UNIVERSITY OF NAIROBI

DETERMINATION OF CHEMICAL AND MICROBIOLOGICAL CONTAMINANTS IN SOILS, WATER AND KALES (*Brassica oleracea*) FROM SELECTED SITES IN EASTERN NAIROBI METROPOLITAN

BY

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DECLARATION

This thesis is my original work and has not been submitted for the award of degree to this or any other institution of learning.

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DEDICATION

This thesis is dedicated to my dear husband Wilfred Ochieng Gose, my daughters Pet and Imani, my parents Mr. and Mrs. Ambuso, my brothers Mzee, Kefans and Brian, my sisters Millicent and Rose, and friends for their moral and financial support.

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Lastly, I thank the almighty God for giving me the strength and finances to accomplish my research.

ABSTRACT

This study investigated the extent of pesticides residues, heavy metals and microbial contaminants in Kales, water and soils from Nairobi metropolitan. Samples were collected from six sites within Nairobi Metropolitan area namely, Kitengela, Mlolongo and Athi River farms and open air markets, covering the wet and dry months between July 2015 and February 2016. Pesticide residues were extracted using organic solvents and analyzed using Gas Chromatography equipped with electron capture detector, whereas heavy metals were analyzed using Atomic Absorption spectrometer. The microbial contaminants were analyzed using 3M kit.

Percentage recoveries for pesticides ranged from 70.00-114.83%, whereas the detection limits ranged between 1.12 ng/L to 3.6 ng/L. The pesticides concentration in kales ranged from BDL to 322.55±9.64 µg/kg. *p,p'*-DDD was the highest detected pesticide during the month of February 2016 from Kitengela market. Soil pesticides concentration ranged from 0.001 to 170.53±3.03 µg/kg, with α-endosulphan recording the highest concentration in soil from Mavoko market. Pesticides residues in water ranged from 0.001 to 3.53±0.02 µg/L, with aldrin recording the highest concentration in February, 2016 from Mlolongo farm irrigation water.

Heavy metals concentrations in kales ranged from <0.01 to 0.74±0.00 mg/kg. Lead was the highest heavy metal detected in vegetables from Mlolongo farm. Concentrations of heavy metals in water ranged from <0.01 to 0.16±0.01 mg/L. Copper was the highest heavy metal detected in Kitengela farm water. Heavy metal in soil ranged from <0.01 to 1.03±0.08 mg/kg, zinc was the highest heavy metal detected in Kitengela market soil samples.

E-coli concentration ranged from 0 to 13±2 cfu/L. The highest levels in kales were measured in samples from Mlolongo market during the month of December 2015. Soil *E-coli* concentrations ranged from 0 to 145±8 cfu/g detected in soils from Kitengela farm. The concentrations in water ranged from 4 to 89 cfu/ml, with the highest levels measured in water samples from Mlolongo farm irrigation water.

Coliform concentrations in vegetables ranged from 8±2 to 353±19 cfu/g, with the highest detected in samples from Mlolongo market in the month of December 2015. For soil, the coliform concentration ranged from 1±0 to 3,214±284cfu/g and the highest detected was from

Mlolongo market during the month of February 2016. For water, the concentration ranged from 81±3 to 3,797±119 cfu/ml, with the highest detected in water from Mlolongo farm in the month of February 2016.

The results showed that organochlorine pesticides such as aldrin, dieldrin, endrin, heptachlor, DDT and its metabolites are still present in samples from Nairobi metropolitan. The presence of high levels of lead, *E. coli* and total coliform in vegetables should be taken seriously by public health sector, and also the kales should not be consumed raw since they expose people to dangers caused by the contaminants.

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LIST OF ABBREVIATIONS

BDL	Below Detection Limit
DDD	Dichlorodiphenyldichloroethane
DDT	DichloDiphenyl Trichloroethane
E Coli	Escherichia coli
ECD	Electron Capture Detector
EPA	Environmental Protection Agency
GC	Gas Chromatography
IRM	Internal Reference Material
IWMI	International Water Management Institute
MRL	Maximum Residue Limit
OCPs	Organochlorine Pesticides
PCPB	Pest Control and Product Board
SPSS	Statistical Programme for Social Scientist
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
UNEP	United Nations Environmental Programme
WHO	World Health Organization
WSDH	Washington state department of health

UNITS OF MEASUREMENTS

µg	Microgram
µL	Microlitre
µS	Micro Siemens
g	Grams
Kg	Kilograms
L	Litre
ml	Millilitre
ng	Nanogram
nm	Nanometre
ppb	Parts per billion
ppm	Parts per million
ppt	Parts per trillion

CHAPTER ONE

1. INTRODUCTION

1.1 Background Information

There is increasing concern about the impact of anthropogenic activities on the sustainability of urban and suburban environment due to the unprecedented growth in urbanization (Karanja *et al.,* 2010). The urban population growth rate reached 5% in the past 20 years, which is five times compared to the 1960s, particularly in Sub-Saharan Africa (Karanja *et al.,* 2010).

Statistics show that the absolute numbers of poor people in urban areas are increasing faster than the growth of poverty (Haddad *et al.*, 1999). For instance, the population of Nairobi increased from 118,000 people in 1901 to 343,500 people in 1962, a factor which was attributed to rural-urban migration in search for employment (NEMA, 2003). Presently the residents of Nairobi are approximately over four million people which is approximately one quarter of Kenya's metropolitan inhabitants (KNBS, 2010). In addition, a large percentage of people commutes from the nearby towns to Nairobi City daily, either to work or to bring goods and supplies. This has resulted in rapid growth of urban informal settlements like Kibera, coupled with increased population and low standard of living. The rapidly increasing number of informal settlements in the city has hindered has proper delivery of social amenities (Tibaijuka, 2007). Micro scale and informal business activities are very common (including begging, theft, illegal brewing and prostitution) since most poor people have no regular jobs and rely on casual work (Foeken and Mwangi, 2000).

Today, about two-thirds of the working population in Nairobi depend on the informal sector for livelihood (Karanja *et al.,* 2010). High levels of poverty in urban areas, inadequate urban planning and lack of employment opportunities have also conspired in the gradual growth of urban farming in informal settlements in Nairobi and its environs (Karanja *et al.,* 2010). Elsewhere, urban farming has also been reported to contribute approximately 70% of Kales consumption in Dakar and 90% in Dar es Salaam (Karanja *et al.*, 2010).

According to WHO, (1993) vegetables (Kales) are common components of the human diet taken by various populations throughout the world due to the significant role they play in nutrition. However, vegetables can also absorb heavy metals, pesticide residues and also get contaminated with fecal coliforms, which have negative effects on public health (WHO, 1993; Kihampa *et al.,* 2011). Elevated levels of heavy metals, pesticides and Microbial contaminants in the urban environment, especially in vegetables, soils and surface waters have increased due to unplanned developments together with inappropriate waste disposal in the cities (Kihampa *et al.*, 2011).

