (Wandiga *et al.*, 2002; Kithure, 2013; Osoro, 2015; Aucha *et al.*, 2016). Kithure (2013) found various concentrations of organochlorines in water and sediment of River Tana which flows through the mount Kenya region where agricultural activities within the catchment were intensive, but could not completely explain the sources of these persistent pesticide residues. In this study, it was established from the survey that some of the organochlorines are still being used in the farms despite their ban. It is in this study that it has been established that organochlorines are actually still being by farmers. Studies done on organochlorine residues presence in water resource and air samples have often found high concentrations of these residues in these compartments and they only reported that their presence could be due to recycling and/ or deposition from the environment. No one has established before that these banned pesticides are still being used and could be the source of high residue concentrations detected in various compartments. Some of the organochlorines which were found in the farm soil including, isomers of lindane, endosulfan, dieldrin, endrin, heptachlor and aldrin are endocrine disruptive compounds and their presence in human blood have been linked to markers of diabetes 2. They have been banned in the western countries and also in Kenya.

The analysis of soil samples from three Sub County in Meru County with each having twenty sampling sites showed presence of seventeen (17) organochlorine pesticide residues at varying concentrations. The average pesticides levels ranged from below detection limits (BDL) to 79.755±8.45µg/Kg. The highest concentration was recorded in soil samples collected from Imenti North Sub County.

4.3.5.1 Organochlorine Pesticides in horticultural farm soils from Imenti North Sub County

Organochlorine pesticide residues detected in soil from Imenti North Sub County ranged between BDL to79.755±8.45µg/Kg. Methoxychlor was the highest detected in soil from sampling site Six. The mean concentration of hexachlorocyclohexanes (HCH) isomers ranged between BDL- 60.602±8.18µg/Kg for α-HCH, β-HCH (BDL-50.0911±7.22 µg/Kg), γ-HCH (BDL-40.713±1.86 µg/Kg), δ- HCH (BDL - 0.5801±0.07 µg/Kg).

The Mean concentration of heptachlor ranged from BDL-45.618±4.11 µg/Kg, aldrin (BDL-49.7081±5.26 µg/Kg), heptachlor epoxide (BDL-0.705±0.01 µg/Kg), α-endosulfan (BDL - 3.085±0.98 µg/Kg), β-endosulfan (BDL-48.046±5.68 µg/Kg), endrin aldehyde (BDL - 24.787±1.95 µg/Kg), endosulphan sulfate (BDL-46.699±1.90 µg/Kg), Dieldrin (BDL-24.788±1.95µg/Kg) and methoxychlor (BDL - 79.755±1.45 µg/Kg), while endrin, was not detected in all the sites. The mean concentration of *p,p'*-DDT ranged between BDL-64.8069±3.51µg/Kg, while the mean concentration of its metabolite *p,p'*-DDE ranged between BDL-76.78±6.18 µg/Kg and *p,p'*-DDD was not detected.

4.3.5.1.1 Comparison of OCPs levels in horticultural farm soils from different sampling sites

Methoxychlor had the highest pesticide residue levels (79.755±8.45 µg/Kg) detected in soil from sampling site six, followed by *pp'*-DDE (76.78±6.18 µg/Kg), *pp*'-DDT (64.8069 ±0.00 µg/Kg), α-HCH (60.602±8.18 µg/Kg), β -HCH (50.0911±7.22 µg/Kg), aldrin (49.7081±5.26 µg/Kg) Aldrin (49.7081±5.26 µg/Kg). The rest of the pesticides are shown in Figure 4.11 and in the Appendix section.

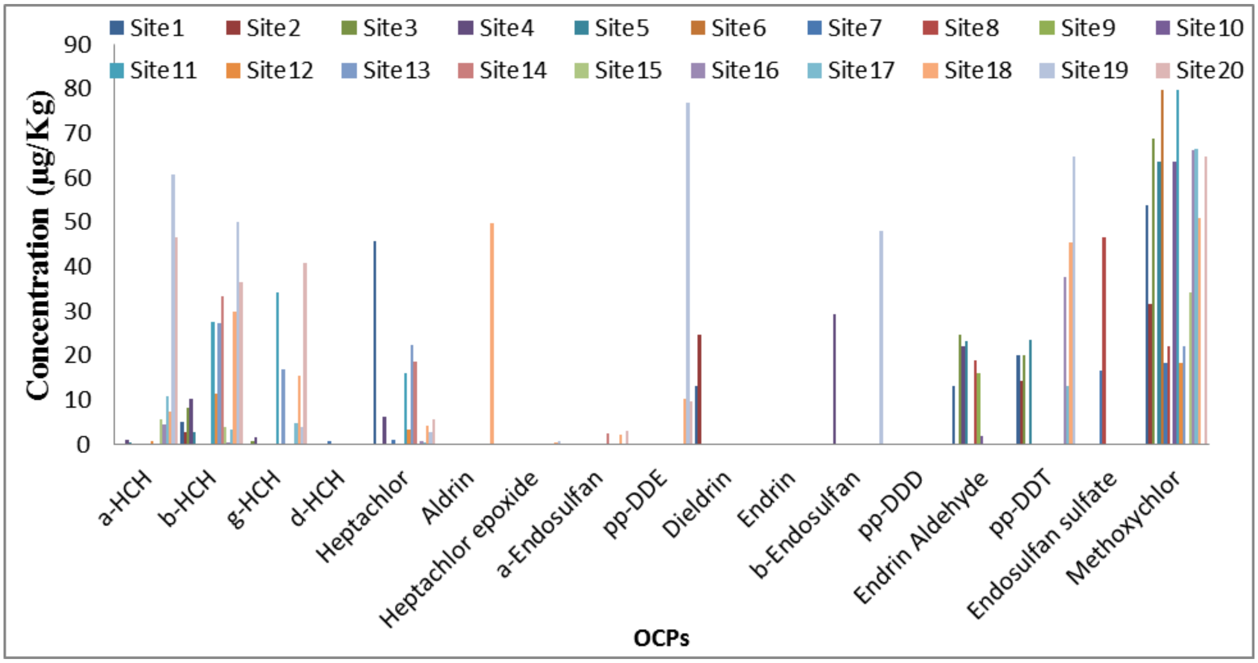

Figure 4.16: Organochlorine Pesticides in horticultural farm soils from Imenti North Sub County

4.3.5.2 Organochlorine Pesticides in horticultural farm soils from Imenti South Sub County.

Organochlorine pesticide residues detected in soil from Imenti South Sub County ranged between BDL to 85.825±1.98 µg/Kg. Methoxychlor was the highest detected in soil from sampling site twelve (12). The mean concentration of hexachlorocyclohexanes (HCH) isomers ranged between BDL- 2.352±0.36 µg/Kg for α-HCH, β-HCH (BDL-14.873±2.17 µg/Kg), γ-HCH (BDL-2.768±0.12 µg/Kg), δ- HCH (BDL - 0.513±0.04 µg/Kg).

The Mean concentration of heptachlor ranged from BDL-3.181±0.04 µg/Kg, β -endosulfan (BDL - 12.017±0.68 µg/Kg), endrin aldehyde (BDL - 63.015±6.12 µg/Kg), endosulphan sulfate (BDL-64.638±9.69 µg/Kg), while heptachlor epoxide, α-Endosulfan, pp-DDE, dieldrin, endrinendrin, were not detected in all the sites. The mean concentration of *p,p'*-DDT ranged between BDL-43.627±2.13 µg/Kg, while the mean concentration of its metabolite *p,p'*-DDD ranged between BDL-60.514±8.77 µg/Kg and *p,p'*-DDE was not detected.

4.3.5.2.1 Comparison of OCPs levels in hroticultural farm soils from different sampling sites

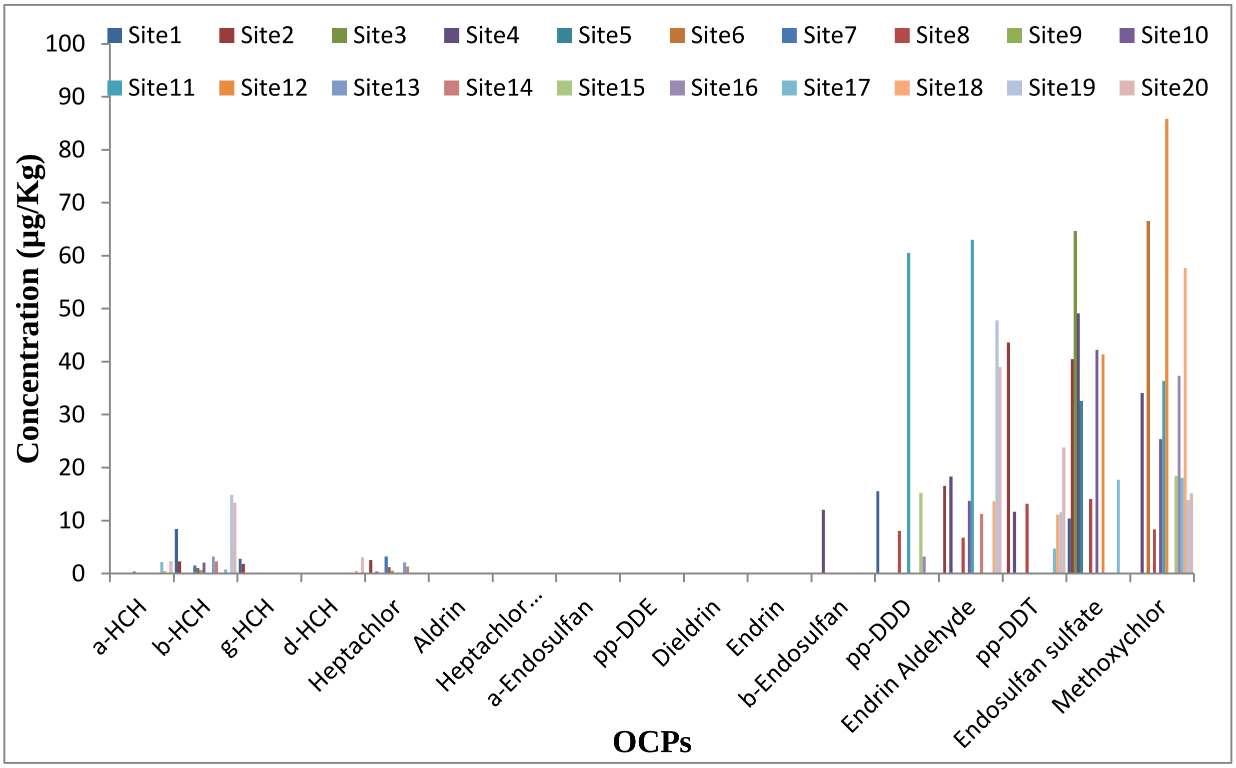

Figure 4.17: Organochlorine Pesticides in horticultural farm soils from Imenti South Sub County

Methoxychlor had the highest pesticide residue levels (85.825±1.98 µg/Kg) detected in soil from sampling site twelve, followed byendosulfan sulfate (64.638±9.69 µg/Kg), endrin aldehyde (63.015±6.12µg/Kg), *pp*'-DDD (60.514±8.77µg/Kg), β-HCH (8.392±0.41µg/Kg), α-HCH (2.155±0.24 µg/Kg). The rest of the pesticides are shown in Figure 4.12 and in the table in the Appendix section.

4.3.5.3 Organochlorine Pesticides in horticultural farm soils from Buuri Sub County

Organochlorine pesticide residues detected in soil from Buuri Sub County ranged between BDL to72.95±5.06 µg/Kg. Methoxychlor was the highest detected in soil from sampling site Thirteen. The mean concentration of Hexachlorocyclohexanes (HCH) isomers ranged between BDL-29.239±4.25 µg/Kg for α-HCH, β-HCH (BDL-3.481±0.54 µg/Kg), γ-HCH (BDL-1.009±0.00 µg/Kg), δ- HCH (BDL - 0.064±0.00 µg/Kg). The Mean concentration of heptachlor ranged from BDL-0.526±0.056 µg/Kg, β -endosulfan (BDL - 12.017±0.68 µg/Kg), andrin (BDL - 0.841±0.00 µg/Kg), heptachlor epoxide (BDL - 0.805±0.00 µg/Kg), α-Endosulfan (BDL-0.803±0.00µg/Kg), pp'-DDE (BDL - 0.7336±0.00µg/Kg), dieldrin (BDL-0.803±0.00µg/Kg), endrin aldehyde (BDL - 63.015±6.12 µg/Kg), endosulphan sulfate (31.992±2.04µg/Kg), while β-endosulfan, endrin were not detected in all the sites. The mean concentration of *p,p'*-DDT was below detection limit while the mean concentration of its *p,p'*-DDD ranged between BDL-5.408±0.05µg/Kg and *p,p'*-DDE ranged between BDL- 0.7336±0.00 µg/Kg.

4.3.5.3.1 Comparison of OCPs levels in horticultural farm soils from different sampling sites

Methoxychlor had the highest pesticide residue levels (72.95±5.06 µg/Kg) detected in soil from sampling site thirteen, followed byendosulfan sulfate (38.508±3.71 µg/Kg), α -HCH (9.293±1.06 µg/Kg) and β -HCH (3.481±0.54 µg/Kg). The rest of the pesticides are shown in Figure 4.13 and in the table in Appendix section.

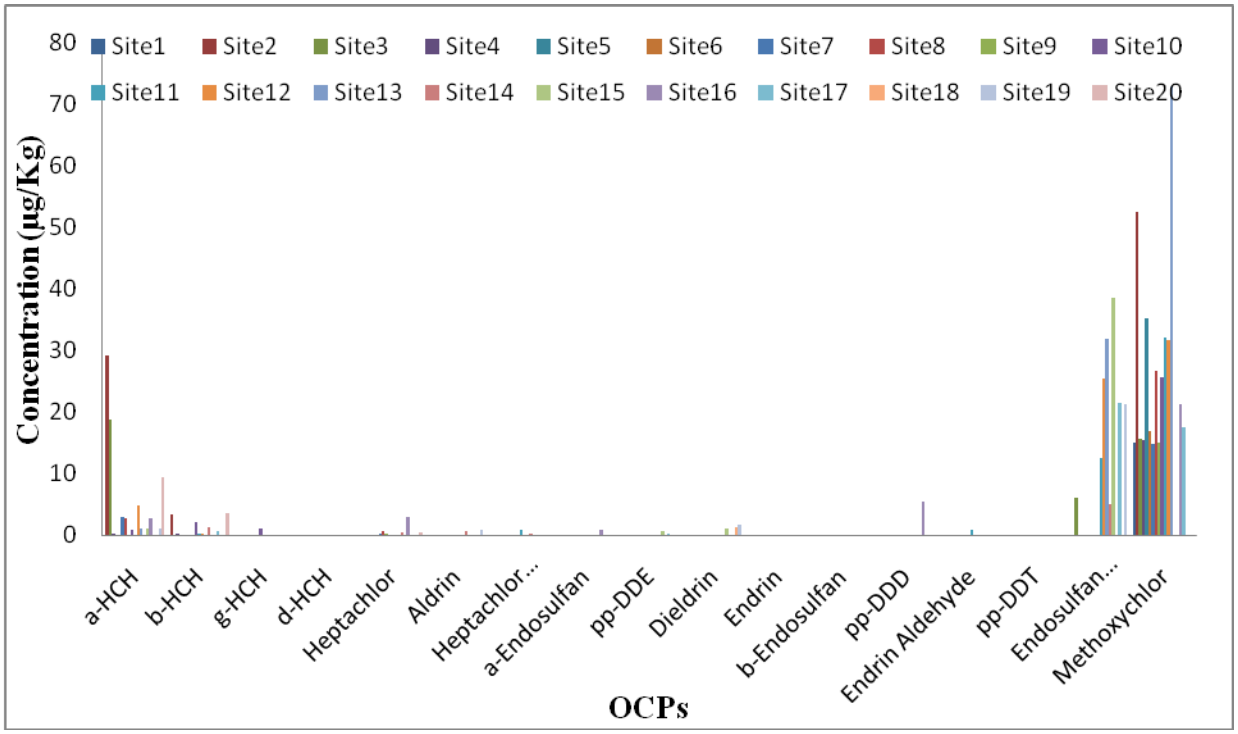

Figure 4.18: Residue levels of carbendazim pesticides in tomatoes from Meru County

Both aldrin and dieldrin have been used in the past as insecticides for soil-dwelling pests and for the protection of wooden structures against termites. But dieldrin was also used as an insecticide against insects of public health concern. The use of the two compounds has been banned in Kenya and many other countries due to their deleterious effects on human health and environment.

Methoxychlor is an organochlorine insecticide used for the control of livestock parasites and a variety of pests on ornamentals, fruits and vegetables. Due to persistence in environment, the use of methoxychlor in Kenya was banned in 1984 (PCPB, 2010). According to previous studies, endrin is more hydrophobic and less likely to accumulate in the water column compared to its metabolites endrin ketone and aldehyde which are slightly soluble. Once in the water, endrin strongly adsorbs to sediment, thereby partitioning itself from the water and concentrating in the sediment (ATSDR, 1996). Methoxychlor is known to be poorly soluble in water and highly immobile in most soils, whereas the main environmental degradation metabolites are dechlorinated and demethylated products, which are formed preferentially under anaerobic rather than aerobic conditions. Also it's likely to get higher concentration of the pesticides in the soil than in water. The findings of the current study agree with these previous studies.

Although the use of most organochhlorine pesticides was banned in the 80s and 90s in the country, elevated levels of these compounds are still detectable in Kenyan soils. Soil provides a more convenient environment for accumulation of hydrophobic chemicals such as organochlorine pesticides, due its heterogeneous nature and high organic carbon content, compared to water. Pesticides bound to soil organic matter are less accessible to microbial and other modes of degradation, and therefore tend to persist for longer periods. Consequently, analysis of soil samples would provide a good indicator of environmental contamination by these compounds compared to water.

Endosulphan is a sulphur bearing polychlorinated cyclodiene and the technically active parent compound is a diastereomeric mixture of two biologically active isomers; 70% alpha (α)- and 30% beta (β)-endosulphan (Rand *et al.*, 2010). In environment, endosulphan can adsorb to particulates and persist in soil and/or sediment, but is also known to dissipate as a result of volatility and drift to locations far removed from the initial site of use (GFEA, 2007).

Endosulphan sulphate is the main transformation product through oxidation in freshwater and saltwater, including sediment (Shivaramaiah *et al.*, 2005), but the diol, a-hydroxy-ether, ether and lactone have also been reported (NRCC, 1975). The beta isomer (β-endosulphan) and endosulphan sulphate are documented as highly persistent compounds, especially in sediment

(NRCC 1975). The main isomers of endosulphan analysed in soil were: α-Endosulphan, β-endosulphan and endosulphan sulphate, the main metabolite.

According to Nash and Woolson, (1967) endrin is highly persistent in the soil and is less susceptible to biodegradation and hydrolysis processe. But EPA (1998) observed that under a combination of processes such as volatilization, photodegradation and heat transformation endrin could be transformed primarily to endrin ketone, with minor amounts of endrin aldehyde which accounted for rapid decrease in endrin residues on soil surfaces exposed to bright sunlight. This study revealed higher frequency endrin aldehyde in soil compared to the parent compound (endrin).

In the environment, aldrin breaks down slowly by oxidation to dieldrin. But the metabolite, dieldrin, has equally slow degradation rate with an estimated half-life of 5 years in temperate regions. In the tropics, both oxidation and dissipation rates of dieldrin are faster, whereby volatilisation alone is reported to contribute to over 90% disappearance of the compound within 1 month (WHO, 1989).

Lindane was one of the most widely used insecticides [Quintero *et al.,* 2005] prior to its banning due to toxicity to non-target species, persistence in environment, long-range transport effects and potential carcinogenic effects (Jansen, Stoks & Coors, 2011; Zenser, Vijaya,, Herman, Schut, Josephy, 2009). The persistence of lindane and other HCH isomers in soil is attributed to resistance to microbial degradation (Alexander, 1981). Degradation of lindane has been reported to form different intermediate metabolites such as tetrachlorocyclohexene (TCCH) and tetrachlorocyclohexenol (TCCOL) (Singh & Kuhad, 2000), or organochloride compounds such as ethanone-1-(3-chloro-4-methoxyphenyl)- and 1-benzenecarbonyl chloride, 2,4-dichloro-3-

methoxy under fungal degradation (Quintero *et al.,* 2008]). Usually α and γ isomers are less persistent in soil than the β and δ isomers (Quintero *et al.,* 2005).

Heptachlor is a cyclodiene insecticide widely used in the control of termites prior to its banning due to persistence and toxicity to non-target organisms. Its presence in the soils is mainly due to volatilization from the surfaces of previous application, especially in moist soils. However, volatilization of heptachlor incorporated into soil is slower due to high adsorption coefficient. In soil, heptachlor may degrade to 1-hydroxychlordene, heptachlor epoxide and an unidentified metabolite less hydrophilic than heptachlor epoxide depending on environmental conditions.

The analysis of organochlorine pesticides in tomatoes, French beans and Kale samples from Buuri, Imenti South and Imenti North was done but the results gave below detection limits, which indicated that there were no residues of organochlorine pesticide in these horticultural produce.

4.4 Analysis of other (non-organochlorine) Pesticides in Farm soil and Horticultural Produce Samples from Buuri, Imenti North and Imenti South.

Residues of other pesticides including carbendazine, imidacloprid, acetamiprid, metalxyl, diazinon, azoxystrobin, chlorpyrifos, acephate, thiomethoxam and triadimefon were found in Farm soil and the three horticultural produce in the three Subcounties. Some of these other pesticides that were detected are given in the Table 4.20b below. The calibration curves used for these pesticides can be found in Appendix section.

Table 4.33: List of other (non-organochlorine) pesticides detected in Samples of Farm Soil, Tomatoes, Kales and French Beans taken from Imenti North, Imenti South and Buuri Subcounties in Meru County.

Pesticides detected in farm soil, tomatoes, kales and French beans	Pesticide class	Active ingredient (a.i.)	LD_{50} (oral, rat) of a.i. (mg/kg bw)
Carbendazim	Fungicide	Carbendazim	>10,000
Imidacloprid	Neonicotinoid insecticide	Imidacloprid	450
Acetamiprid	Neonicotinoid insecticide	Acetamiprid	134-193
Metalalxyl[a]	Fungicide	Metalalxyl	669
Diazinon[a]	Organophosphate insecticide	Diazinon	150-220
Azoxystrobin	Fungicide	Azoxystrobin	>5,000
Chlorpyrifos[a]	Organophosphate insecticide	Chlorpyrifos	96-270
Triadimefon	Fungicide	Triadimeform	363-563
Acephate	Organophosphate insecticide	Acephate	1,400
Thiamethoxim	Neonicotinoid insecticide	Thiamethoxim	1563

Note: [a]pesticides reported in the survey; bw = body weight.

In samples of soil and horticultural produce taken randomly from the three subcounties, the various pesticides in the category of fungicides, neonicotinoids and organophosphates, were detected in various concentrations (see Table 4.20b). Some of these pesticides were not reported in the Survey, e.g. carbendazim, imidacloprid, azoxystrobin, triadimefon, acephate and thiamethoxim were not reported by farmer in the survey of pesticide usage. However, diazinon, metalaxyl and chlorpyrifos were reported in the survey of pesticide use by farmers. Acephate and thiamethoxam were found in only two samples each of French beans (see Appendix XXV and XXVI) but were not found in any of the farm soil, tomato or kale samples. Though some of these products have relatively low mammalian toxicity such as metalaxyl, carbendazine, azoxystrobin, acephate and thiamethoxam, it is not clear why the farmers failed to report their use in farming in the area during the survey. It could be because these are relatively newer products and the farmers could not remember them or that farmers which used them were not sampled during the survey (Karasek & Clement, 2008).

Imidacloprid is now the most widely used insecticide worldwide with application on soil, crop and seed dressing. The neonicotinoids are highly toxic to insects at very low concentrations but they are a potential threat to the ecosystem due to the negative impacts on bees which have been reported globally (Migdal *et al.*, 2018). Migdal et al (2018) recently reported on the impact of pesticides on honey bees, in which some of the effects were reported as being deterioration of health and adverse effect on general behavior of the bees such as mortality and accumulation, in experiments with thiamethoxam (Actara 25W) and a-cypermethrin (Fastac 100EC) insecticides as well as copper oxychloride (Miedzia 50WP), a fungicide. Neonicotinoids such as imidacloprid have become popular due to their low mammalian toxicities and use in low concentrations in food crops which enable them to conform easily to Maximum Residue Limit requirements (Jurewicz & Hanke, 2006). Some of the fungicides detected in the horticultural produce in this study are no longer allowed for use in some countries, e.g. acephate is no longer allowed for use in green peas in the USA (Extoxnet, 1995). The concentrations of these pesticides in soil and horticultural produce are presented in the following sections and also in the Appendix section. Although neonicotinoids are recognized as extremely toxic to bees, fungicides have also shown to be toxic to bees and should be include in environmental monitoring and risk assessment (Migdal *et al.*, 2018).

4.4.1 Carbendazim Pesticide Residue Levels in Horticultural products

Carbendazim'standard calibration curve was constructed by plotting analyte concentrations against peak areas. A linearity (y=133896x -7841.3) was obtained with a correlation coefficient of R^2=0.9979. The calibration curve is attached at Appendix section. Recoveries were done for the French beans, tomatoes, kales and soil. Spiking was done at 1 µg/kg of carbendazim standard. Average recoveries from fortified samples for each matrix were in the range of 81.76±1.35 (Tomatoes) - 90.80±5.21% (Kales). Table 4.21 shows the recoveries for French beans, tomatoes, kales and soil. The kales showed the highest percentage recovery (90.80±5.21% %). Table 4.21 shows the summary of carbendazim pesticides levels from Meru County in the three sub counties (Buuri, Imenti North and Imenti South) and their recovery levels.

Table 4.34: The Mean Concentrations of Carbendazim (µg/ kg, wet weight) detected in Hoticultural products from Buuri, Imenti North and Imenti South sub counties.

Sub-Couty	**Site**	**Tomatoes**	**French Beans**	**Kales**
%Recovery		81.76±1.35	88.42±3.98	90.80±5.21
	C1	11.81±2.71	0.21±0.00	BDL
Buuri	C2	48.65±3.58	0.22±0.00	BDL
	C3	0.24±0.00	0.23±0.00	BDL
	C4	0.37±0.00	0.23±0.00	BDL
	C5	6.58±0.35	16.00±0.52	BDL
	C6	0.93±0.00	0.92±0.00	BDL
	C7	0.33±0.00	0.31±0.00	BDL
Imenti North	C8	1.03±0.08	0.31±0.00	BDL
	C9	0.58±0.00	0.29±0.00	BDL
	C10	1.52±0.00	10.11±0.96	BDL
	C11	1.43±0.00	0.24±0.00	BDL
	C12	3.04±0.06	0.32±0.00	BDL
	C13	6.17±0.52	0.5±0.00	BDL
	C14	0.65±0.00	1.27±0.01	BDL
Imenti South	C15	1.1±0.00	2.16±0.08	BDL
	C16	0.56±0.00	1.11±0.00	BDL
	C17	6.4±0.63	0.3±0.00	BDL
	C18	0.98±0.00	0.38±0.00	BDL
	C19	12.97±1.64	0.33±0.00	BDL
	C20	1.65±0.87	0.3±0.00	BDL
	C21	0.79±0.00	0.93±0.01	BDL
	C22	BDL	0.45±0.00	BDL

4.4.2 Carbendazim Pesticide Residue Levels in Tomatoes

Carbendazim is a widely used, broad-spectrum benzimidazole fungicide and a metabolite of benomyl. It is also employed as a casting worm control agent in amenity turf situations such as golf greens, tennis courts. Carbendazim pesticide residues detected in tomatoes from Meru County ranged between 0.33±0.00 to 48.65±1.38 µg/Kg. Figure 4.15 shows the residue levels of carbendazim pesticides in tomatoes from Meru County.

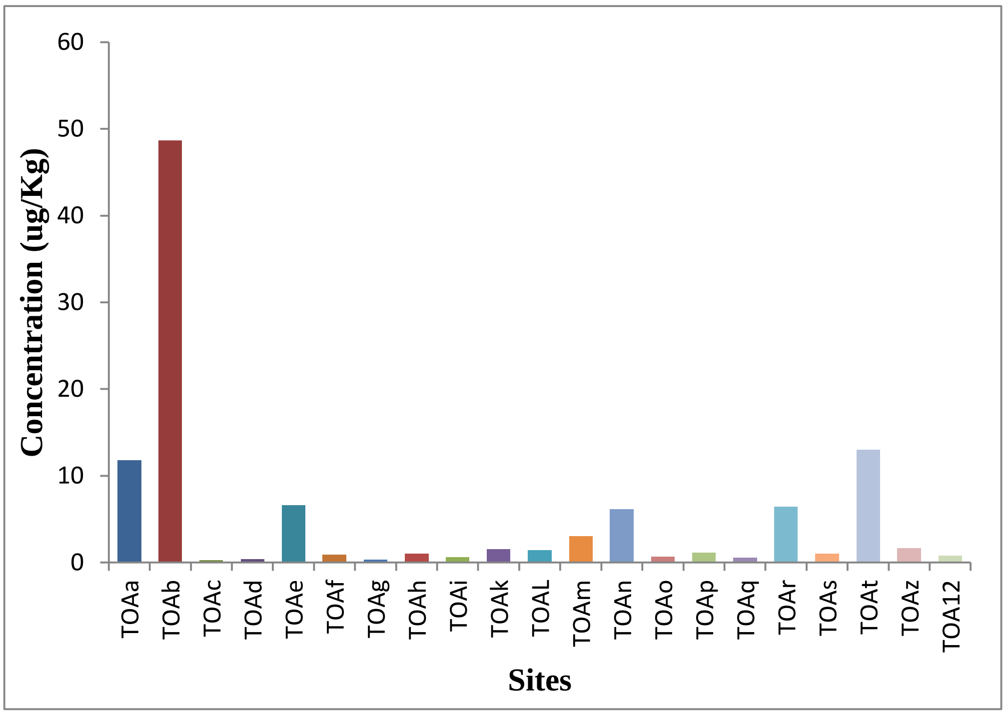

Figure 4.19: Figure: Residue levels of carbendazim pesticides in Tomatoes from Meru County

4.4.3 Carbendazim Pesticide Residue Levels in French Beans

Carbendazim pesticide residues detected in French beans from Meru County ranged between 0.21±0.00 to 10.11±0.86 µg/Kg. Figure 4.16 shows the residue levels of carbendazim pesticides in French beans from Meru County.

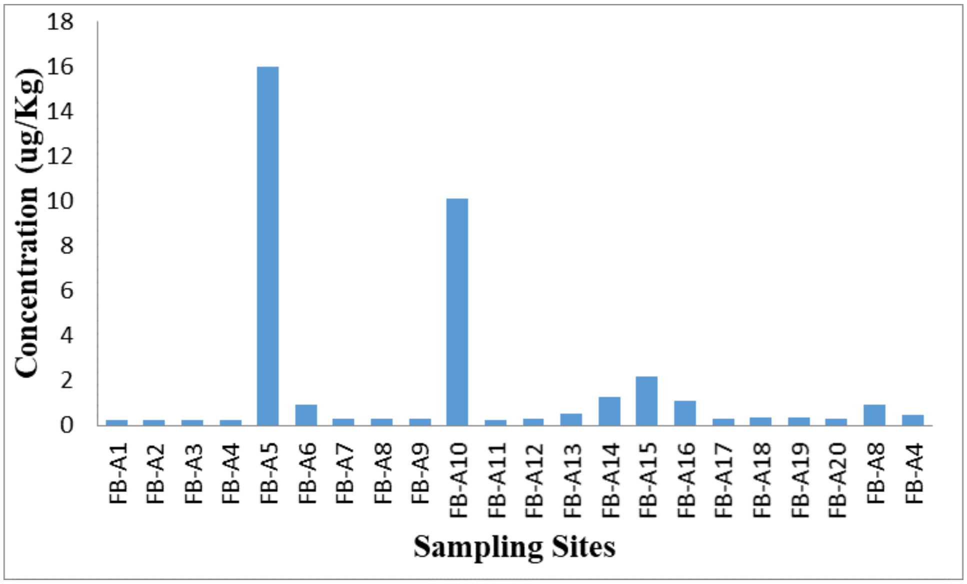

Figure 4.20: Residue levels of carbendazim pesticides in French beans from Meru County

4.4.4 Carbendazim Pesticide Residue Levels in Kales

The determination of carbendazim in kales from Meru County showed that all the samples hand the concentration below detection limit (0.10 ppb). This shows that the Kale farmers in Meru County applied efficiently the pesticide or the pesticide is not used in kale farming.

4.5 Imidacloprid Pesticide Residue Levels in Horticultural Products

Imidacloprid'standard calibration curve was constructed by plotting analyte concentrations against peak areas. A linearity (y=2395.9x -4442.3) was obtained with a correlation coefficient of R^2=0.98. Calibration curve of Imidacloprid is attached in Appendix section. Recoveries were done for the French beans, tomatoes, kales and soil. Spiking was done using 1 µg/kg of imidaclopridstandard. Average recoveries from fortified samples for each matrix were in the range of 76.84±1.32 (Kales) – 82.45±2.65% (Tomatoes). Table 4.22 below shows the recoveries for French beans, tomatoes, kales and soil. The kales showed the highest percentage recovery (82.45±2.65%). The limit of detection was determined and found to be 0.10ppb. Table 4.22: The

Mean Concentration of Imidacloprid pesticides (µg/ kg, dry weight) detected in Hoticultural products from Buuri, Imenti North and Imenti South sub counties.

Table 4.35: The Mean Concentration of Imidacloprid pesticides (µg/ kg, wet weight) detected in Horticultural products from Buuri, Imenti North and Imenti South sub counties

Sub-Couty	Site	Tomatoes	French Beans	Kales
%Recovery		82.45±2.65	77.35±1.26	76.84±1.32
	C1	196.47±19.63	BDL	BDL
Buuri	C2	290.76±26.34	BDL	BDL
	C3	0.24±0.00	BDL	BDL
	C4	0.88±0.00	BDL	BDL
	C5	33.57±1.82	BDL	BDL
	C6	1.44±0.00	BDL	BDL
	C7	0.58±0.00	BDL	BDL
Imenti North	C8	0.12±0.00	BDL	BDL
	C9	1.25±0.05	21.18±0.96	BDL
	C10	1.52±0.06	BDL	BDL
	C11	8.56±0.97	BDL	BDL
	C12	0.51±0.00	BDL	BDL
	C13	1.09±0.07	0.85±0.00	BDL
	C14	2.24±0.00	4.3±0.05	BDL
Imenti South	C15	2.87±0.04	10.12±1.07	BDL
	C16	0.1±0.00	10.12±0.36	BDL
	C17	0.56±0.00	BDL	BDL
	C18	2.7±0.08	BDL	BDL
	C19	0.11±0.00	BDL	BDL
	C20	9.24±1.42	BDL	BDL
	C21	0.56±0.00	BDL	BDL
	C22	BDL	0.45±0.00	BDL

4.5.1 Pesticide Residue Levels in Tomatoes

Imidacloprid is an insecticide that was made to mimic nicotine. Nicotine is naturally found in many plants, including tobacco, and is toxic to insects. Imidacloprid is used to control sucking insects, termites, some soil insects, and fleas on pets. Imidacloprid pesticide residues detected in tomatoes from Meru County ranged between BDL to 290.76 ±1.38 µg/Kg. Figure 4.21 shows the residue levels of Imidacloprid pesticides in tomatoes from Meru County.

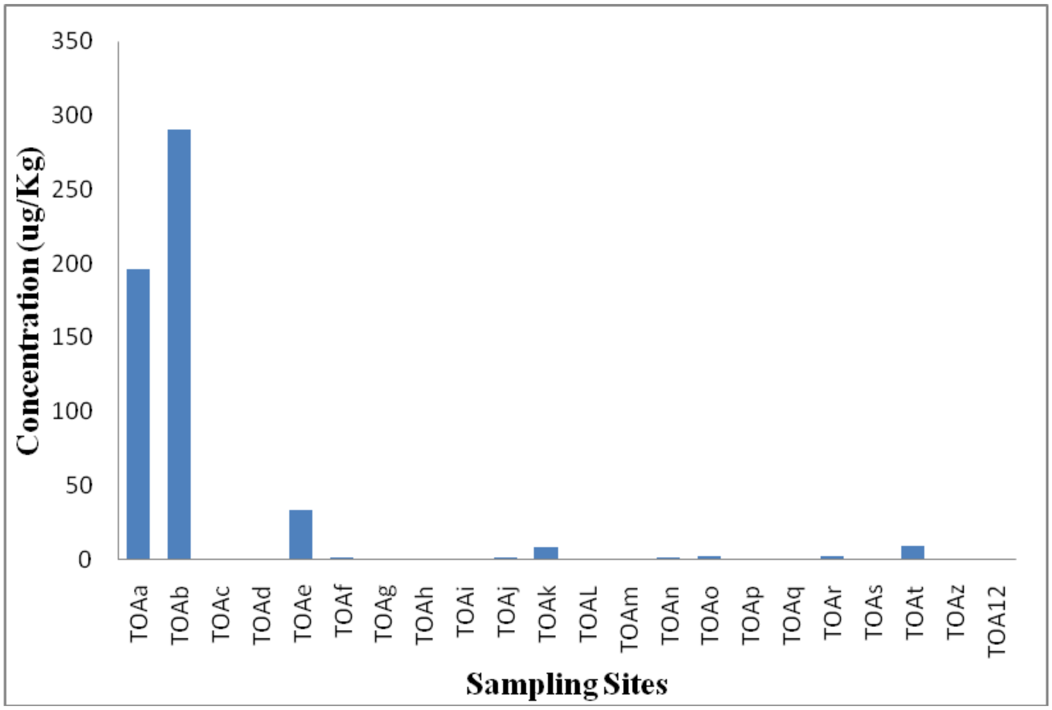

Figure 4.21: Residue levels of Imidacloprid pesticides in tomatoes from Meru County

4.5.2 Pesticide Residue Levels in French Beans

Imidacloprid is an insecticide that was made to mimic nicotine. Nicotine is naturally found in many plants, including tobacco, and is toxic to insects. Imidacloprid is used to control sucking insects, termites, some soil insects, and fleas on pets. Imidacloprid pesticide residues detected in French beans from Meru County ranged between BDL to 21.18±0.99 µg/Kg. Figure 4.22 shows the residue levels of Imidacloprid pesticides in French Beans from Meru County.