1.2 Pesticides

1.2.1 Pesticides regulation in Kenya

Pesticide products are managed in Kenya by the Pest Control Products Board (PCPB) which is an organization of the Kenyan Government established under an Act of Parliament, the Pest Control Products Act, Cap 346, of the Laws of Kenya (PCPB, 2008). The functions of PCPB are: educate people of the public on the pest control product board activities, regulate the production and supply of pesticides and their formulation, monitor and regulate the importation, exportation and use of pest control products, to ensure proper siting of production and formulating plants and sumps for containment of effluents (PCPB, 2008). In addition, PCPB is charged with the

responsibility to compile and keep a catalogue of obsolete stock and expired chemical pesticides, used containers, come up with strategies for discarding them and to guarantee that only competent workers handle controlled pest control products (PCPB, 2008). PCPB is also charged with the responsibility of informing the industries, extension agencies and the ministry of agriculture, of the authorized use of crop protection products (PCPB, 2008).

According to common trade report, the horticultural industry in Kenya has greatly expanded in the past ten years, with exports to the EU increasing progressively by nearly 300% (Mwangi, 2013). The EU, at the moment, absorbs 90 percent of Kenya's total horticultural exports. There is need, therefore, for the horticultural sector in Kenya to comply with the EU regulations (Eurep-gap) which require maintenance of high levels of sanitary and phytosanitary standards (SPS) and conformity to maximum residue levels at analytical zero (MTTI, 1999). Failure to conform with recommended Maximum Residue Level (MRLs) leads to consumers' exposure to pesticides at dangerous levels. This could lead to adverse side effects especially if one is exposed to these pesticides in high doses (MTTI, 1999). Much emphasis has been put on export of vegetables while the local farmer may not be aware of these latest developments (Mutai *et al.,* 2015). There is need therefore to analyze different vegetables in the market and determine whether the residue levels of pesticides in them are acquiescent with the international standards (Mutai *et al.*, 2015).

1.2.2 Pesticides use and implication in Kenya

Pesticides have increased agricultural production in Kenya and also saved many lives through control of disease vectors (Njogu, 2013). Uncontrolled, pests usually lead to poor crop production leading to food insecurity (Nderitu *et al.,* 2007). However, despite the economic role played by pesticides, they also form a very vital group of compounds that have to be restricted

due to their toxicity and wide spread application in the environment through agricultural intensification. The negative impact of pesticides use in agriculture is the occurrence of pesticide in food above the MRL. Pesticides also contaminate environmental flora and fauna including human foodstuff, increasing exposure risks (UNEP/GEMS, 1992). Hence, there is need for monitoring the pesticide residues in environmental media including fish and birds and vegetables (Njagi, 2011).

1.2.3 Possible routes of pesticides into vegetables, soil and water

Food and water are the two main ways human beings get exposed to pesticides (Bouwman *et al.*, 2006). Pesticides that have been banned or restricted from use such as most organochlorine pesticides persist in the environment for a long period of time, and continue to be detected in the food chain (Cornell, 2007). In addition, pesticide formulation sprayed on agricultural farms may penetrate or leak through the soil, or get washed to the surface water through runoff (Barlas, 2002).

1.3 Heavy Metals

A heavy metal is a common term applying to the group of elements that have atomic density greater than 5 mg/m^3. Examples of heavy metals are: copper, cadmium, mercury, nickel, chromium, zinc and lead. Some of these metals are highly toxic, pollute environment and also cause ill health effects to human life (Alloway and Ayres, 1997).

1.3.1 Heavy metals contamination in Kenya

Food safety has become a major concern worldwide and in Kenya, especially in the last few decades. This has stimulated research on the dangers related to eating food contaminated with heavy metals (Omambia and Simiyu, 2015). Rapid urban expansion, industrial developments

coupled with inadequate waste management contribute to accumulation of municipal waste causing significant alterations in the physical environment and degradation of ecosystems (Njagi, 2013). Some towns in the country lack appropriate municipal waste policies and good disposal amenities for dangerous wastes (Kimani, 2007), contributing to the releases of these toxicants into the wider environment. Such wastes may eventually find their way to human body through inhalation, and consumption of contaminated water and foodstuff that increase diseases burden and environmentally related morbidities (Inoti *et al.,* 2012). Whereas some heavy metals like Cu, Zn, Mn, Co and Mo act as micronutrients for the growth and wellbeing of human and animals when present in small amount, cadmium, chromium and arsenic are suspected carcinogens (Trichopoulos, 1997).

1.3.2 Possible routes of heavy metals in vegetables, soil and water

Use of fossil as source of energy is the main source of copper in the environment (Kihampa *et al.,* 2011). Copper persist in the environment before it is deposited by precipitation into the soil. It also bioccumulates in the food chain when in higher concentrations. Zinc, on the other hand, occurs naturally in the environment but it is also widely found in food stuffs containers (Kihampa *et al.,* 2011). Some soils are heavily contaminated with Zn, particularly in areas where Zn is being mined or processed, or in factory waste sludge or manure (Kihampa *et al.,* 2011**).** Most of the Cd found in plants originates from the soil, while Pb contamination is usually air borne (Bergeson, 2008). Part of heavy metal precipitated on plants remains on the surfaces of the leaves and can easily be removed by washing (Omambia and Simiyu, 2015). However, part of the precipitate may migrate into the plant tissue through the pores and cannot be removed by washing (Omambia and Simiyu, 2015).

1.4 Feacal Coli forms and *E-Coli* in vegetables, soil and water

Proliferation of informal settlements in Africa has led to challenges of food safety and food insecurity due to poor urban wastewater management (Lydecker and Drechsel, 2010). In addition, to satisfy the growing requirement for vegetables and demand for plant nutrients in soils, farmers tend to increase production by applying manure and pesticides contributing to contamination (Lydecker and Drechsel, 2010).

1.4.1 Possible routes of Coli forms bacteria in vegetables, soil and water

According to Cornish and Lawrence (2001), irrigation water may contain high concentrations of faecal coliforms; causing high risk to end users and vegetable consumers, especially for fresh salad and other vegetables that are eaten uncooked. It is therefore important for the fecal coliform counts to be assessed on a regular basis to reduce associated health risks (WSDH, 2016). The Figure below shows the theoretical framework of feacal contamination in different media (IWMI, 2011).

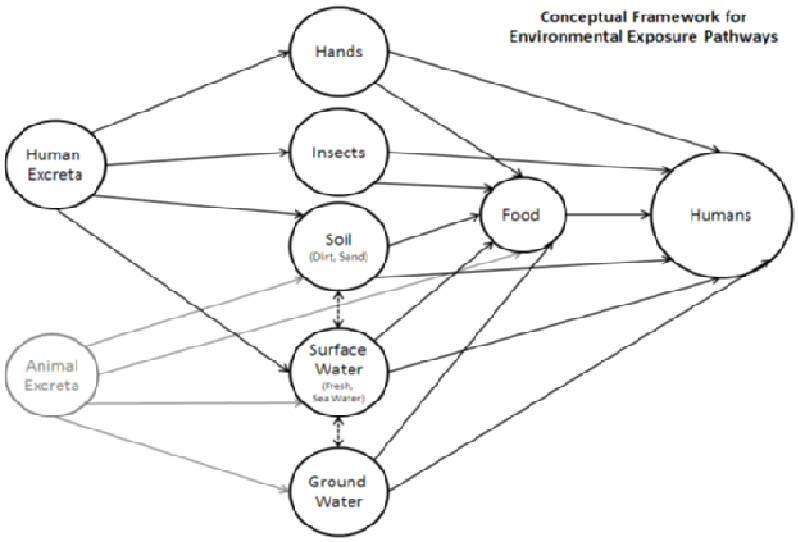


Figure 1.1: Conceptual framework for coliforms and E- coli in water, soil and vegetables

According to Shi-Bo and coworkers (2009), although various studies have been conducted covering spatial and temporal distribution of chemicals, bioavailability and toxicity of heavy metal and pesticides in soil and in food chains, human health risks and control measures of soil chemical pollution, these studies mainly focused on limited locations, particularly in urban areas or major pollution sites, whereas metropolitan areas were excluded. There are few studies on heavy metals, pesticides and fecal coliform distribution in soils along the urban-metropolitan gradient, especially in agricultural soils in the eastern part of Nairobi metropolitan (Inoti *et al.,* 2012). The aim of this study was therefore to investigate the extent of heavy metal, pesticides and coliform contamination and distributions in vegetables (kales), water and in the soils from the Eastern part of Nairobi Metropolitan areas.

1.5 Problem statement

Rapidly increasing informal settlements in urban centers in Kenya has increased exposure of the population to hardship associated with lack of proper housing and social amenities. This makes them more vulnerable to environmental stress factors (UN-Habitat, 2007). Nairobi Metropolitan area has witnessed increased urban and peri-urban agriculture in order to provide food for the large City population. However, the urban areas are often more contaminated compared to rural areas hence the urban crops may be exposed to higher levels of contaminants due to traffic emissions and industrial activities (Mielke *et al*., 2011). The major source of health problems in urban areas is consumption of crops contaminated with pesticides, heavy metals, coli forms and *E. coli*.

Although some research has been carried out on heavy metals, pesticides, coli forms and *E. coli* contaminant in soil, kales and water in some parts of Kenya (Osoro, 2015; Kingola, 2015; Too, 2016; Madadi, 2005; Maiyo 2014), no comprehensive study has been carried out in Nairobi

metropolitan. Also accumulation of residues in vegetables need more attention because they are either consumed raw or without much treatment (Gupta *et al.,* 2008).

The rapid urbanization and industrialization in Nairobi county and the Neighboring counties like Machakos, Kiambu and Kajiado has led to increased contamination as evident with the rivers are now heavily polluted with heavy metals, organic pollutants and nutrients (Budambula and Mwachiro, 2005). However, water from these rivers is widely used for irrigation in the urban farming. This study sought to provide information on the level of organochlorine pesticides, heavy metals, coli forms and *E. coli* contamination in soil, water and vegetables in the selected sites in Nairobi metropolitan.

1.6 Objectives

1.6.1 Overall Objectives

To determine the pesticides residues, heavy metal and fecal coliforms contaminants in Kales, water and soils in the eastern part of Nairobi Metropolitan area.

1.6.2 Specific Objectives

1. Identify pesticides used by urban farmers in the eastern part of Nairobi Metropolitan.
2. Quantifying the residue levels of pesticide, heavy metals and fecal coliforms contamination in water, kales and soil from selected sites in the Eastern part of Nairobi metropolitan.
3. Determining the effect seasonal variation of pesticides, heavy metals and coliforms contaminants in water, kales and soil.

1.7 Justification

Assessing the levels of pesticides residues, heavy metals, fecal coliform in kales in Nairobi metropolitan as well as in water and soils where these kales are grown and sold both from the

market and the farms is critical. This will help in reducing exposure to toxic pollutants by the end users. Reduction in exposure to pesticides, heavy metals and biological contaminants will requires improved management of pesticides in terms of registration, production and use to prevent environmental contamination.

Data on pesticide residues, heavy metal contamination and coliform contamination in kales, soil and water is limited in Kenya. This research is important because it will be a source of information to farmers around Eastern part of Nairobi metropolitan area and all other parts of the country to support decision making regarding pesticides application to crops.

The findings of this research will be significant to consumers and policy makers since it will provide data on the residue level of pesticide, heavy metal contamination and coliform contamination in water soil and kales sold in the markets.

Lastly, the study is important to environmental scientists and other scientists in the area of research since it contributes to understanding of the role they can play in promoting knowledge about best practises in order to reduce pesticides residues in the environment and crop produce.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Pesticides

Pesticides are substances or mixtures of substances intended for preventing, destroying, repelling or mitigating any pest (Oudejans, 1991). They help to reduce, and in some cases eliminate, the negative impacts of insects, bacteria, weeds, viruses, parasites and fungi, thereby improving the quantity and quality of agricultural produce as well as human health.

2.2 Classification of pesticides

Pesticides are divided into organic and inorganic. Inorganic pesticides are naturally occurring non-carbon elements, and are generally stable, nonvolatile 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 consist organochlorines, organophosphorus, organosulfur, carbamates and pyrethroids depending on the element bonded to the hydrocarbon system (Wasswa, 2008).

2.2.1 Organochlorine Pesticides

Organochlorine pesticides (OCPs) belong to a class of chlorinated hydrocarbon chemicals that break down slowly in the environment where they are applied and end up accumulating in fatty tissues in animals (Shokrzadeh *et al.,* 2009). These OCPs remains in the environment and food web for a long period of time after application in environment. Most of the OCPs have bad toxic effects on the body's hormonal systems because of the characteristic endocrine disrupting properties which normally resemble the body's natural hormones, but the mode of elimination

from the body is different, hence they build up and interfere with the usual functioning of the body resulting in adverse health problems. OCPs include: mirex, toxaphene, dichlorodiphenyltrichloroethane (DDT), dieldrin, hexachlorobenzene (HCB), hexachlorohexane ($\alpha, \beta, \gamma, \delta$-HCH), heptachlor, chlordane, aldrin and endrin.

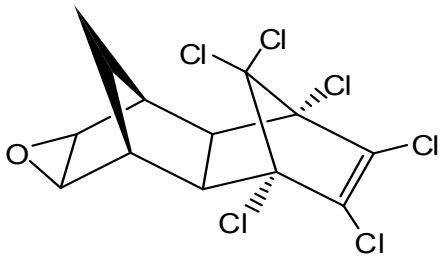


Figure 2. 1: Moleculer Structure of endrin

The structures of other OCPs are shown in appendix II. OCPs are commonly used to protect crops, livestock, buildings and households against various pests such as ticks, locust, termites and mosquitoes.