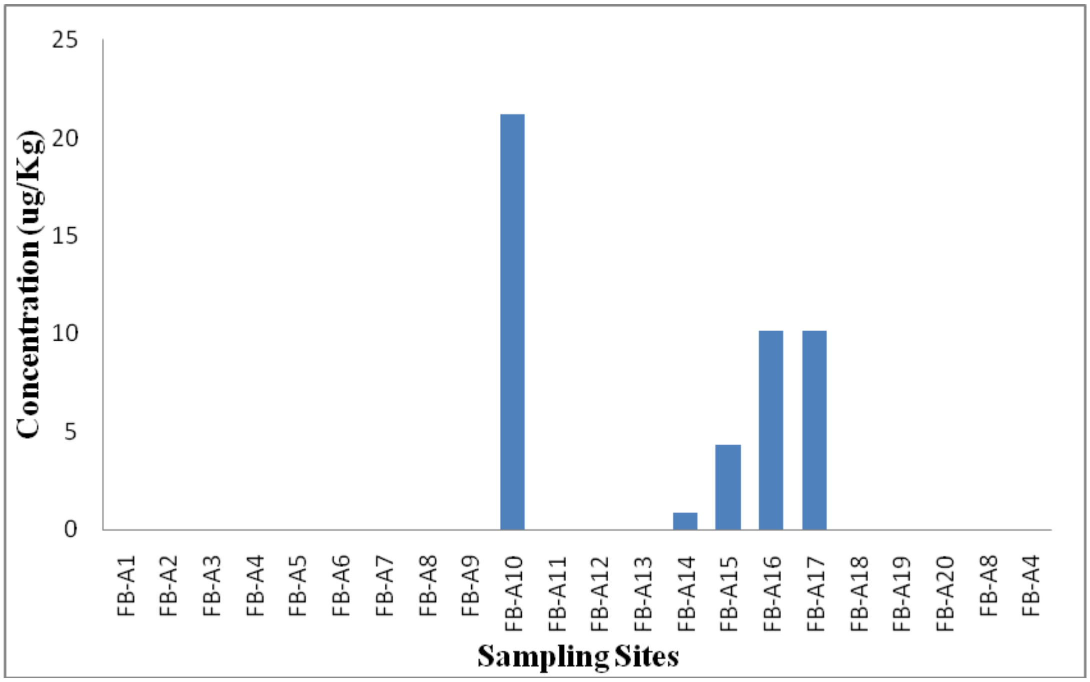

Figure 4.22: Residue levels of Imidacloprid pesticides in French Beans from Meru County

4.5.3 Imidacloprid Pesticide Residue Levels in Kales

The determination of Imidacloprid in kales from Meru County showed that all the samples hand the concentration below detection limit (0.10 ppb). This shows that the Kale farmers in Meru County applied efficiently the pesticide or the pesticide is not used in kale farming.

4.6 Acetamiprid Pesticide Residue Levels in Horticultural Products

Acetamiprid standard calibration curve was constructed by plotting analyte concentrations against peak areas. A linearity (y=25490x +10430) was obtained with a correlation coefficient of R^2=0.99. Figure 4.26 shows the calibration curve of Acetamiprid. Calibration curve is attached in Appendix section. Recoveries were done for the French beans, tomatoes, kales and soil. Spiking was done using 1 µg/kg of Acetamiprid standard. Average recoveries from fortified samples for each matrix were in the range of 96.32±3.78 (French Beans) – 79.21±0.96% (Kales). Table 4.23 below shows the recoveries for French beans, tomatoes, kales and soil. The kales showed the highest percentage recovery (82.45±2.65%). The limit of detection was determined and found to be 0.10ppb.

Table 4.23 shows the Mean Concentration of acetaprimid pesticides (µg/ kg, dry weight) detected in Horticultural products from Buuri, Imenti North and Imenti South sub counties.

Table 4.36: Mean Concentrations of acetaprimid pesticides (µg/ kg, wet weight) detected in Horticultural products from Buuri, Imenti North and Imenti South sub counties

Sub-Couty	Site	Tomatoes	French Beans	Kales
%Recovery		79.21±2.0.96	96.32±3.78	86.39±5.09
	C1	0.29±0.01	0.18±0.01	BDL
Buuri	C2	0.11±0.00	0.23±0.00	BDL
	C3	BDL	0.23±0.00	BDL
	C4	BDL	0.2±0.00	BDL
	C5	BDL	0.12±0.00	BDL
	C6	BDL	BDL	BDL
	C7	BDL	0.1±0.00	BDL
Imenti North	C8	BDL	BDL	BDL
	C9	BDL	0.13±0.00	BDL
	C10	BDL	1.51±0.06	BDL
	C11	BDL	0.13±0.00	BDL
	C12	BDL	BDL	BDL
	C13	BDL	2.81±0.05	BDL
	C14	BDL	2.49±0.06	BDL
Imenti South	C15	BDL	0.16±0.00	BDL
	C16	BDL	1.56±0.05	BDL
	C17	BDL	0.14±0.00	BDL
	C18	BDL	BDL	BDL
	C19	BDL	0.2±0.00	BDL
	C20	BDL	0.16±0.00	BDL
	C21	BDL	0.16±0.00	BDL
	C22	BDL	0.23±0.00	BDL

4.6.1 Pesticide Residue Levels in Tomatoes

Acetamiprid is an organic compound with the chemical formula $C_{10}H_{11}ClN_4$. It is an odorless neonicotinoid insecticide produced under the trade names Assail, and Chipco by Aventis Crop

Sciences. Acetamiprid pesticide residues detected in tomatoes from Meru County ranged between BDL to 0.29±0.00 µg/Kg. Figure 4.17 shows the residue levels of Acetamiprid pesticides in tomatoes from Meru County.

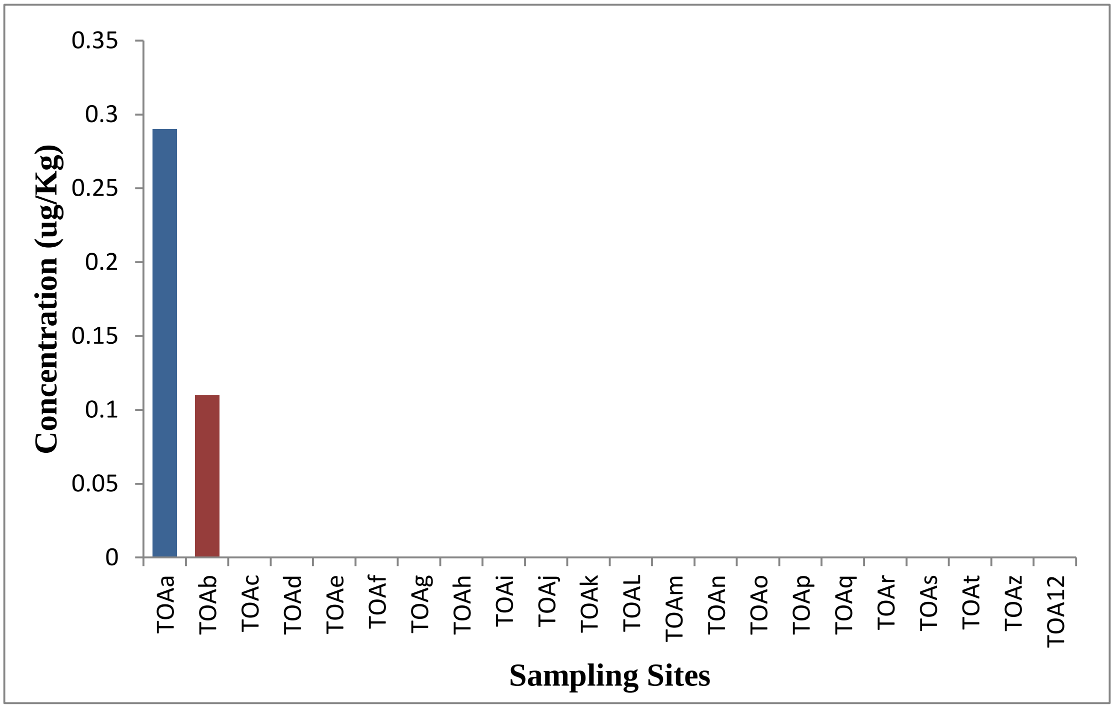

Figure 4.23: Residue levels of Acetamiprid pesticides in tomatoes from Meru County

4.6.2 Pesticide Residue Levels in French Beans

Acetamiprid is an organic compound with the chemical formula $C_{10}H_{11}ClN_4$. It is an odorless neonicotinoid insecticide produced under the trade names Assail, and Chipco by Aventis Crop Sciences. Acetamipridpesticide residues detected in French beans from Meru County ranged between BDL to 2.81 ±0.09 µg/Kg. Figure 4.18 shows the residue levels of Acetamiprid pesticides in French Beans from Meru County.

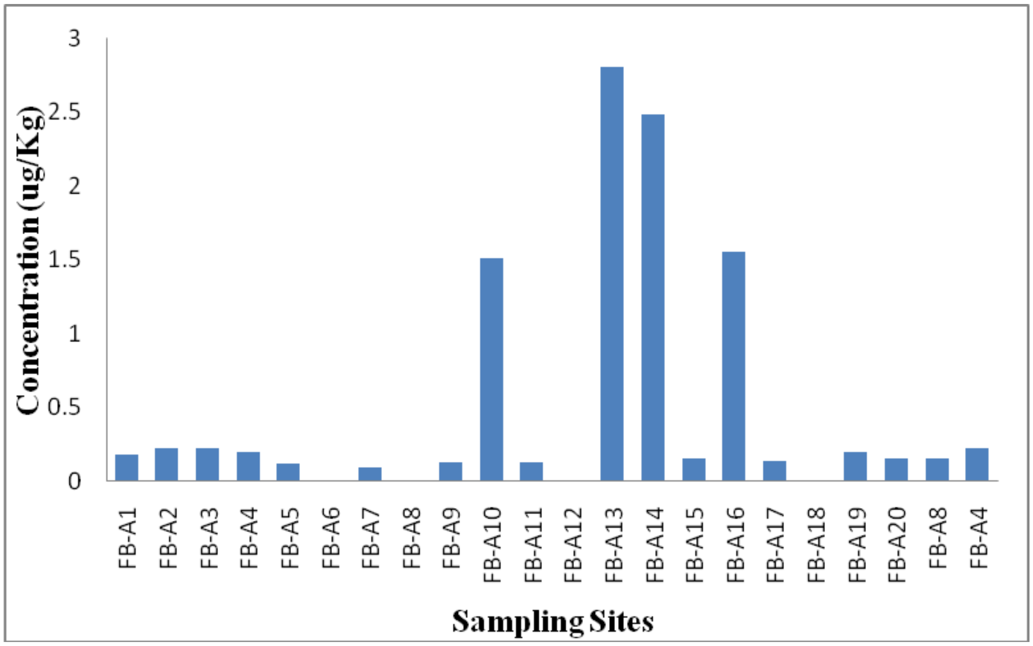

Figure 4.24: Residue levels of Acetamiprid pesticides in French Beans from Meru County

4.6.3Acetamiprid Pesticide Residue Levels in Kales

The determination of Acetamiprid in kales from Meru County showed that all the samples hand the concentration below detection limit (0.10 ppb). This shows that the Kale farmers in Meru County applied efficiently the pesticide or the pesticide is not used in kale farming.

4.7Azoxystrobin Pesticide Residue Levels in Horticultural Products

Azoxystrobin'standard calibration curve was constructed by plotting analyte concentrations against peak areas. A linearity (y=8187.6x + 2006.9) was obtained with a correlation coefficient of R^2=0.99. Calibration curve of Azoxystrobin is attached in Appendix section. Recoveries were done for the French beans, tomatoes, kales and soil. Spiking was done using 1 µg/kg of Azoxystrobin standard. Average recoveries from fortified samples for each matrix were in the range of 88.63±6.11% (French Beans) – 81.32±3.53% (Kales). Table 4.37 below shows the recoveries for French beans, tomatoes, kales and soil. The kales showed the highest percentage recovery (88.63±6.11%). The limit of detection was determined and found to be 0.10ppb. Table

4.37 shows mean concentration of Azoxystrobin pesticides (µg/ kg, dry weight) detected in horticultural products from Buuri, Imenti North and Imenti South sub counties.

Table 4.37: Mean Concentration of Azoxystrobin pesticides (µg/ kg, wet weight) detected in Hoticultural products from Buuri, Imenti North and Imenti South sub counties

Sub-Couty	Site	Tomatoes	French Beans	Kales
%Recovery		82.89±4.32	88.63±6.11	81.32±3.54
	C1	BDL	BDL	BDL
Buuri	C2	0.1±0.00	BDL	BDL
	C3	0.33±0.00	BDL	BDL
	C4	0.95±0.00	0.19±0.00	BDL
	C5	0.96±0.00	1.84±0.08	BDL
	C6	0.15±0.08	BDL	BDL
	C7	0.54±0.00	0.2±0.00	BDL
Imenti North	C8	BDL	0.11±0.00	BDL
	C9	BDL	0.16±0.00	BDL
	C10	0.25±0.00	2.49±0.07	BDL
	C11	3.73±0.87	BDL	BDL
	C12	BDL	0.11±0.00	BDL
	C13	1.87±0.00	6.96±0.85	BDL
	C14	2.12±0.09	1.22±0.06	BDL
Imenti South	C15	15.93±1.48	1.35±0.02	BDL
	C16	BDL	3.68±0.01	BDL
	C17	1.26±0.63	BDL	BDL
	C18	2.9±0.00	0.1±0.00	BDL
	C19	BDL	0.19±0.00	BDL
	C20	0.69±0.00	0.21±0.00	BDL
	C21	BDL	25.76±1.68	BDL
	C22	BDL	0.13±0.00	BDL

4.7.1 Pesticide Residue Levels in Tomatoes

Azoxystrobin is a systemic fungicide commonly used in agriculture. The substance is used as an active agent protecting plants and fruit/vegetables from fungal diseases. Its chemical formula is $C_{22}H_{17}N_3O_5$. Azoxystrobin pesticide residues detected in tomatoes from Meru County ranged between BDL to 15.93±2.31 µg/Kg. Figure 4.33 shows the residue levels of Azoxystrobin pesticides in tomatoes from Meru County.

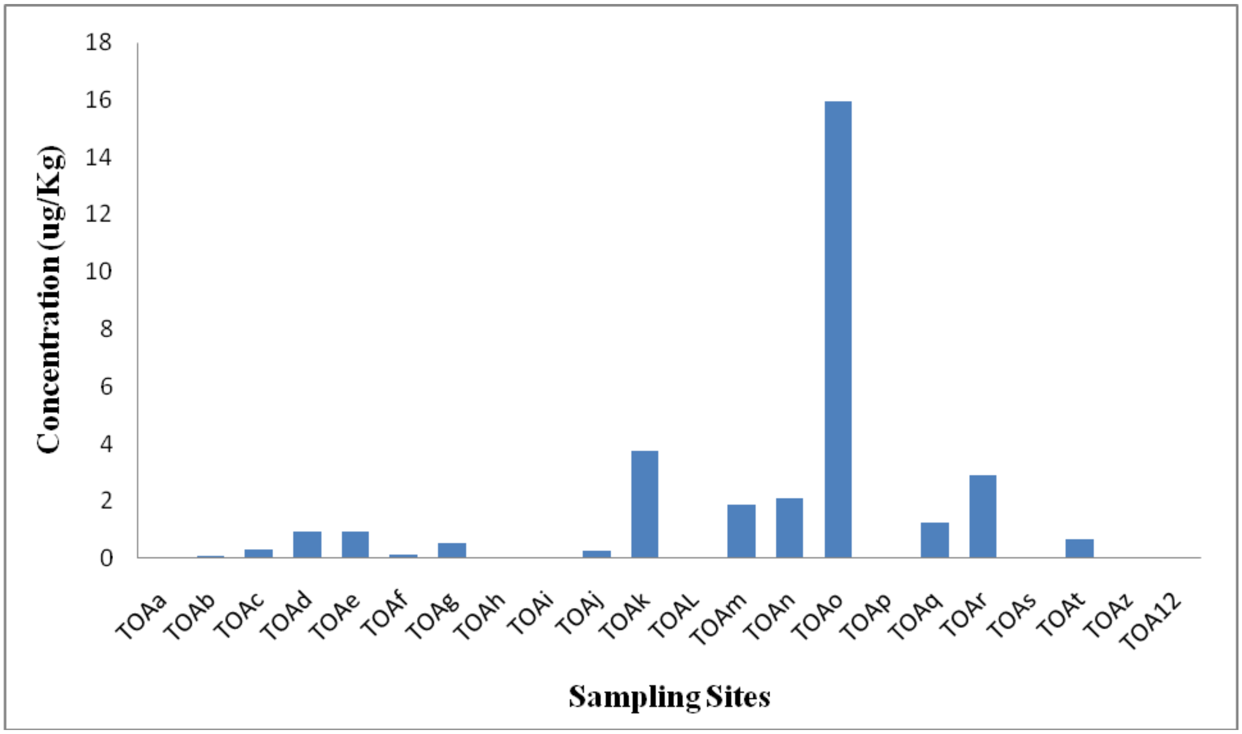

Figure 4.25: Residue levels of Azoxystrobin pesticides in tomatoes from Meru County

4.7.2 Pesticide Residue Levels in French Beans

Azoxystrobin is a systemic fungicide commonly used in agriculture. The substance is used as an active agent protecting plants and fruit/vegetables from fungal diseases. Its chemical formula is $C_{22}H_{17}N_3O_5$. Azoxystrobin pesticide residues detected in French Beans from Meru County ranged between BDL to 25.76±1.95 µg/Kg. Figure 4.20 shows the residue levels of Azoxystrobin pesticides in tomatoes from Meru County.

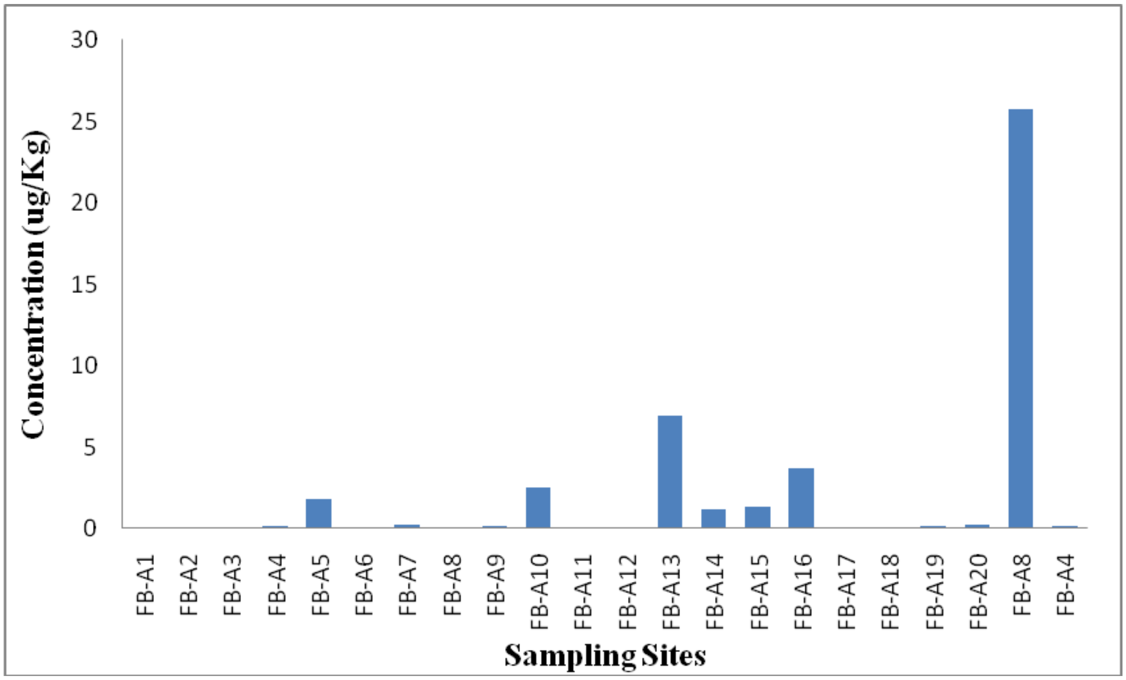

Figure 4.26: Residue levels of Azoxystrobin pesticides in tomatoes from Meru County

4.7.3 Azoxystrobin Pesticide Residue Levels in Kales

The determination of Azoxystrobin in kales from Meru County showed that all the samples hand the concentration below detection limit (0.10 ppb). This shows that the Kale farmers in Meru County applied efficiently the pesticide or the pesticide is not used in kale farming.

4.8 Metalaxyl Pesticide Residue Levels in Horticultural Products

Metalaxyl standard calibration curve was constructed by plotting analyte concentrations against peak areas. A linearity (y=25490x + 10430) was obtained with a correlation coefficient of R^2=0.99. The calibration curve of Metalaxyl is attached in Appendix section. Recoveries were done for the French beans, tomatoes, kales and soil. Spiking was done using 1 µg/kg of Metalaxyl standard. Average recoveries from fortified samples for each matrix were in the range of 92.06±6.39% (French Beans) – 85.36±5.45% (Kales). Table 4.38 below shows the recoveries for French beans, tomatoes, kales and soil. The kales showed the highest percentage recovery (92.06±6.39%). The limit of detection was determined and found to be 0.10ppb. Table 4.38

shows mean concentration of metalaxyl pesticides (µg/ kg, dry weight) detected in horticultural products from Buuri, Imenti North and Imenti South sub counties.

Table 4.38: Mean Concentration of Metalaxyl pesticides (µg/ kg, wet weight) detected in Horticultural products from Buuri, Imenti North and Imenti South sub counties.

Sub-Couty	**Site**	**Tomatoes**	**French Beans**	**Kales**
%Recovery		88.56±2.78	92.06±6.39	85.36±5.45
	C1	2.27±0.01	BDL	BDL
Buuri	C2	105.18±6.32	BDL	BDL
	C3	6.58±0.69	BDL	BDL
	C4	4.68±0.54	BDL	BDL
	C5	1.59±0.07	0.11±0.00	BDL
	C6	BDL	BDL	BDL
	C7	2.1±0.18	BDL	BDL
Imenti North	C8	BDL	BDL	BDL
	C9	BDL	BDL	BDL
	C10	BDL	BDL	BDL
	C11	BDL	0.11±0.00	BDL
	C12	BDL	BDL	BDL
	C13	BDL	0.13±0.00	BDL
	C14	BDL	BDL	BDL
Imenti South	C15	1.05±0.01	BDL	BDL
	C16	BDL	BDL	BDL
	C17	BDL	BDL	BDL
	C18	BDL	BDL	BDL
	C19	BDL	BDL	BDL
	C20	BDL	BDL	BDL
	C21	BDL	BDL	BDL
	C22	BDL	BDL	BDL

4.8.1 Pesticide Residue Levels in Tomatoes

Metalaxyl is an acylalanine fungicide with systemic function. Its chemical name is methyl N--N--DL-alaninate. It can be used to control Pythium in a number of vegetable crops, and Phytophthora in peas. Its chemical formula is $C_{15}H_{21}NO_4$. Metalaxylpesticide residues detected in tomatoes from Meru County ranged between BDL to 105.18±3.65 µg/Kg. Figure 4.36 shows the residue levels of Metalaxyl pesticides in tomatoes from Meru County.

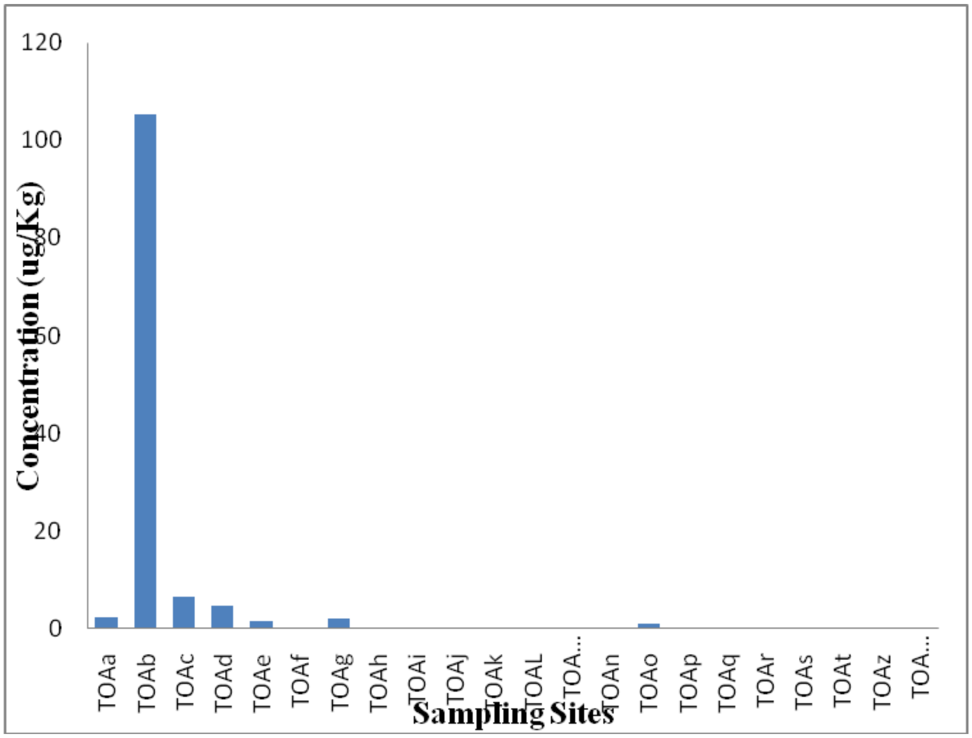

Figure 4.27: Horticultural products from Buuri, Imenti North and Imenti South sub counties.

4.8.2 Pesticide Residue Levels in French Beans

Metalaxyl is an acylalanine fungicide with systemic function. Its chemical name is methyl N--N--DL-alaninate. It can be used to control Pythium in a number of vegetable crops, and Phytophthora in peas. Its chemical formula is $C_{15}H_{21}NO_4$. Metalaxylpesticide residues detected in French beans from Meru County ranged between BDL to 105.18±8.44 µg/Kg. Figure 4.22 shows the residue levels of Metalaxyl pesticides in French Beans from Meru County.

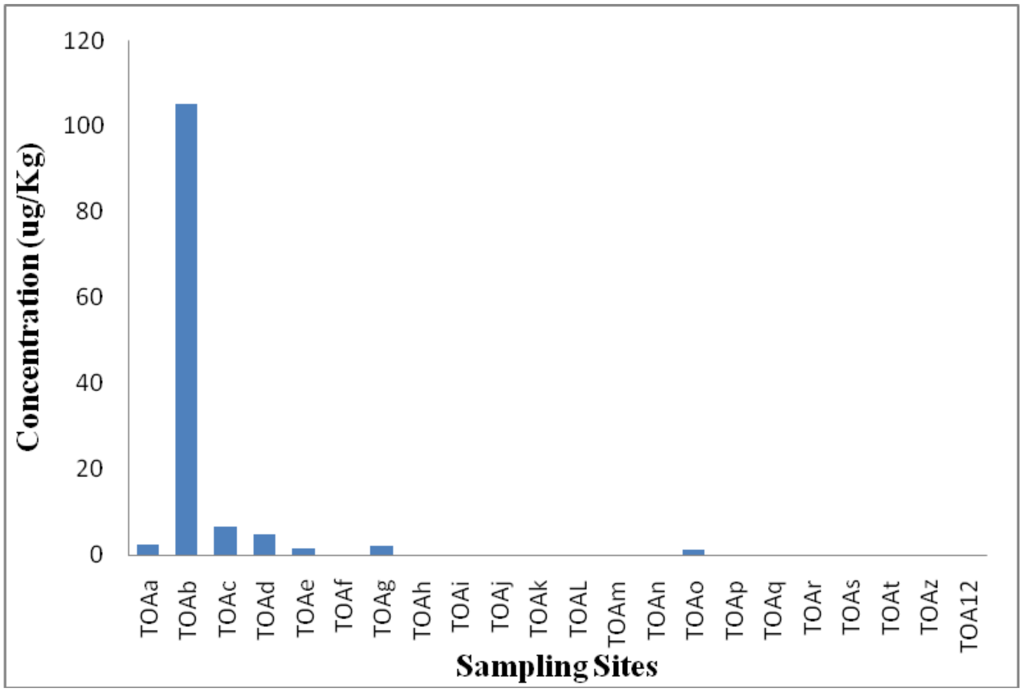

Figure 4.28: Residue levels of Metalaxyl pesticides in tomatoes from Meru County

4.8.3 Metalaxyl Pesticide Residue Levels in Kales

The determination of Metalaxyl in kales from Meru County showed that all the samples hand the concentration below detection limit (0.10 ppb). This shows that the Kale farmers in Meru County applied efficiently the pesticide or the pesticide is not used in kale farming.

4.9 Diazinon Pesticide Residue Levels in Horticultural Products

Diazinon'standard calibration curve was constructed by plotting analyte concentrations against peak areas. A linearity (y=3594.9 + 17431) was obtained with a correlation coefficient of R^2=0.99. Calibration curve of diazinon is attached in Appendix section. Recoveries were done for the French beans, tomatoes, kales and soil. Spiking was done using 1µg/kg of diazinon standard. Average recoveries from fortified samples for each matrix were in the range of 86.94±7.19% (French Beans) – 81.91±6.07% (Kales). Table 4.26 below shows the recoveries for French beans, tomatoes, kales and soil. The kales showed the highest percentage recovery (86.94±7.19%). The limit of detection was determined and found to be 0.10ppb.

Table 4.39 shows mean concentrations of diazinon pesticides (μg/ kg, dry weight) detected in Hoticultural products from Buuri, Imenti North and Imenti South sub counties.

Table 4.39: The Mean Concentration of Diazinon pesticides (μg/ kg, wet weight) detected in Horticultural products from Buuri, Imenti North and Imenti South sub counties.

Sub-Couty	Site	Tomatoes	French Beans	Kales
%Recovery		81.91±6.07	86.94±7.19	86.41±1.89
	C1	BDL	0.14±0.00	BDL
Buuri	C2	BDL	0.12±0.00	BDL
	C3	BDL	BDL	BDL
	C4	BDL	BDL	BDL
	C5	BDL	BDL	BDL
	C6	BDL	BDL	BDL
	C7	BDL	BDL	0.13±0.00
Imenti North	C8	BDL	0.1±0.00	BDL
	C9	BDL	0.15±0.00	BDL
	C10	BDL	BDL	BDL
	C11	BDL	BDL	BDL
	C12	BDL	0.11±0.00	BDL
	C13	BDL	0.11±0.01	0.14±0.00
	C14	BDL	BDL	BDL
Imenti South	C15	BDL	BDL	0.14±0.00
	C16	BDL	BDL	BDL
	C17	BDL	BDL	0.12±0.00
	C18	BDL	BDL	BDL
	C19	BDL	0.11±0.00	BDL
	C20	BDL	BDL	BDL
	C21	BDL	0.15±0.00	BDL
	C22	BDL	BDL	BDL

4.9.1 Diazinon Pesticide Residue Levels in Tomatoes

The determination of diazinon in tomatoes from Meru County showed that all the samples hand concentration below detection limit (0.10 ppb). This shows that the Kale farmers in Meru County applied efficiently the pesticide or the pesticide is not used in kale farming.

4.9.2 Pesticide Residue Levels in French Beans

Diazinon is an insecticide that belongs to a group of chemicals known as organophosphates. Diazinon is used in agriculture to control insects on fruit, vegetable, nut and field crops. It is also used to make ear tags for cattle. Its chemical formula is $C_{12}H_{21}N_2O_3PS$. Diazinon pesticide residues detected in French beans from Meru County ranged between BDL to 0.14±0.00 µg/Kg. Figure 4.23 shows the residue levels of diazinon pesticides in French Beans from Meru County.

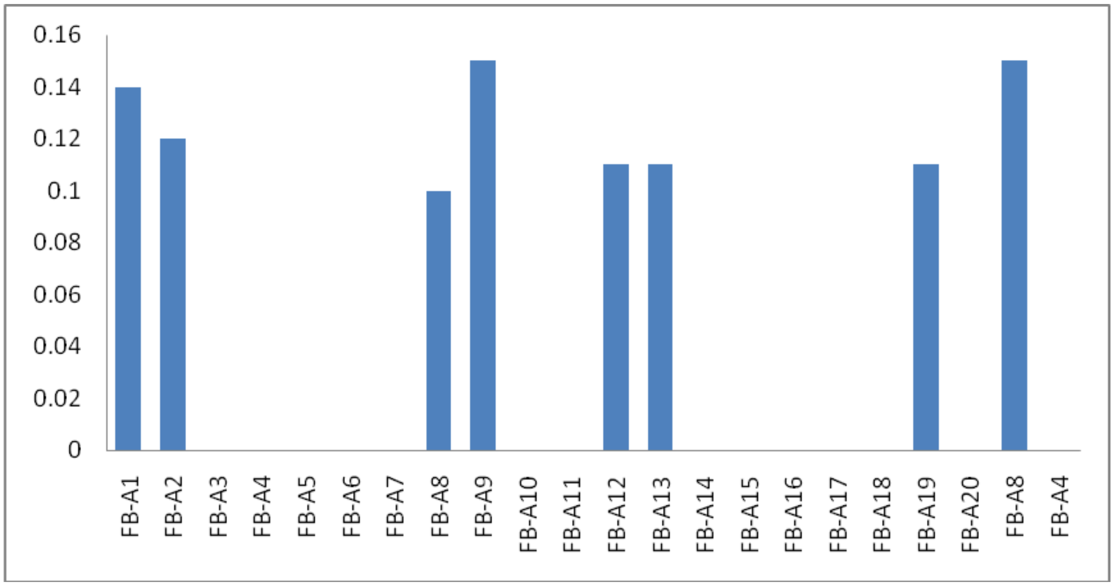

Figure 4.29: Residue levels of Metalaxyl pesticides in French Beans from Meru County

4.9.3 Diazinon Pesticide Residue Levels in Kales

Diazinon is an insecticide that belongs to a group of chemicals known as organophosphates. Diazinon is used in agriculture to control insects on fruit, vegetable, nut and field crops. It is also used to make ear tags for cattle. Its chemical formula is $C_{12}H_{21}N_2O_3PS$. Diazinon pesticide residues detected in kales from Meru County ranged between BDL to 0.14 ±0.00 µg/Kg. Figure 4.43 shows the residue levels of Diazinon pesticides in French Beans from Meru County.

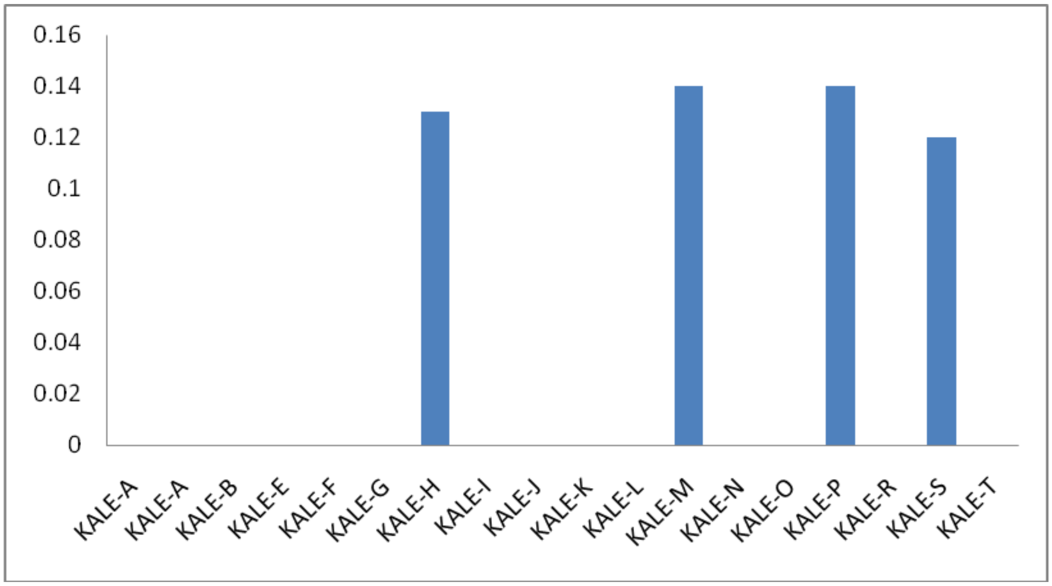

Figure 4.30: Residue levels of Diazinon pesticides in French Beans from Meru County

4.10 Chlorpyrifos Pesticide Residue Levels

Chlorpyrifos standard calibration curve was constructed by plotting analyte concentrations against peak areas. A linearity (y=743.31x + 2178.5) was obtained with a correlation coefficient of R^2=0.99. Calibration curve of Chlorpyrifos is attached at Appendix section. Recoveries were done for the French beans, tomatoes, kales and soil. Spiking was done at 1 µg/kg of Chlorpyrifos standard. Average recoveries from fortified samples for each matrix were in the range of 83.79±5.94 (soil)-91.65±9.23% (French beans). Table 4.40 below shows the mean concentrations of chlorpyrifos pesticides (µg/ kg, wet weight) detected in horticultural products from Buuri, Imenti North and Imenti South sub counties.

Table 4.40: Mean Concentration of chlorpyrifos pesticides (µg/ kg, wet weight) detected in Hoticultural products from Buuri, Imenti North and Imenti South sub counties.

Sub-Couty	Site	Tomatoes	French Beans	Kales
%Recovery		86.16±5.62	91.65±9.23	88.36±7.27
	C1	2.27±0.01	BDL	BDL
Buuri	C2	105.18±6.32	0.46±0.00	BDL
	C3	6.58±0.69	BDL	BDL
	C4	4.68±0.54	0.34±0.00	BDL

	C5	1.59±0.07	BDL	BDL
	C6	0	BDL	BDL
	C7	2.1±0.18	BDL	BDL
Imenti North	C8	0	BDL	BDL
	C9	0	BDL	BDL
	C10	0	3.83±0.00	BDL
	C11	0	BDL	BDL
	C12	0	BDL	BDL
	C13	0	0.11±0.00	BDL
	C14	0	0.18±0.00	BDL
Imenti South	C15	1.05±0.01	0.85±0.00	BDL
	C16	0	0.22±0.00	BDL
	C17	0	BDL	BDL
	C18	0	BDL	BDL
	C19	0	0.13±0.00	BDL
	C20	0	0.12±0.00	BDL
	C21	0	0.62±0.00	BDL
	C22	0	BDL	BDL

4.10.1 Chlorpyrifos Pesticide Residue Levels in Tomatoes

Chlorpyrifos (O O-diethy O-3, 5, 6- trichloro-2pyridyl phosphorus thioate) is an emulsifiable broad-spectrum Organophosphate contact and stomach poison with a long residual action for the control of flies, mosquitoes, cockroaches, bedbugs and ants on a wide variety of crop types (EPA, 1984). Chlorpyrifos has been registered in the U.S. since 1965 (U.S. EPA, 1984) and is manufactured by DowElanco, formerly the Dow Chemical Company. Common brand names are Dursban (for household products) and Lorsban (for agricultural products) (Racke, 1993). Chlorpyrifos pesticide residues detected in tomatoes from Meru County ranged between BDL to 0.17±0.00 µg/Kg. Figure 4.48 shows the residue levels of Chlorpyrifos pesticides in tomatoes from Meru County.