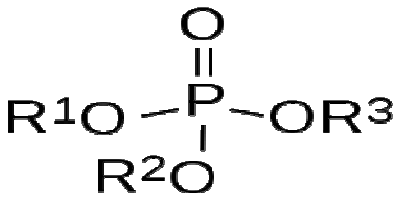
2.2.2 Organophosphorus Pesticides (OPs)

Organophosphorus Pesticides (OP) are phosphate esters derived from phosphoric acid comprising a central phosphate atom and three organic side chains (R), two of which are ethyl or methyl groups. Examples of OPs include; acephate, dichlorvos, dimethoate, ethion, malathion, mevinphos, chlorfenvinphos, parathion, chlorpyrifos and diazinon. OPs are chemically unstable, less-persistent and toxic to man and vertebrate animals compared to organochlorine pesticides. This group of pesticides has virtually replaced the persistent OCPs (Briggs, 1992). The major disadvantage of organophosphates is the lack of selectivity to non-target organisms. These compounds irreversibly inactivate the acetylcholinesterase (AchE) enzyme; an enzyme essential for neurotransmission and central nervous system of organisms (Moretto, 1998). This results in

the accumulation of acetylcholine (Ach) which interferes with the neuromuscular function thereby producing rapid twitching of voluntary muscles and finally paralysis (Byoung, 2003).

OPs are neurotoxic even at very low levels of exposure (Bachmann, 2000). Short-term exposure to these chemicals has been shown to produce muscle twitching, headache, nausea, dizziness, loss of memory, weakness, tremor, diarrhea, sweating, salivation, tearing, constriction of pupils, and slowed heartbeat. Long-term exposure can produce delayed neurotoxicity, such as tingling and burning in the extremities. This delayed neurotoxicity can progress to paralysis and is seldom reversible. Damage may also occur to the liver, kidney, immune system and bone marrow (Bachmann, 2000).

Organophosphate pesticides degrade rapidly by hydrolysis on exposure to sunlight, air, and soil, although small amounts can be detected in food and drinking water. Their ability to degrade makes them an attractive alternative to the persistent organochlorine pesticides such as DDT, aldrin and dieldrin (Kingola, 2015). Figure 2.2 shows the general structure of Organophosphates.



General structure of organophosphates

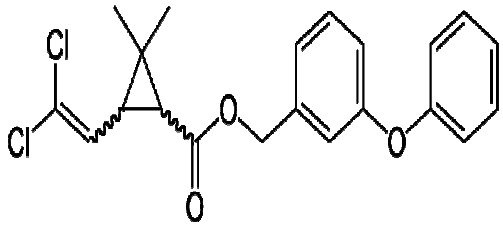
2.2.3 Organosulfurs

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. Common examples of organosulfurs are aramite, propargite, tetradifon, and tetrasul.

2.2.4 Pyrethroids

Pyrethrin is a natural insecticide extracted from Chrysanthemum cineraria folium (pyrethrum)- the crude flower dust. The synthetic pesticide pyrethroids are derivative of pyrethrins 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 split under UV light making them unsuitable for agricultural use but effective for indoor insect pest control. 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. Examples of pyrethroids are permethrin, deltmethrin, fenvalerate and tetramethrin. Figure 2.3 shows the general structure of pyrethroid.



General Structure of Perethroid

2.2.5 Carbamate

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. R2 is always an aromatic or aliphatic moiety. The major difference among the carbamate pesticides is in the functional group attached at R1. For instance, carbamate insecticides have R1 as an ethyl group, herbicides have R1 is an aromatic group, whereas fungicides have R1 is a benzimidazole moiety. Some of the known carbamates are carbaryl, carbofurans and aldicarbs. Biologically, carbamates resemble the organophosphates in their activity. They inhibit the cholinesterase enzyme required for nerve function in animals. Some carbamates are also suspected carcinogens (Briggs, 1992). 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).

2.3 Pesticides Residues in Vegetables, Water and Soils

Contamination of vegetables by pesticides occurs mainly through root uptake from contaminated soil (Otani *et al.,* 2007), and aerial spraying of the pesticide to the vegetables (Otani *et al.,* 2007). The solubility of pesticides in plant is dependent on factors such as the solubility of the pesticide, level of the pesticide in soil, water and air, plant species and proximity to pollution sources such as roads or highways and industries (Saumel *et al*., 2012). A study by Too, (2016) reported the presence of organochlorine pesticides in vegetables from Naivasha sub-county, and another study carried out in Ghana by Ntow (2001) reported that the crops were contaminated by OCPs.

From the studies carried out by various researchers, there were higher levels of pesticide residues in vegetables during the dry seasons than during the wet seasons in samples collected from both urban and rural areas. The trend was attributed to dilution by the rain water and lower frequency of pesticide application during the wet seasons due to less crop infestation by pests and diseases. Studies in other countries such as Benin also established that pesticide use in vegetables was a growing threat to human health and environment. This stimulated studies using *Aedes aegypti* larvae as a bio-indicator to assess the pesticide pollution in soil, groundwater and vegetables (Ahouangninou *et al.,* 2013). They recommended the use of organism as a bio-indicator to measure and monitor risk of pesticide contamination of vegetables in southern Benin.

Contamination of soil by pesticides occurs mainly through direct application to the soil and during application to crops. OCPs have been used in East Africa since 1940s and they have tended to accumulate in soil (Madadi *et al.*, 2006). The levels of OCPs in soil depend on organic matter and the type of soil (Farenhorst, 2006; Bassey, 2011). Getenga and co-workers (2004) found α-BHC, β-BHC, lindane, endosulfan, heptachlor, aldrin, heptachlor epoxide, dieldrin, endrin and methoxychlor in soil from the sugar belt zone of Lake Victoria. Analysis of soil samples from the River Nyando agricultural farms revealed the presence of the organochlorine pesticides (Abong'o *et al.,* 2014).

Contamination of water by pesticides mainly occurs through surface runoff, spray drift, leaching through the soil and direct application (Jayanthi and Muralidharan, 2014; Bassey, 2011). The pesticide contamination in water is usually affected by factors such as the properties of pesticide, weather conditions, landscape and proximity of the water source to application site (Carabias *et. al.,* 2003). Organochlorine pesticides residues have been detected in surface and ground water all over the world (Anasco *et al.,* 2010). Studies conducted in Lake Victoria have shown the

presence of OCPs in the lake water (Madadi, 2005, Osoro, 2016). Another study on River Nyando has also showed the presence of OCPs (Getenga, 2004). OCPs residues have also been detected in Indian Ocean by Wandiga and co-workers (2002). The concentrations ranged from 0.50 to 9.03 ng/L in water. In Uganda, the mean concentrations of aldrin (<0.01ng/ml) and dieldrin (0.01ng/ml) in surface water from Napoleon Gulf were reported by (Kasozi, 2002).

Exposure of pesticide residues to human through food products is an issue of concern and continuous discussion. There is effort made to reduce the exposure of pesticides to human and the general environment through national legislative frameworks that include registration, monitoring and training. In addition, the establishment of maximum residue limits is based on statistics from high-quality farming practices on food generated from commodities (UNEP/GEMS, 1992).

2.4 Health Effects of Pesticides

Use of pesticides has caused negative impacts such as pollution to the environment, agricultural land, fisheries, fauna and flora (Musa *et al.*, 2011). World Health Organization and UN Environment Programme estimate that 18,000 farmers die yearly in the developing countries while 3 million experience severe injuries (Miller, 2004).

Over the past years pesticide toxicity has increased due to the increasing evidence effects in experimental exposed animals (Tahir *et al.,* 2009; Engel *et al.,* 2000). Effects of pesticides depend on the factors such as the type of pesticide, dose, the duration of exposure and susceptibility of the exposed organism (Xavier *et al.,* 2004). Pesticide toxicity contributes to many acute and chronic illnesses (Bassey, 2011). Prolonged exposure to multiple pesticide, affects body organs such as liver and kidney (Azmi *et al.,* 2006).

The development of testicular germ cell tumours in early stages of development could be associated with exposure to *p,p'*-DDE either during pregnancy or through breast feeding (Katherine *et al*., 2008). A number of researchers have found the association between breast cancer and other neoplastic diseases in humans with long-term exposure to OCPs (Mathur *et al.,* 2002).

2.5 Heavy Metals

Inorganic and organic complexation, oxidation-reduction reactions, precipitation/dissolution reactions, and adsorption/desorption reactions processes govern the metal concentration in the soil at a given time (Muinde, 2009). Aquatic sediments constitute the most important reservoir of metals and other pollutants in the aquatic systems which later through biogeochemical processes, the metals and other pollutants remobilizes and released back to the overlying water causing water pollution (Simpson *et al*., 2002).

Metal solubilisation depends on various reactions involving water, sediment and specific metal of interest (Simpson *et al*., 2002). Adsorption is the process whereby metals are removed from the water column and stored it in the substrate, while desorption returns the metal to the water column, where recirculation and bioassimilation may take place (Simpson *et al*., 2002). Metals maybe desorbed from the sediment if the water salinity increases, redox potential decreases, or the pH decreases (Bartram and Balance, 1996).

2.5.1 Toxicity of Heavy metals

The amount of heavy metals in kales may differ from one sampling site to the other and from one class of kales to the other. This can be attributed to disparity in uptake capability of vegetables for different heavy metals via the roots to the other parts of the plant (Agrawal, 2003). According to Omambia and Simiyu (2015) physico- chemical characteristics of the soil can

also influence availability of different heavy metals to the vegetables. The metals may enter the vegetables through absorption (Agrawal, 2003). Some heavy metals act as micronutrients for the growth of flora and fauna when present in small amounts. However, at high concentrations, heavy mental have been associated with diseases like cancer (Trichopoulos, 1997), and abnormalities in unborn children (Pilot and Dragan, 1996). In Kenya, especially in Machakos County, there is limited data on heavy metal concentrations in the kales from the market and farm sites despite being in the neighborhood of several industries (Agrawal, 2003). The research carried out in Thika town indicated that kales from urban farming recorded high concentrations of heavy metals, which was associated with depositions from seepage from factories, pesticide and farm manure (Inoti *et al*., 2012). This is similar to the finding of Karanja *et al.* (2010) research which stated that the quality of the water used to irrigate crops influenced soil characteristics especially of the top 0-30 cm layer in farms and vegetables consumed.

2.5.2 Release of heavy metals to air, soils and vegetables

The major sources of heavy metals into the environment include smelting and smoldering metal containing materials. The elements are transported to far places and deposited into the water, or soil and vegetation (Nguyen *et al.*, 2005). The chemical, physical and biological processes that occur in aquatic environment often affect the concentrations of inorganic elements and heavy metals absorbed by vegetables. Human activities based on these processes have been reported to increase the concentration of heavy metals in natural water systems, which finally end up in vegetables (Nguyen *et al.*, 2005). Some heavy metals have also been reported to be released into environment by combustion of petroleum products. These create harmful effects to the environment and human health due to their toxicity and bioaccumulation in various environmental compartments (Makhoha *et al.*, 2012).

2.5.3 Guidelines concerning heavy metals concentration in Kenya

Guidelines on heavy metals concentrations in crops are provided by Kenya Bureau of Standards (KEBS) which is 0.1 ppm in food stuffs (KEBS, 1996). The guidelines for assessing heavy metal contamination in vegetables, water and soil appear somewhat inadequate in addressing plant uptake or phytotoxicity of these heavy metals. This is because the guidelines do not account for site specific factors such as plant type, soil characteristics and the bioavailable heavy metal concentrations (Kachenko & Singh, 2006). This study aimed at assessing the levels of heavy metals Pb, Zn, Cu and Cd in vegetables, water and soils in selected sites in Nairobi metropolitan. The emphasis was placed on kales which are grown in all season and also being one of the most frequently used fresh vegetables in Nairobi and its surroundings. Several studies have reported that fruits accumulate fewer amounts of heavy metals than leafy vegetables (Yusuf et *al*., 2003; Nabulo *et al*., 2008).

2.6 Total Coliform

Total Coliforms are bacteria that come from the environment and faeces of all animals and human beings. Total Coliform consists of fecal coliforms and *E. coli*. Most *E. coli* exist in intestines of animals of most warm blooded animals like human beings. The presence of *E. coli* in vegetables, soil and water indicates recent fecal contamination and may also show the likely existence of disease-causing micro-organisms such as bacteria, viruses, and parasite (Suslow, 2002). Coliform bacteria exist in three groups that determine quality of water for irrigation purposes and also exhibit different levels of risk. Fecal coliform are sub group of total coliform that exist in feces, while *E. coli* is a subgroup of fecal coliform (*WSDH, 2016*). Total coliforms are the sum total of all colon forming bacteria. The coliforms can grow in the existence of bile sodium chloride or same condition and generate acid and gas from sugar

within two days (*WSDH, 2016*). Figure 2.2 below from *WSDH, (2016)* illustrates the categorization.