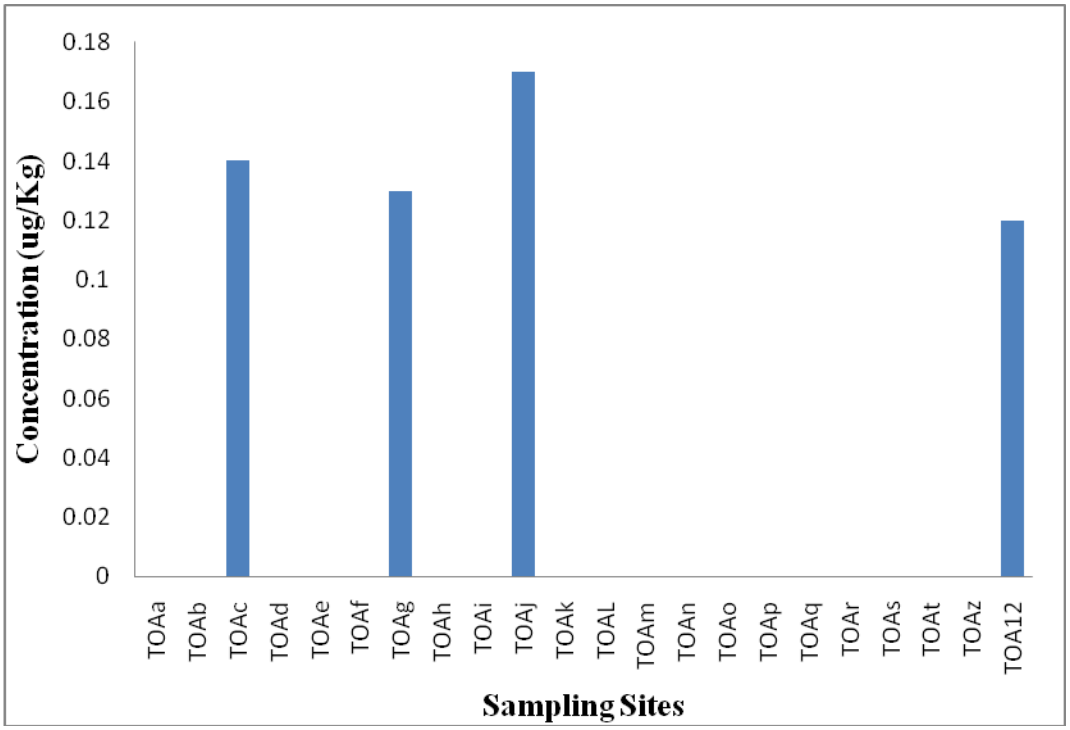

Figure 4.31: Residue levels of Chlorpyrifos pesticides in tomatoes from Meru County

4.10.2 Chlorpyrifos Pesticide Residue Levels in French Beans

Chlorpyrifos pesticide residues detected in French beans from Meru County ranged between BDL to 0.46±0.00 µg/Kg. Figure 4. 25 shows the residue levels of chlorpyrifos pesticides in French beans from Meru County.

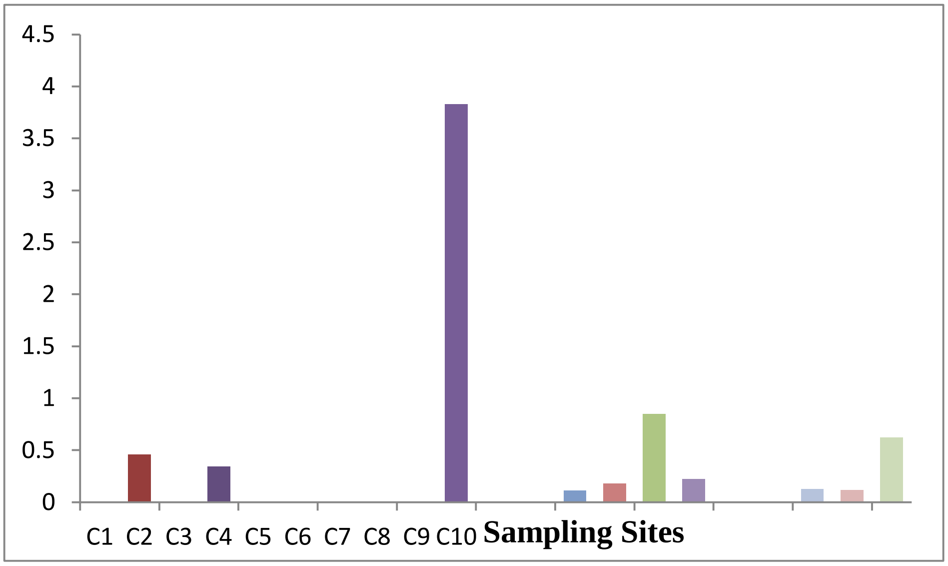

Figure 4.32: Residue levels of chlorpyrifos pesticides in French beans from Meru County

4.10.3 Chlorpyrifos Pesticide Residue Levels in Kales

The determination of chlorpyrifos in kales from Meru County showed that all the samples hand the concentration below detection limit (0.10 ppb). This shows that the Kale farmers in Meru County applied efficiently the pesticide or the pesticide is not used in kale farming.

4.11 Other Pesticide Residue Levels in Horticultural farm soils

4.11.1 Carbendazim Pesticide Residue Levels in Horticultural farm soils

The analysis of soil samples from Meru County showed presence of carbendazim pesticide residues at varying concentrations. The average pesticides levels ranged from 115.6 ±6.38 to 13030.46± 25.68 µg/Kg. The highest concentration was recorded in soil samples from Imenti North sub County. Table 4.41 shows the mean concentrations of Carbendazim pesticides (µg/ kg, dry weight) detected in agricultural soil from Buuri, Imenti North and Imenti South sub counties.

Table 4.41: Mean Concentrations of Carbendazim pesticides (µg/ kg, dry weight) detected in Horticultural farm soils from Buuri, Imenti North and Imenti South sub counties.

Site/ Sub County	Imenti North	Imenti Sounth	Buuri
C1	10259.34±56.2	10259.34±57.8	5215.39±68.4
C2	8501.74±49.8	8501.74±34.6	1008.35±45.2
C3	1000.18±55.1	1000.18±98.3	5284.54±47.1
C4	5569.92±17.3	5569.92±23.7	3628.12±66.2
C5	1628.44±87.2	1628.44±82.9	115.6±98.9
C6	1552.53±102.7	1552.53±44.3	5629.45±36.1
C7	1052.53±64.1	1052.53±667	1071.6±59.8
C8	13030.46±79.5	13030.46±72.1	1550.06±68.4
C9	4499.52±88.2	4499.52±25.3	975.38±92.7
C10	1202.07±67.2	1202.07±89.8	1026.23±101.64

4.11.1.1 Carbendazim Pesticide Residue Levels in Horticultural farm soils from Imenti North Sub County

Ten sampling sites were selected in Imenti North Sub County in Meru County for the analysis of the presence of carbendazim pesticides residue levels. Carbendazim pesticide residues detected in soil from Imenti North Sub County ranged between 1008.61±52.63 to 11661.64±35.26 µg/Kg. Figure 4.41 shows the residue levels of carbendazim pesticides in soil from Imenti North Sub County.

Ten sampling sites were selected in Imenti South Sub County in Meru County for analysis of the presence of carbendazim pesticides. Carbendazim pesticide residues detected in soil from Imenti South Sub County ranged between 1052.53±76.18 to 13030.46±89.74 µg/Kg. Figure 4.27 shows the residue levels of carbendazim pesticides in soil from Imenti South Sub County.

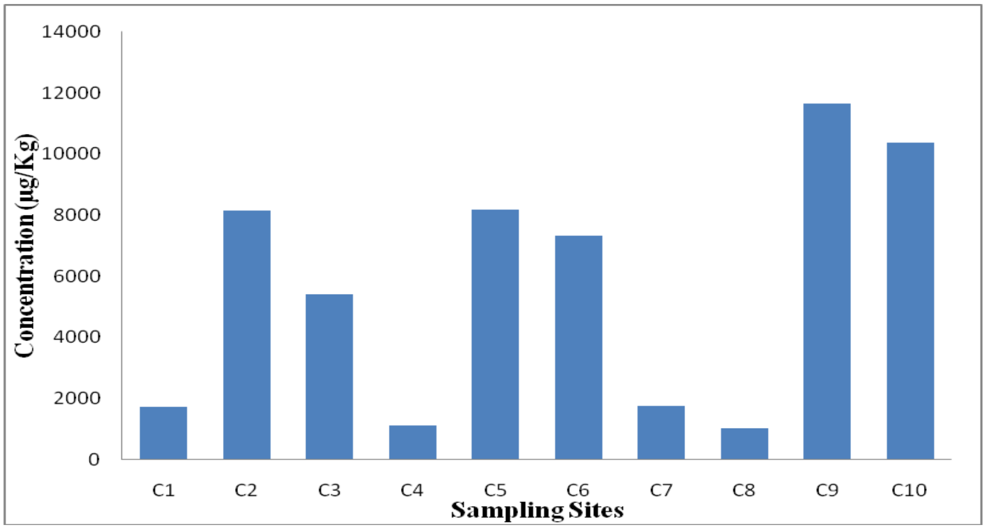

Figure 4.33: Residue levels of carbendazim pesticides in horticultural farm soils

4.11.1.2 Carbendazim Pesticide Residue Levels in Horticultural farm soils from Imenti South Sub County

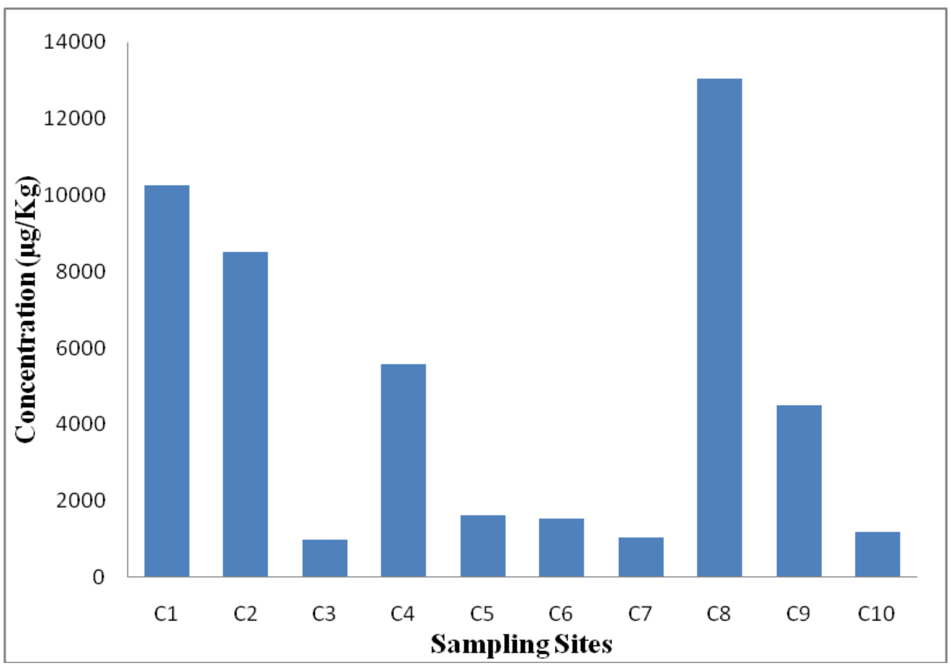

Figure 4.34: Residue levels of carbendazim pesticides in Horticultural farm soils

4.11.1.3 Carbendazim Pesticide Residue Levels in Horticultural farm soils from Buuri Sub County

Ten sampling sites were selected in Buuri Sub County in Meru County for analysis of the presence of carbendazim pesticides. Carbendazim pesticide residues detected in soil from Buuri Sub County ranged between 115.56±3.27 to 5629.45±67.12 µg/Kg. Figure 4.29 shows the residue levels of carbendazim pesticides in soil from Buuri Sub County.

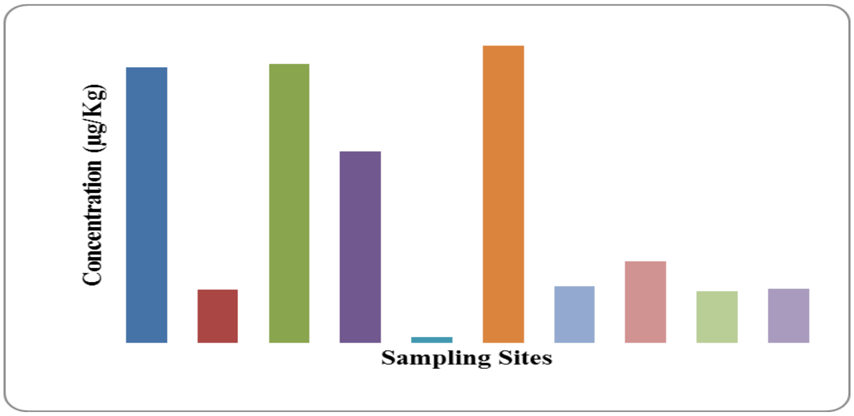

Figure 4.35: Carbendazim Pesticide Residue Levels in Horticultural farm soils

4.11.2 Imidacloprid Pesticide Residue Levels in Horticultural farm soils

The analysis of soil samples from Meru County showed presence of Imidacloprid pesticide residues at varying concentrations. The average pesticides levels ranged from 24.87 ±0.85 to 547.89 ± 32.16 µg/Kg.The highest concentration was recorded in soil samples from Buuri Sub County. Table 4.42 shows the mean concentrations of Imidacloprid pesticides (µg/ kg, dry weight) detected in agricultural soil from Buuri, Imenti North and Imenti South sub counties.

Table 4.42: Mean Concentrations of Imidacloprid pesticides (µg/ kg, dry weight) detected in Horticultural farm soils from Buuri, Imenti North and Imenti South sub counties.

Site/ Sub County	Imenti North	Imenti Sounth	Buuri
C1	91.57±6.45	26.41±3.47	135.3±0.78
C2	27.09±5.1	26.43±2.28	28.09±1.62
C3	65.38±10.22	28.82±1.99	62.02±5.41
C4	26.7±0.97	61.75±2.49	23.78±2.56
C5	24.98±8.14	48.21±6.93	321.1±33.51
C6	24.46±0.88	45.21±6.92	48.77±5.77
C7	45.93±7.96	34.86±3.43	33.49±2.53
C8	30.15±6.45	51.02±9.38	80.74±15.68
C9	26.13±2.17	101.18±11.42	24.87±0.98
C10	27.21±6.33	280.2±25.32	547.89±363.45

4.11.2.1 Imidacloprid Pesticide Residue Levels in Horticultural farm soils from Imenti North Sub County

Ten sampling sites were selected in Imenti North Sub County in Meru County for the analysis of the presence of Imidacloprid pesticides residue levels. Imidacloprid pesticide residues detected in soil from Imenti North Sub County ranged between 24.46±0.63 to 91.57 ±3.54 µg/Kg. Figure 4.30 shows the residue levels of Imidacloprid pesticides in soil from Imenti North Sub County.

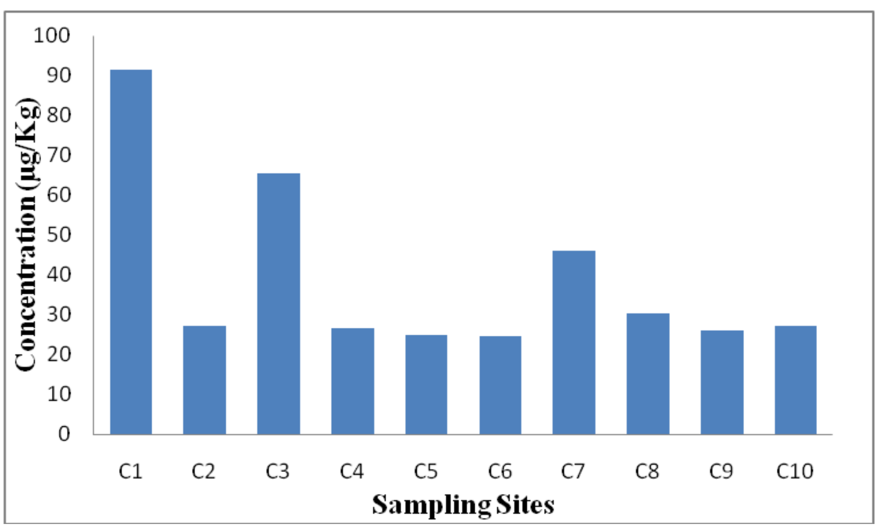

Figure 4.36: Residue levels of Imidacloprid pesticides in Horticultural farm soils

4.11.2.2 Imidacloprid Pesticide Residue Levels in **Horticultural farm soils from Imenti South Sub County**

Ten sampling sites were selected in Imenti South Sub County in Meru County for analysis of the presence of Imidacloprid pesticides. Imidacloprid pesticide residues detected in soil from Imenti South Sub County ranged between 26.41±2.84 to 280.2 ±10.71 µg/Kg. Figure 4.31 shows the residue levels of Imidacloprid pesticides in soil from Imenti South Sub County.

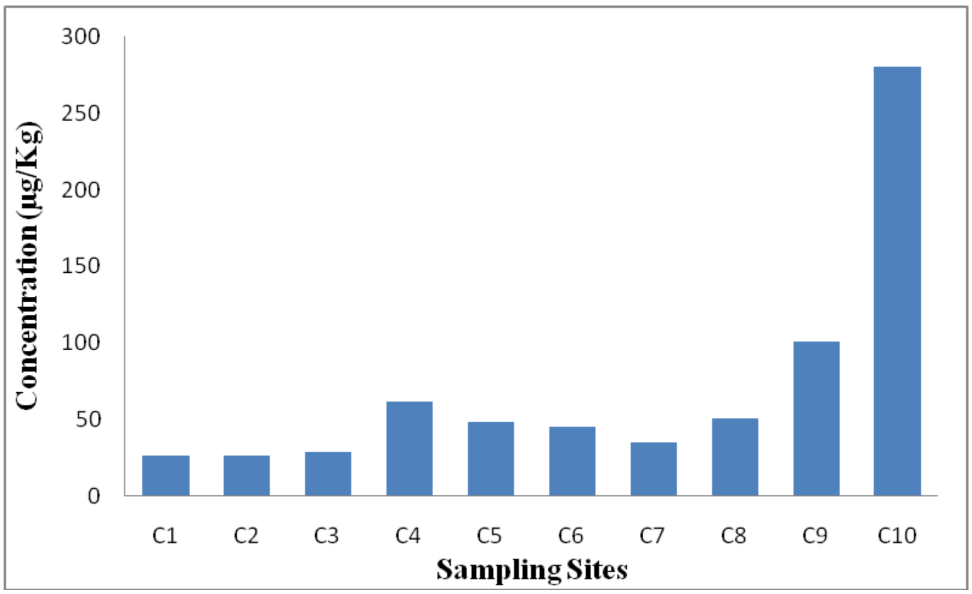

Figure 4.37: Residue levels of Imidacloprid pesticides in Horticultural farm soils

4.11.2.3 Imidacloprid Pesticide Residue Levels in Horticultural farm soils from Buuri Sub County

Ten sampling sites were selected in Buuri Sub County in Meru County for analysis of the presence of Imidacloprid pesticides. Imidacloprid pesticide residues detected in soil from Buuri Sub County ranged between 28.09±2.74 to 547.89 ±44.27 µg/Kg. Figure 4.32 shows the residue levels of Imidacloprid pesticides in soil from Buuri Sub County.

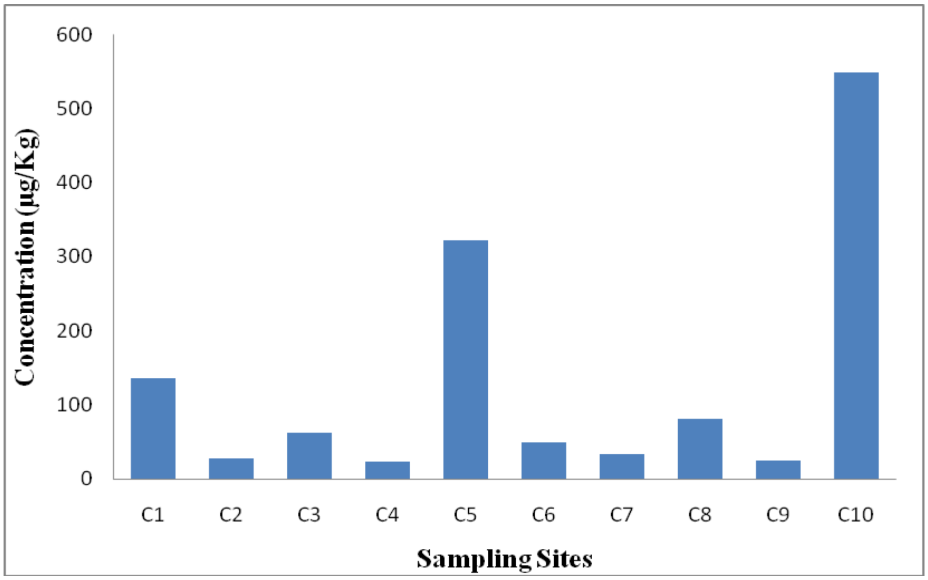

Figure 4.38: Imidacloprid Pesticide Residue Levels in Horticultural farm soils from Buuri Sub County.

4.11.3 Acetamiprid Pesticide Residue Levels in Horticultural farm soils

The analysis of soil samples from Meru County showed presence of Acetamiprid pesticide residues at varying concentrations. The average pesticides levels ranged from 49.65 ±2.54 to 64.92 ± 6.19 µg/Kg. The highest concentration was recorded in soil samples from Imenti South Sub County. Table 4.43 shows the Mean Concentration of acetamiprid pesticides (µg/ kg, dry weight) detected in agricultural soil from Buuri, Imenti North and Imenti South sub counties.

Table 4.43: Mean Concentrations of acetaprimid pesticides (µg/ kg, dry weight) detected in Horticultural farm soils from Buuri, Imenti North and Imenti South sub counties.

Site/ Sub County	Imenti North	Imenti Sounth	Buuri
C1	49.36±6.25	60.59±3.14	56.38±6.72
C2	58.34±8.16	57.71±3.36	67.05±9.25
C3	60.08±3.45	62.67±9.63	58.82±11.83
C4	61±1.89	64.73±13.43	49.65±6.16
C5	60.01±8.72	62.12±10.82	55.48±7.24
C6	60.14±3.17	58.44±11.4	61.65±10.85
C7	56.14±2.96	64.92±9.08	63.5±3.34
C8	60.37±7.08	61.9±8.13	44.22±15.2
C9	60.76±10.77	70±13.63	54.58±16.3
C10	63.15±9.36	60.48±18.5	63.73±6.66

4.11.3.1 Acetamiprid Pesticide Residue Levels in Horticultural farm soils from Imenti North Sub County

Ten sampling sites were selected in Imenti North Sub County in Meru County for the analysis of the presence of Acetamiprid pesticides residue levels. Acetamiprid pesticide residues detected in soil from Imenti North Sub County ranged between 49.36±0.63 to 63.15±5.01 µg/Kg. Figure 4.33 shows the residue levels of Acetamiprid pesticides in soil from Imenti North Sub County.

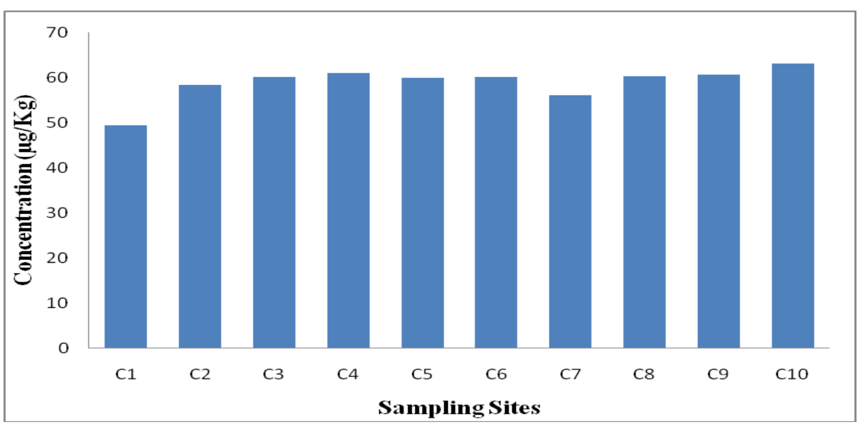

Figure 4.39: Residue levels of Acetamiprid pesticides in Horticultural farm soils from Imenti North Sub County

4.11.3.2 Acetamiprid Pesticide Residue Levels in Horticultural farm soils from Imenti South Sub County

Ten sampling sites were selected in Imenti South Sub County in Meru County for analysis of the presence of Acetamiprid pesticides. Acetamiprid pesticide residues detected in soil from Imenti South Sub County ranged between 57.71±6.32 to 70.00±9.71 µg/Kg. Figure 4.34 shows the residue levels of Acetamiprid pesticides in soil from Imenti South Sub County.

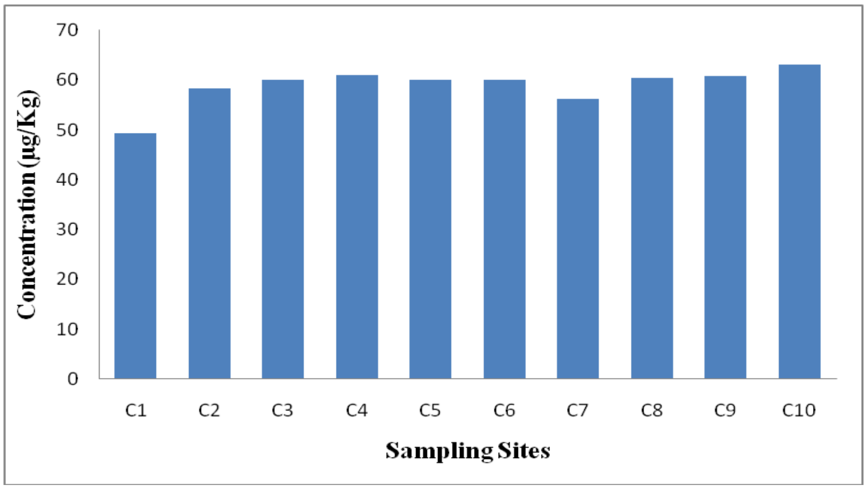

Figure 4.40: Residue levels of Acetamiprid pesticides in Horticultural farm soils from Imenti South Sub County

4.11.3.3 Acetamiprid Pesticide Residue Levels in Horticultural farm soils from Buuri Sub County

Ten sampling sites were selected in Buuri Sub County in Meru County for analysis of the presence of Acetamiprid pesticides. Acetamiprid pesticide residues detected in soil from Buuri Sub County ranged between 44.22±2.19 to 67.07±8.16 µg/Kg. Figure 4.34 shows the residue levels of Acetamiprid pesticides in soil from Buuri Sub County.

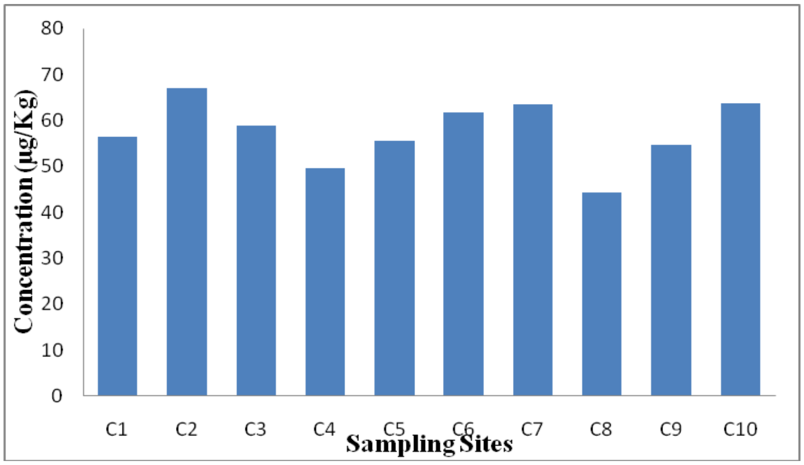

Figure 4.41: Acetamiprid Pesticide Residue Levels in Horticultural farm soils from Buuri Sub County

4.11.4 Azoxystrobin Pesticide Residue Levels in Horticultural farm soils

The determination of Azoxystrobin in soil from Meru County showed that all the samples hand the concentration below detection limit (0.10 ppb). This shows that the pesticide in soil in Meru County degraded quickly from soil.

4.11.5 Metalaxyl Pesticide Residue Levels in Horticultural farm soils

The analysis of soil samples from Meru County showed presence of Metalaxyl pesticide residues at varying concentrations. The average pesticides levels ranged from 2.66 ±0.06 to 296.69 ± 10.17 µg/Kg. The highest concentration was recorded in soil samples from Imenti South Sub County. Table 4.44 shows the Mean Concentration of metalaxyl pesticides (µg/ kg, dry weight) detected in agricultural soil from Buuri, Imenti North and Imenti South sub counties.

Table 4.44: Mean Concentrations of metalaxyl pesticides (µg/ kg, dry weight) detected in Horticultural farm soils from Buuri, Imenti North and Imenti South sub counties.

Site/ Sub County	Imenti North	Imenti Sounth	Buuri
C1	6.39±0.36	2.95±0.05	35.98±1.41
C2	3.19±0.00	2.8±0.07	2.82±0.63
C3	293.7±58.12	2.79±0.06	290.17±25.14
C4	3.41±0.6	296.69±36.19	3.17±0.96
C5	2.88±0.00	16.54±2.47	12.95±0.96
C6	2.86±0.01	16.31±1.33	3.21±0.63
C7	16.52±2.65	6.17±1.54	2.68±0.71
C8	6.12±1.4	3.28±0.84	6.34±1.32
C9	2.72±0.00	13.32±0.96	3.33±0.09
C10	2.66±0.01	13.16±1.05	3.54±0.35

4.11.5.1 Metalaxyl Pesticide Residue Levels in Horticultural farm soils from Imenti North Sub County

Ten sampling sites were selected in Imenti North Sub County in Meru County for the analysis of the presence of Metalaxyl pesticides residue levels. Metalaxyl pesticide residues detected in soil from Imenti North Sub County ranged between 2.73±0.04 to 293.7±16.93 µg/Kg. Figure 4.35 shows the residue levels of Metalaxyl pesticides in soil from Imenti North Sub County.

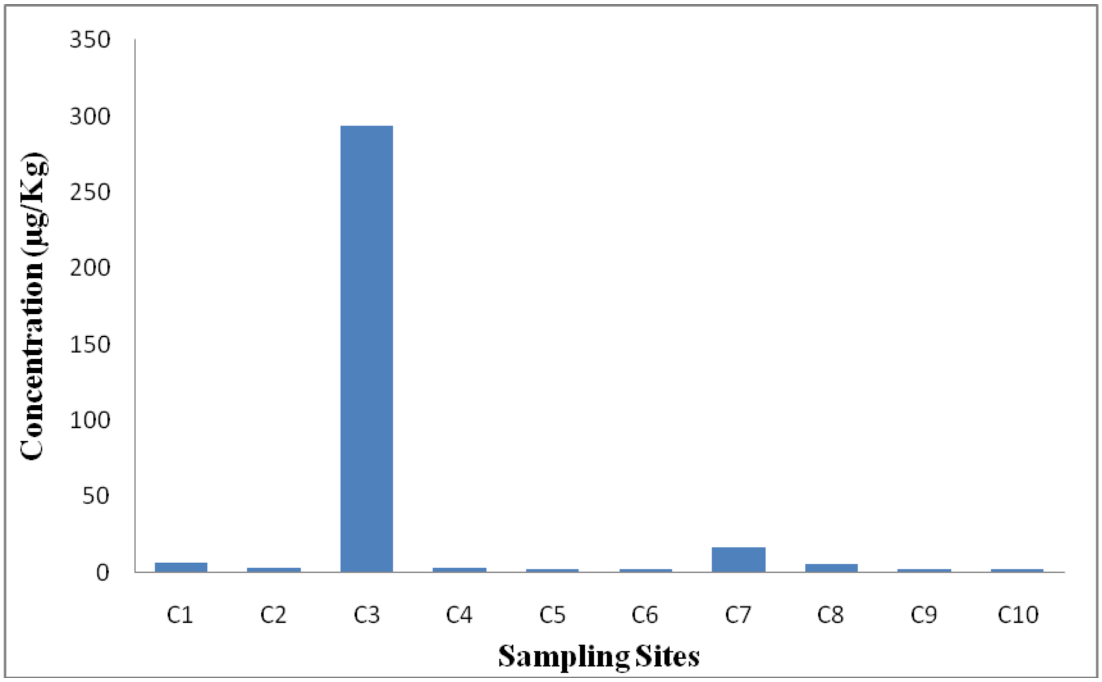

Figure 4.42: Residue levels of Metalaxyl pesticides in Horticultural farm soils from Imenti North Sub County

4.11.5.2 Metalaxyl Pesticide Residue Levels in Horticultural farm Horticultural farm soils from Imenti South Sub County

Ten sampling sites were selected in Imenti South Sub County in Meru County for analysis of the presence of Metalaxyl pesticides. Metalaxyl pesticide residues detected in soil from Imenti South Sub County ranged between 2.71±0.03 to 296.69±15.32 µg/Kg. Figure 4.36 shows the residue levels of Metalaxyl pesticides in soil from Imenti South Sub County.

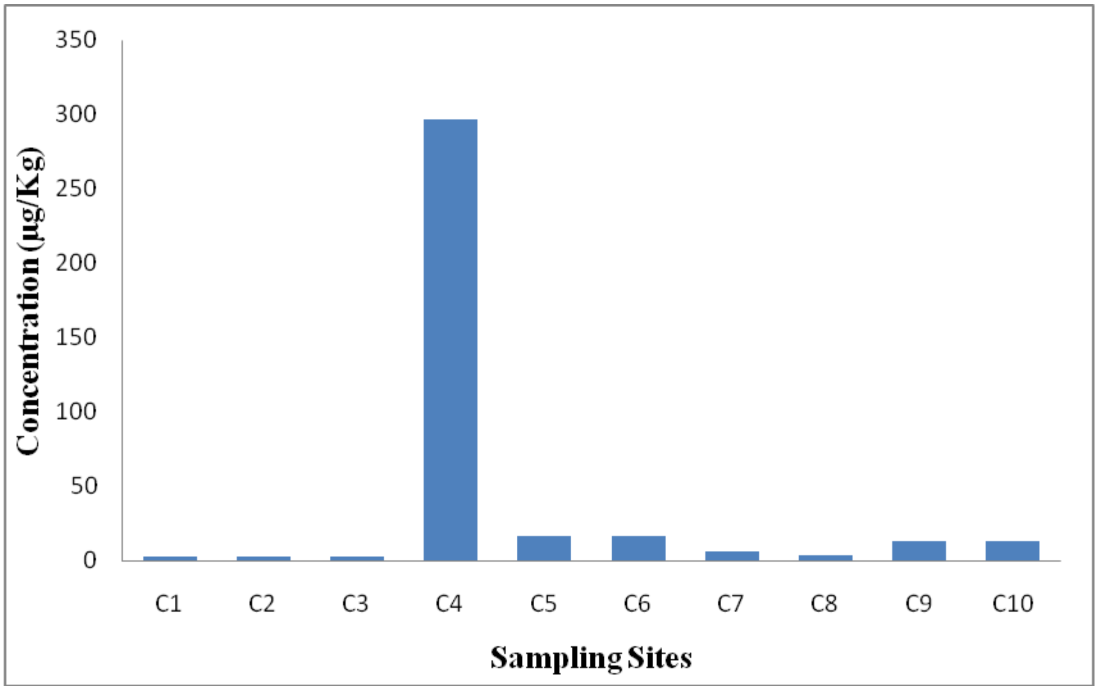

Figure 4.43: Residue levels of Metalaxyl pesticides in Horticultural farm soils from Imenti South Sub County

4.11.5.3 Metalaxyl Pesticide Residue Levels in Horticultural farm soils from Buuri Sub County

Ten sampling sites were selected in Buuri Sub County in Meru County for analysis of the presence of Metalaxyl pesticides. Metalaxyl pesticide residues detected in soil from Buuri Sub County ranged between 2.68±9.75 to 290.18±15.32 µg/Kg. Figure 4.37 shows the residue levels of Metalaxyl pesticides in soil from Buuri Sub County.

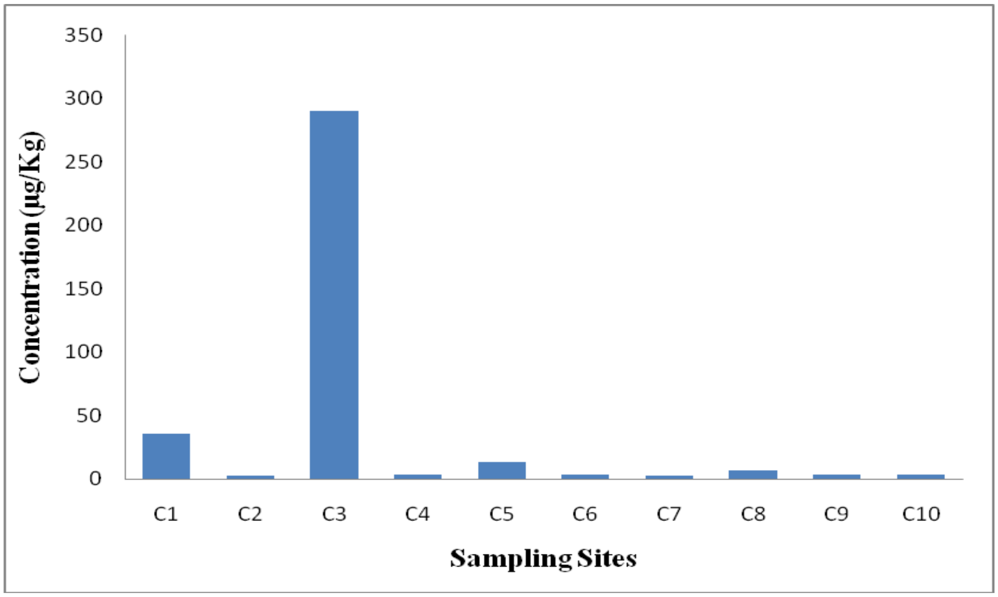

Figure 4.44: Residue levels of Metalaxyl pesticides in Horticultural farm soils from Buuri Sub County

4.11.6 Diazinon Pesticide Residue Levels in Horticultural farm soils

The analysis of soil samples from Meru County showed presence of diazinon pesticide residues at varying concentrations. The average pesticides levels ranged from 1.98 ±0.01 to 54.78 ± 6.22 µg/Kg. The highest concentration was recorded in soil samples from Buuri Sub County. Table 4.45 shows the Mean Concentration of diazinon pesticides (µg/ kg, dry weight) detected in agricultural soil from Buuri, Imenti North and Imenti South sub counties.