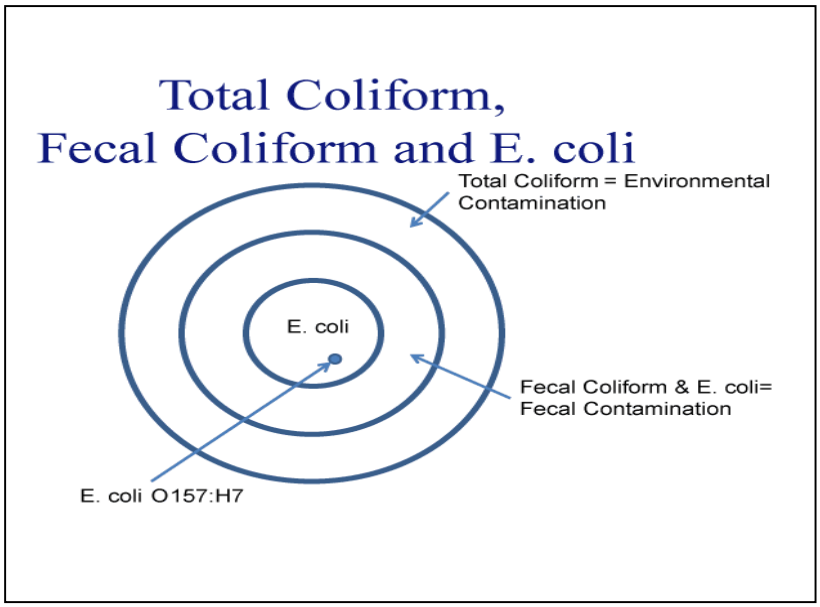


Figure 2. 2 Diagram of total coliforms, fecal coliforms and E.coli

2.6.1 Sources of fecal coliforms on vegetables, water and soil

Vegetables get contaminated with fecal coliform due to poor sanitation and the use of contaminated irrigation water (Karanja *et al*., 2010). Similarly, according to Cornish & Lawrence, (2001) high coliform pollution in irrigation water, pose high risks to the people using the water. The sources of pathogens in irrigation water is through recent contamination from human or animal waste, leaching of animal manure from improperly treated septic and sewage discharges, domestic animals or wildlife and storm water runoff (Nova, 2005). Another point of microbial contamination is market-related treatment, particularly under conditions of poor hygiene (Amoah *et al.*, 2005).

CHAPTER THREE

3. METHODOLOGY

3.1 Study Design

Structured field questionnaires were used to collect information on the type and frequency of application of pesticides used by farmers. The second component involved collection, extraction and analysis of kales, soil and water samples to determine the levels of OCPs, heavy metals and microbial contaminants.

3.2 Description of the sampling sites

3.2.1 Mlolongo

Mlolongo is under Mavoko Sub-County in Machakos County. The name Mlolongo is a Kiswahili word for "queuing". From a small long-distance truck stopover, the township has recently been included in Nairobi's metropolitan plan, which will improve its living conditions and the provision of urban services that are currently lacking (UN-Habitat, 2007). The sampling sites covered the peri-urban farms, open markets and sources of irrigation water used on the farms.

3.2.2 Athi River

Athi River is under Mavoko Sub-County in Machakos County. It is the headquarter of Mavoko Sub-County, with a population of about 137,211 (KNBS, 2010). Athi River town is industrialized, with six cement industries. Sampling was conducted at Athi River, Mavoko market and the farm near the market. Water was collected from the river which is the main source of water for irrigation.

3.2.3 Kitengela

Kitengela town is in Kajiado County and is located 20 miles from Nairobi. The municipality is part of the Nairobi Metropolitan Area with an estimated urban population of 8,378 people (KNBS, 2010). Sampling was done at Kitengela Prison farm and kitengela market. Overhead sprinklers were the main form of irrigation at Prison farm and the source of irrigation water was the borehole.

Soil samples were collected from the three markets. Table 3.1 show geographic locations of sampling sites, samples collected and the source of irrigation water.

Table 3. 1: Name, Altitude, location of the Sampling sites, samples collected and the source of irrigation water

Site Name	GPS Position	Altitude (m)	Samples collected	Source of irrigation water
Mlolongo Market	36°56'27.84"E 1°23'42.82"S	1589	Soil, kales and borehole water	Borehole
Mlolongo Farm	36°57'35.66"E 1°23'35.35"S	1602	Soil, River water and kales	River
Kitengela farm	36°56'55.44"E 1°28'23.97"S	1556	Soil, kales and Borehole water	Borehole
Kitengela Market	36°57'32.86"E 1°28'33.99"S	1570	Soil, Tap water and kales	Piped water
Mavoko Farm	36°59'25.45"E 1°27'21.55"S	1526	Soil, kales and River Water	River
Mavoko Market	36°58'38.41"E 1°26'52.62"S	1499	Soil, Tap water and kales	Piped water

Figure 3.1 below shows the location of sampling sites in the study area of Nairobi Metropolitan District.

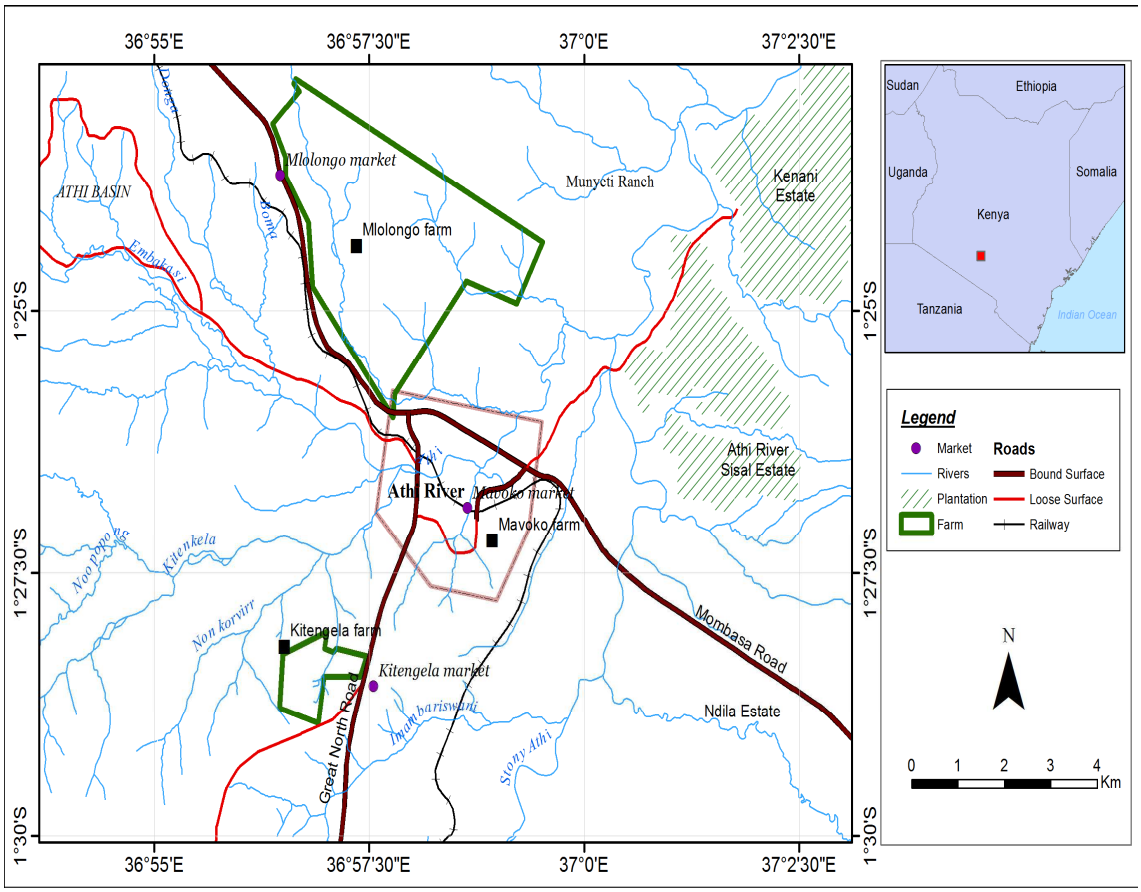


Figure 3. 1: Map of Sampling Sites

3.3 Materials and Reagents

3.3.1 Instruments and apparatus

Extraction of soil samples was done using a soxhlet set up comprising of heating mantles, soxhlet extractors and condensers. Extraction of water was done using 2.0 L glass separatory funnel. Glass column of length 20 cm and 2 cm internal diameter was used in clean-up procedure, whereas LABCONCO rotary evaporator was used for concentrating sample extracts. Fractional distiller was used for distillation of solvents. Scientific pH meter model IQ 150 was used to measure pH of samples, TDS and electrical conductivity was measured using scientific Martin instruments model Mi 306. Digital thermometer was used to measure the temperature. All weights were taken using analytical Fisher scientific A-160 weighing balance. A lab-line

explosion proof refrigerator was used for temporal storage of sample extracts before analysis and deep freezer was used for temporal storage of soil samples before extraction.

Agilent technologies gas chromatograph (GC)) was used for analysis of organochlorine pesticides. Atomic absorption spectrophotometer was used to analyse heavy metals, hot plate was used in digestion of the samples. Glassware used in this study included; Beakers, glass vials (10 ml and 30 ml), auto sampler vial(1.5ml), conical flasks (25 ml, 100 ml, 250 ml and 1000 ml), Pasteur pipettes, desiccators, measuring cylinders (20 ml, 100ml, 500ml and 1000ml) and syringes for sample injection (10 µl, 25 µl, 50 µl, 100 µl).

3.3.2 Reagents

Reagents which were used in the study comprise the following: analytical grade acids ($HClO_4$, HNO_3, H_2SO_4, HCl) were purchased from Kobian Kenya, distilled water, n-hexane, acetone, anhydrous sodium sulphate, aluminium oxide, Isooctane, dichloromethane, sodium chloride, dipotassium hydrogen phosphate, sodium hydroxide, high purity nitrogen gas, high purity hydrogen, white sport nitrogen and oxygen and high purity pesticide standard mixture.

3.4 Data collection using questionnaires

Structured field questionnaire with both closed ended and open ended questions were distributed to seventy respondents within Nairobi metropolitan area. Data was collected on the socio-economic background of the respondents such as gender, age brackets, education level and whether they are trained or untrained on the handling of agrochemicals. Also data was collected on the type of pesticides used on the vegetable farms, the frequency of application and other methods they use apart from pesticides, in controlling pest and weeds in their farm. Attached in appendix I.

3.5 Methods

3.5.1 Sampling and Preservation Water

Water was sampled from the study locations by grab method using 2 L amber glass bottles in triplicate. 100 g of Sodium chloride was added to all samples for preservation. The bottles were covered with a cork and put in ice-box containing cool ice then transported to the laboratory for analysis. They were kept in the refrigerator at 4 ^{o}C.

3.5.2 Sampling and preservation of soil

Surface soil for pesticides analysis were collected in triplicate using pre-cleaned shovel to the depth of 0-20 cm from five different points at the sampling site and mixed thoroughly on aluminium foil. Three replicates were taken and placed in aluminium foil then packed in self-sealing bags and labeled. The samples were packed in ice-box and transported to the laboratory the same day. They were then stored in a deep freezer at temperatures of -20 °C before analysis. Soil samples for metal analysis were collected and stored in plastic bags.

3.5.3 Sampling and preservation of Kales

Kales were collected in triplicate from sites (farm and market) in brown paper bags. They were collected randomly from five different points at the sampling site, mixed and placed in bags and labeled. The samples were placed in Coleman Cooler boxes packed with chillers and transported to the laboratory the same day. Upon reaching the laboratory, they were stored in a refrigerator prior to extraction.

3.5.4 Preparation of Reagents and standards

3.5.4.1 Reagents

Anhydrous Sodium Sulphate was baked-out for 24 hours at 200 °C to remove all the impurities. The copper metal fine particles were activated by shaking Cu with concentrated hydrochloric acid that had been diluted by a factor of 3 with de-ionised water. It was then centrifuged for 1 minute at 300 rpm to separate the copper from the liquid. The liquid was discarded while the copper was washed thrice using CH_3OH and centrifuged to remove all the hydrochloric acid. The copper was then desiccated under a mild flow of nitrogen gas.

Aluminium oxide was dried overnight at 200 °C to activate it, cooled and deactivated with 8% HPLC water. Deactivation of Al_2O_3 was performed by adding 8 ml of ultrapure water to 92 g of activated Al_2O_3 in round bottomed flask and shaken until all lumps were removed. After mixing the deactivated Al_2O_3 was left overnight to condition.

Preparation of the buffer was done by addition of 29.6 ml of 0.2M hydrochloric acid and 50 ml of 0.2 M K_2HPO_4. Acetone, hexane and dichloromethane were each triple distilled to analytical grade level.

3.5.4.2 Standards

Standard solution of Cu, Cd, Zn and Pb were prepared from stock solutions of metal salts by serial dilution. Stock solutions with a concentration of 1,000 mg/L were diluted to obtain standard solutions of low concentration. The absorbance obtained from AAS instrument for each standard of a particular heavy metal was used in drawing calibration curves for Cu, Cd, Zn and Pb as attached in the Appendix III (Figure 1, 2, 3, 4 and 5).

3.6 Determination and quantification of heavy metals

3.6.1 Analytical conditions for AAS model Spectra AA-10 sample analysis

Table 3.2 below shows the optimal conditions for analysis of the selected heavy metals using Atomic Absorption Spectrophotometer model Spectra AA-10.

Table 3. 1: The operating conditions for the AAS instrument model Spectra AA-10 used for analysis(Air/acetylene flame)

Metal	Wavelength (nm)	Lamp current(mA)	Detection limit(µg/L)	Slit width (nm)
Cd	228.8	3	0.6	0.5
Zn	213.9	5	2	1.0
Pb	217	8	20.0	1.0
Cu	324.7	3	3	0.5

3.6.2 Determination and quantification of heavy metal in Soil

Soil samples were oven dried for 72 hours at 70 ºC, ground into fine particles and 1 g was measured into a 250 ml conical flask. Digestion of the sample was done using the method suggested by Gupta *et al.* (2008). 5 ml of an acid mixture of concentrated sulphuric acid, perchloric acid and nitric acid mixed in the ratio of 6:3:1 was measured and added to the sample then heated on hot plate at 60 ºC for 45 minutes. The digest was removed from the hot plate, cooled, filtered and made up to 100 ml using distilled water. The solution was analysed for total heavy metals using atomic absorption spectrophotometer.