Table 4.45: Mean Concentrations of diazinon pesticides (µg/ kg, dry weight) detected in Horticultural farm soils from Buuri, Imenti North and Imenti South sub counties.

Site/ Sub County	Imenti North	Imenti Sounth	Buuri
C1	3.13±0.00	19.34±1.44	44.16±6.22
C2	3.78±0.04	28.48±1.53	15.22±0.68
C3	5.82±0.85	2.6±0.62	54.3±3.63
C4	14.08±1.23	5.37±0.96	1.98±0.54
C5	4.97±0.36	4.57±0.62	4.53±0.27
C6	1.27±0.09	5.98±0.41	20.45±1.24
C7	7.17±0.85	1.68±00.09	2.04±0.00
C8	4.98±0.72	2.3±0.00	5.5±1.63
C9	3.75±0.71	5.76±0.68	14.73±0.32
C10	6.74±0.28	4.68±0.42	54.74±5.47

4.11.6.1 Diazinon Pesticide Residue Levels in Horticultural farm soils from Imenti North Sub County

Ten sampling sites were selected in Imenti North Sub County in Meru County for the analysis of the presence of diazinon pesticides residue levels. Diazinon pesticide residues detected in soil from Imenti North Sub County ranged between 1.27±0.02 to 14.28±0.99 µg/Kg. Figure 4.38 shows the residue levels of diazinon pesticides in soil from Imenti North Sub County.

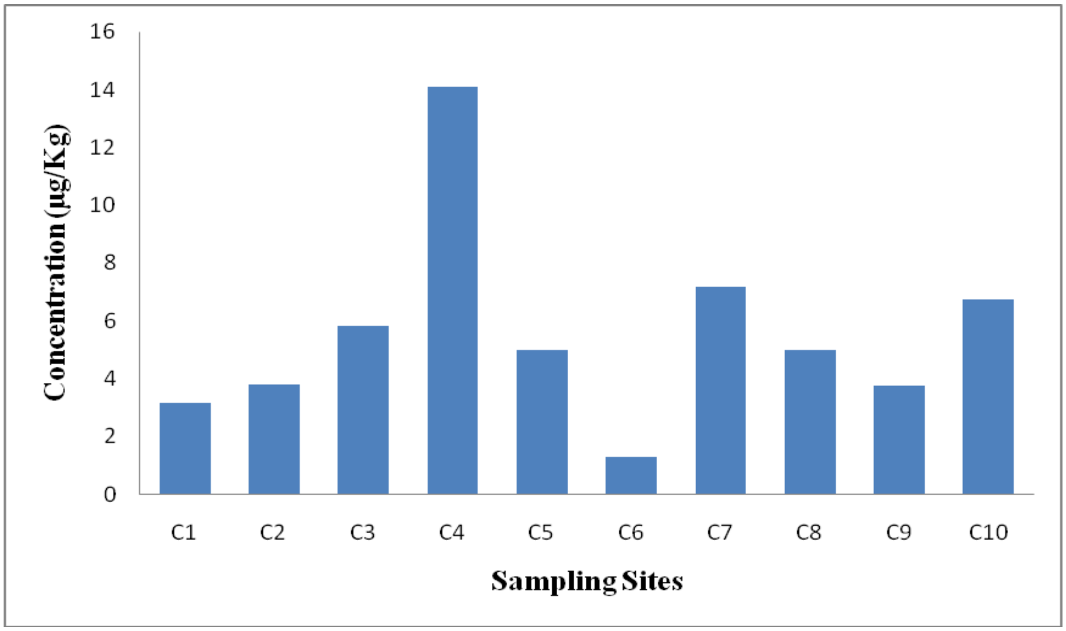

Figure 4.45: Residue levels of diazinon pesticides in Horticultural farm soils from Imenti North Sub County

4.11.6.2 Diazinon Pesticide Residue Levels in Horticultural farm soils from Imenti South Sub County

Ten sampling sites were selected in Imenti South Sub County in Meru County for analysis of the presence of diazinon pesticides. Diazinon pesticide residues detected in soil from Imenti South Sub County ranged between 2.3±0.01 to 28.43±1.64 µg/Kg. Figure 4.39 shows the residue levels of diazinon pesticides in soil from Imenti South Sub County.

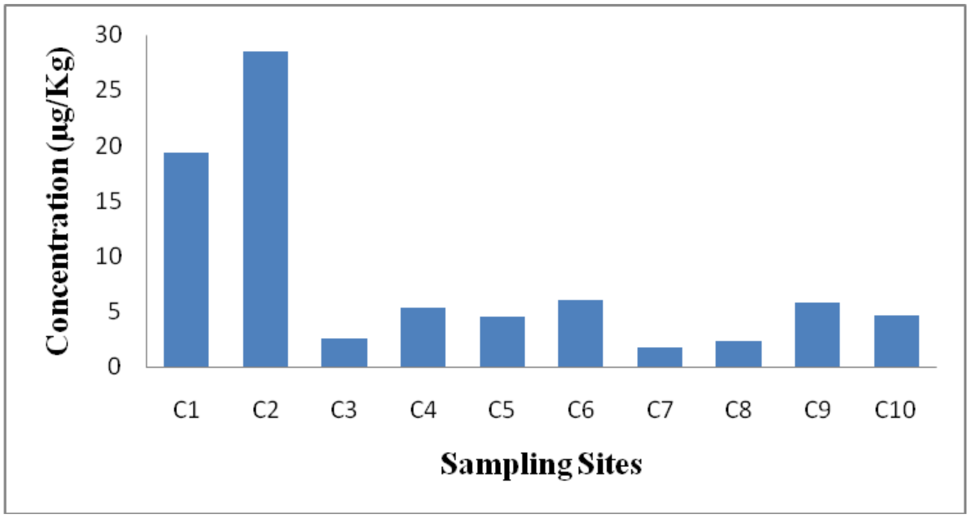

Figure 4.46: Residue levels of diazinon pesticides in Horticultural farm soils from Buuri Sub County

4.11.6.3 Diazinon Pesticide Residue Levels in Horticultural farm soils from Buuri Sub County

Ten sampling sites were selected in Buuri Sub County in Meru County for analysis of the presence of diazinon pesticides. Diazinon pesticide residues detected in soil from Buuri Sub County ranged between 1.98±0.03 to 54.6±2.75 µg/Kg. Figure 4.40 shows the residue levels of diazinon pesticides in soil from Buuri Sub County.

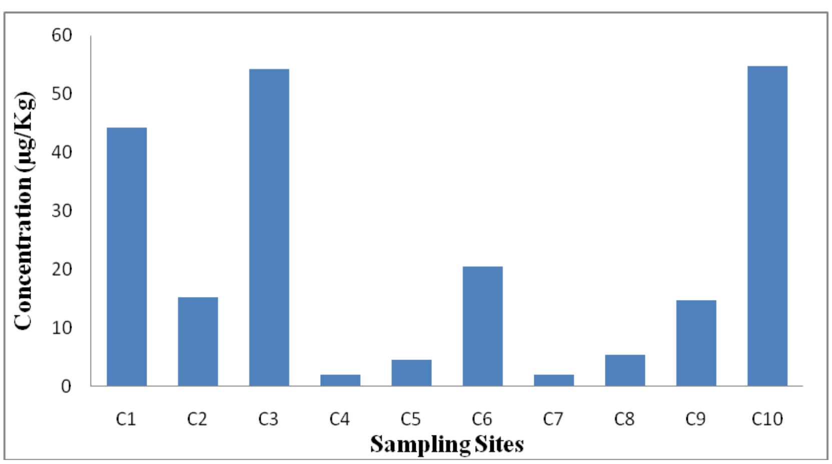

Figure 4.47: Residue levels of diazinon pesticides in Horticultural farm Horticultural farm soils from Imenti South Sub County

4.11.7 Chlorpyrifos Pesticide Residue Levels in Horticultural farm soils

The analysis of soil samples from Meru County showed presence of chlorpyrifos pesticide residues at varying concentrations. The average pesticides levels ranged from 2.12 ±0.01 to 6.95± 0.18 µg/Kg.The highest concentration was recorded in soil samples from Imenti North Sub County. Table 4.46 shows the Mean Concentration of chlorpyrifos pesticides (µg/ kg, dry weight) detected in agricultural soil from Buuri, Imenti North and Imenti South sub counties.

Table 4.46: Mean Concentrations of chlorpyrifos pesticides (µg/ kg, dry weight) detected in Horticultural farm soils from Buuri, Imenti North and Imenti South sub counties

Site/ Sub County	Imenti North	Imenti Sounth	Buuri
C1	3.35±0.01	5.15±0.96	6.79±1.24
C2	2.98±0.06	3.38±0.62	3.18±0.05
C3	8.48±1.5	2.12±0.00	3.68±0.12
C4	3.26±0.00	5.29±0.02	2.91±0.03
C5	3.34±0.04	6.07±0.05	4.03±0.01
C6	3.28±0.00	5.22±0.07	6.95±0.99
C7	3.1±0.08	4.18±0.06	2.52±0.01
C8	2.92±0.01	3.28±0.00	5.83±0.02
C9	3.89±0.00	2.8±0.00	2.84±0.04
C10	6.2±0.00	3.57±0.07	3.35±0.04

4.11.7.1 Chlorpyrifos Pesticide Residue Levels in Soil from Imenti North Sub County

Ten sampling sites were selected in Imenti North Sub County in Meru County for the analysis of the presence of chlorpyrifos pesticides residue levels. Chlorpyrifos pesticide residues detected in soil from Imenti North Sub County ranged between 2.98±0.00 to 6.20±0.85 µg/Kg. Figure 4.41 shows the residue levels of chlorpyrifos pesticides in soil from Buuri Sub County.

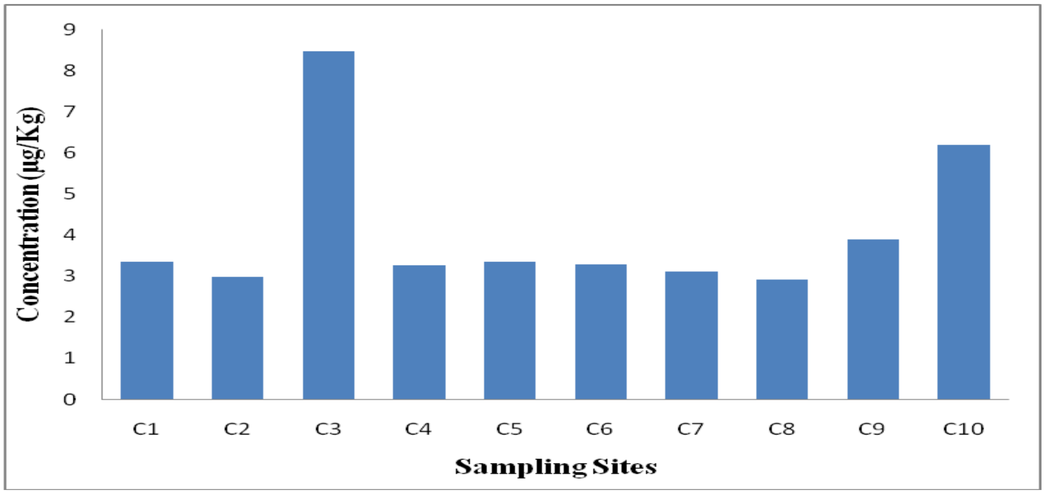

Figure 4.48: Residue levels of chlorpyrifos pesticides in soil from Buuri Sub County

4.11.7.2 Chlorpyrifos Pesticide Residue Levels in Horticultural farm soils from Imenti South Sub County

Ten sampling sites were selected in Imenti South Sub County in Meru County for analysis of the presence of chlorpyrifos pesticides. Pesticide residues detected in soil from Imenti South Sub County ranged between 2.12±0.01 to 6.07±0.81 µg/Kg. Figure 4.42 shows the residue levels of chlorpyrifos pesticides in soil from Imenti South Sub County.

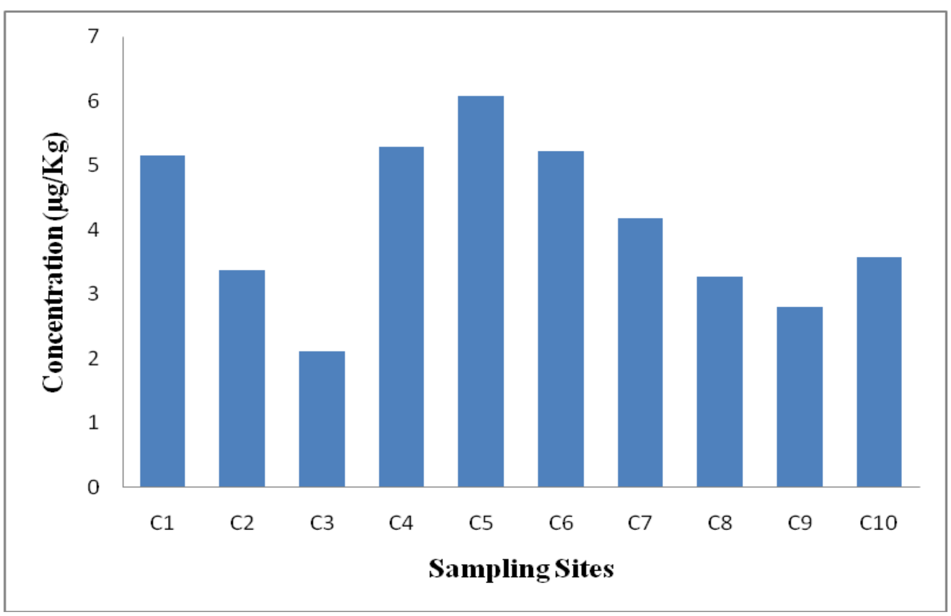

Figure 4.49: Residue levels of Diazinon pesticides in French Beans from Meru County

4.11.7.3 Chlorpyrifos Pesticide Residue Levels in Horticultural farm soils from Buuri Sub County

Ten sampling sites were selected in Buuri Sub County in Meru County for analysis of the presence of chlorpyrifos pesticides. Chlorpyrifos pesticide residues detected in soil from Buuri Sub County ranged between 2.52±0.03 to 6.95±0.85 µg/Kg. Figure 4.43 shows the residue levels of chlorpyrifos pesticides in soil from Buuri Sub County.

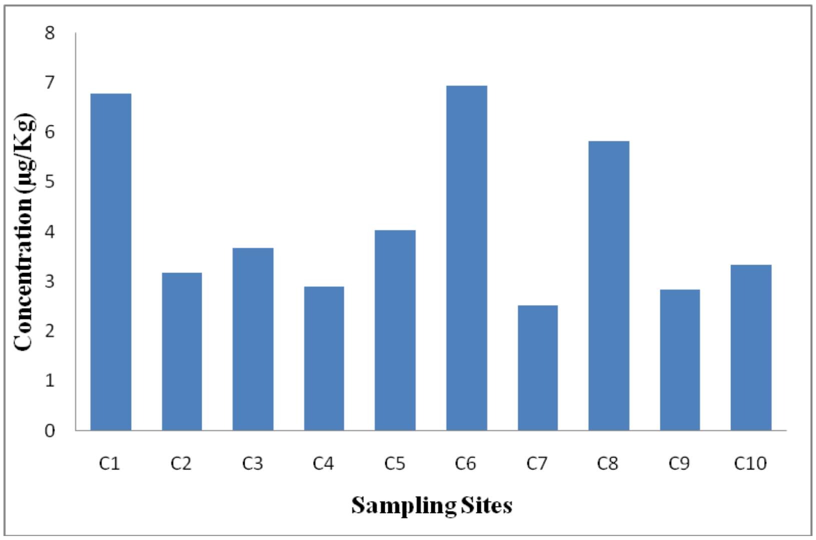

Figure 4.50: Residue levels of chlorpyrifos pesticides in horticultural farm soils from Imenti South Sub County

4.11.8 Dimethoate Pesticide Residue Levels in Horticultural farm soils.

Dimethoate'standard calibration curve was constructed by plotting analyte concentrations against peak areas. A linearity (y=25805x + 92822) was obtained with a correlation coefficient of R^2=0.99. Calibration curve of dimethoate is attached at Appendix section. Recoveries were done for soil samples. Spiking was done at 1 µg/kg of dimethoate standard. Average recoveries from fortified samples for soil matrix were found to beb87.41±10.65%. Table 4.33 shows the Mean Concentration of dimethoate pesticides (µg/ kg, dry weight) detected in agricultural soil from Buuri, Imenti North and Imenti South sub counties.

Table 4.47: Mean Concentrations of dimethoate pesticides (µg/ kg, dry weight) detected in Horticultural farm soils from Buuri, Imenti North and Imenti South sub counties

Site/ Sub County	Imenti North	Imenti Sounth	Buuri
C1	2.6±0.00	0.22±0.04	1.96±0.05
C2	BDL	0.26±0.00	BDL
C3	1.26±0.01	0.65±0.00	0.96±0.00
C4		0.22±0.00	0.44±0.00
C5	0.63±0.00	4.16±0.87	0.63±0.00
C6	0.56±0.00	3.26±0.05	0.44±0.01
C7	3.02±0.85	BDL	0.44±0.00
C8	BDL	BDL	2.8±0.56
C9	BDL	4.52±0.3	BDL
C10	BDL	0.62.07±0.08	BDL

4.11.8.1 Dimethoate Pesticide Residue Levels in Horticultural farm soils from Imenti North Sub County.

Ten sampling sites were selected in Imenti North Sub County in Meru County for the analysis of the presence of dimethoate pesticides residue levels. Pesticide residues detected in soil fromImenti North Sub County ranged between BDL to 3.02±0.85 µg/Kg. Figure 4.44 shows the residue levels of chlorpyrifos pesticide in soil from Buuri Sub county.

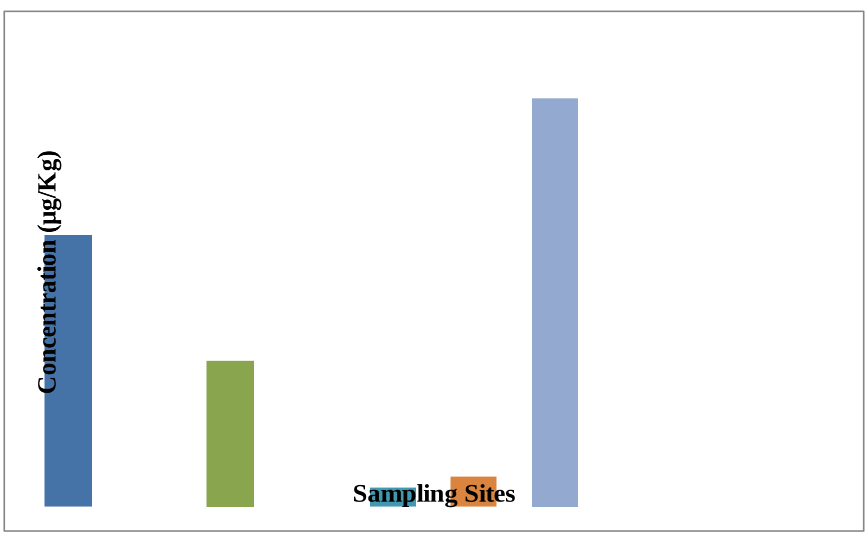

Figure 4.51: Residue levels of chlorpyrifos pesticides in Horticultural farm soils from Buuri Sub County.

4.11.8.2 Dimethoate Pesticide Residue Levels in Horticultural farm soils from Imenti South Sub County

Ten sampling sites were selected in Imenti South Sub County in Meru County for analysis of the presence of dimethoate pesticides. Pesticide residues detected in soil from Imenti South Sub County ranged between BDL to 4.56±0.33 µg/Kg. Figure 4.45 shows the residue levels of dimethoate pesticides in soil from Imenti South Sub County.

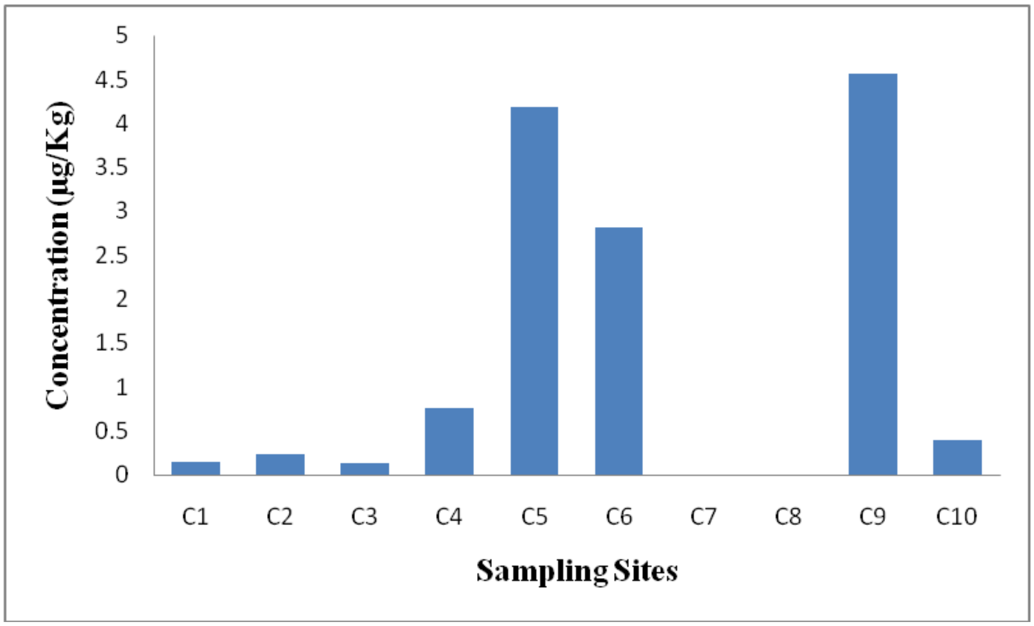

Figure 4.52: Residue levels of chlorpyrifos pesticides in Horticultural farm soils from Buuri Sub County

4.11.8.3 Dimethoate Pesticide Residue Levels in Horticultural farm soils from Buuri Sub County

Ten sampling sites were selected in Buuri Sub County in Meru County for analysis of the presence of dimethoate pesticides. Dimethoate pesticide residues detected in soil from Buuri Sub County ranged between BDL to 2.59±0.07 µg/Kg. Figure 4.46 shows the residue levels of dimethoate pesticides in soil from Buuri Sub County.

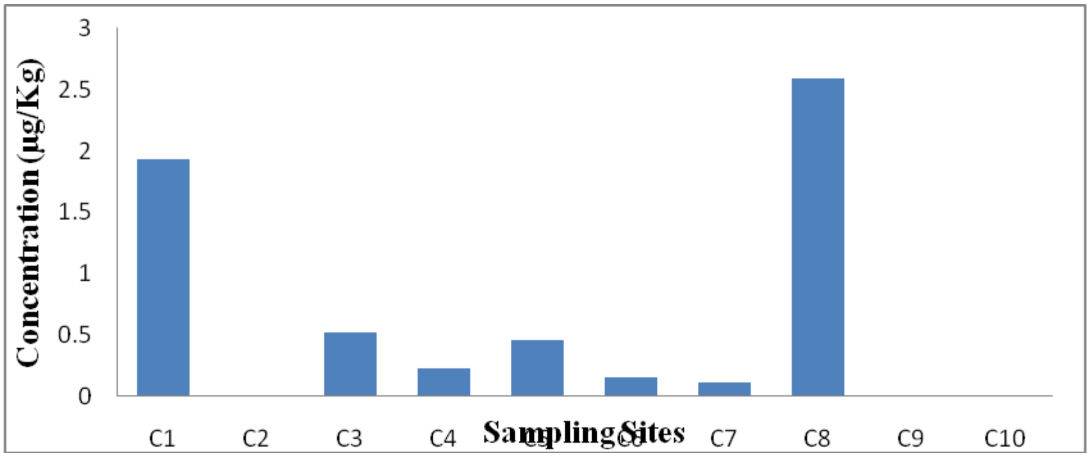

Figure 4.53: Residue levels of dimethoate pesticides in Horticultural farm soils from Imenti South Sub County

4.11.9 Diuron Pesticide Residue Levels in Horticultural farm soils

Table 4.48: Mean Concentrations of diuron pesticides (µg/ kg, dry weight) detected in Horticultural farm soils from Buuri, Imenti North and Imenti South sub counties.

Site/ Sub County	Imenti North	Imenti Sounth	Buuri
C1	125.63±15.36	138.22±16.04	125.96±0.05
C2	147.89±19.78	140.26±20.00	146.96±0.00
C3	136±15.01	140.65±0.00	135.96±0.00
C4	0.63±0.00	132.22±16.15	125.44±17.35
C5	143.62±12.49	134.16±15.87	145.63±22.14
C6	140.58±10.00	133.26±0.05	138.44±28.01
C7	137.02±22.85	133.26±0.05	132.44±18.25
C8	130.66±16.71	133.26±0.05	122.8±11.56
C9	139.72±35.67	125.52±0.3	142.8±25.32
C10	147.02±25.36	12.62±0.08	148.8±36.56

Diuron'standard calibration curve was constructed by plotting analyte concentrations against peak areas. A linearity (y=557.89x +3311.7) was obtained with a correlation coefficient of R^2=0.973. Calibration curve of diuron attached in Appendix section. Recoveries were done for soil samples. Spiking was done at 1 µg/kg of dimethoate standard. Average recoveries from fortified samples for soil matrix was found to be 87.41±10.65%. Table 4.48 shows the Mean Concentration of diuron pesticides (µg/ kg, dry weight) detected in agricultural soil from Buuri, Imenti North and Imenti South sub counties. The analysis of soil samples from Meru County showed presence of diuron pesticide residues at varying concentrations. The average pesticides levels ranged from BDL 124.56 ± 7.12 to 164.82 ± 11.96 µg/Kg.The highest concentrations was recorded in soil samples from Imenti South Sub County.

4.11.9.1 Diuron Pesticide Residue Levels in Horticultural farm soils from Imenti North Sub County.

Ten sampling sites were selected in Imenti North Sub County in Meru County for the analysis of the presence of diuron pesticides residue levels. Pesticide residues detected in soil from Imenti North Sub County ranged between 125.42 ±9.73 to 146.03±10.64 µg/Kg. Figure 4.47 shows the residue levels of diuron pesticides in soil from Buuri Sub County.

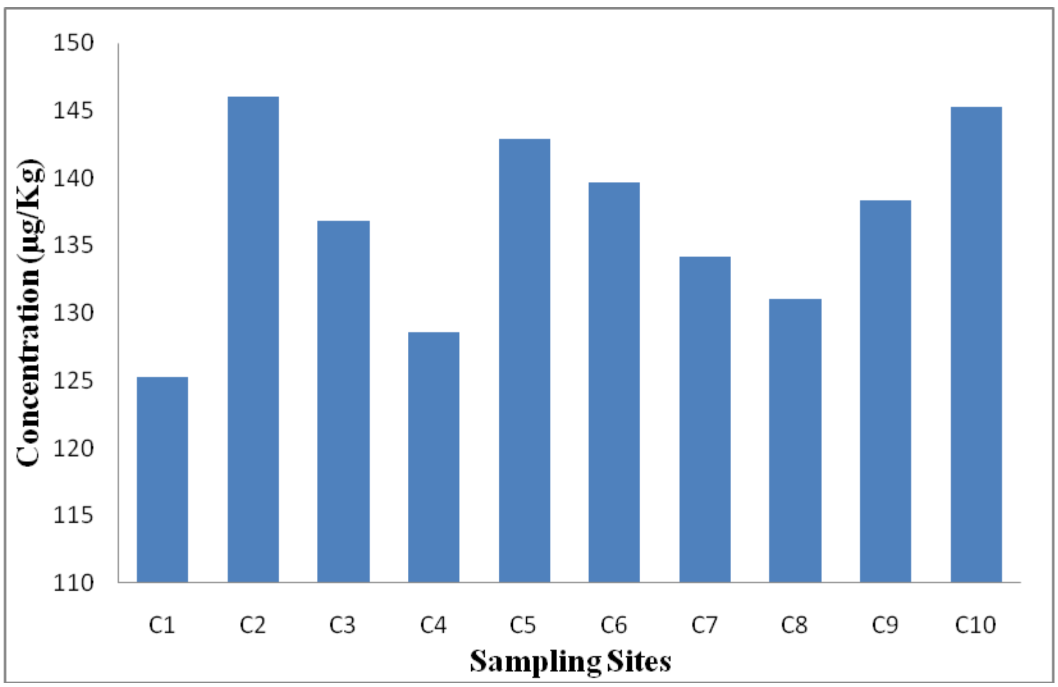

Figure 4.54: Residue levels of diuron pesticides in Horticultural farm soils from Buuri Sub County

4.11.9.2 Diuron Pesticide Residue Levels in Horticultural farm soils from Imenti South Sub County

Ten sampling sites were selected in Imenti South Sub County in Meru County for analysis of the presence of diuron pesticides. Pesticide residues detected in soil from Imenti South Sub County ranged between 133.57±13.44 to 164.82±11.96 µg/Kg. Figure 4.48 shows the residue levels of diuron pesticides in soil from Imenti South Sub County.

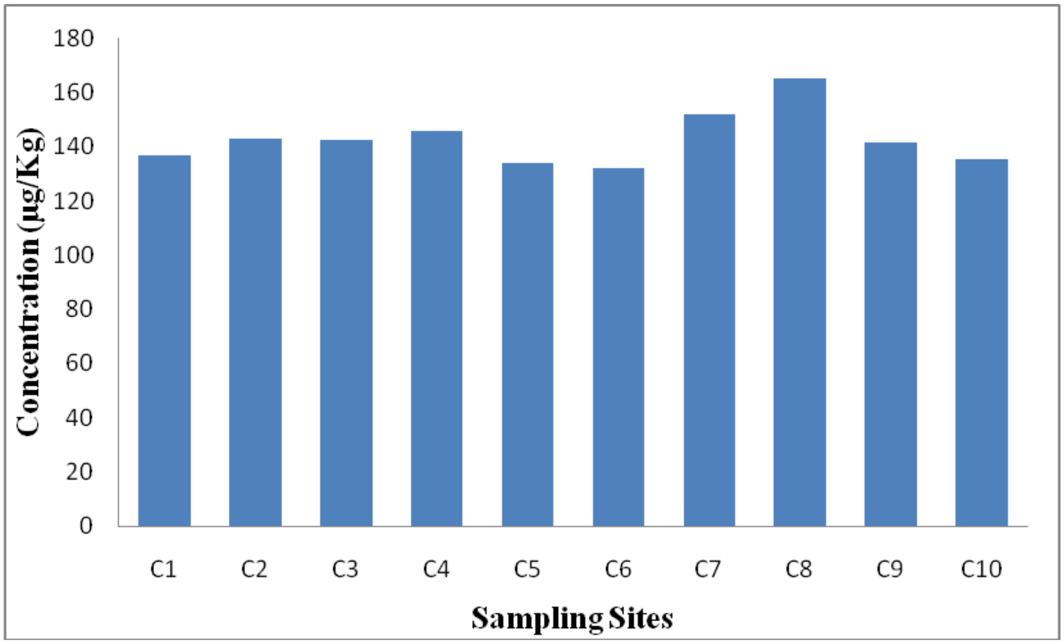

Figure 4.55: Residue levels of diuron pesticides in Horticultural farm soils from Imenti South Sub County

4.11.9.3 Diuron Pesticide Residue Levels in Horticultural farm soils from Buuri Sub County

Ten sampling sites were selected in Buuri Sub County in Meru County for analysis of the presence of diuron pesticides. Pesticide residues detected in soil from Buuri Sub County ranged between 124.56 ± 7.12 to 156.17±10.62 µg/Kg. Figure 4.49 shows the residue levels of diuronpesticides in soil from Buuri Sub County.

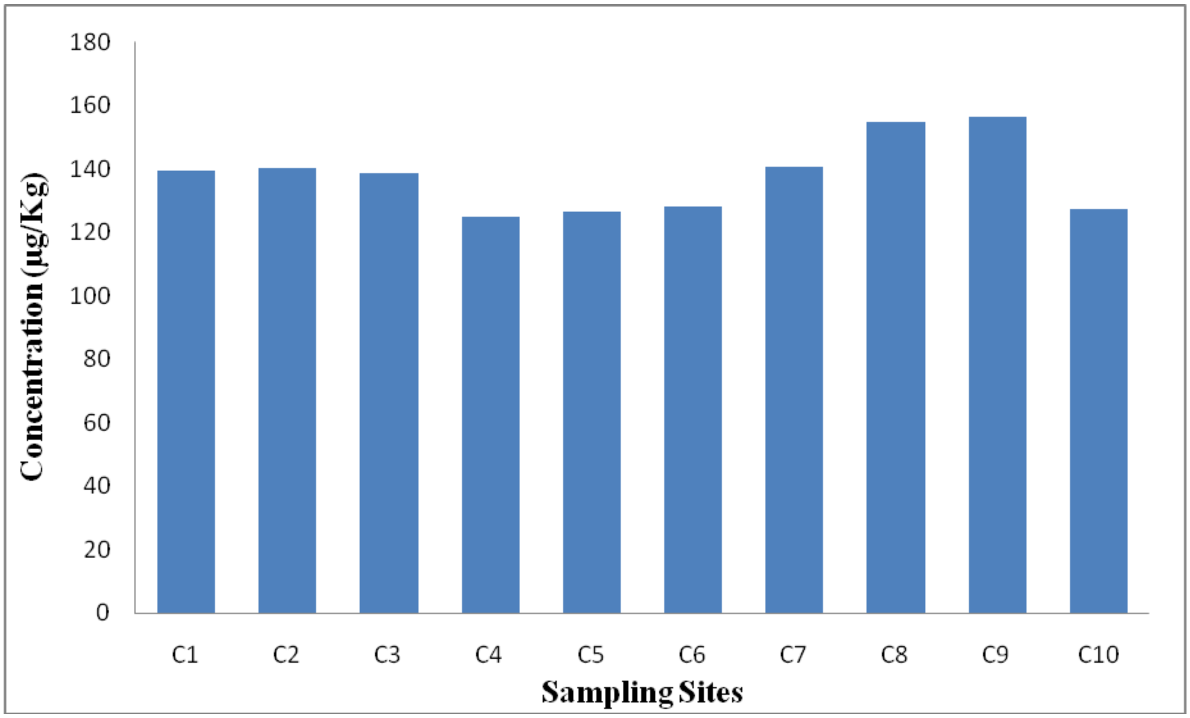

Figure 4.56: Residue levels of diuron pesticides in Horticultural farm soils from Buuri Sub County

4.12 Correlations

Correlation analysis was carried out for organochlorine pesticides and other pesticides in horticultural products and soil. SPSS was applied for determination of Pearson's correlation coefficients which have numerical values (r) ranging between -1.00 to +1.00 (APA, 2001).

4.12.1. Correlation of Carbendazim in Horticultural Products and Agricultural Soil

There was a positive correlation of Carbendazimin soil and French Beans as indicated by positive Pearson r values of 0.559. Carbendazim in kales and soil showed positive correlation r values of 0.499, while the Carbendazim in soil with tomatoes had negatively as indicated by negative Pearson r values of -0.008.

Table 4.49 shows a correlation of Correlation of Carbendazim in Horticultural Products and Agricultural Soil.

Table 4.49: Correlation of Carbendazim in Horticultural Products and Agricultural Soil

		Carbendazim in Soil	Carbendazim in French Beans	Carbendazim in Kales	Carbendazim in Tomatoes
Carbendazim in Soil	Pearson Correlation	1	.559	.499	-.008
	Sig. (2-tailed)		.249	.313	.989
	N	6	6	6	6
Carbendazim in French Beans	Pearson Correlation	.559	1	.961**	.788
	Sig. (2-tailed)	.249		.002	.063
	N	6	6	6	6
Carbendazim in Kales	Pearson Correlation	.499	.961**	1	.869*
	Sig. (2-tailed)	.313	.002		.025
	N	6	6	6	6
	Sig. (2-tailed)	.917	.822	.572	.487
	N	6	6	6	6
Carbendazim in Tomatoes	Pearson Correlation	-.008	.788	.869*	1
	Sig. (2-tailed)	.989	.063	.025	
	N	6	6	6	6

4.12.2. Correlation of Imidacloprid in Horticultural Products and farm soils

There was a positive correlation of Carbendazimin soil and French Beans as indicated by positive Pearson r values of 0.137. Carbendazim in kales and soil showed positive correlation r values of 0.368, while the Carbendazim in soil with tomatoes had positive correlation with Pearson r values of 0.368. Table 4.50 shows a correlation of Imidacloprid in horticultural products and farm soils.

Table 4.50: Correlation of Imidacloprid in Horticultural Products and Agricultural Soil

		Imidacloprid in Soil	Imidacloprid in French Beans	Imidacloprid in Tomatoes	Imidacloprid in Kales
Imidacloprid in Soil	Pearson Correlation	1	.137	.139	.368
	Sig. (2-tailed)		.796	.793	.473
	N	6	6	6	6
midacloprid in French Beans	Pearson Correlation	.137	1	1.000**	.427
	Sig. (2-tailed)	.796		.000	.398
	N	6	6	6	6
Imidacloprid in Tomatoes	Pearson Correlation	.139	1.000**	1	.426
	Sig. (2-tailed)	.793	.000		.400
	N	6	6	6	6
Imidacloprid in Kales	Pearson Correlation	.368	.427	.426	1
	Sig. (2-tailed)	.473	.398	.400	
	N	6	6	6	6
	Sig. (2-tailed)	.284	.122	.123	.017
	N	6	6	6	6

4.12.3 Correlation of Acetamiprid in Horticultural Products and farm soils

There was a negative correlation of Acetamiprid in soil, tomatoes, kales and French Beans as indicated by positive Pearson r values of -0.248, -0.252 and -0.598. Table 4.51 shows a correlation of Acetamiprid in Horticultural Products and Agricultural Soil.

Table 4.51: Correlation of Acetamiprid in Horticultural Products and farm soils

		Acetamiprid in Soil	Acetamiprid in French beans	Acetamiprid in Tomatoes	Acetamiprid in Kales
Acetamiprid in Soil	Pearson Correlation	1	-.248	-.252	-.598
	Sig. (2-tailed)		.635	.631	.210
	N	6	6	6	6
Acetamiprid in French beans	Pearson Correlation	-.248	1	1.000**	.745
	Sig. (2-tailed)	.635		.000	.089
	N	6	6	6	6
Acetamiprid in Tomatoes	Pearson Correlation	-.252	1.000**	1	.749
	Sig. (2-tailed)	.631	.000		.087
	N	6	6	6	6
Acetamiprid in Kales	Pearson Correlation	-.598	.745	.749	1
	Sig. (2-tailed)	.210	.089	.087	
	N	6	6	6	6
	Sig. (2-tailed)	.786	.012	.012	.054
	N	6	6	6	6

4.12.4 Correlation of Metalaxyl in Horticultural Products and farm soils

There was a negative correlation of Metalaxyl in soil, tomatoes, kales and French Beans as indicated by positive Pearson r values of -0.119, -0.258 and -0.256. Table 4.52 shows a correlation of Metalaxyl in Horticultural Products and Agricultural Soil.

Table 4.52: Correlation of Metalaxyl in Horticultural Products and farm soils

		Metalaxyl in Soil	Metalaxyl in Tomatoes	Metalaxyl in Kales	Metalaxyl in French beans
Metalaxyl in Soil	Pearson Correlation	1	-.119	-.258	-.256
	Sig. (2-tailed)		.822	.622	.625
	N	6	6	6	6
Metalaxyl in Tomatoes	Pearson Correlation	-.119	1	.427	.426
	Sig. (2-tailed)	.822		.398	.400
	N	6	6	6	6
Metalaxyl in Kales	Pearson Correlation	-.258	.427	1	1.000**
	Sig. (2-tailed)	.622	.398		.000
	N	6	6	6	6
Metalaxyl in French beans	Pearson Correlation	-.256	.426	1.000**	1
	Sig. (2-tailed)	.625	.400	.000	
	N	6	6	6	6
	Sig. (2-tailed)	.878	.017	.122	.123
	N	6	6	6	6

4.12.5 Correlation of Diazinon in Horticultural Products and farm soils

There was a negative correlation of diazinon in soil, tomatoes, kales and French Beans as indicated by positive Pearson r values of -0.770, -0.491 and -0.494. Table 4.53 shows a correlation of diazinon in Horticultural Products and Agricultural Soil.

Table 4.53: Correlation of Diazinon in Horticultural Products and farm soils

		Diazinon in Soil	Diazinon in French Beans	Diazinon in Tomatoes	Diazinon in Kales
Diazinon in Soil	Pearson Correlation	1	-.770	-.491	-.494
	Sig. (2-tailed)		.073	.322	.320
	N	6	6	6	6
Diazinon in French Beans	Pearson Correlation	-.770	1	.745	.749
	Sig. (2-tailed)	.073		.089	.087
	N	6	6	6	6
Diazinon in Tomatoes	Pearson Correlation	-.491	.745	1	1.000**
	Sig. (2-tailed)	.322	.089		.000
	N	6	6	6	6
Diazinon in Kales	Pearson Correlation	-.494	.749	1.000**	1
	Sig. (2-tailed)	.320	.087	.000	
	N	6	6	6	6
	Sig. (2-tailed)	.201	.041	.002	.002
	N	6	6	6	6

4.12.6 Correlation of Chlorpyrifos in Horticultural Products and farm soils

There was a positive correlation of chlorpyrifos in soil, tomatoes, kales and French Beans as indicated by positive Pearson r values of 0.736, 0.434 and 0.460. Table 4.56 shows a correlation of chlorpyrifos in Horticultural Products and farm soils.

Table 4.54: Correlation of Chlorpyrifos in Horticultural Products and Agricultural Soil

		Chlorpyrifos in Soil	Chlorpyrifos in Tomatoes	Chlorpyrifos in Kales	Chlorpyrifos in French beans
Chlorpyrifos in Soil	Pearson Correlation	1	.736	.434	.360
	Sig. (2-tailed)		.095	.390	.484
	N	6	6	6	6
Chlorpyrifos in Tomatoes	Pearson Correlation	.736	1	.775	.426
	Sig. (2-tailed)	.095		.070	.399
	N	6	6	6	6
Chlorpyrifos in Kales	Pearson Correlation	.434	.775	1	.278
	Sig. (2-tailed)	.390	.070		.593
	N	6	6	6	6
Chlorpyrifos in French beans	Pearson Correlation	.360	.426	.278	1
	Sig. (2-tailed)	.484	.399	.593	
	N	6	6	6	6
	Sig. (2-tailed)	.289	.768	.637	.724
	N	6	6	6	6

CHAPTER FIVE: CONCLUSION

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

From the household questionnaire, most farmers were between 46-60 years (39% of 173 respondents) and 31-45 years old (32%), while above 60 years 21% responded, and below 15 years only 2 respondents recorded. 87% of the famers were married. The education background was 62% (at least secondary school level and above), 29% primeary school level and 9% were illiterate. A large percentage of farmers (67% in Imenti North, 57% in Buuri and 46% in Imenti South) hired or employed farm workers for piece work, or daily or monthly employment basis. Therefore this could have effects on proper use of pesticides because these casual workers may not have any training on pesticide usage.

Farming experience was very varied, ranging from 6-30 years, with only 10% having less than 5 years farming experience. This can have to impacts with respect to pesticides, i.e. they can be able to use pesticides effectively and secondly they have been exposed to pesticide for a long time which could indicate impact on their health.

52% of the farmers were involved in food crop production while 29% and 12% in cash crop and livestock production, respectively. The majority relied on on rainfall agriculture (60%), 29% (both irrigation and rain fed) and 10% (irrigation). Various livestock were kept including cattle (mostly), followed by chicken and beehives. This therefore influenced pesticide use as reported by the survey. There was acaricide usage, in addition to pesticides used in agricultural food production.

Most farmers had contact with agricultural extension workesr and engaged in various social groupings that would enable them to get access to information including information on pesticide usage. They also had access to credit, mostly through Saccos and therefore could afford to apply pesticides in farming activities. However only 31%-43% of the farmers had received training on pesticide application even though they all had information from various sources. The analysis of the questionaires showed that majority of the respondents in Imenti North, Imenti South and Buuri Sub County, in Meru County were male and in the age bracket of youth. Also the respondents in Imenti North, Imenti South and Buuri Sub County, in Meru County have different levels of literacy and most of them were untrained on safe handling of pesticides.

The farmers reported health effects (64%) after using pesticides with most effect felt after using dimethoate (67%)m Karate (lambda-cyhalothryn), Plantvax (oxycarboxin fungicide) and Dithane (mancozeb). The types of health effects included headaches, sneezing, stomach aches, diarrhea, dizziness, skin rashes and irritations, among others. Most (99%) had easy access to health services (at least 2.9km away). Mostly men (household heads and their sons) were involved in spraying using pesticides which they obtained from vet shop (67%), old stock (13%) and open markets (10%), which they sprayed mostly during sunny and cloudy (86%) as opposed to during rainfall (20%). Therefore mostly men had health effects from pesticide usage in Meru county. The use of old stock was a siginifact factor because some of the old stock could be obsolute chemicals such as organochlorines which were reported in the pesticide use survey. This needs to be further investigated. Only 24% of the farmers were smokers.

Expenditure on purchase of pesticides was high and rose from 73% to 83% in 2015, implying that pesticide demand and usage was increasing. Most farmers (65%) reported that they understood recommened safe pesticide handling procedures such as labeling on packages and wearing protective clothing during application. However, most farmers (44% in Buuri, 57% in Imenti South, and 60% in Imenti North) did not have protective clothing, which they blamed on lack of money and discomfort whenever they wore them.

Seventy (70) health care workers (32 female and 38 male of age about 42 and 45 years, respectyively) and 73 agricultural extension workers (32 female and 41 male of age about 41 and 45 years, respectively) were covered by the survey. The health care workers were mostly diploma holders in Community/Development and Sanitation profession. Most health care workers (71%) reported that they knew how to administer 1st Aid against pesticide poisoning. The AEW were mostly married (63%) and mostly diploma holders (38%) compared with 16% certificate and degree holders and 29% form four leavers. They were mostly trained in agriculture and horticulture. Most of the AEW had dealt with pesticides (95%) in their work and 84% reported having offered advice on pesticide usage.

In the pesticide use survey it was reported by farmers that several types of pesticides were used in farming in Meru County, including organophosphates, organochlorines, carbamates, pyrethroids and fungicides. The differences in chemical structures of these different pesticides can be found in the Appendix section. The most frequently (more than 40 respondents out of 173) used pesticides were parathion, diazinon, dimethoate, permethrin, pirimiphos methyl, carbaryl, deltamethrin, dieldrin, methoxychlor, cypermethrin, propoxur, and carbofuran. Some of these most frequently used pesticides such as dieldrin; parathion and carbofuran are being used illegally because they have been banned. Dieldrin is among the most persistent organochlorine which have been banned, while parathion was banned because of its high mammalian toxicity and volatility and carbofuran (as furadan) was withdrawn from the shelves through an act of parliament due to its misuse in killing predators including vultures. Farmers (95%) also reported use of non synthetic chemical pesticides such as plant extracts, biopesticides and hand picking, among others for crop production as well as for use in animal production.

Analysis of organochlorine pesticide residues in soil, French beans, Kales and tomatoes samples taken randomly from the selected horticultural farms found high contamination of the farm soil with pesticide residues, with total (Σall OCs analysed) ranging from 15.78 – 307.7 μg/Kg dry weight in all 20 sites in Imenti North, from 1.25 – 159.88 μg/Kg in Imenti South, and from 14.96 – 106.13 μg/Kg in Buuri, respectively, which shows that horticultural soils in Imenti North were more contaminated with respect to organochlorine pesticides. However, organochlorine pesticide residues were not detected in French beans, Kales and tomatoes, despite their presence in farm soil. The disparities can be attributed to differences in the locations of the site, environmental factors, previous and current use of organochlorine pesticides as well as physical chemical properties of the pesticides. The highest concentration was recorded in soil samples collected from Imenti North Sub County. Methoxychlor was the highest detected in soil from sampling site Six. Endrin was not detected in any of the sampling sites in the three sub couties.

Other pesticides, including chlorpyrifos, carbendazine, imidacloprid, acetaprimid, metalaxyl, diazinon, azoxystribin, triadimefon, acephate, thiamethoxim and diuron (a herbicide) were found in farm soils and in the three horticultural produce (fresh French beans, kales and tomatoes). All these (except chlropyrifos and diazinon) were not reported by farmers in the pesticide use survey. However some of them belonged to other pesticides which were reported in the survey but were not specified. Notable are the neonicotinoids such as thiamethoxim. The concentrations (in μg/Kg wet weight) of these pesticides in French beans, kales and tomatoes sampled from all the three subcounties ranged from BDL-48.65 (carbendazin), BDL-290.76 (imidacloprid), BDL-2.81 (acetaprimid), BDL-25.76 (azoxystrobin), BDL-105.18 (metalaxyl), and BDL-0.15 (diazinon). In farm soil samples from selected horticultural farms in the three sub counties, the concentrations (in μg/Kg dry weight) of pesticiude residues ranged from 115.6-13030.46 (carbendazin), 23.78 – 547.9 (imidacloprid), 44.22-67.05 (acetamiprid), 2.66-296.69 (metalaxyl), 1.27-54.74 (diazinon), 2.12-8.48 (chlorpyrifos), BDL-4.16 (dimethoate), 0.63-148.8 (diuron) and BDL (azoxystrobin). The highest level of carbendazin was detected in soil from Imenti North sub County, while the highest concentration of imidacloprid was recorded in soil samples from Buuri Sub County. The highest concentration of acetamiprid was recorded in soil samples from Imenti South Sub County. The highest concentration of azoxystrobin was recorded in French beans. The highest concentration of chlorpyrifos was recorded in soil samples from Imenti North Sub County and the highest concentration of diazinon was recorded in soil samples from Buuri Sub County; while the highest concentration of metalaxyl was recorded in soil samples from Imenti South Sub County.

5.2 Recommendations

5.2.1 Policy Recommendations

1) Based on the organochlorine residue levels that were detected in soil there is need for constant monitoring of these pesticides in vegetables, soil and water in order to safe guard aquatic biota and end users.
2) The farmers and locals in this area should be informed and trained on the risks involved in the use of pesticides for pest control through awareness creation activities.
3) Based on the OCP residue levels detected, investigations should be carried to determine whether there is current use of the banned organochlorine pesticides and their source.
4) Based on the organophosphate residue levels detected, farmers and consumers should be educated on post-harvest interval to be observed before harvesting of vegetables.
5) There is need to monitor water used for irrigation so as to minimize contamination of vegetables.
6) From the survey it was found that generally there was low level of understanding on the safe use of pesticides, therefore Steps should be taken to educate the public on the safe use of pesticides in order to reduce contamination of the environment with the pesticide. These should be done with the help of the government, agrochemical industries and NGOs

5.2.2 Research Recommendations

1) One of the major concerns that came out of this study is that some banned organochlorines and organophosphates are still being used. This should be investigated further and the Pest Control Products Board be engaged to ensure this stops.

2) Since the fresh produce analysed were targeting the market, the farmers and regulatory authorities should be informed so that pre harvest intervals are determined and observed for each pesticide being applied.
3) Research should be carried out on other vegetable varieties and other food crops around this area so as to determine whether they are also contaminated.
4) Further research is necessary on human beings in this area to establish the level of pesticides exposure in their bodies.
5) Further research should be carried out to determine point and non-point sources of OCP and other pesticides in aquatic environment in this area to determine fresh water and drinking water quality.
6) Further research should be carried out to determine the health effects of consuming the contaminated kales, tomatoes and French beans.
7) Further research should be carried out to determine the application of pesticides in other regions using PRECEDE-PROCEED model.

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APPENDICES

Appendix 1: Samples of Questionnaire

QUESTIONAIRE ON OCCUPATIONAL PESTICIDES EXPOSURE AND THEIR EFFECTS ON ECOSYSTEMS AND HUMAN HEALTH IN MERU COUNTY

Preamble

This questionnaire seeks to gather information on knowledge concerning the types and use of pesticides in Meru county .please note that this is not a test and there are no wrong or right answers. Your time and honest opinions are appreciated.

Section 1. General information (kindly fill where applicable)

Questionnaire

No…………………………………………….Date…………………………………………

1. Address……………………………………………………………………………………

2. Gender………………………………….Age………occupation……………………………

3. How long have you lived in this area……………………………

4. The highest level of education reached. Please tick (primary, secondary, post-secondary)

Section 2 pesticides used in Meru County

(I) Do you have any information on the chemicals used in this area for spraying farm animals (cow, goats, sheep, and dogs Cats) spraying crops (vegetables, potatoes, beans, fruits,and coffee,tomatoes,French beans, kales etc.

2. Please list some of the chemicals you have mentioned in (i) above

Animals…………………..,……………………,…………………,…………………………

Crops……………………..,………………………,………………..,……………………

3. Reasons for using pesticides mentioned in question two above.

4. Are there any guidelines given to you before buying any pesticides? Who gives them…………………..,…………………………….,……………………,…………………

5. Have you ever had any training on pesticides management and safety……………………….

6 (a) in which institute were you trained...

b) How long did the training take?

c) What role did the government play in your training…………………………………………..

d) Do you use any form of protection when handling pesticides?

e) If yes which are they?

7. Where do you dispose containers after use?.............................

8. Do you have any information on the pesticides related pollution in this area?.............

If yes give some details……………………….

9. Have you ever used any unlabeled pesticides...

(b) If yes where did you get the pesticides from………………………

10. Do you know any banned pesticides……………………..

(b) If yes name them………………………..,…………………………..,……………………

11. Do you know anybody that regulates the use of pesticides in Kenya?...

If yes give its name……………………………………………..

SECTION 3, CHEMICAL DEALERS

1(a) have you been trained on how pesticides can be used in a safe manner?...........................

(b) If yes to above where were they trained...

2. List the chemicals that are commonly used by the farmers…………………………………….

3. Do you provide any after sale services or technical advice to your clients?

4. If yes in (3) above, indicate the kind of services or advice provided (tick the one applicable), dosage, safety disposal of containers application, others specify………………………………..

5. Do you know any rules and regulations for pesticides handling in Kenya?................................

6. How often are these rules enforced by the government officers?

7. When do you have farmers seminars and who come to facilates

HEALTH EFFECTS OF CHEMICAL USE

1(a) have you or the family members experienced intoxication from pesticides in the past three years? (i) Yes ………… (ii) No………………….

(b) State the symptoms…………,………………………….,……………………,………………

(c) Which pesticides did you apply when you got sick

(i) Dimethoate

(ii) Karate

(iv) Fastac

(v) Bulldock

(vi) Pencozeb

(vii) Plantvax

(viii) Dithane

Others specify………………..

2. How much did you spend on the purchase of pesticides in the year 2015?

3. Have you received training on crop protection products? (i) Yes………….. (ii) No……………………

4. Who is making the decision on pesticides use on your farm?

5. (a) where do you get your information about quality of pesticides used?

(b) How often do you receive new information?

6. Do you use any other method other than chemicals to protect your crops from pests and? (i) YES……………….. (II) NO…………………………….

(b) If other methods other than chemical control, which are they?

(i) Bio pesticides

(ii) Plant extract

(iii) Concotions

(iv) Hand picking

(v) Physical killing

(vi) More than one of these types

(vii) Others specify………………………..

(c) if other method other than chemical control, why are they preferred?

(i) Risk aversion

(ii) Does not work

(iii)Lower yield

(iv)No enough knowledge

(v) Not interested

(vi)Too expensive

(vii) Others specify………………………

7.(a) Do you take alcohol regularly (i)YES……………………..(ii)NO……………………

(b) If yes, for how long?

8.(a) Do you smoke regularly (i)YES…………..(NO)…………………..

(b) If yes for how long………………………………….. (years)

9.Do you have any separate storage place for chemicals and the equipment

(i) YES………………………………….(ii) NO…………………………….

10. How do you evaluate the expenditure on purchase of pesticides during the season 2015 compared to past years?

11. Do you understand the meaning of label on how to use pesticides?

(i) Yes (ii) No

12.(a)Are the workers equipped with suitable protective clothing in accordance with label instructions when handling and applying pesticides?

(i) YES…………………………… (NO)………………………………………

(b) If no, what are the reasons for not using protective clothing?

(i) No money to buy

(ii)Uncorfortable

(iii)Not suitable for local condition

(iv) Unnecesarry

(v) Other reasons specifify………………………..

13.(i)Do you have access to health services?

(i) Yes………………………(ii)No……………………………

(ii) How far is the health centre from your house?

(iii) During the last season, have you or any member of the family visited a health service?

((i) Yes……………………… (ii)No…………………………..

(iv) Briefly explain your expenditure on health during the year 2015/2016 in Ksh…………….

(v) Have you or any other member of the household got any training on how to handle chemicals or in first aid training?

Appendix II: List of pesticides used in Meru County: from the survey of farmers

Row Labels
CHLORPYRIFOS, PARATHION. MALATHION, DIAZINON, DIMETHOATE, PERMETTRIN
ACTELIC, ARTHO, DELTA MECTNIN, MARATHION
AGRINATE,DRAZINON,FULADAN,RAT AND RAT
AGRINATE,KARATE,MALATHION COOPER
CATTLE DIP,SEVIN DUDU DUST ETC
CHLOPYRIFOS
CHLOPYRIFOS,PARATHION,MALATHION,DIAZION,DIMETHOATE,HEPTACHLOR,ENDOSULFAN,ENDRIN
CHLORPYRIFOS,PARATHION ,MALATHION, DIAZINON,DIMETHOATE,HEPTACHLOR,ENDOSULPHAN,DIEDRIN ENDRIN ,METHOMYL,CARBARYL AND CARBONFURAN
CHLORPYRIFOS,PARATHION ,MALATHION, DIAZINON,DIMETHOATE,HEPTACHLOR,ENDOSULPHAN,DIEDRIN ENDRIN ,METHOXYCHLOR,AND ENDRIN ALDEHYDE
CHRORPYRIFOS, DIMETTODE, DIAZINON.MALATHION, PARATION, ESFENVALERATE
CYPERMENTHRIN,PERMETHRIN,ESFENVALERATE,DELTAMETHRIN,CHLORIFOS,PARATHION,MALATHION,DIAZINON,DIMETHOATE,HEPTACHLOR,DELDRIN,ENDRIN,HEPTACHLOR

EPOXIDE,PROPOXUR,CARBOFURAM,CARBOXYL,MENTHONYL
CYPERMENTHRIN,PERMETHRIN,ESFENVALERATE,DELTAMETHRIN,PARATHION,MALATHION,DIAZINON,DIMETHOATE,HEPTACHLOR,DELDRIN,ENDRIN,MELTHOXYCHLOR[ENDOCULPHARN SULPHATE P'P'-DDT]
CYPERMETHRIN,DELTAMENTHRIN,PERMETHRIN,MALATHION,DIZION,DIMETHOATE,PARATHION, ENDRIN,DELDRIN,HEPTACHLOR,CARBARYL,CARBOFURANPROPOXUS,METHOXY CHLOR,CHLORPYRIFOS
DATHAME, DIASINON, MARATHION
DECIS DIMETHOATE FURADON KARETE ALDRIN DIEDRIN DITHANE
DECIS FURADAN ALDRIN DITHANE KARETED ZENLOB DIMETHOATE
DECIS FURADAN ALDRIN ZENCOB DIMETHOATE KARETE PLANTVAT DITHANE
DECIS FURADAN DIMETHOATE ALDRIN DIEDRIN KARATE THIOVIL DITHANE BULDOCK
DECIS FURADAN DIMETHOATE KARATE ALDRIN DITHANE BULLDOCK
DECIS FURADAN DIMETHOATE KARETE ZENCOB ALDRIN
DECIS FURADAN DIMETTOATE KARATE BULLDOCK ZANLOB
DECIS FURADAN KARETE DIMETHOATE
DECIS KARET, DITHAR, PLANT VAX, 20EC, DIMETHOATE, BULLDOCK, WESTSORF
DECIS KARETE DIKMETHOATE FURADAN DIEDRIN ALDRIN
DECIS, FURADON DIEDIN. DIMETHOATE, KARETE ADRIN LINDANT,ENDRIN. CARBOFURAN/THIRAN, METHYLPARATHION
DECIS,FURADAN, ALDRIN, KARETE ZERONKOB. MALATHION
DECIS,PERMETHRIS,DELTAMETHRIN,CYPERMENTHRIN,CHLORPYRIFOS,PARATHION,MALATHIO,DIAZINON,DIMENTHOATEDELDRIN ,EDRIN,EDOSULTAN,HEPTACHLOR EPOXIDE,HEPTACHLOR
DECIS,PERMETHRIS,DELTAMETHRIN,CYPERMENTHRIN,CHLORPYRITOS,PARATHION,MALATHIO,DIAZINON,DIMENTHOATEDELDRIN EDRIN,EDOSULTAN,HEPTACHLOR,METHOXYCHLOR P'P'DDT
DELDRIN ENDRIN,HEPTACHLOR,HEPTACHLOR EPOXIDE,METHOXYCHLOR,ENDOSULPHAN SULPHATE,P'P' DDT,DIAZINON,MALATHION,PARATHION,CHLORPYRIFOS
DELTAMETHRIN,CYPERMETRIN,ENDRI ALDEHYDEHEPTACHLOR,HEPTACHLOR EPOXIDE,METHOXYCHLOR,ENDOSULPHAN SULPHATE,P'P' DDT,DIAZINON,MALATHION,PARATHION,CHLORPYRIFOS
DIEDRIN,ENDRIN,ENDOSULFAN,HEPTACHLOR,METHOXYCHLOR,ENDOSULPHAN ,CHLORPY,ENDRIN ALDEHYDE,DIMETHOATE DIAZINE,PARATHION,CHLORPYRIFOSCYPERMETHRIN,DELTA

METHRIN,PERMETHRIN,ESFERVALETERATE
DIEDRIN,ENDRIN,ENDOSULFAN,HEPTACHLOR,METHOXYCHLOR,ENDOSULPHAN SULPHATE,CHLORPY,ENDRIN ALDEHYDE,DIMETHOATE DIAZINE,PARATHION,CHLORPYRIFOSCYPERMETHRIN,DELTA METHRIN,PERMETHRIN,ESFERVALETERATE
DITHANE M45,GRAMAXONE,ROUND UP,BALLOCK,MALATHION,DIMETHOATE
DITHANE,DRAZINON,MURAS,MARATHION
DITHONE
DRAZENON,COOPERS
DRAZINON, KARETE BULLOCK,
ENDRIN DIEDRIN,ENDOSULFAN,HEPTACHLOR EPOXIDE,PERMETHRIN,DELTAMETHRIN,CYPERMENTHRIN,CHLORPYRIFOS,PARATHION,MALATHION P'P'DDT,DIAZINON,DIMETHOATE,HEPTACHLOR ,ENDOSULT
ESFENVALERATE,PERMETHRIN,DELTAMETHRIN,CYPERMENTHRIN,CHLORPYRIFOS,PARATHION ,MALATHION ,DIAZINON,DIMETHOATE,HEPTACHLOR ,ENDOSULT
FURADAN DECIS KARETE DIMTHOATE
GRAMOXIONE,KARATE ,ROUND UP AD WEEDALL
GRAMOXIONE,KARATE AND DUSTBURN
KARATE ,ICON ,ROUND UP AND GRAMOXION
KARATE ,SUPERKILL ,ROUND UP AND GRAMOXION
KARATE,DECIS,DIMETHOATE,DITHANE,RIDOML,FURADAN
KARATE,DIASNON,ROUND UP AND GRAMAXIONE
MALATHION,DIAZINON,CHLORPYRIFOS,PARATHON,DIMETHOATE,HEPTACHLOR,HEPTACLOR EPOXIDE,ENDOSULFAN,DIEDRIN ENDRIN,METHOXYCHLOR,ENDOSULPHAN SULPHATE
MALATHION,DIAZINON,DIMETHOATE,TRIATIX,REDCAT,FURADAN
MITHONYL,CARBARYL,CARBOFURAM,PROPOXUS,ENDOSULTAN,HEPTACHLOR,DELDRIN,ENDRIN, MALATHION,DIAZINON,PARATHION,CHLORPYRIFOS,PERMENTHRIN,CYPERMENTHRIN,DELTAMENTHRIN
OGOR,DRAZION,FULADAN,KARATE,THUNDER,GRAMOXONE
ORGANOPHOSPHATES-LIKE A CARICIDES USED IN DIPS
PERMETHRIN,CHLORPYRIFOS,PARATHION ,MALATHION,DIAZINON,DIMETHOATE,HEPTACHLOR,DIECHRIN ENDRIN,PROPOSUR

CARBARYL,METHOMYL
PERMETHRIN,CYPERMENTHRIN,PARATHION ,MALATHION,DIAZINON,DIMETHOATE,HEPTACHLOR,DIECHRIN ENDRIN,PROPOXUR CARBARYL,METHOMYL
PERMETHRIN,DELTAMETHRIN,CYPERMETHRIN,ESFENVALERATE,CHLORPYRIFOS,PARATHION,MALATHION,DIAZINON,DIMETHOATE,HEPTACHLOR,ENDOSUPHANE.DIEDRIN ENDRIN
PERMETTHRIN,CYPERMENTRIN,DELTATHRIN,PARATHION MALATHION,DIAZION,DIMETHOATE,HEPTACHLOR,ENDOLSUFAN
RAT AND RAT ,DITHANE,SUMMITHION
RAT AND RAT,LYBACID,DIAZENON,,DITHANE
RED CAT,SUMITHION,MAZATHION
ROUND UP,,KARETE,MALATHION,BALLOCK GRAMOXOLE,DIMETHOATE ETC
ROUND UP,GRAMOXIONE,DUSTBURN
ROUND UP,REDOCUIL,KARETE,MALATHION,BALLOCK DOOM ETC
SUPER DOOM,ROUND UP,ACTELIC SUPER
TOUCH DOWN,KARATE,DOOM SPRAY
TOUCH DOWN,ROUND UP AND GRAMOXIONE

Appendix III: GC MS used for analysis of organochlorine pesticides

Appendix IV: Using GC-MS during analysis

Appendix Va: The Mean Concentrations (µg/kg) of OCP Pesticides detected in Soil from Imenti North Sub-County (Sites 1-10)

OCPs/Site	1	2	3	4	5	6	7	8	9	10
a-HCH	BDL	BDL	BDL	0.86 ±0.28	0.086 ±0.02	BDL	BDL	BDL	BDL	BDL
b-HCH	5.00 ±0.96	2.88 ±0.85	8.16 ±0.78	10.34 ±3.07	2.61 ±0.75	BDL	BDL	BDL	BDL	BDL
g-HCH	BDL	BDL	0.77 ±0.03	1.57 ±0.09	BDL	BDL	BDL	BDL	BDL	BDL
d-HCH	BDL	BDL	BDL	BDL	BDL	BDL	0.58 ±0.07	BDL	BDL	BDL
Heptachlor	45.61 ±4.11	BDL	BDL	6.16 ±0.49	BDL	BDL	0.92 ±0.011	BDL	BDL	BDL
Aldrin	bDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Heptachlor epoxide	bDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
a-Endosulfan	bDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
pp-DDE	bDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Dieldrin	13.26 ±1.13	24.7 ±1.9	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Endrin	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
b-Endosulfan	BDL	BDL	BDL	29.36 ±2.58	BDL	BDL	BDL	BDL	BDL	BDL
pp-DDD	BDL	BDL	BDL		BDL	BDL	BDL	BDL	BDL	BDL
Endrin Aldehyde	13.26 ±1.13	BDL	24.78 ±1.95	22.13 ±0.59	23.11 ±1.04	BDL	BDL	18.87 ±0.64	15.87 ±5.76	1.85 ±0.23
pp-DDT	20.04 ±1.02	14.32 ±0.3	19.95 ±1.21	BDL	23.50 ±0.6	BDL	BDL	BDL	BDL	BDL
Endosulfan sulfate	BDL	BDL	BDL	BDL		BDL	16.71 ±2.31	46.69 ±1.90	BDL	BDL
Methoxychlor	53.78 ±2.89	31.51 ±0.78	68.73 ±9.65	BDL	63.77 ±3.25	79.76 ±8.45	18.35 ±0.01	22.18 ±0.87	BDL	63.77 ±2.87
Total OCP	150.96	73.49	122.41	70.44	113.08	79.76	36.57	87.75	15.87	65.62

Appendix Vb: The Mean Concentrations (µg/kg) of OCP Pesticides detected in Soil from Imenti North Sub-County (Sites 11-20)

OCPs/ Site	11	12	13	14	15	66	17	18	19	20
a-HCH	BDL	0.7489 ±0.02	BDL	BDL	5.6389± 2.10	4.603± 0.39	10.93± 0.58	7.492± 3	60.602 ±8.18	46.548 ±3.23
b-HCH	27.591 ±0.80	11.465 ±0.72	27.21299 ±4.936	33.3100 2±0.83	3.8229± 0.47	0.494± 0.16	3.243± 0.31	29.856 ±0.19	50.0911 ±7.22	36.627 ±0.16
g-HCH	34.315 ±2.18	16.944 ±0.36	BDL	BDL	BDL	4.8614 ±0.66	15.365 ±0.77	3.9291 ±0.55	40.713 ±1.86	BDL
d-HCH	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Heptachlor	16.063 ±1.82	3.39±0 .23	22.378±1 .20	18.647± 6.35	0.589±0. 03	0.437± 0.02	4.326± 0.21	2.831± 0.37	5.613± 0.46	BDL
Aldrin	BDL	BDL	BDL	BDL	BDL	BDL	BDL	49.7081 ±5.26	BDL	BDL
Heptachlor epoxide	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.51943 ±0.01	0.705± 0.01	BDL
a-Endosulfan	BDL	BDL	BDL	2.473±0. 51	BDL	BDL	BDL	2.285± 0.19	1.81±0. 22	3.085± 0.98
pp-DDE	BDL	BDL	BDL	BDL	BDL	BDL	BDL	10.3016 ±0.73	76.78± 6.18	9.67±1 .28
Dieldrin	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Endrin	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
b-Endosulfan	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	48.046 ±5.68	BDL
pp-DDD	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Endrin Aldehyde	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
pp-DDT	BDL	BDL	BDL	BDL	BDL	37.538 ±	13.069 8±	45.304 ±	64.8069	BDL
Endosulfan sulfate	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Methoxychlor	79.755 ±1.45	18.358 ±6.89	22.1841± 0.38	34.0812 ±0.95	66.0812 ±10.49	66.532 ±2.78	50.974 ±0.89	64.8069 ±1.89	BDL	25.383 ±1.89
Total OCP	157.72 4	33.961 9	88.71909	54.4300 2	43.543	109.30 52	99.073 2	216.131 1	307.7	207.06 29

Appendix VIa: The Mean Concentrations (µg/kg) of OCP Pesticides detected in Soil from Imenti South Sub-County (Sites 1-10)

OCPs/ Site	1	2	3	4	5	6	7	8	9	10
a-HCH	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.385± 0.00	BDL	BDL
b-HCH	8.392± 0.41	2.321± 0.55	BDL	BDL	BDL	BDL	1.543± 0.36	1.046± 0.04	0.6722 ±0.05	2.057±0 .37
g-HCH	2.768± 0.12	1.824± 0.52	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
d-HCH	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Heptach lor	BDL	2.536± 0.59	BDL	0.338± 0.03	BDL	BDL	3.181± 0.04	1.225± 0.01	0.573± 0.05	BDL
Aldrin	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Heptach lor epoxide	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
a-Endosul fan	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
pp-DDE	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Dieldrin	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Endrin	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
b-Endosul fan	BDL	BDL	BDL	12.017 ±0.68	BDL	BDL	BDL	BDL	BDL	BDL
pp-DDD	15.558 ±0.47	BDL	BDL	BDL	BDL	BDL	BDL	8.027± 1.75	BDL	BDL
Endrin Aldehyd e	BDL	16.55± 1.41	BDL	18.304 ±0.54	BDL	BDL	BDL	6.787± 0.70	BDL	13.699± 0.78
pp-DDT	BDL	43.627 ±2.13	BDL	11.638 ±0.84	BDL	BDL	BDL	13.189 ±0.80	BDL	BDL
Endosul fan sulfate	10.399 ±0.69	40.464 ±3.87	64.638 ±9.69	49.142 ±4.83	32.482 ±2.40	BDL	BDL	14.107 ±3.42	BDL	42.222± 1.04
Methoxy chlor	BDL	BDL	BDL	34.081 ±1.25	BDL	66.539 ±3.89	BDL	8.348± 0.00	BDL	25.3836 ±1.89
Total OCP	37.117	107.32 2	64.638	125.52	32.482	66.539	4.724	53.114	1.2452	83.3616

Appendix VIb: The Mean Concentrations (µg/kg) of OCP Pesticides detected in Soil from Imenti South Sub-County (Sites 11-20)

OCPs/ Site	11	12	13	14	15	66	17	18	19	20
a-HCH	BDL	BDL	BDL	BDL	BDL	BDL	2.155± 0.24	0.514± 0.03	2.352± 0.36	46.548 ±3.23
b-HCH	BDL	BDL	3.229± 0.76	2.281± 0.60	BDL		0.791± 0.02	14.873 ±2.17	13.371 ±3.75	36.627 ±0.16
g-HCH	BDL	BDL	0.079± 0.00	BDL	BDL	BDL	BDL	BDL	BDL	BDL
d-HCH	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.513± 0.04	3.071± 0.54	BDL
Heptachlor	BDL	BDL	2.122± 0.33	1.359± 0.19	BDL	BDL	BDL	BDL	BDL	BDL
Aldrin	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Heptachlor epoxide	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
a-Endosulfan	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
pp-DDE	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Dieldrin	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Endrin	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
b-Endosulfan	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
pp-DDD	60.514 ±8.77	BDL	BDL		15.246 ±0.68	3.227± 0.00	BDL	BDL	BDL	BDL
Endrin Aldehyde	63.015 ±6.12	BDL	BDL	11.268 ±2.26	BDL	BDL	BDL	13.642 ±0.03	47.791 ±3.79	38.94± 2.98
pp-DDT	BDL	BDL	BDL	BDL	BDL	BDL	4.741± 0.73	11.124 ±1.36	11.539 ±4.26	23.825 ±0.39
Endosulfan sulfate	BDL	41.387 ±4.23	BDL	BDL	BDL	BDL	17.73± 2.09	BDL	BDL	BDL
Methoxychlor	36.351 ±5.24	85.825 ±1.98	BDL	BDL	18.41± 0.01	37.316 ±5.14	18.070 ±0.00	57.667 ±2.87	13.911 ±0.00	15.158 ±0.00
Total OCP	159.88	127.212	5.43	14.908	33.656	40.543	43.487	83.46	88.114	96.717

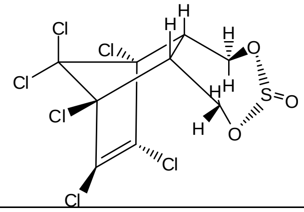
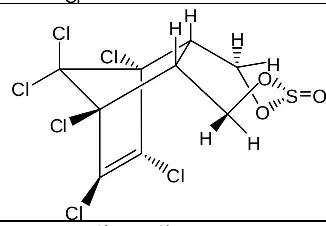
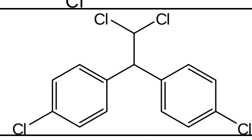
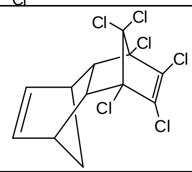
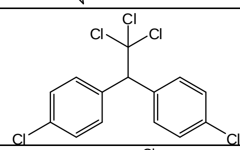
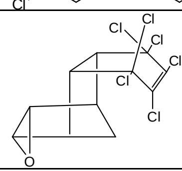
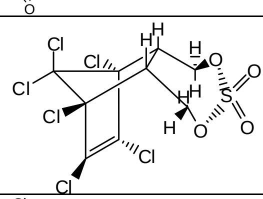
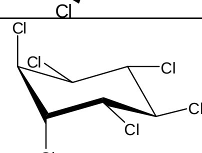
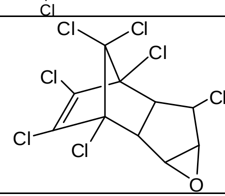
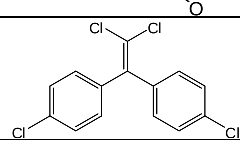
Appendix VIIa: The Mean Concentrations (µg/kg) of OCP Pesticides detected in Soil from Buuri Sub-County (Sites 1-10)

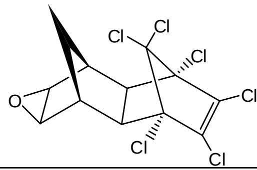
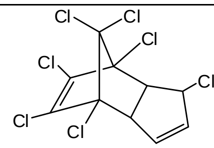
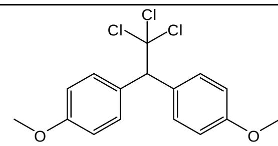
OCPs/ Site	1	2	3	4	5	6	7	8	9	10
a-HCH	BDL	29.239 ±4.25	18.793 ±0.12	0.144± 0.01	BDL	BDL	2.986± 0.07	2.619± 0.01	BDL	BDL
b-HCH	BDL	3.419± 0.94	BDL	0.122± 0.08	BDL	BDL	BDL	BDL	BDL	2.057±0 .37
g-HCH	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
d-HCH	BDL	BDL	BDL	BDL	BDL	0.064± 0.00	BDL	BDL	BDL	BDL
Heptach lor	BDL	BDL	BDL	BDL	BDL	BDL	0.19±0. 02	0.526± 0.056	0.173± 0.02	BDL
Aldrin	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Heptach lor epoxide	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
a-Endosul fan	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
pp-DDE	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Dieldrin	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Endrin	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
b-Endosul fan	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
pp-DDD	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Endrin Aldehyd e	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	13.699± 0.78
pp-DDT	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Endosul fan sulfate	BDL	BDL	6.139± 0.96	BDL	BDL	BDL	BDL	BDL	BDL	42.222± 1.04
Methoxy chlor	14.957 ±3.37	52.56± 2.98	15.721 ±0.63	15.365 ±0.19	35.307 ±2.66	16.855 ±2.32	14.777 ±2.31	26.631 ±0.22	15.041 ±0.19	25.3836 ±1.89
Total OCP	14.957	85.218	40.653	15.631	35.307	16.919	17.953	29.776	15.214	83.3616

Appendix VIIb: The Mean Concentrations (µg/kg) of OCP Pesticides detected in Soil from Buuri Sub-County (Sites 11-20)

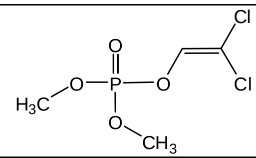
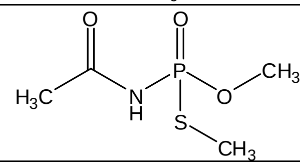
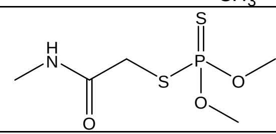
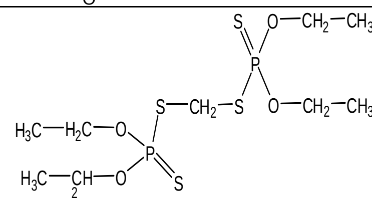
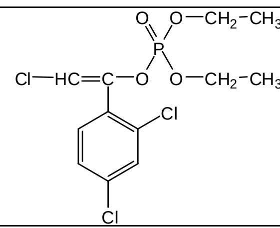
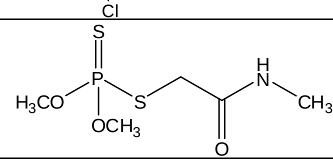
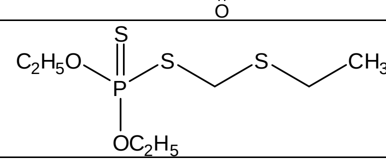
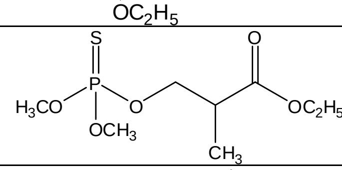
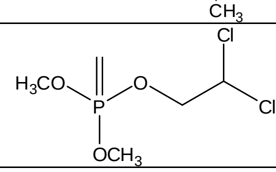
OCPs/ Site	11	12	13	14	15	66	17	18	19	20
a-HCH	BDL	4.743±0.28	1.12±0.04	BDL	1.066±0.08	2.808±0.95	BDL	BDL	0.966±0.09	9.293±1.06
b-HCH	0.268±0.01	0.218±0.06	0.065±0.00	1.159±0.07	BDL	BDL	0.632±0.01	BDL	BDL	3.481±0.54
g-HCH	BDL	BDL	BDL	BDL	0.064±0.00	BDL	BDL	BDL	BDL	BDL
d-HCH	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Heptachlor	BDL	BDL	BDL	0.389±0.05	BDL	2.999±0.92	BDL	BDL	BDL	0.321±0.00
Aldrin	BDL	BDL	BDL	0.636±0.00	BDL	BDL	BDL	BDL	0.841±0.00	BDL
Heptachlor epoxide	0.805±0.00	BDL	BDL	0.251±0.00	BDL	BDL	BDL	BDL	BDL	BDL
a-Endosulfan	BDL	BDL	BDL	BDL	BDL	0.803±0.00	BDL	BDL	BDL	BDL
pp-DDE	BDL	BDL	BDL	BDL	0.7336±0.00	BDL	0.308±0.00	BDL	BDL	BDL
Dieldrin	BDL	BDL	BDL	BDL	1.027±0.09	BDL	BDL	1.162±0.31	1.675±0.08	BDL
Endrin	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
b-Endosulfan	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
pp-DDD	BDL	BDL	BDL	BDL	BDL	5.408±0.05	BDL	BDL	BDL	BDL
Endrin Aldehyde	0.805±0.03	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
pp-DDT	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Endosulfan sulfate	12.418±1.87	25.504±0.97	31.992±2.04	5.088±0.00	38.508±3.71	BDL	21.495±1.54	BDL	21.284±0.84	BDL
Methoxychlor	31.992±9.28	31.758±5.23	72.95±5.06	BDL	BDL	21.299±1.14	17.525±0.26	BDL	BDL	BDL
Total OCP	46.288	62.223	106.127	7.523	41.3986	33.317	39.96	1.162	24.766	13.095

Appendix VIII: Chemical Structures of Organochlorine Pesticides

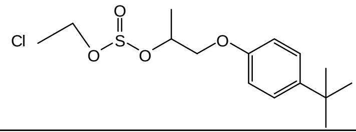
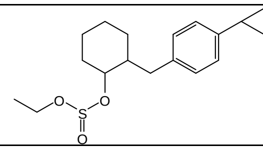
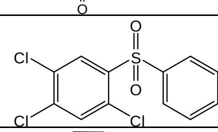
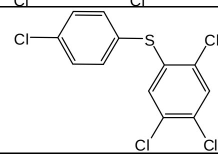
SN	Name	Structures
1	α–Endosulphan	
2	β–Endosulphan	
3	(1,1-dichloro-2,2-bis (4-chlorophenyl) ethane) *p,p* DDD	
4	Aldrin	
5	dichloro-diphenyl-trichloro-ethane (*pp*-DDT)	
6	Dieldrin	
7	EndosulphanSulfate	
8	hexachlorocyclohexane (HCH),	
9	Heptachlor epoxide	
10	2,2-bis p-chlorophenyl1, 1-dichloroethylene- p,p'-DDE	

11	Endrin	
12	Heptachlor	
13	Methoxychlor	

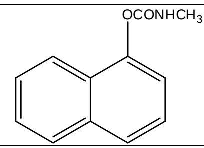
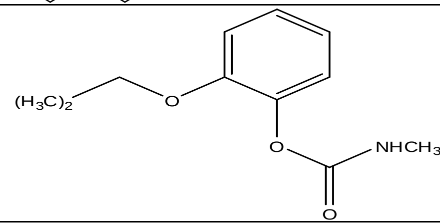
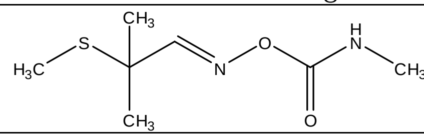
Appendix IX: Some Organophosphorus pesticides

SN	Name	Structures
1	Dichloros	
2	Acephate	
3	Dimethoate	
4	Ethion	
5	Chlorfenvinphos	
6	Diazinon	
7	Disulfoton	
8	Mevinphos	
9	Dichlorvos	

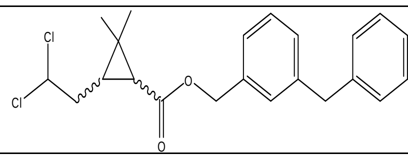
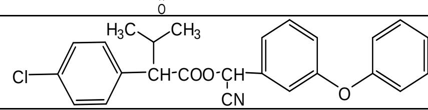
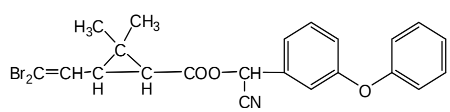
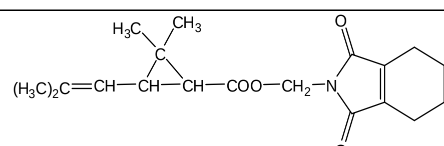
Appendix X: Some Organosulfur Pesticides

SN	Name	structures
1	Aramite	
2	Propargite	
3	Tetradifon	
4	Tetrasulf	

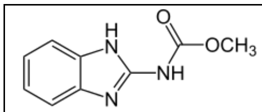
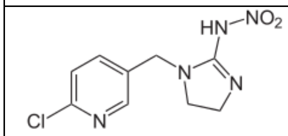
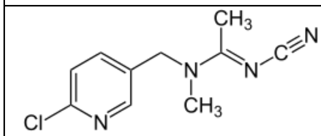
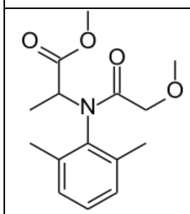
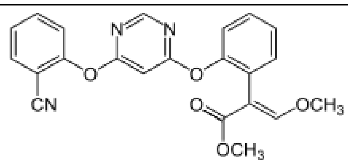
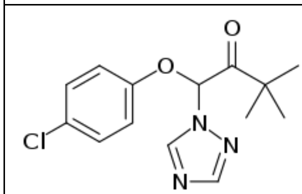
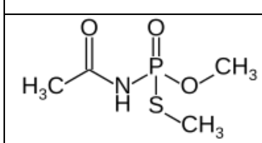
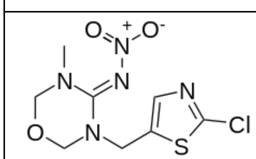
Appendix XI: Some Carbamate Pesticides

SN	Name	structures
1	Carbryl	
2	Carbofurans	
3	Aldicarbs	

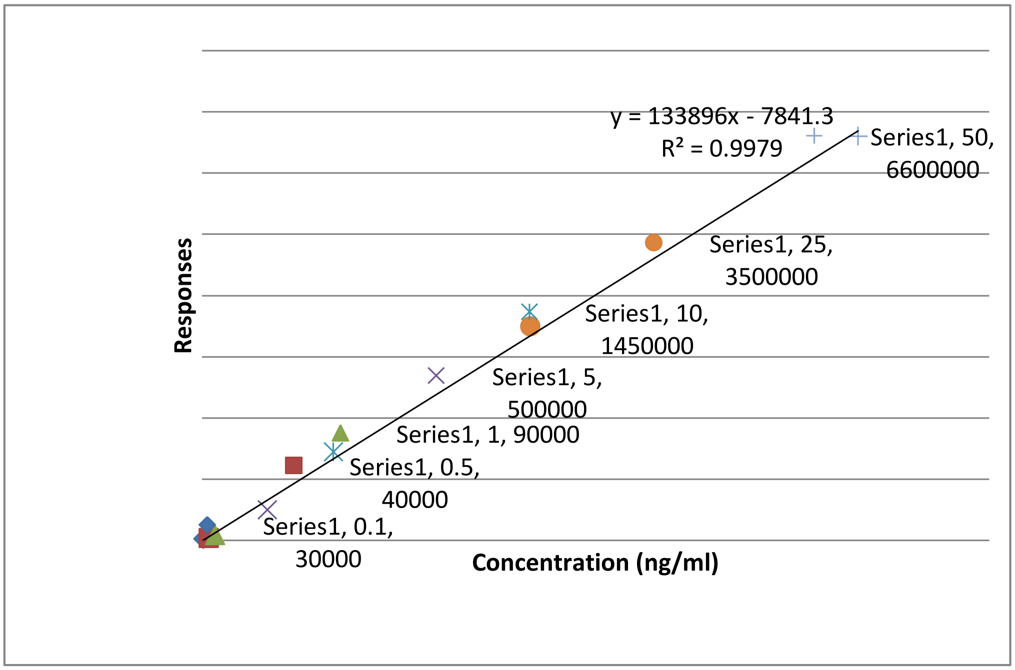
Appendix XII: Some Pyrethroids Pesticides

SN	Name	structures
1	Permethrin	
2	Fenvalerate	
3	Deltmethrin	
4	Tetramethrin	

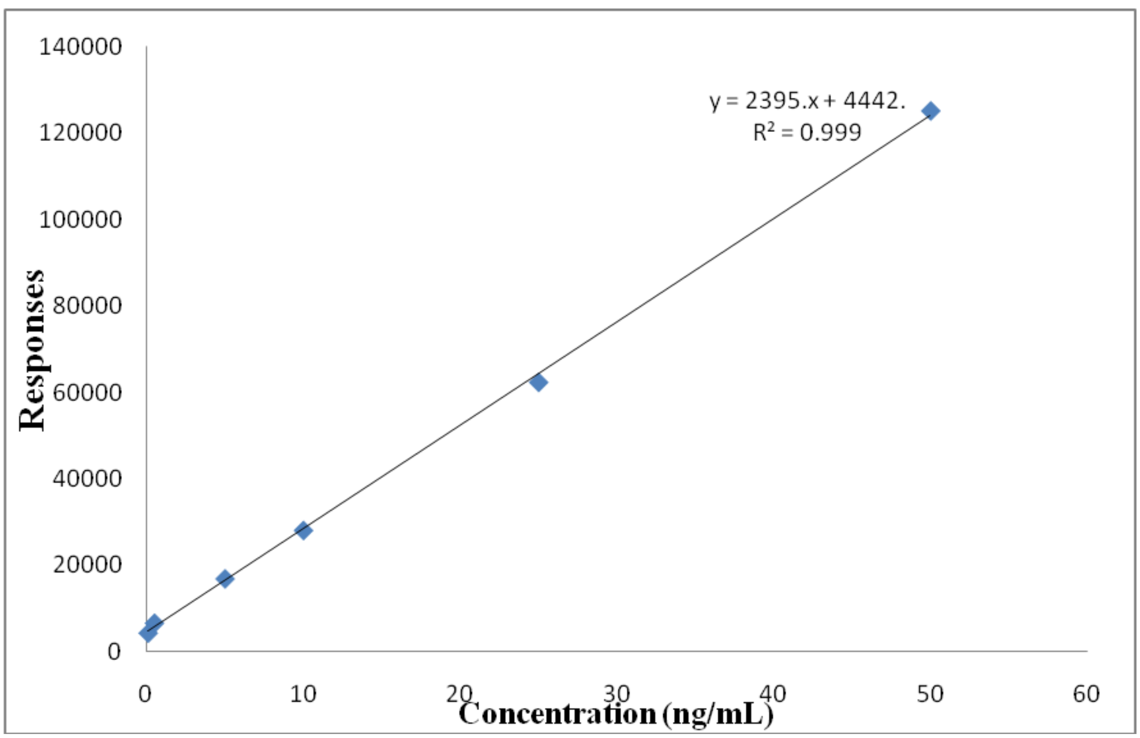
Appendix XIII: Structures of other pesticide detected in horticultural products (but not reported in the survey).

	carbendazim
	imidachloprid
	acetamiprid
	metalaxyl
	azoxystrobin
	triadimefon
	acephate
	thiamethoxam

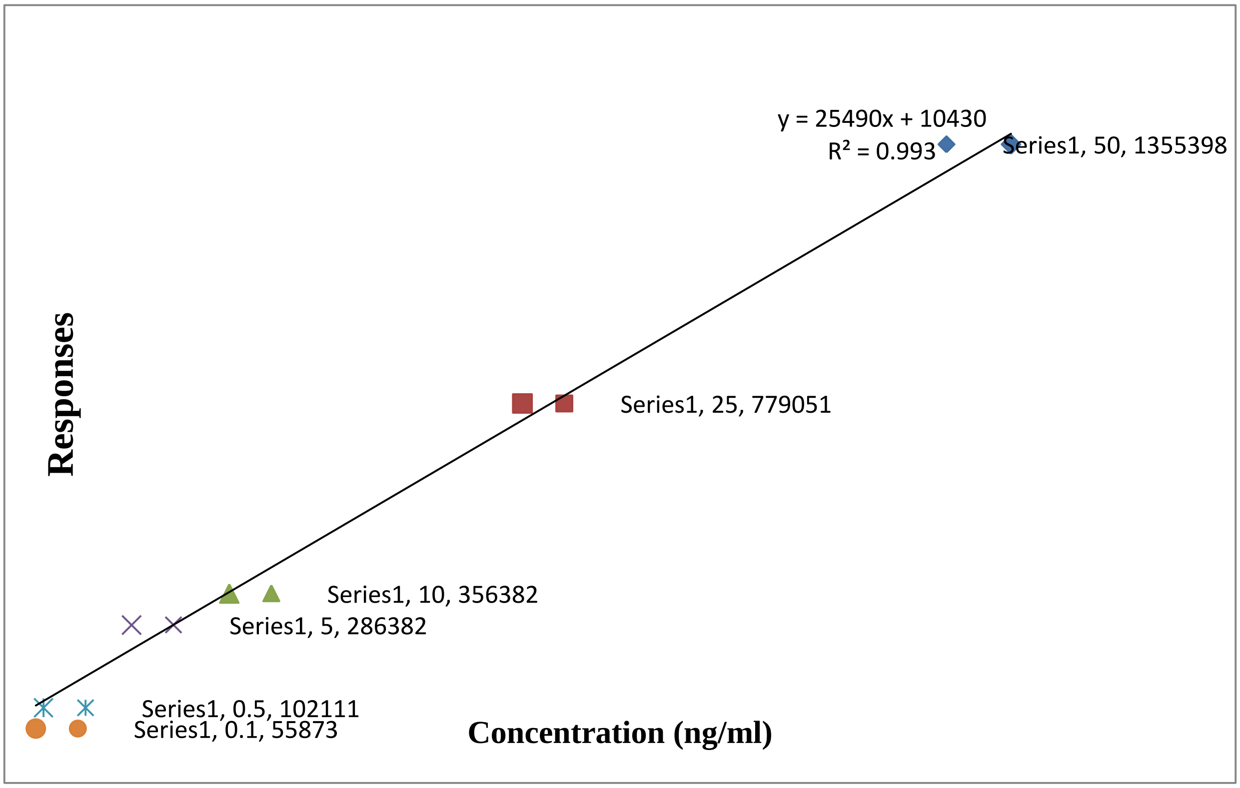
Appendix XIV: Calibration Curve for Carbendazim



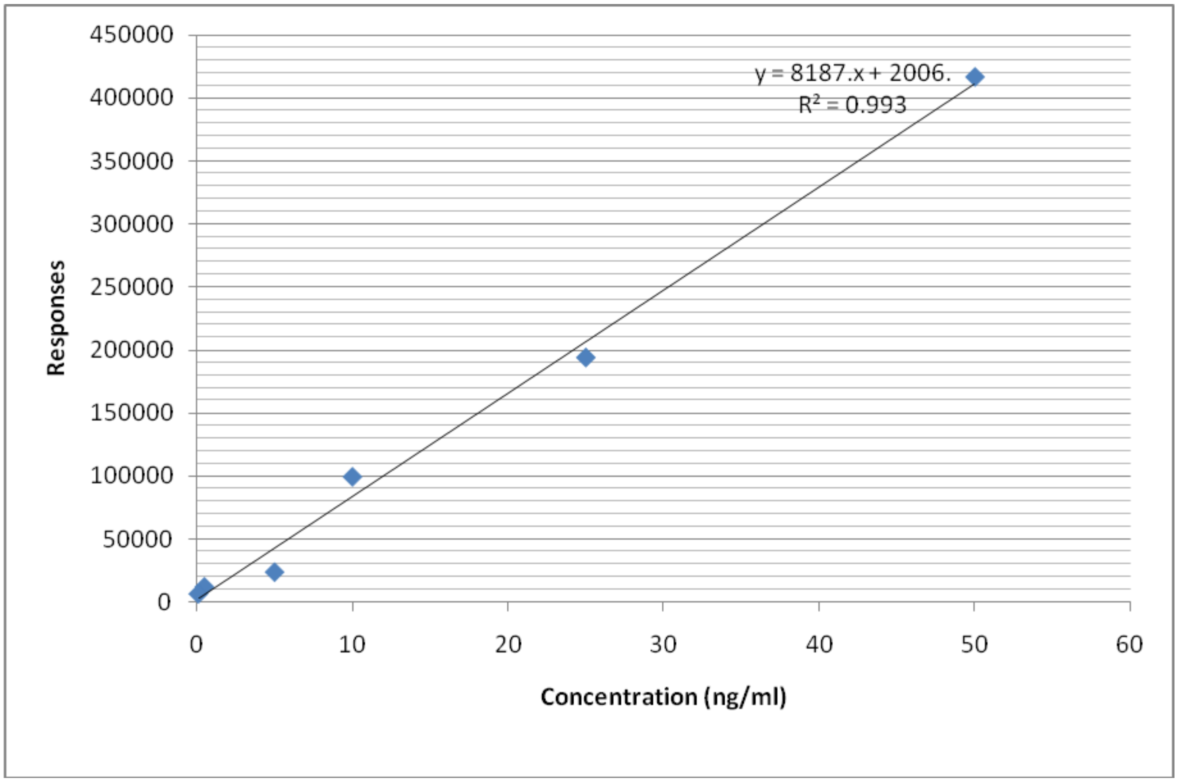
Appendix XV: Calibration Curve for Imidacloprid



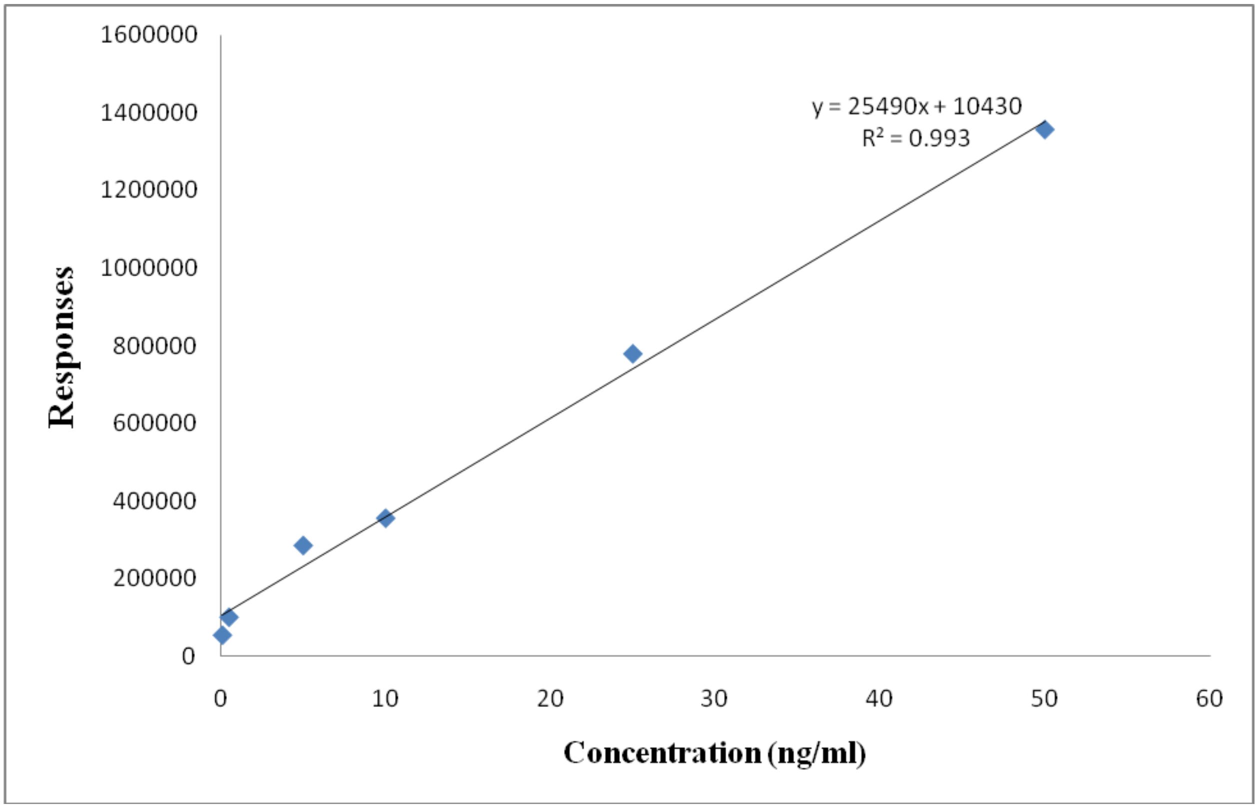
Appendix XVI: Calibration Curve for Acetamiprid



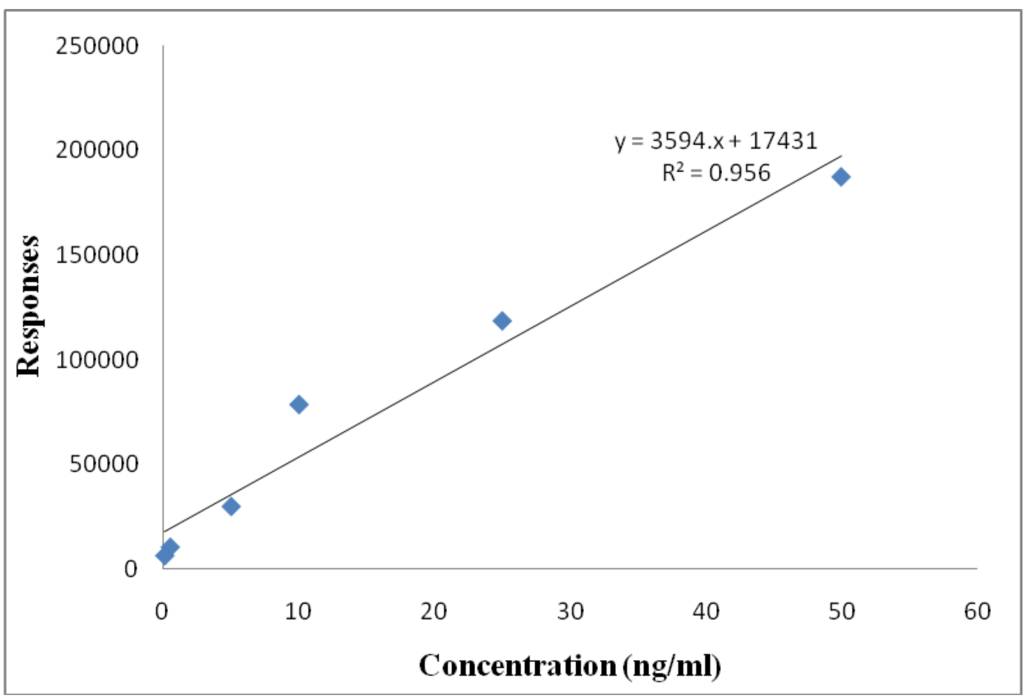
Appendix XVII: Calibration Curve for Azoxystrobin



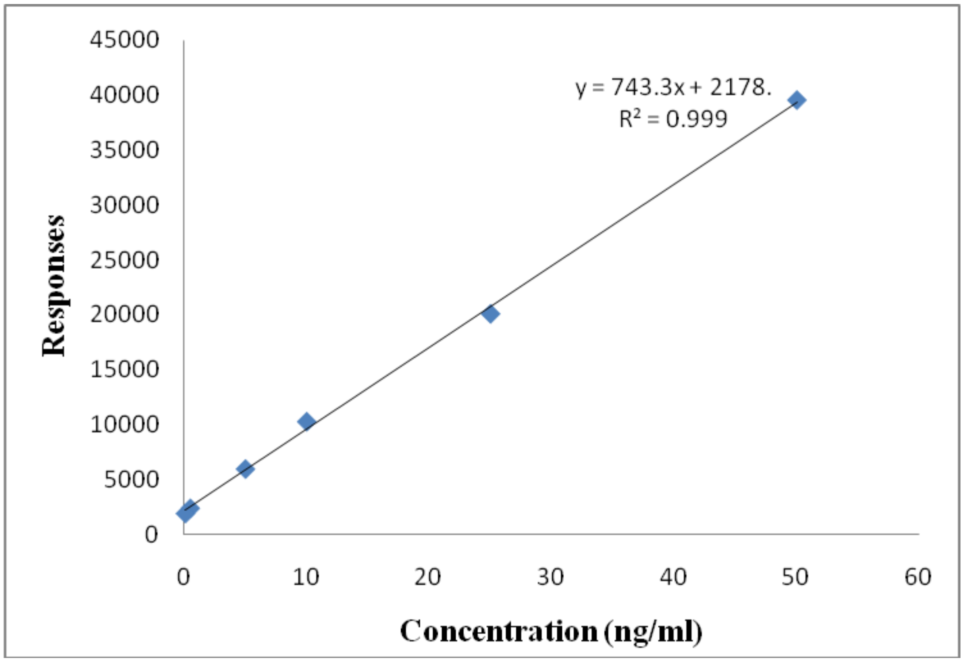
Appendix XVIII: Calibration Curve for Metalaxyl



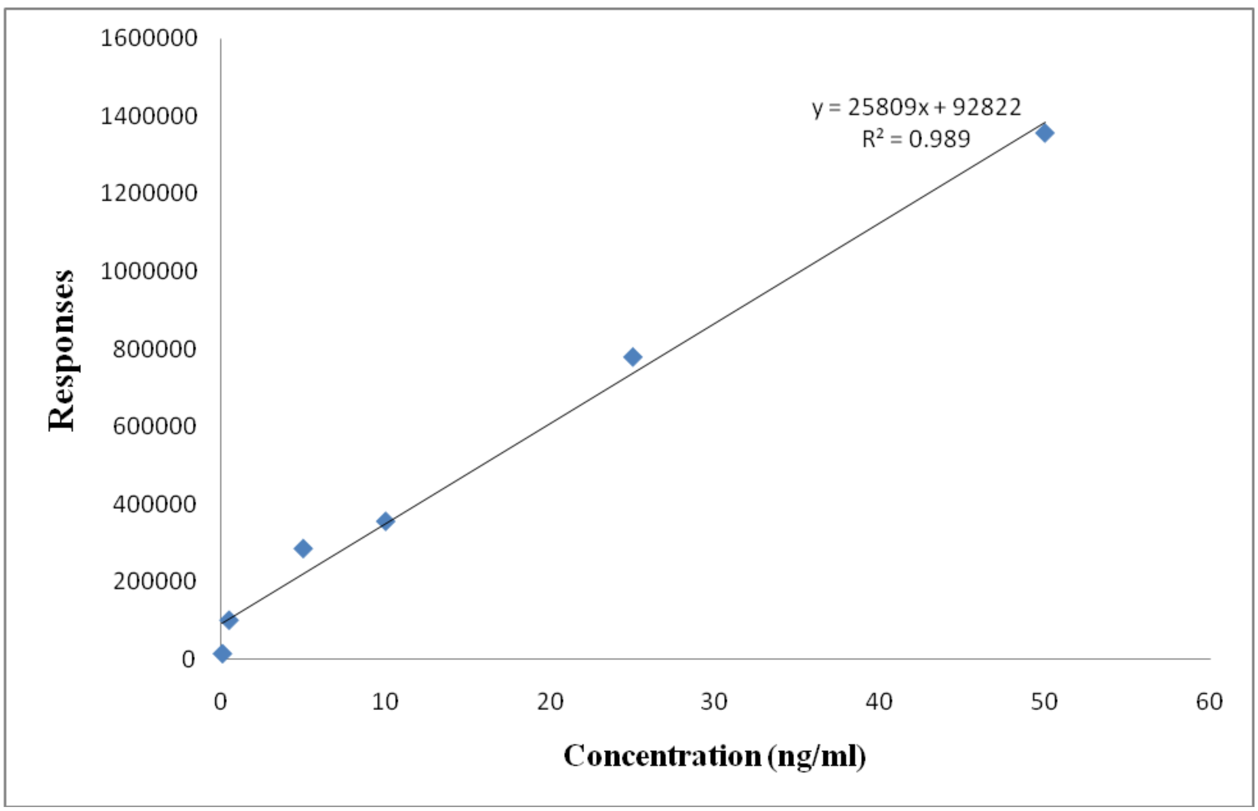
AppendixXIX: Calibration Curve for Diazinon



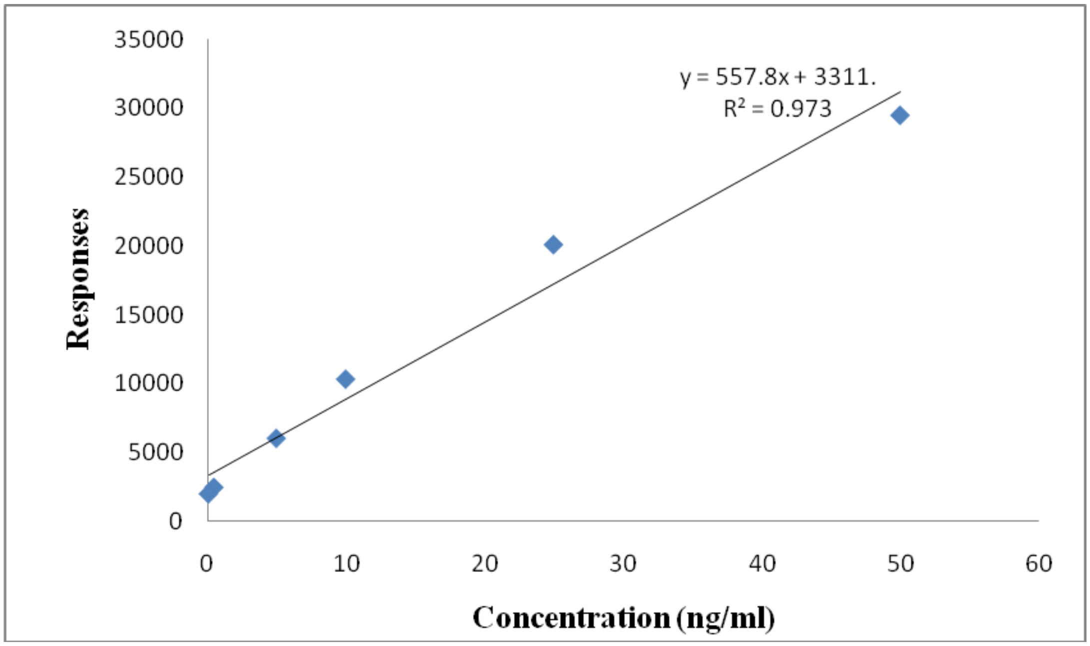
Appendix XX: Calibration Curve for Chlorpyrifos



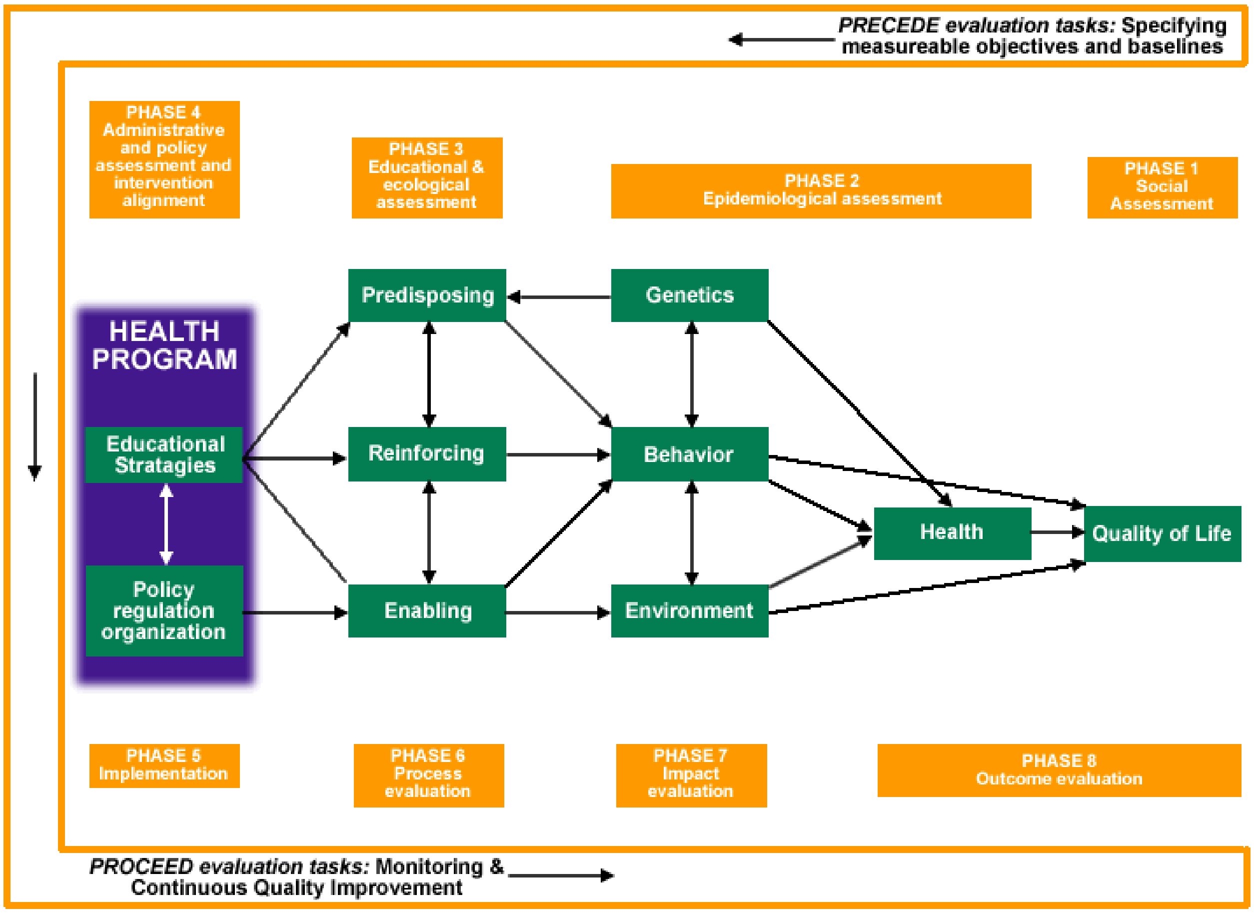
Appendix XXI: Calibration Curve for Dimethoate



Appendix XXII: Calibration Curve for Diuron



Appendix XXIII: PRECEDE-PROCEED MODEL



Appendix XXIV. The detected residues (µg kg^{-1}) in tomato samples

Label	Residue	Method	Results	LOQ	MRL	Units
To-Aa	**Carbendazim**	AOAC,2007	**11.81**	**0.10**	**300**	µg kg^{-1}
	Imidacloprid	AOAC,2007	**196.47**	**0.10**	**500**	µg kg^{-1}
	Acetamiprid	AOAC,2007	**0.29**	**0.10**	**500**	µg kg^{-1}
	Metalaxyl	AOAC,2007	**2.27**	**1.00**	**200**	µg kg^{-1}
	Diazinon	AOAC,2007	**<0.10**	**0.10**	**10**	**µg kg^{-1}**
	Azoxystrobin	AOAC,2007	**<0.10**	**0.10**	**3000**	µg kg^{-1}
	Chlorpyriphos	AOAC,2007	**<0.10**	**0.10**	**10**	µg kg^{-1}
To - Ab	**Carbendazim**	AOAC,2007	**48.65**	**0.10**	**300**	µg kg^{-1}
	Imidacloprid	AOAC,2007	**290.76**	**0.10**	**500**	µg kg^{-1}
	Acetamiprid	AOAC,2007	**3.76**	**0.10**	**500**	µg kg^{-1}
	Metalaxyl	AOAC,2007	**105.18**	**1.00**	**200**	µg kg^{-1}
	Azoxystrobin	AOAC,2007	**0.10**	**0.10**	**3000**	µg kg^{-1}
	Diazinon	AOAC,2007	**<0.10**	**0.10**	**10**	**µg kg^{-1}**
	Chlorpyriphos	AOAC,2007	**<0.10**	**0.10**	**10**	µg kg^{-1}
To - Ac	**Carbendazim**	AOAC,2007	**0.24**	**0.10**	**300**	µg kg^{-1}
	Imidacloprid	AOAC,2007	**0.84**	**0.10**	**500**	µg kg^{-1}
	Acetamiprid	AOAC,2007	**0.11**	**0.10**	**500**	µg kg^{-1}
	Metalaxyl	AOAC,2007	**6.58**	**1.00**	**200**	µg kg^{-1}
	Azoxystrobin	AOAC,2007	**0.33**	**0.10**	**3000**	µg kg^{-1}
	Diazinon	AOAC,2007	**<0.10**	**0.10**	**10**	**µg kg^{-1}**
	Chlorpyriphos	AOAC,2007	**0.14**	**0.10**	**10**	µg kg^{-1}
To - Ad	**Carbendazim**	AOAC,2007	**0.37**	**0.10**	**300**	µg kg^{-1}
	Imidacloprid	AOAC,2007	**0.88**	**0.10**	**500**	µg kg^{-1}
	Acetamiprid	AOAC,2007	**<0.10**	**0.10**	**500**	µg kg^{-1}
	Metalaxyl	AOAC,2007	**4.68**	**1.00**	**200**	µg kg^{-1}
	Azoxystrobin	AOAC,2007	**0.96**	**0.10**	**3000**	µg kg^{-1}
	Diazinon	AOAC,2007	**<0.10**	**0.10**	**10**	**µg kg^{-1}**
	Chlorpyriphos	AOAC,2007	**<0.10**	**0.10**	**10**	µg kg^{-1}
To - Ae	**Carbendazim**	AOAC,2007	**6.58**	**0.10**	**300**	µg kg^{-1}
	Imidacloprid	AOAC,2007	**33.57**	**0.10**	**500**	µg kg^{-1}
	Acetamiprid	AOAC,2007	**<0.10**	**0.10**	**500**	µg kg^{-1}
	Metalaxyl	AOAC,2007	**1.59**	**1.00**	**200**	µg kg^{-1}
	Azoxystrobin	AOAC,2007	**0.95**	**0.10**	**3000**	µg kg^{-1}
	Diazinon	AOAC,2007	**<0.10**	**0.10**	**10**	**µg kg^{-1}**
	Chlorpyriphos	AOAC,2007	**<0.10**	**0.10**	**10**	µg kg^{-1}
To - Af	**Carbendazim**	AOAC,2007	**0.93**	**0.10**	**300**	µg kg^{-1}
	Imidacloprid	AOAC,2007	**1.44**	**0.10**	**500**	µg kg^{-1}
	Metalaxyl	AOAC,2007	**<1.00**	**1.00**	**200**	µg kg^{-1}
	Azoxystrobin	AOAC,2007	**0.15**	**0.10**	**3000**	µg kg^{-1}
	Triadimefon	AOAC,2007	**0.19**	**0.10**	**1000**	µg kg^{-1}
	Diazinon	AOAC,2007	**<0.10**	**0.10**	**10**	**µg kg^{-1}**
	Chlorpyriphos	AOAC,2007	**<0.10**	**0.10**	**10**	µg kg^{-1}
To - Ag	**Carbendazim**	AOAC,2007	**0.33**	**0.10**	**1000**	µg kg^{-1}
	Imidacloprid	AOAC,2007	**0.58**	**0.10**	**500**	µg kg^{-1}
To - Ag	**Acetamiprid**	AOAC,2007	**0.32**	**0.10**	**500**	µg kg^{-1}

Label	Residue	Method	Results	LOQ	MRL	Units
To - Ag	Metalaxyl	AOAC,2007	2.10	1.00	200	µg kg^{-1}
	Azoxystrobin	AOAC,2007	0.54	0.10	3000	µg kg^{-1}
	Diazinon	AOAC,2007	<0.10	0.10	10	µg kg^{-1}
	Chlorpyriphos	AOAC,2007	0.13	0.10	10	µg kg^{-1}
To - Ah	Carbendazim	AOAC,2007	1.03	0.10	300	µg kg^{-1}
	Imidacloprid	AOAC,2007	0.12	0.10	500	µg kg^{-1}
	Metalaxyl	AOAC,2007	<1.00	1.00	200	µg kg^{-1}
	Triadimefon	AOAC,2007	0.11	0.10	1000	µg kg^{-1}
	Diazinon	AOAC,2007	<0.10	0.10	10	µg kg^{-1}
	Chlorpyriphos	AOAC,2007	0.13	0.10	10	µg kg^{-1}
To - Ai	Carbendazim	AOAC,2007	0.58	0.10	300	µg kg^{-1}
	Imidacloprid	AOAC,2007	0.25	0.10	500	µg kg^{-1}
	Metalaxyl	AOAC,2007	<1.00	1.00	200	µg kg^{-1}
	Triadimefon	AOAC,2007	<0.10	0.10	1000	µg kg^{-1}
	Diazinon	AOAC,2007	<0.10	0.10	10	µg kg^{-1}
	Chlorpyriphos	AOAC,2007	<0.10	0.10	10	µg kg^{-1}
To - Aj	Carbendazim	AOAC,2007	1.52	0.10	300	µg kg^{-1}
	Metalaxyl	AOAC,2007	<1.00	1.00	200	µg kg^{-1}
	Azoxystrobin	AOAC,2007	0.25	0.10	3000	µg kg^{-1}
	Diazinon	AOAC,2007	<0.10	0.10	10	µg kg^{-1}
	Triadimefon	AOAC,2007	0.10	0.10	1000	µg kg^{-1}
	Chlorpyriphos	AOAC,2007	0.17	0.10	10	µg kg^{-1}
To - Ak	Carbendazim	AOAC,2007	7.42	0.10	1000	µg kg^{-1}
	Imidacloprid	AOAC,2007	8.56	0.10	500	µg kg^{-1}
	Azoxystrobin	AOAC,2007	3.73	0.10	3000	µg kg^{-1}
	Metalaxyl	AOAC,2007	1.16	1.00	200	µg kg^{-1}
	Diazinon	AOAC,2007	<0.10	0.10	10	µg kg^{-1}
	Chlorpyriphos	AOAC,2007	<0.10	0.10	10	µg kg^{-1}
To - AL	Carbendazim	AOAC,2007	1.43	0.10	300	µg kg^{-1}
	Imidacloprid	AOAC,2007	0.51	0.10	500	µg kg^{-1}
	Azoxystrobin	AOAC,2007	<0.10	0.10	3000	µg kg^{-1}
	Triadimefon	AOAC,2007	<0.10	0.10	1000	µg kg^{-1}
	Diazinon	AOAC,2007	<0.10	0.10	10	µg kg^{-1}
	Chlorpyriphos	AOAC,2007	<0.10	0.10	10	µg kg^{-1}
	Metalaxyl	AOAC,2007	<1.00	1.00	200	µg kg^{-1}
To - Am	Carbendazim	AOAC,2007	3.04	0.10	300	µg kg^{-1}
	Imidacloprid	AOAC,2007	1.09	0.10	500	µg kg^{-1}
	Metalaxyl	AOAC,2007	<1.00	1.00	200	µg kg^{-1}
	Azoxystrobin	AOAC,2007	1.87	0.10	3000	µg kg^{-1}
	Triadimefon	AOAC,2007	<0.10	0.10	1000	µg kg^{-1}
	Diazinon	AOAC,2007	<0.10	0.10	10	µg kg^{-1}
	Chlorpyriphos	AOAC,2007	<0.10	0.10	10	µg kg^{-1}
To - An	Carbendazim	AOAC,2007	6.17	0.10	300	µg kg^{-1}
	Imidacloprid	AOAC,2007	2.24	0.10	500	µg kg^{-1}
	Metalaxyl	AOAC,2007	<1.00	1.00	200	µg kg^{-1}
	Azoxystrobin	AOAC,2007	2.12	0.10	3000	µg kg^{-1}
	Diazinon	AOAC,2007	<0.10	0.10	10	µg kg^{-1}
To - An	Chlorpyriphos	AOAC,2007	<0.10	0.10	10	µg kg^{-1}

Label	Residue	Method	Results	LOQ	MRL	Units
To - Ao	Carbendazim	AOAC,2007	0.65	0.10	300	µg kg^{-1}

	Imidacloprid	AOAC,2007	2.87	**0.10**	**500**	µg kg^{-1}
	Metalaxyl	AOAC,2007	1.05	**1.00**	**200**	µg kg^{-1}
	Azoxystrobin	AOAC,2007	**15.93**	**0.10**	**3000**	µg kg^{-1}
	Diazinon	AOAC,2007	**<0.10**	**0.10**	**10**	**µg kg^{-1}**
	Chlorpyriphos	AOAC,2007	**<0.10**	**0.10**	**10**	µg kg^{-1}
To - Ap	**Carbendazim**	AOAC,2007	1.10	**0.10**	**300**	µg kg^{-1}
	Imidacloprid	AOAC,2007	0.10	**0.10**	**500**	µg kg^{-1}
	Triadimefon	AOAC,2007	**0.27**	**0.10**	**100**	µg kg^{-1}
	Metalaxyl	AOAC,2007	**<1.00**	**1.00**	**200**	µg kg^{-1}
	Chlorpyriphos	AOAC,2007	**<0.10**	**0.10**	**10**	µg kg^{-1}
To - Aq	**Carbendazim**	AOAC,2007	1.11	**0.10**	**300**	µg kg^{-1}
	Imidacloprid	AOAC,2007	0.56	**0.10**	**500**	µg kg^{-1}
	Azoxystrobin	AOAC,2007	**0.26**	**0.10**	**3000**	µg kg^{-1}
	Metalaxyl	AOAC,2007	**<1.00**	**1.00**	**200**	µg kg^{-1}
	Triadimefon	AOAC,2007	**<0.10**	**0.10**	**1000**	µg kg^{-1}
	Diazinon	AOAC,2007	**<0.10**	**0.10**	**10**	**µg kg^{-1}**
	Chlorpyriphos	AOAC,2007	**<0.10**	**0.10**	**10**	µg kg^{-1}
To - Ar	**Carbendazim**	AOAC,2007	6.40	**0.10**	**300**	µg kg^{-1}
	Imidacloprid	AOAC,2007	**2.70**	**0.10**	**500**	**µg kg^{-1}**
	Azoxystrobin	AOAC,2007	**2.90**	**0.10**	**3000**	µg kg^{-1}
	Metalaxyl	AOAC,2007	**<1.00**	**1.00**	**200**	**µg kg^{-1}**
	Diazinon	AOAC,2007	**<0.10**	**0.10**	**10**	**µg kg^{-1}**
	Chlorpyriphos	AOAC,2007	**<0.10**	**0.10**	**10**	**µg kg^{-1}**
To - As	**Carbendazim**	AOAC,2007	**0.98**	**0.10**	**3000**	**µg kg^{-1}**
	Imidacloprid	AOAC,2007	**0.11**	**0.10**	**500**	**µg kg^{-1}**
	Metalaxyl	AOAC,2007	**<1.00**	**1.00**	**200**	µg kg^{-1}
	Triadimefon	AOAC,2007	**0.18**	**0.10**	**1000**	µg kg^{-1}
	Diazinon	AOAC,2007	**<0.10**	**0.10**	**10**	**µg kg^{-1}**
To - At	**Carbendazim**	AOAC,2007	**12.97**	**0.10**	**300**	**µg kg^{-1}**
	Imidacloprid	AOAC,2007	**9.24**	**0.10**	**500**	**µg kg^{-1}**
	Metalaxyl	AOAC,2007	**<1.00**	**1.00**	**200**	µg kg^{-1}
	Azoxystrobin	AOAC,2007	**0.69**	**0.10**	**3000**	µg kg^{-1}
	Diazinon	AOAC,2007	**<0.10**	**0.10**	**10**	**µg kg^{-1}**
	Chlorpyriphos	AOAC,2007	**<0.10**	**0.10**	**10**	**µg kg^{-1}**
To - Az	**Carbendazim**	AOAC,2007	**1.65**	**0.10**	**300**	**µg kg^{-1}**
	Imidacloprid	AOAC,2007	**0.56**	**0.10**	**500**	**µg kg^{-1}**
	Triadimefon	AOAC,2007	**0.28**	**0.10**	**1000**	µg kg^{-1}
	Metalaxyl	AOAC,2007	**<1.00**	**1.00**	**200**	**µg kg^{-1}**
	Diazinon	AOAC,2007	**<0.10**	**0.10**	**10**	**µg kg^{-1}**
	Chlorpyriphos	AOAC,2007	**0.16**	**0.10**	**10**	**µg kg^{-1}**
To – A12	**Carbendazim**	AOAC,2007	**0.79**	**0.10**	**300**	**µg kg^{-1}**
	Metalaxyl	AOAC,2007	**<1.00**	**1.00**	**200**	**µg kg^{-1}**
	Triadimefon	AOAC,2007	**0.20**	**0.10**	**1000**	µg kg^{-1}
	Diazinon	AOAC,2007	**0.11**	**0.10**	**10**	**µg kg^{-1}**
	Chlorpyriphos	AOAC,2007	**0.12**	**0.10**	**10**	**µg kg^{-1}**
						LOD=0.05 *µg kg^{-1}*

Appendix XXV. The detected residues (µg kg^{-1}) in French beans samples

Label	Residue	Method	Results	LOQ	MRL	Units
FB – A1	Carbendazim	AOAC,2007	0.21	0.10	100	µg kg^{-1}
	Acetamiprid	AOAC,2007	0.18	0.10	150	µg kg^{-1}
	Azoxystrobin	AOAC,2007	<0.10	0.10	150	µg kg^{-1}
	Metalaxyl	AOAC,2007	<1.00	1.00	50	µg kg^{-1}
	Diazinon	AOAC,2007	0.14	0.10	10	µg kg^{-1}
FB – A2	Carbendazim	AOAC,2007	0.22	0.10	100	µg kg^{-1}
	Azoxystrobin	AOAC,2007	<0.10	0.10	150	µg kg^{-1}
	Acetamiprid	AOAC,2007	0.31	0.10	150	µg kg^{-1}
	Metalaxyl	AOAC,2007	<1.00	1.00	50	µg kg^{-1}
	Diazinon	AOAC,2007	0.12	0.10	10	µg kg^{-1}
	Chlorpyriphos	AOAC,2007	0.46	0.10	50	µg kg^{-1}
	Metalaxyl	AOAC,2007	1.68	1.00	50	µg kg^{-1}
FB – A3	Carbendazim	AOAC,2007	0.23	0.10	100	µg kg^{-1}
	Acetamiprid	AOAC,2007	0.23	0.10	150	µg kg^{-1}
	Diazinon	AOAC,2007	<0.10	0.10	10	µg kg^{-1}
	Metalaxyl	AOAC,2007	<1.00	1.00	50	µg kg^{-1}
	Azoxystrobin	AOAC,2007	<0.10	0.10	150	µg kg^{-1}
	Chlorpyriphos	AOAC,2007	<0.10	0.10	50	µg kg^{-1}
FB – A4	Carbendazim	AOAC,2007	0.23	0.10	100	µg kg^{-1}
	Acetamiprid	AOAC,2007	0.20	0.10	150	µg kg^{-1}
	Diazinon	AOAC,2007	<0.10	0.10	10	µg kg^{-1}
	Chlorpyriphos	AOAC,2007	<0.10	0.10	50	µg kg^{-1}
	Metalaxyl	AOAC,2007	<1.00	1.00	50	µg kg^{-1}
	Azoxystrobin	AOAC,2007	0.19	0.10	150	µg kg^{-1}
FB – A5	Carbendazim	AOAC,2007	16.0	0.10	100	µg kg^{-1}
	Acephate	AOAC,2007	0.95	0.10	10	µg kg^{-1}
	Azoxystrobin	AOAC,2007	1.84	0.10	150	µg kg^{-1}
	Diazinon	AOAC,2007	<0.1	0.10	10	µg kg^{-1}
	Acetamiprid	AOAC,2007	0.12	0.10	150	µg kg^{-1}
	Metalaxyl	AOAC,2007	0.11	1.00	50	µg kg^{-1}
	Chlorpyriphos	AOAC,2007	0.34	0.10	50	µg kg^{-1}
FB – A6	Carbendazim	AOAC,2007	0.92	0.10	100	µg kg^{-1}
	Acetamiprid	AOAC,2007	<0.10	0.10	150	µg kg^{-1}
	Azoxystrobin	AOAC,2007	<0.10	0.10	150	µg kg^{-1}
	Metalaxyl	AOAC,2007	<1.00	1.00	50	µg kg^{-1}
	Diazinon	AOAC,2007	<0.10	0.10	10	µg kg^{-1}
	Chlorpyriphos	AOAC,2007	<0.10	0.10	50	µg kg^{-1}
FB – A7	Carbendazim	AOAC,2007	0.31	0.10	100	µg kg^{-1}
	Acetamiprid	AOAC,2007	0.10	0.10	150	µg kg^{-1}
	Metalaxyl	AOAC,2007	<1.00	1.00	50	µg kg^{-1}
	Azoxystrobin	AOAC,2007	0.20	0.10	150	µg kg^{-1}
	Diazinon	AOAC,2007	<0.10	0.10	10	µg kg^{-1}

	Chlorpyriphos	AOAC,2007	<0.10	0.10	50	µg kg^{-1}
FB – A8	Carbendazim	AOAC,2007	0.31	0.10	100	µg kg^{-1}
	Acetamiprid	AOAC,2007	<0.10	0.10	150	µg kg^{-1}
	Metalaxyl	AOAC,2007	<1.00	0.10	50	µg kg^{-1}
	Azoxystrobin	AOAC,2007	0.11	0.10	150	µg kg^{-1}

Label	Residue	Method	Results	LOQ	MRL	Units
FB – A8	Diazinon	AOAC,2007	0.10	0.10	10	µg kg^{-1}
FB – A9	Carbendazim	AOAC,2007	0.29	0.10	100	µg kg^{-1}
	Acetamiprid	AOAC,2007	<0.10	0.10	150	µg kg^{-1}
	Metalaxyl	AOAC,2007	<1.00	0.10	50	µg kg^{-1}
	Azoxystrobin	AOAC,2007	0.16	0.10	150	µg kg^{-1}
	Diazinon	AOAC,2007	0.15	0.10	10	µg kg^{-1}
FB – A10	Carbendazim	AOAC,2007	10.11	0.10	100	µg kg^{-1}
	Imidacloprid	AOAC,2007	21.18	0.10	2000	µg kg^{-1}
	Acetamiprid	AOAC,2007	1.51	0.10	150	µg kg^{-1}
	Metalaxyl	AOAC,2007	<1.00	1.00	50	µg kg^{-1}
	Azoxystrobin	AOAC,2007	2.49	0.10	150	µg kg^{-1}
	Diazinon	AOAC,2007	<0.10	0.10	10	µg kg^{-1}
	Chlorpyriphos	AOAC,2007	3.83	0.10	50	µg kg^{-1}
FB – A11	Carbendazim	AOAC,2007	0.24	0.10	100	µg kg^{-1}
	Acetamiprid	AOAC,2007	0.13	0.10	150	µg kg^{-1}
	Metalaxyl	AOAC,2007	0.11	0.10	50	µg kg^{-1}
	Azoxystrobin	AOAC,2007	<0.10	0.10	150	µg kg^{-1}
	Diazinon	AOAC,2007	<0.10	0.10	10	µg kg^{-1}
	Chlorpyriphos	AOAC,2007	<0.10	0.10	50	µg kg^{-1}
FB – A12	Carbendazim	AOAC,2007	0.32	0.10	100	µg kg^{-1}
	Acetamiprid	AOAC,2007	<0.10	0.10	150	µg kg^{-1}
	Metalaxyl	AOAC,2007	<1.00	1.00	50	µg kg^{-1}
	Azoxystrobin	AOAC,2007	0.11	0.10	150	µg kg^{-1}
	Diazinon	AOAC,2007	0.11	0.10	10	µg kg^{-1}
	Chlorpyriphos	AOAC,2007	<0.10	0.10	50	µg kg^{-1}
	Triadimefon	AOAC,2007	<0.10	0.10	100	µg kg^{-1}
FB – A13	Carbendazim	AOAC,2007	0.50	0.10	100	µg kg^{-1}
	Acetamiprid	AOAC,2007	2.81	0.10	150	µg kg^{-1}
	Metalaxyl	AOAC,2007	0.13	0.10	50	µg kg^{-1}
	Azoxystrobin	AOAC,2007	6.96	0.10	150	µg kg^{-1}
	Diazinon	AOAC,2007	0.11	0.10	10	µg kg^{-1}
	Chlorpyriphos	AOAC,2007	0.11	0.10	50	µg kg^{-1}
	Imidacloprid	AOAC,2007	3.95	0.10	2000	µg kg^{-1}
FB – A14	Carbendazim	AOAC,2007	1.27	0.10	100	µg kg^{-1}
	Acetamiprid	AOAC,2007	2.49	0.10	150	µg kg^{-1}
	Metalaxyl	AOAC,2007	<1.00	1.00	50	µg kg^{-1}
	Azoxystrobin	AOAC,2007	1.22	0.10	150	µg kg^{-1}

	Diazinon	AOAC,2007	<0.10	0.10	10	µg kg^{-1}
	Chlorpyriphos	AOAC,2007	0.18	0.10	50	µg kg^{-1}
	Imidacloprid	AOAC,2007	0.85	0.10	2000	µg kg^{-1}
FB – A15	Carbendazim	AOAC,2007	2.16	0.10	100	µg kg^{-1}
	Acetamiprid	AOAC,2007	0.16	0.10	150	µg kg^{-1}
	Metalaxyl	AOAC,2007	<1.00	1.00	50	µg kg^{-1}
	Azoxystrobin	AOAC,2007	1.35	0.10	150	µg kg^{-1}
	Diazinon	AOAC,2007	<0.10	0.10	10	µg kg^{-1}
	Chlorpyriphos	AOAC,2007	0.85	0.10	50	µg kg^{-1}
	Imidacloprid	AOAC,2007	4.30	0.10	2000	µg kg^{-1}
	Acephate	AOAC,2007	0.39	0.10	10	µg kg^{-1}
Label	**Residue**	**Method**	**Results**	**LOQ**	**MRL**	**Units**
FB – A16	Carbendazim	AOAC,2007	1.11	0.10	100	µg kg^{-1}
	Acetamiprid	AOAC,2007	1.56	0.10	150	µg kg^{-1}
	Metalaxyl	AOAC,2007	<1.00	1.00	50	µg kg^{-1}
	Azoxystrobin	AOAC,2007	3.68	0.10	150	µg kg^{-1}
	Diazinon	AOAC,2007	<0.10	0.10	10	µg kg^{-1}
	Chlorpyriphos	AOAC,2007	0.22	0.10	50	µg kg^{-1}
	Imidacloprid	AOAC,2007	10.12	0.10	2000	µg kg^{-1}
	Acephate	AOAC,2007	2.94	0.10	10	µg kg^{-1}
	Thiamethoxam	AOAC,2007	<0.10	0.10	40	µg kg^{-1}
FB – A17	Carbendazim	AOAC,2007	0.30	0.10	100	µg kg^{-1}
	Acetamiprid	AOAC,2007	0.14	0.10	150	µg kg^{-1}
	Metalaxyl	AOAC,2007	<1.00	1.00	50	µg kg^{-1}
	Azoxystrobin	AOAC,2007	<0.10	0.10	150	µg kg^{-1}
	Diazinon	AOAC,2007	<0.10	0.10	10	µg kg^{-1}
	Chlorpyriphos	AOAC,2007	<0.10	0.10	50	µg kg^{-1}
	Imidacloprid	AOAC,2007	10.12	0.10	2000	µg kg^{-1}
	Acephate	AOAC,2007	2.94	0.10	10	µg kg^{-1}
	Thiamethoxam	AOAC,2007	<0.10	0.10	40	µg kg^{-1}
FB – A18	Carbendazim	AOAC,2007	0.38	0.10	100	µg kg^{-1}
	Acetamiprid	AOAC,2007	<0.10	0.10	150	µg kg^{-1}
	Metalaxyl	AOAC,2007	<1.00	1.00	50	µg kg^{-1}
	Azoxystrobin	AOAC,2007	0.10	0.10	150	µg kg^{-1}
	Diazinon	AOAC,2007	<0.10	0.10	10	µg kg^{-1}
	Chlorpyriphos	AOAC,2007	<0.10	0.10	50	µg kg^{-1}
FB – A19	Carbendazim	AOAC,2007	0.33	0.10	100	µg kg^{-1}
	Acetamiprid	AOAC,2007	0.20	0.10	150	µg kg^{-1}
	Metalaxyl	AOAC,2007	<1.00	1.00	50	µg kg^{-1}
	Azoxystrobin	AOAC,2007	0.19	0.10	150	µg kg^{-1}
	Diazinon	AOAC,2007	0.11	0.10	10	µg kg^{-1}
	Chlorpyriphos	AOAC,2007	0.13	0.10	50	µg kg^{-1}
FB – A20	Carbendazim	AOAC,2007	0.30	0.10	100	µg kg^{-1}
	Acetamiprid	AOAC,2007	0.16	0.10	150	µg kg^{-1}

	Metalaxyl	AOAC,2007	**<1.00**	**1.00**	**50**	**µg kg^{-1}**
	Azoxystrobin	AOAC,2007	**0.21**	**0.10**	**150**	**µg kg^{-1}**
	Chlorpyriphos	AOAC,2007	**0.12**	**0.10**	**50**	**µg kg^{-1}**
FB – A8	**Carbendazim**	AOAC,2007	**0.93**	**0.10**	**100**	**µg kg^{-1}**
	Acetamiprid	AOAC,2007	**0.16**	**0.10**	**150**	**µg kg^{-1}**
	Metalaxyl	AOAC,2007	**<1.00**	**1.00**	**50**	**µg kg^{-1}**
	Azoxystrobin	AOAC,2007	**25.76**	**0.10**	**150**	**µg kg^{-1}**
	Diazinon	AOAC,2007	**0.15**	**0.10**	**10**	**µg kg^{-1}**
	Chlorpyriphos	AOAC,2007	**0.62**	**0.10**	**50**	**µg kg^{-1}**
	Triadimefon	AOAC,2007	**0.18**	**0.10**	**100**	µg kg^{-1}
FB – A4	**Carbendazim**	AOAC,2007	**0.45**	**0.10**	**100**	**µg kg^{-1}**
	Acetamiprid	AOAC,2007	**0.23**	**0.1**	**150**	**µg kg^{-1}**
	Metalaxyl	AOAC,2007	**<1.00**	**1.00**	**50**	**µg kg^{-1}**
	Azoxystrobin	AOAC,2007	**0.13**	**0.10**	**6000**	**µg kg^{-1}**
	Diazinon	AOAC,2007	**<0.10**	**0.10**	**10**	**µg kg^{-1}**
						LOD=0.05 *µg kg^{-1}*

Appendix XXVI. The detected residues (µg kg^{-1}) in Kales samples

Label	**Residue**	**Method**	**Results**	**LOQ**	**MRL**	**Units**
Kale-A	**Azoxystrobin**	AOAC,2007	**0.29**	**0.10**	**6000**	**µg kg^{-1}**
Kale-A	**Diazinon**	AOAC,2007	**<0.10**	**0.10**	**10**	**µg kg^{-1}**
Kale-B	**Diazinon**	AOAC,2007	**<0.10**	**0.10**	**10**	**µg kg^{-1}**
Kale-E	**Azoxystrobin**	AOAC,2007	**<0.10**	**0.10**	**6000**	**µg kg^{-1}**
	Diazinon	AOAC,2007	**<0.10**	**0.10**	**10**	**µg kg^{-1}**
Kale-F	**Azoxystrobin**	AOAC,2007	**<0.10**	**0.10**	**6000**	**µg kg^{-1}**
	Diazinon	AOAC,2007	**<0.10**	**0.10**	**10**	**µg kg^{-1}**
Kale-G	**Azoxystrobin**	AOAC,2007	**<0.10**	**0.10**	**6000**	**µg kg^{-1}**
	Diazinon	AOAC,2007	**<0.10**	**0.10**	**10**	**µg kg^{-1}**
Kale-H	**Diazinon**	AOAC,2007	**0.13**	**0.10**	**10**	**µg kg^{-1}**
Kale-I	**Diazinon**	AOAC,2007	**<0.10**	**0.10**	**10**	**µg kg^{-1}**
Kale-J	**Diazinon**	AOAC,2007	**<0.10**	**0.10**	**10**	**µg kg^{-1}**
Kale-K	**Azoxystrobin**	AOAC,2007	**<0.10**	**0.10**	**6000**	**µg kg^{-1}**
	Diazinon	AOAC,2007	**<0.10**	**0.10**	**10**	**µg kg^{-1}**
Kale-L	**Diazinon**	AOAC,2007	**<0.10**	**0.10**	**10**	**µg kg^{-1}**
Kale-M	**Diazinon**	AOAC,2007	**0.14**	**0.10**	**10**	**µg kg^{-1}**
Kale-N	**Diazinon**	AOAC,2007	**<0.10**	**0.10**	**10**	**µg kg^{-1}**
Kale-O	**Diazinon**	AOAC,2007	**<0.10**	**0.10**	**10**	**µg kg^{-1}**
	Azoxystrobin	AOAC,2007	**<0.10**	**0.10**	**6000**	**µg kg^{-1}**
Kale-P	**Diazinon**	AOAC,2007	**0.14**	**0.10**	**10**	**µg kg^{-1}**
Kale-R	**Diazinon**	AOAC,2007	**<0.10**	**0.10**	**10**	**µg kg^{-1}**
Kale-S	**Diazinon**	AOAC,2007	**0.12**	**0.10**	**10**	**µg kg^{-1}**
Kale-T	**Diazinon**	AOAC,2007	**<0.10**	**0.10**	**10**	**µg kg^{-1}**
					LOD=0.05 *µg kg^{-1}*	

Appendix XXVII: The Mean Concentrations (µg/kg dry weight) of other Pesticides detected in Tomatoes from Meru County.

	Site	Carb	Imida	Aceta	Azoxy	Metalax	Diazi	Chlorpy
Buuri	1	11.81±2.71	196.47± 19.63	0.29±0.01	BDL	2.27±0.01	BDL	BDL
	2	48.65±3.58	290.76± 26.34	0.11±0.00	0.1±0.00	105.18± 6.32	BDL	BDL
	3	0.24±0.00	0.24±0.00	BDL	0.33±0.00	6.58±0.69	BDL	0.14±0.00
	4	0.37±0.00	0.88±0.00	BDL	0.95±0.00	4.68±0.54	BDL	BDL
	5	6.58±0.35	33.57±1.82	BDL	0.96±0.00	1.59±0.07	BDL	BDL
	6	0.93±0.00	1.44±0.00	BDL	0.15±0.08	0	BDL	BDL
	7	0.33±0.00	0.58±0.00	BDL	0.54±0.00	2.1±0.18	BDL	0.13±
Imenti North	1	1.03±0.08	0.12±0.00	BDL	BDL	0	BDL	BDL
	2	0.58±0.00	1.25±0.05	BDL	0	0	BDL	BDL
	3	1.52±0.00	1.52±0.06	BDL	0.25±0.00	0	BDL	0.17±0.00
	4	1.43±0.00	8.56±0.97	BDL	3.73±0.87	0	BDL	BDL
	5	3.04±0.06	0.51±0.00	BDL	0	0	BDL	BDL
	6	6.17±0.52	1.09±0.07	BDL	1.87±0.00	0	BDL	BDL
	7	0.65±0.00	2.24±0.00	BDL	2.12±0.09	0	BDL	BDL
Imenti South	1	1.1±0.00	2.87±0.04	BDL	15.93±1.48	1.05±0.01	BDL	BDL
	2	0.56±0.00	0.1±0.00	BDL	0	0	BDL	BDL
	3	6.4±0.63	0.56±0.00	BDL	1.26±0.63	0	BDL	BDL
	4	0.98±0.00	2.7±0.08	BDL	2.9±0.00	0	BDL	BDL
	5	12.97±1.64	0.11±0.00	BDL	0	0	BDL	BDL
	6	1.65±0.87	9.24±1.42	BDL	0.69±0.00	0	BDL	BDL
	7	0.79±0.00	0.56±0.00	BDL	0	0	BDL	BDL
	8	BDL	BDL	BDL	0	0	BDL	0.12±0.00

Note: Carb: Carbendazim; Imida: Imidacloprid; Aceta: Acetamiprid; Azoxy: Azoxystrobin; metalax: Metalaxyl; Diaz: Diazinon; Chlorpy: Chlorpyrifos.

Appendix XXVIII: The Mean Concentrations (µg/kg dry weight) of other Pesticides detected in French Beans from Meru County

	Site	Carb	Imida	Aceta	Azoxy	Metalax	Diaz	Chlorpy
Buuri	1	0.21±0.00	BDL	0.18±0.01	BDL	BDL	0.14±0.00	BDL
	2	0.22±0.00	BDL	0.23±0.00	BDL	BDL	0.12±0.00	0.46±0.00
	3	0.23±0.00	BDL	0.23±0.00	BDL	BDL	BDL	BDL
	4	0.23±0.00	BDL	0.2±0.00	0.19±0.00	BDL	BDL	0.34±0.00
	5	16.00±0.52	BDL	0.12±0.00	1.84±0.08	0.11±0.00	BDL	BDL
	6	0.92±0.00	BDL	BDL	BDL	BDL	BDL	BDL
	7	0.31±0.00	BDL	0.1±0.00	0.2±0.00	BDL	BDL	BDL
Imenti North	1	0.31±0.00	BDL	BDL	0.11±0.00	BDL	0.1±0.00	BDL
	2	0.29±0.00	BDL	0.13±0.00	0.16±0.00	BDL	0.15±0.00	BDL
	3	10.11±0.96	21.18±0.96	1.51±0.06	2.49±0.07	BDL	BDL	3.83±0.00
	4	0.24±0.00	BDL	0.13±0.00	BDL	0.11±0.00	BDL	BDL
	5	0.32±0.00	BDL	BDL	0.11±0.00	BDL	0.11±0.00	BDL
	6	0.5±0.00	BDL	2.81±0.05	6.96±0.85	0.13±0.00	0.11±0.01	0.11±0.00
	7	1.27±0.01	0.85±0.00	2.49±0.06	1.22±0.06	BDL	BDL	0.18±0.00
Imenti South	1	2.16±0.08	4.3±0.05	0.16±0.00	1.35±0.02	BDL	BDL	0.85±0.00
	2	1.11±0.00	10.12±1.07	1.56±0.05	3.68±0.01	BDL	BDL	0.22±0.00
	3	0.3±0.00	10.12±0.36	0.14±0.00	BDL	BDL	BDL	BDL
	4	0.38±0.00	BDL	BDL	0.1±0.00	BDL	BDL	BDL
	5	0.33±0.00	BDL	0.2±0.00	0.19±0.00	BDL	0.11±0.00	0.13±0.00
	6	0.3±0.00	BDL	0.16±0.00	0.21±0.00	BDL	BDL	0.12±0.00
	7	0.93±0.01	BDL	0.16±0.00	25.76±1.68	BDL	0.15±0.00	0.62±0.00
	8	0.45±0.00	BDL	0.23±0.00	0.13±0.00	BDL	BDL	BDL

Note: Carb: Carbendazim; Imida: Imidacloprid; Aceta: Acetamiprid; Azoxy: Azoxystrobin; metalax: Metalaxyl; Diaz: Diazinon; Chlorpy: Chlorpyrifos.

Appendix XXIX: The Mean Concentrations (µg/kg dry weight) of other Pesticides detected in Kales from Meru County

	Site	Carb	Imida	Aceta	Azoxy	Metalax	Diazi	Chlorpy
Buuri	1	BDL	BDL	BDL	0.29±0.00	BDL	BDL	BDL
	2	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	3	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	4	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	5	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	6	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	7	BDL	BDL	BDL	BDL	BDL	0.13±0.00	BDL
Imenti North	1	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	2	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	3	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	4	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	5	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	6	BDL	BDL	BDL	BDL	BDL	0.14±0.00	BDL
	7	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Imenti South	1	BDL	BDL	BDL	BDL	BDL	0.14±0.00	BDL
	2	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	3	BDL	BDL	BDL	BDL	BDL	0.12±0.00	BDL
	4	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	5	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	6	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	7	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	8	BDL	BDL	BDL	BDL	BDL	BDL	BDL

Note: Carb: Carbendazim; Imida: Imidacloprid; Aceta: Acetamiprid; Azoxy: Azoxystrobin; metalax: Metalaxyl; Diaz: Diazinon; Chlorpy: Chlorpyrifos.

Appendix XXX: List of chemicals that AEW dealt with.

Chemicals
ACARICIDES , DEWORMERS ,INSECTICIDES
ACARICIDES , DEWORMERS
ACARICIDES , DEWORMERS ,MITES,INTERNAL , EXTERNAL WORMS
ACARICIDES , INSECTICIDES
ACARICIDES,DEWORMERS
ACARICIDES,DEWORMERS ,INSECTICIDES
ACARICIDES,DEWORMERS,INSECTICIDES
ACARICIDES,TICK FREE , DEWORMERS
ACARICIDES, PESTICIDES FOR ANIMAL INSECT
ACTARA,DRAGNET,CONFIDOR,METHOMEX,BULLOCK AGRINET
AGROCHEMICALS
BESTOX,DECIS,BULLDOCK
CHLORPYRIFOS,PARATION,MALATHION,DIAZINON,DIMETHOATE,PERMETHRINE,DELTAMETHRIN,CYPERMETHRIN
CONTACT PESTICIDES,SYSTEMIC INSECTICIDE,NITICIDE,RODEOTICIDES
COPPER FUNGICIDES,SUMITHION,KARATE LEVO
COPPER OXYCLORIDE,VICTORY,SUMICIDINE,GYCOGEN
DECIS,KARATE,BULL DOSE,MALATHION,DITHANE,
DECIS,MALATHION,ALDRIN,DIEDRIN,CHLORDANE,METHOXYCHLOR,HEPTACHLOR EDRIN,ENDOSULFAN,LINDANE,, HEXACHLOROBENZENE
DEWORMERS
DEWORMERS , ACARICIDES
DEWORMERS , EXTERNAL PEST LIKE FLEES , TICKS
DEWORMERS , TICK FREE CHEMICALS
DIMETHOATE,KARATE,DUSTBURN,GLAMOXINE , ROUND UP
DIMETHOATE,KARATE,DUSTBURN,RIDOMYL ,DITHANE
DIMETHOATE,RIDOMYL,DITHANE,DECIS,MALATHION,KARATE
DITHANE FUNGICIDES,OSHOTHANE,INSECTICIDES,MITICIDES-ABAMECTIN,OGOR
ECS,SLS,WLS , DUST
FUNGICIDES,HERBICIDES,INSECTICIDES,MITICIDES,ACARICIDES
FUNGICIDES,NEMATICIDES,INSECTIDES
FUNGICIDES,NEMATICIDES,INSECTIDES,MITICIDES,HERBICIDES
GLAMOXINE,R,OMYL,ACTELIC,KARATE , DITHANE
HERBICIDDES,FUNGICIDES,NEMATICIDES FUNGICIDES
HERBICIDDES,FUNGICIDES,STORAGE DUST
HERBICIDE,FUNGICIDES,INSECTICIDES
HERBICIDE,FUNGICIDES,INSECTICIDES
HERBICIDES,FUNGICIDES,INSECTIDES,NEMATICIDES,SEED DUST ETC
HERBICIDES,FUNGICIDES,NEMATICIDES
HERBICIDES,INSECTICIDES,ACARICIDES,MITICIDES

HERBICIDES,INSECTICIDES,FUNGICIDES,ACARICIDES,, MITICIDES
HERBICIDES,INSECTICIDES,FUNGICIDES,BESTOX,DUDUTHRIN,MALATHION,ROUND UP,DITHANE,RIDOMYL
HERICIDES,FUNGICIDES,BIONEMATICIDES,NAEMATICIDES
INSECTICIDES,HERBICIDES,FUNGICIDES,NEMATICIDES
KARATE ,ACTELIC,DIMETHOATE,GLAMOXONE,ROUND UP
KARATE,DITHANE,DUSTBURN,ACTELIC
KARATE,DITHANE,DUSTBURN,GLAMOXINE , ROUND UP
KARATE,DITHANE,GLAMOXINE,RIDOMYL,ACTELIC
KARATE,DITHANE,GLAMOXINE,RIDOMYL,ROUND UP
KARATE,ECTOPAL,SELADONE
KARATE,GRAMOXONE,ROUND UP,ACTELIC , DITHANE
KARATE,OGOR,NOVAPOLYTRIN,BULLOCK,METHOMESE,PYRINESE CONFIDOR,DRAGNET,ACTARA,AGRINATE,ATOM THUNDER ETC
KARATE,THUNDER,AGRINATE,CONFIDOR,BULLOCK
KARATE,THUNDER.OGOR.ECTOPOL.VECTOCID.AGRINET.NORA
LEVAMISOLE,,KARATE,THUNDER,OGOR
NEMATICIDES,FUNGICIDES,INSECTICIDES
ORGANOCHLORIES,ORGANOPHOSPHATE
PERMETHRIN,DELTAMETHRIN,ESFENVALERATE,MALATHION,DIAZINON,DIMETHOATE,CHLORPYRIFOS,HEPTACHLOR EPOXIDE,DIEDRIN ENDRIN,METHOXYCHLOR,METHOMYL,CARBOXYL
PERMETHRIN,DELTAMETHRIN,ESFENVALERATE,PARATHION,CHLORPYRIFOS,MALATHION,DIAZINON,HEPTACHLOR,DELDRIN ALDRIN
PERMETHRIN,DELTAMETHRIN,ESFENVALERATE,PARATHION,CHLORPYRIFOS,MALATHION,DIAZINON,HEPTACHLOR,DELDRIN ALDRIN,METHOXYCHLOR,P'P'DDT,METHOMYL,CARBO
ROUND UP THAT WAS USED FOR WEED CONTROL ON MAIZE FARM PERIMETERS
SUMITHION,COPPER FUNGICIDE,RIDOMYL,KARATE,DUDUTHRIN,THUNDER ETC
VECTOCID,ECTOPAL,KARATE,THUNDER AGRINATE

Appendix XXXI: Service to Farmers by AEW

What do you give to the farmers on the use of the above pesticides
TECHNICAL USE AND PRACTICES
ADVICE THEM TO WEAR PERSONAL PROTECTIVE EQUIPMENTS WHEN SPRAYING,ON HOW TO MIX THE PESTICIDES AND WHEN AND WHICH CHEMICAL TO USE AT WHAT TIME
APPLICATION RATES,PRECAUTION ESPECIALLY ON PROTECTION OF THE ONE APPLYING
EXTENSION MESSAGES
EXTENSION ON THE USE AND DANGERS IF NOT USED TOWARDS PRODUCTION
GIVE THEM ADVICES ON PESTICIDES USAGE
GOOD STORAGE AND CAREFUL HANDLING
HOW TO USE THEM,WHERE TO BUY THEM AND HOW TO STORE THEM
HOW TO USE THEM
HOW TO USE THEM AND DEMOSTRATIONS ON THEIR ANIMALS DURING TREATMENT PERIOD
I DEWORM MYSELF

INFORMATION ON THEIR USE AND SAFETY
METHODS OF THEIR APPLICATION AND TIME,EXPIRY DATE AFTER USE,DISPOSAL OF CONTAINERS
NO RESPONSE
NOTHING BUT EMPHASIZED ON THE USE OF PERIMETERS
OBSERVE ALL RULES
PESTICIDES ARE POISONOUS AND SHOULD BE HANDLED WITH CARE
POISONOUS
PRECAUTION
PRECAUTIONARY MEASURES,EXPIRY DATES,TRANSPRTATION,PROTECTIVE CLOTHING WHEN USING,TIME OF APPLICATION
PROTECTIVE ATTIRES,GLOOVES,BREATHERS,OVERALL,GUM BOOTS,SPRAYERS BUT FROM THE OFFICE ONLY FOR DEMONSTRATION
PURCHASE AND TRANSPORTATION OF PESTICIDES,SHORTAGE OF PESTICIDES,FORMULATION AND RATE OF APPLICATION
RATE OF APPLICATION,POST HARVEST INTERVIEWS,FORMULATION DEATAILS,LOCATION OF PURCHACE AND STORAGE
RATE OF APPLICATION,POST HARVEST INTERVIEWS,LOCATION OF PURCHACE AND STORAGE
RATES OF APPLICATIONPOOR HARVEST INTERVALS,FORMULATION,USE PROTECTIVE CLOTHING
READ ALL THE RULES IN THE LABEL BEFORE APPLICATION
READ THE LABEL BEFORE USE
REQUIRE INFORMATION FROM AGRI- EXTENSION OFFICERS OR ANY OTHER AUTHORIZED PERSON
SAFE USE AND HANDLING OF PESTICIDES
SAFE USE OF PESTICIDESS,TRAININGS,PURCHASE,BANNED PESTICIDES,TRANSPORT, HANDLING AND DISPOSAL
SAFETY METHODS OF APPLICATION,SPECIFICS PESTICIDES FOR PESTS AND DISEASES FOR PLANTS
SAFETY PRECAUTIONS ON PESTICIDES HANDLING,PESTICIDES USAGE AND CONDUCTING DEMONSTRATIONS ON THE SAME
SERVICES AND EDUCATION ON THEIR USE
TECHICAL ADVICE
TECHNICAL ADVICE ON HOW TO APPLY THE PESTICIDES THAT IS WHEN AND HOW TO APPLY AND THE RATES TO USE
TECHNICAL ADVICE ON THEIR USE AND DEMONSTRATION DURING TREATMENT SERVICES
TECHNICAL ADVICE ON USE AND SAFETY
TECHNICAL ADVICES AND DEMONSTRATIONS ON ALL ASPECTS RELATED TO PESTICIDES USE AND SAFETY PRECAUTION
TECHNICAL ADVIVE ON THEIR USE AND DEMONSTRATION WHILE DOING TREATMENT
TECHNICAL USAGE OF THEM
TECHNICAL USE AND SAFETY
THEY ARE POISONOUS
THEY SHOULD BE HANDLED WITH CARE THEY ARE POISONOUS
TRAININGS
TRAININGS ON SAFE USE OF PESTICIDES
USAGE OF THEM
USAGE-WHY,HOW AND WHEN TO USE PESTICIDES

USE PROTECTIVE CLOTHOTING
WAYS OF APPLICATION,DOSAGE,DATE OF EXPIRY
WE TRAIN THEM ON SAFE USE OF CHEMICALS
WHAT CHEMICAL TO USE AND SAFE USE OF CHEMICALS

Appendix XXXII: List of Pesticides

NAME THE PESTICIDES USED BY FARMERS WITHIN YOUR AREA
THUNDER,OGOR,METHOMASE,STELADONE,ECTOMIN
PYRINEX,ACTARA,AGRINET,KARATE.OGOR
DETHANE,FURADEN,ALDRIN,DIEDRIN,GRAMOXINE
KARATE,RIDOMYL,GRAMOXENE,DITHANE
KARATE,DIMETHOATE,DITHANE,FURADON,GLAXOMINE ETC
KARATE,ACTELIC AND DIMETHOATE
ORRGANOCHLORINE,ORGANOPHOSPHATE,CARBAMATES
KARATE,DIMETHOATE,DITHANE,ACTELIC,GLAXOMINE ETC
DEWORMERS EG WORMICID PLUS,TRIATISE,POUR ON,KARATE
ORRGANOCHLORINE,ORGANOPHOSPHATE,CARBAMATES
ORRGANOCHLORINE,ORGANOPHOSPHATE,CARBAMATES
DUSTBURN,ACTELIC,DITHANE,KARATE,ROUND UP,GRANEMOPHANE
DUSTBURN,ACTELIC,DITHANE,KARATE,ROUND UP,GRAMOXONE
LEVAMISOLE,ECTOPAL,KARATE,THUNDER,OGOR
KARATE,DITHANE,OGOR,GRAMAXONE,ROUND UP,DIAXIMONE
KARETE DITHANE M45,BULLOCK,OGOR,THUNDER ETC
TRIATIX,BAYGON,VECTOCID,WORMICID PLUS
CROP PESTICIDES ,HERBICIDES
CROP PESTICIDES,ANIMAL PESTICIDES
VECTOCID,KARATE,BULLOCK,ROUND UO,GRAMOXONE
VECTOCID,ECTOPAL,KARATE, THUNDER,AGRINATE
HERBIKILL,ROUND UP,KARATE,OGOR,BULLOCK,DITHANE M45
KARATE ,THUNDER,AGRINATE,BULLOCK ETC
VECTOCIDS,DEWORMERS,THUNDER,AGRINATE
KARATE.NORA.THUNDER.OGOR.ROUND UP;GRAMAXOINE
KARATE,THUNDER,ECTOPAL,VECTOACID,AGRINATE
ECTOPAL,DEWORMERS,VECTOACID
EMERCIFIED CONCENTRATES,SOLUBLE LIQUIDS,WETTABLE POWDERS,PRESSURIZED EMERSION,DUETS
DITHANE M45,DUDUTHRIN I.TEC,ROUND UP TULBO,ACTELIC SUPER,GRAMOXONE
COPPER FUNGICIDES,SUMITHION,KARATE,DUSTPAN
KARATE,DUDUTHRINE,DITHANE ,RIDOMYL,
KARATE,THUNDER,ACUL,WEED OUT,

INSECTICIDES,FUNGICIDES,NEMATICIDES,HERBICIDES
JACKPOT ,KARATE,RIDOMY,DUDUTHRIN,BESTOX
KARATE,DUDUTHRINE,DITHANE ,SKANIA,MALATHION
DUDUTHRIN,THUNDER,JACKPOT,MALATHION DUST,ACTELIC DUST
KARATE,BEXTOX,DITHANE M45,DUDUTHRIN,ACTELLIC SUPER
KARATE,DECIS,JACKPOT,DIMATIODES,HABIL KOOL,ACTELIC SUPPER,SKANA SUPPER
DUDUTHRIN,THUNDER,BULLDOCK,AXUL,WEED OUT,SUMITHION,,MALATHION DUST,ACTELIC DUST
OSHOTHANE,DITHANE M45,RIDOMYL,SUMITHIONWIPE OUT,WEED ALL2,4D
BULLDOCK,RIDOMYL,DITHANE,THUNDER,JACKPOT
GLYPHOSATES,PARAQUAT,PYRETHRIN,MALATHION,LANNATE
24D,AGIL,DUDUTHRINGRAMAXONE
ACTELIC SUPPER,SPINITOR DUST
DITHANE M45,DUDUTHRIN I.TEC,ROUND UP TULBO,ACTELIC SUPER,GRAMOXONE
KARATE,SUMICOMBI,DURSABAN,DIMETHOATE,SUMITHION,ACARICIDES
DITHANE M45,PERMETHRINE,ALDRIN,HEPTACHLOR UP TULBO,RIDOMYL
DIMETHOATE,RIDOMYL,DITHANE,DECIS,MALATHION AND KARATE
PERMETHRIN,DIAZINON,MALATHION,RIDOMYL,DITHANE,CHLORPYRIFOS
PERMETHRIN,DIAZINON,MALATHION,RIDOMYL,DITHANE,CHLORPYRIFOS
DELTAMETHRIN,PERMETHRIN,MALATHION,PARATHION,DIAZINON,DIMETHOATE,HEPTACHLOR,DIEDRIN,ENDRIN, METHOXYCHLOR,P'P'DDT,ENDOSPHARM,CARBORYL,CARBOFURAN
ALDRIN,DIEDRIN,METHOXYCHLOR,ENDRIN,ENDOSULTAN,LINDANE,CYPERMETHRINE,DELTAMETHRINE,PERMET HRIN,ESFENVALERATE,CHLORPYRIFOS,PARATHION,MALATHION,DIAZINON,DIMETHOATE
PERMETHRIN,DIAZINON,MALATHION,RIDOMYL,DITHANE,CHLORPYRIFOS
DIMETHOATE,KARATE,DECIS,BULLDOSE,PENCOZEB,DITHANE
BESTOX,BRIGADE,BULLDOCK STAR,GOLAN,KESHET,KARATE,DUDUTHRINE,THUNDER
KARATE,ACTELIC SUPER,BRIGADE,
DIMETHOATE,D M45,RIDOMYL,PORAGUNTE,GLYPHOSPHATE SALTS,CHLORPYRIFOS,METHOMYL,ABAMECTIN,DELTAMETHRIN,DIAZINON
ROUND UP,MALATHION,GRAMOXONE,SYGENTA FORMULATION LIKE KARATE
DITHANE M 45,ACTELIC SUPER,MALATHION,ROUND UP,WEEDALL
OSHOTHANE,DITHANE M45,RIDOMYL,KARATE,ROUNDUP
KARATE,DACOMYL,POLYTRIN,GRAMAXONE,ROUND UP
KARATE ,ROUND UP,DITHANE M 45,ACTELLIC SUPER,BULLOCK ETC
KARATE,OGOR,THUNDER,POLYTRIN,PYRINEX,AGRINATE,ACTARA,ATOM
STELADONE,ECTOPAL,ECTOMIN,TRIATIX,DEWORMERS
KARATE,NORA,ECTOPAL,POUR ON,STELADONONE
EMALSIFIABLE CONCENTRATES,DUSTS,POWDERS,ULV,SOLUBLE POWDERS
OGOR,STELADONE,ECTOPAL,ECTOMIN,THUNDER
KARATE,BULLOCK,DITHANE M 45,ROUND UP AND GRAMOXONE
LEVAMISOLE,ECTOPAL,KARATE,THUNDER,OGOR

Appendix XXXIII: Do the Farmers read the label before applying the Pesticides

DO THE FARMERS READ THE LABEL BEFORE APPLYING THE PESTICIDES	No.	PCT
A few	27	38
Most of them do read the label	1	1
No	8	10
Only those who can read and write	2	3
Yes	35	49
Grand Total	**73**	**100**

Appendix XXXIV: Source of information for pesticide use

Where do these farmers get the information on the pesticides to use?
AGRICULTURE AL EXTENSION OFFICER,OTHER FARMER,STOCKISTS,NGOS,MEDIA
AGRICULTURE EXTENSION OFFICERS,COMMUNITY,WORKERS AND HEALTH WORKERS,NEIGHBOURS AND PESTICIDE RETAILERS
AGRICULTURE EXTENSION OFFICERS,COMMUNITY,WORKERS AND HEALTH WORKERS,NEIGHBOURS AND PESTICIDE RETAILERS,NEWSPAPERS.AGRODEALERS AND OTHER FARMERS
AGRICULTURE OFFICE,RADIO,NEIGHBOURS
AGROVETS AND PRIVATE PRACTIONERES
AGROVETS,AGRO STAFF AND LIVESTOCK STAFF INVOLVED
AGROVETS,EXTENSION WORKS AND PRIVATE PRACTIONERS
AGROVETS,EXTENSION WORKS,RADIOS
BY READING LABELS,LISTENING TO THE MEDIA,ATTENDING SIDESHOW AND AGRICULTURAL SHOW,AGRICULTURAL EXTENSION WORKERS VISIT THEM
CHEMICAL SHOPS,NEIGHBOURS,RADIO,EXTENSION OFFICERS
CHEMISTS,AGRICULTURAL STUFF AND OTHER EXTENSION WORKERS
CHEMISTS,AGRICULTURAL STUFF AND OTHER FARMERS
CONSULTING AGRICULTURAL OFFICES IN THE AREA,ADVICES THE TECHNICAL STAFF THE AGRO-IN THE AREA
EXTENSIO OFFICER,RADIOS,COMPANY EXTENSION OFFICER
EXTENSION AGRICULTURAL OFFICERS,SHOPS,RADIOS,TVS,NEWSPAPERS ETC
EXTENSION AGRICULTURAL OFFICERS,SHOPS,RADIOS,TVS,NEWSPAPERS FACTORIES,AGROVETS ETC
EXTENSION OFFICER,STOCKIST
EXTENSION OFFICER,STOCKIST AND OTHER SERVICE PROVIDERS
EXTENSION OFFICER,STOCKIST,SERVICE PROVIDER
EXTENSION OFFICER,STOCKISTS,RADIOS
EXTENSION OFFICER,STOCKISTS,RADIOS AND SERVICE PROVIDER
EXTENSION OFFICERS,SERVICE PROVIDES,STOCKISTS,RADIOS

EXTENSION OFFICERS,SERVICE PROVIDES,STOCKISTS,RADIOS,INTERNET,OTHER STAKEHOLDERS AND OTHER FARMERS
EXTENSTION OFFICER,NEWS PAPER,RADIOS AND SMALL SCALE FARMERS
AEO AND THE AGROCHEMICALS WHERE THEY BUY THE CHEMICALS
AGRI AND PRIVATE PRACTIONERS
AGRICULTURAL EXTENSION ,AGRO CHEMICAL DEALERS,LIVESTOCK EXTENSION WORKERS AND OTHER FARMERS
AGRICULTURAL OFFICERS AND PRIVATE PRACTITIONERS
AGROVET DEALERS AND MINISTRY OF AGRICULTURE AND LIVESTOCK EXTENSION OFFICERS
AGROVETS
CHEMIST AND AGROVET
CHEMISTS,EXTENSION WORKERS AND OTHER FARMERS
DEALERS
EXTENSION OFFICER,NGO
EXTENSION OFFICERS,CHEMISTS,FARMERS AND SOME TIMES WHEN WE HAVE FIELD DAYS THE REPRESENTATIVES OF THE COMPANIES
LICENCED AGROVETS LIKE MARKET CENTRES
LIVESTOCK PRODUCTION AND PRIVATE PRCTIONERS LIKE US IN THE FIELD
PRIVATE PRACTITIONERS,MINISTRY OF AGRICULTURE AND LIVESTOCK OFFICERS, AGROVET DEALERS
EXTENSION [AGRICULTURE] OFFICER AGRO- CHEMICAL DEALESR AND DURING FIELD DAYS
THE OFFICE
STOCKISTS, AGRICULTURAL EXTENSION OFFICERS
TECHNICAL AGRICULTURAL OFFICERS IN THE FIELD OR BY CONSULTING THE AGRICULTURAL OFFICES WITHIN THEIR AREA
EXTENSION OFFICERS IN LIVESTOCK OF AGRICULTURE , CHEMIST
GOK STAFF, PRIVATE AHAs AND AGROVETS
MEDIA,EXTENSION OFFICERS,STOCKISTS
MINISTRY OF AGRICULTURE STAFF THROUGH EXTENSION WORKERS,STAKEHOLDERS,COLLABORATOR LIKE AGROVETS AND CHEMISTS,SOME OTHER FSRMERS
NEWS PAPERS,RADIOS,EXTENSION OFFICERS
NEWS PAPERS,RADIOS,MAGAZINES,EXTENSION OFFICERS AND NEIGHBOURS
NEWS PAPERS,RADIOS,SEMINARS,AGRICULTURAL EXTENSION WORKER
NEWSPAPERS,RADIOS,NEIGHBOURS,STREET QUAKS,AGRICULTURAL EXTENSION OFFICERS,SEMINARS AND OTHER FARMERS
RADIO,SHOP STOCKIST,CHEMICAL STOCKIST,EXTENSION WORKERS,
RADIOS,EXTENSION WORKERS,NEIGHBOURS
RADIOS,NEIGHBOURS,EXTENSION OFFICERS,TVS
RADIOS,TVS,NEWSPAPERS,EXTENSIN OFFICERS
READING OF THE LABELS TOGETHER WITH BASIC GUIDE BY AGRICULTURAL EXTENSION WORKER
RETAIL STOCKISTS,RADIO,AGRICULTURE EXTENSION OFFICER
RETAIL STOCKISTS,RADIO,AGRICULTURE EXTENSION OFFICER,INTERNET,STAKEHOLDERS AND COLLABORATORS
CHEMIST AND AGRICULTURAL OFFICERS

STOCKIST SHOPS,EXTENSION OFFICERS ,RADIOS
STOCKIST SHOPS,EXTENSION OFFICERS ,SERVICE PROVIDERS
STOCKIST,EXTENSION OFFICER AND SERVICE PROVIDER
STOCKIST,OTHER FARMERS,EXTENSION OFFICERS,RADIO,TVS
THE INFORMATION IS THE AGRO DEALERS EXTENSION OFFICERS,AAK,KEPHIS AND PCPB

Appendix XXXV: Where pesticides were bought by farmers

WHERE DO THEY BUY THEM
THE LOCAL STOCKISTS
LOCAL AGROVETS DEALERS
SHOP FACTORIES,SHOPS AND AGROVETS
SHOP FACTORIES,SHOPS AND AGROVETS
FACTORIES ,AGROVET SHOPS
SHOP FACTORIES,SHOPS AND AGROVETS
AGROVETS,FACTORIES AND STOCKISTS
FACTORIES ,AGROVET SHOPS
AT MAUA AND KIENGU AGROVET SHOPS
AGROVETS SHOPS AND STOCKISTS
AGROVET SHOPS,FACTORIES
AGROVET SHOPS,FACTORIES
AGROVETS AND SHOPS
AGROVET DEALERS
AT MAUA AGROVET SHOPS
AT MAUA AGROVET SHOPS
AT KANGETA AND MAUA
AT MAUA AGROVET SHOPS
MAUA AND KANUNI AGROVETS SHOPS
KANUNA AND MAUA CHEMISTS
AGROVET DEALERS
CHEMIST
LOCAL AGROVETS DEALERS IN MUTUATI,LARE AND MAUA
AGROVETS AT MAUA
AGROVET AT LARE
AGROVETSDEALERS
AGROVETS
AT AGROVET DEALER
AGROVET
KAAGA MARKET AND MERU TOWN MARKET
STOCKIST SHOP
STOCKIST,AGROVETS

MERU TOWN
MPURI MARKET CENTRE,KAKINYO MARKET,GITIMBINE,MERU TOWN
AGROVET SHOPS,FACTORIES
STOCKISTS/SHOPS
AGROVET RETAIL SHOPS,
AGROVET SHOPS,FACTORIES
STOCKISTS/SHOPS
TIMAU KISIMA MARKET
STOCKIST
STOCKISTS/SHOPS
AGROVET,STOCKIST
STOCKIST
GIAKI MERU TOWN
THIMAGIRI,MUNITHU MARKET,MERU
AGRO-CHEMICAL SHOPS
CHEMICAL STOCKIST,FACTORIES
SHOP FACTORIES,SHOPS AND AGROVETS
FACTORIES ,AGROVET SHOPS
CHEMICAL STOCKIST,FACTORIES
SHOPS,CHEMICAL SUPPLIES,FACTORIES
CHEMICAL STOCKIST,FACTORIES,CHEMICALS VENDORS SHOPS
SOCIETIES[RETAILERS AND CHEMICALS
SHOPS,PEOPLE WHO ACTS AS BROKERS
AGROVET
AGRO DEALERS LAARE MARKET
AGRO-CHEMICAL STOCKISTS
LOCAL MARKET IN MAUMA TOWN ,AGRO CHEMISTS
LOCAL MARKET IN MAUMA TOWN ,AGRO CHEMISTS
KANGETA,MAUA,ANDMERU
AGROVETS IN MAUA
KANGETA MARKET AND MAUA TOWN
STOCKISTS AND AGROVET STORES
AGROVET THAT ARE ALSO FARM INPUT STORES
THE LOCAL AGROVET DEALERS OR CHEMISTS IN THE LOCALITIES
AGROVET DEALERS
AGROVETS
AGRO-DEALERS
AGROVET DEALERS
AGROVETS AT LARE
AGROVE DEALERS

Appendix XXXVI: Are farmers keen on expiry dates written on labels

ARE THEY KEEN ON THE EXPIRY DATES ON THE LABELS	%
A FEW	26%
NO	38%
YES	36%
Grand Total	**100%**

Appendix XXXVII: Do Extension worker educate farmers on dangers

DO THE AEW EDUCATE FARMERS ON THE DANGERS ASSOCIATED WITH PEST ICIDES	No.
NR	1%
ON FIELD DAYS/ASK SHOWS/SEMINARS	10%
YES	84%
YES BUT NOT REGULARLY DUE TO LACK OF FUNDS AND FIELD STAFFS	5%
Grand Total	**100%**

Appendix XXXVIII: Do farmers know when to apply pesticides

DO THE SMALL SCALE FARMERS KNOW WHEN TO APPLY PESTICIDES	No.
NO	20%
SOME	18%
YES	61%
Grand Total	**100%**

Appendix XXXIX: Is pesticide poisoning a problem in the community

IS PESTICIDE POISONING A PROBLEM TO THE COMMUNITY	%
NO	43%
YES	57%
Grand Total	**100%**

Appendix XXXX: List of pesticides involved in poisoning

NAME THE PESTICIDES
DIMETHOATE,OGOR-OSHO CHEMICALS LTD
ORGANOCHLORINES,
ORGANOCHLORINES,ORGANO PROSPHALIS
ORGANOCHLORINES,ORGANO PROSPHALIS
ORGANO PHOSPHATE,ORGANOCHLORINES,CARBONADIS
CARBAMALIS,ORGANO PROSPHALIS
KARATE,DIMETHOATE,ACTELIC,GLAMOXINE
DIAXINON,KARATE,OGOR,OSHOCHEMICALS
ORGANOPHOSPHOLIS,ORGANOCHLORINE,
ORGANOCHLORINES,LINDANE
KARATE,FURADAN,ORGANO PROSPHALIS
ORGANOPHATES,ORGANOCHLORINES
KARATE,DUSTBURN
ROUND UP,
DIAXIONE, KARATE,OSHO CHEMICALS ,TWIGA CHEMICALS
THUNDER,OSHO CHEMICALS LTD
VECTOCID,UNGA FARM CARE LTD
THUNDER,
OGOR,OSHO CHEMICALS LTD
KARATE,THUNDER,
NOVA,KARATE,NOVA CHEMICALS
THUNDER,OGOR,BAYER,OSHO RESPECTIVELY
THUNDER,BAYER,OSHO RESPECTIVELY
OGOR,THUNDER,AGRINATE,SEANER,OSHO,TWIGA,BAYER ETC
MANCOZEB,DITHANE M45
MALATHION,ACTELLIC SUPPER
ABEMENTIN,3 DYNAMED
DIMETHOATE,WEED ALL,ROUND UP,
MANCOZEB,DITHANE M45
CARBONATES,ORGANOCHLORINES
PERMETHRIN,DIAZINON,ORGANO CHLORINES,ORGANO PHOSPHATES
ORGANOCHLORIES,PYRETHROIDS
METHOMYL,CARBOFURAN,PROPOXUR,ORGANOPHOSPHATE AND ORGANOCHLORIES
ORGANOCHLORIES,PYRETHROIDS,I DON'T KNOW
ORGANOPHOSPHOLIS,ORGANOCHLORINE,CARBONATES
ORGANOCHLORINES
DELTAMETHRIN,AMIRAN KENYA LTD-KESHET
GRAMOXONE-THIORIT JET ,KARATE ZEON,PARAQUAT,SYGENTA

PARAQUET,GRAMAXONE
KARATE,SYGENTA GROUP
ALMATIX
ORGANOPHOSPHATE LIKE CATTLE DIPS,SEVIAN DUDU DUST
THIAMETHOX,ACTARA
OGOR,THUNDER,MALATHION,OSHO CHEMICALS LTD
AGRINET GOSP,METHOMYL
OGOR,OSHO CHEMICALS LTD
DIASIMONE,OSHO CHEMICALS LTD
THUNDER,BAYER

Appendix XXXXII: Do HCW have knowledge of first Aid

DO YOU KNOW FIRST AID PROCEDURES FOR PESTICIDES POISONING	%
NO	21%
SOME	7%
YES	71%
Grand Total	**100%**

Appendix XXXXIII: Effective ways of preventing work related pesticide poisoning

EXPLAIN THE MOST EFFECTIVE WAYS OF PREVENTING WORK RELATED PESTICIDE POISONING.
STORING THE PESTICIDES SEPARATE FROM EDIBLES WEARING PROTECTIVE CLOTHING DURING APPLICATION
MIXING OF CHEMICALS IN THE RIGHT PROPOTIONS WEARING PROTECTIVE CLOTHING, BEING AWARE OF APPLICATION TIMES INTERVALS AFTER SPRAYING WASTEDISPOSAL AFTER SPRAYING.
OBSERVE ALL REGULATIONS
OBSERVE ALL RULES BEFORE AND AFTER APPLYING PESTICIDES
OBSERVE ALL RULES BEFORE AND AFTER APPLYING PESTICIDES
PESTICIDES ARE POISONOUS
OBSERVE ALL RULES ON THE LABEL
THEY ARE POISONOUS
INDUCE VOMITING,GIVE A LOT OF WATER,TAKE THE VICTIM TO HOSPITALS
OBSERVE ALL RULES BEFORE AND AFTER APPLYING PESTICIDES
OBSERVING ALL NECESSARY PRECAUTIONS
OBSERVE ALL RULES BEFORE AND AFTER APPLYING PESTICIDES
BY USE OF PROTECTIVE CLOTHING
USE REQUIRED PROTECTIVE CLOTHING,READ THE LABEL,DISPOSE THEM APPROPRIATELY
INDUCE VOMITING,GIVE A LOT OF WATER,TAKE THE VICTIM TO HOSPITALS
FOLLOW THE INSTRUCTIONS
GIVE STRONG SOLUTION OF SALT TO MAKE THE VICTIM VOMIT THEN GIVE MILK WITH SUGAR

GIVE A LOT OF WATER AND MILK AFTER THEY HAVE VOMITED
DEPENDS WIITH CHEMICAL USED BUT MOSTLY INDUCE VOMITING BY USING EITHER CHARCOAL SOLUTION CONE, SALT SOLUTION OR SOIL SOLUTION,THEN TAKE THE PATIENT TO THE NEAREST HEALTH FACILITY.
FOLLOW LABEL PRESCRIPTIONS AND KEEPING AWAY FROM CHILDREN
KEEP AWAY FROM CHILDREN AND OTHER PEOPLE NOT USING PESTICIDES
USE PROTECTIVE CLOTHING AND HAVING KNOWLEDGE ON THE USAGE
USE PROTECTIVE CLOTHING,KEEP PESTICIDES AWAY FROM CHILDREN
KEEP CHEMICALS SEPARATEFROM EDIBLES,USE PROTECTIVE CLOTHING,AND CLEAN YOURSELF WITH WATER AND SOAP AFTER USE
KEEP AWAY FROM CHILDREN,USE PROTECTIVE CIOTHING; DRINKING MILK AFTER APPLICATION
STORE THEM SEPARATE FROM FOOD STAFF
USE PROTECTIVE CLOTHING AND KEEPING AWAY FROM CHILDREN
USE PROTECTIVE CLOTHING DURING APPLICATION,CLEAN /WASH THOUROUGHLY WITH CLEAN WATER AFTER APLLICATION,KEEP ALL CHEMICALS OUT OF CHILDREN REACH
HANDLE PESTICIDES UPRIGHT ALWAYS,STORE AWAY WHEN NOT IN USE
WEARING PROTECTIVE CLOTHING,READIN LABEL INSTRUCTIONS WELL BEFORE USE
USE OF PROTECTIVE CLOTHING,PURCHASING,STORAGE,TRANSPORTING AND DISPOSAL
USE OF PROTECTIVE CLOTHING,PURCHASING,STORAGE,TRANSPORTING AND DISPOSAL
SPRAY THE RIGHT TIME-NOT SUNNY OR WINDY,PROTECTIVE CLOTHING,PROPER DISPOSAL OF CONTAINERS
PROTECTIVE CLOTHING,STORAGE,DISPOSAL OF EMPTY CONTAINERS
PROTECTIVE CLOTHING,HANDLING,TRANSPORTING,STORAGE,DISPOSAL OF EMPTY CONTAINERS
USE OF PROTECTIVE CLOTHING,HANDLING,STORAGE,TRANSPORTING AND DISPOSAL
READ INSTRUCTIONS ON THE LABEL,WEAR PROTECTIVE CLOTHING,DO NOT SMOKE OR EAT WHILE SPRAYING,PROPER DISPOSAL OF CONTAINERS
TRAININGS,DEMONSTRATIONS AND LAWS TO BE MADE TO PREVENT POOR CHEMICAL HANDLING
PROPER HANDLING,STORAGE AND DISPOSAL
PRECAUTIONARY MEASURES SUCH AS PROTECTIVE CLOTHING,READING INSTRUCTIONS BEFORE USE
USE OF PROTECTIVE CLOTHING,PURCHASING,STORAGE,TRANSPORTING AND DISPOSAL
USE PROTECTIVE CLOTHING,HANDLING,STORAGE,DISPOSAL,TRANSPORT
USE PROTECTIVE CLOTHING,PURCHASE,TRANSPORTATION,STORAGE AND DISPOSAL
WEARING PROTECTIVE CLOTHING,READIN LABEL INSTRUCTIONS WELL BEFORE USE
WEARING PROTECTIVE CLOTHING,READIN LABEL INSTRUCTIONS WELL BEFORE USE
WEAR PROTECTIVE CLOTHING,READ LABEL WELL,DISPOSE CONTAINERS WELL
BUY PESTICIDES WHICH ARE NOT LEAKING AND ARE NOT EXPIRED,CAREFULLY READ THE LABEL,WEAR PROTECTIVE CLOTHING INCLUDING GUMBOOTS,EYE MASK AND ENSURE THE HEAD IS COVERED,USE A GOOD PUMP WHICH IS NOT LEAKING,DON’T SPRAY AGAINST THE WIND
USE PROTECTIVE CLOTHING WHEN DEALING WITH PESTICIDES
USE OF PROTECTIVE CLOTHING,READ THE LABEL WELL,PROPER STORAGE
USE ALL PREVENTIVE MEASURES
FOLLOWING THE RULES ON THE LABEL,USE PROTECTIVE CLOTHES AT ALL TIMES

RESIST FROM USING PESTICIDES
USE OF PROTECTIVE CLOTHING,USE PROPER METHODS WHEN MAKING FORMULARITIES,PROPER HANDLING TO AVOID SPOILLAGE
OBSERVING ALL RULES BEFORE APPLICATION,AFTER APPLICATION AND DURING APPLICATION
BY GIVING THE VICTIM A CHEMICAL CALLED CHARCOAL SOLD IN CHEMISTS.THE CHARCOAL HELPS IN BINDING TOGETHER THE POISON IN THE STOMACH BEFORE IT SPREADS TO OTHER PARTS OF THE BODY.THEN TAKE THE PATIENT TO THE HOSPITAL
EDUCATION TO THE FARMER OF PROPER INTERPRETATION OF THE LABELS AND ENCOURAGING THEM TO USE PROTECTIVE ATTIRE
STORING THE CHEMICALS IN THEIR ORIGINAL PACKAGES,BUYING SMALL QUANTITIES,READING AND UNDERSTANDING THE LABEL,NEVER HANDLING FOOD,DRINKS AND SMOKE WHILE HANDLING CHEMICALS,ENFORCING THE PRE-ENTRY TIME,NOT STORING CHEMICALS TOGETHER WITH FOOD STUFF,NO LEAKING CHEMICAL CONTAINERS,
STORAGE FAR FROM CHILDREN REACH AND OBSERVING THE PRECAUTION,SET OUT ON THE LABELS
OBSERVING THE PRECAUTION SET OUT ON LABEL
READING OF THE PESTICIDE LABELS BEFORE USE,USE OF PROTECTIVE CLOTHING
READING OF THE PESTICIDE LABELS BEFORE USE,USE OF PROTECTIVE CLOTHING
READING OF THE PESTICIDE LABELS CAREFULLY AND FOLLOWING THE INSTRUCTIONS
PUTTING ON MASK TO PREVENT WIND PROPELLED PESTICIDECONTAMINATION
THESE INCLUDES PROTECTIVE CLOTHING , TIME OF APPLICATION,MIXING DIRECTIONS OF SPRAY DRIFTS AND WASTE DISPOSALS AFTER SPRAYING THE PESTICIDES
KEEP AWAY FROM CHILDREN AND WEAR PROCTIVE CLOTHES DURING APPLICATION
KEEP AWAY FRO OTHER INDIVIDUALS
FOLLOW THE SAFE USE OF PESTICIDE PROCEDURES
KEEPING AWAYFORM CHILDREN AND EDIBLE WEARING PROTECTIVE CLOTHING DURING USE
INDUCE VOMITING,GIVE A LOT OF WATER,TAKE THE VICTIM TO HOSPITALS
KEEP POISONOUS AWAY FROM REACH OF CHILDREN