3.6.3 Determination and quantification of heavy metal in Kales

Kale samples were air dried and ground to small particles of around 0.1mm using motor and pestle. 1 g of the powdered sample was weighed into a 250 ml conical flask. Digestion of the sample was done using the method suggested by Gupta *et al.* (2008). Using measuring cylinder 5

ml of acid mixture of concentrated sulphuric acid, perchloric acid and nitric acid mixed in the ratio of 6:3:1 was measured and added to the sample then heated on hot plate at 60 °C for 45 minutes. The digest was removed from the hot plate, cooled, filtered and made up to 100 ml using distilled water. It was then analysed for total heavy metals using atomic absorption spectrophotometer.

3.6.4 Determination and quantification of heavy metal in irrigation water samples

100 ml portions of the irrigation water samples were measured into 250 ml Erlenmeyer flasks using a measuring cylinder. 6 ml of an acid mixture of HCl and HNO_3 (aqua-regia) mixed in the ratio of 3:1 was added to each flask. They were then digested using a Stuart Hot plate until the volume was less than 5 ml of digested solution was obtained. The resulting solution was cooled and topped up to 100 ml using distilled water. The sample was analysed for the heavy metals using AAS.

3.7 Determination and quantification of pesticides contamination

3.7.1 Soil Samples extraction

EPA method 3540 Soxhlet extraction of soil was applied. Soil samples were taken from the freezer and given time to defrost for about 6 hours prior to extraction. Triplicates of 20 g samples were dried with baked out anhydrous Na_2SO_4 overnight before transferring to the Soxhlet thimble and 100 µl of 0.01ppm isodrin solution added as internal standard. This was extracted with 175 ml of hexane: acetone (3:1v/v) in round bottomed flasks for at least 16 hours in the soxhlet set-up. The extracts were reduced to about 2 ml in isooctane using rotating evaporator, transferred into 10 ml glass vials and stored in the fridge prior to clean up

3.7.2 Irrigation water samples extraction

Water samples were extracted using solvent-solvent extraction method. EPA Method 3510C was used where 2.0 L of water samples was measured using a glass measuring cylinder, transferred into 3.0 L beaker. pH of the water was measured and recorded. 50 ml of the buffer solution was added to the sample stirred and the pH recorded. The solution was neutralized by adding drops of 0.1 M HCl or 0.1 M NaOH solutions while stirring carefully to adjust the pH to 7.0. The neutral solution was transferred to 2.0 L separating funnel and 100 g of sodium chloride was added to salt out the pesticides from the aqueous phase to organic phase this was followed by the addition of 60 ml triple distilled dichloromethane. The mixture was shaken vigorously while releasing pressure and allowed to stay for half hour to increase partition into two layers. The lower phase was then collected into a clean and dry 250 ml conical flask. Extraction process was continued twice with 60 ml portions of dichloromethane. Combined extract was dried using anhydrous Na_2SO_4, with 2 ml of isooctane as a keeper, and the reduced using LABCONCO rotary evaporator to 2 ml. The concentrated sample was then put in 20 ml vials and stored in a refrigerator at 4^{o}C prior to clean up.

3.7.3 Kale samples extraction

Kale samples were removed from the refrigerator and allowed to stay for 6 hours before extraction to allow them to thaw. The samples were cut into small pieces, ground in a mortar and pestle and 20 g taken for extraction in triplicates. To each of the 20 g portions 60 g of sodium sulfate was add, ground and allowed to dry overnight. The dried sample was then transferred into Soxhlet extraction thimble and 100 µL of 1 ppm isodrin solution was added as an internal standard before extraction. 200 ml n-hexane and acetone mixture mixed in the ratio of 3:1 was used for extraction for 16 hours. Before heating, two pieces of boiling chips were added into the

round bottomed flask in order to allow smooth boiling. After extraction, isooctane was added as keeper and evaporated to 2 ml using rotary evaporator.

3.8 Sample clean up

A chromatographic column of 25 cm x 1.5 cm diameter was packed with 1 cm of baked-out sodium sulphate followed by 15 g of deactivated alumina and finally 1 cm of baked-out sodium sulphate. 15 ml of hexane was used to condition the collumn. Chlorophyll in kale sample extracts was removed using activated charcoal which was packed in between deactivated alumina and anhydrous sodium sulphate.

The extracted samples were introduced into the column using Pasteur pipette and eluted with 165 ml of hexane into a flask. 2 ml of isooctane was added to each cleaned sample as a keeper and concentrated to 2 ml using LABCONCO rotary evaporator and transferred to clean vial for storage.

3.9 Sulphur removal

Sulphur is a co-extract in soil and sediment extraction and it affects the quality of the result in gas chromatography. Sulphur was removed from all soil samples extracts by adding freshly activated copper powder until no additional coloration of copper sulphide was observed. The extracts were filtered into GC auto sampler vials and reduced to 500 µL under a gentle flow of white sport nitrogen.

3.10 GC Analysis and Quantification of pesticides in the extracts

Analysis of organochlorine pesticides was carried out at the Department of Chemistry, University of Nairobi using Agilent 6890 N Gas-chromatograph equipped with micro Electron Capture Detector (µ-ECD). Temperatures of detector and injector were kept constant at 300 and

250 ºC, respectively. Make- up gas was white spot nitrogen, while helium was used as the carrier gas. The injection volume was 1 µl with a pulsed splitless injection mode. The following temperature program was applied: 100 °C (3 min), 100 °C to 240 °C (at 30 °C/ min and hold time of 10 min), 240 °C to 275 °C (at 10 °C/min and hold time of 3.67 min). Identification was done by high purity pesticide reference standards mixture while quantification followed external standard method based on calibration curves from the reference standards.

3.10.1 Determination of Percentage Recovery

Percentage recovery was done in order to assess the accuracy of method of analysis. It was achieved by spiking unhydrous sodium sulphate and distilled water with known amounts of OCPs standard mixture in the concentration range close to the expected sample concentrations. The percentage recovery of the OCPs was calculated using the formulae shown below.

$$\% \text{ Recovery} = \frac{(D - C) \times 100}{A}$$

Where, D is the µg of OCP in the spiked sample

C is the µg of OCP in un-spiked sample

A is the µg of the OCP used to spike

3.10.2 Determination of limit of detection (LOD)

The LOD of a compound is the lowest concentration of the analytes that an analytical process can reliably detect. The LOD of each of the OC Pesticides was calculated based on the lowest concentration of the calibration standards injected and the corresponding noise signals using the following equation:

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

3.11 Determination of biological contaminants

3.11.1 Sterilization of equipment and material

Standard procedures were used to sterilize all materials that were used. Soap and distilled water were used to wash the materials after which they were dried at 160 ºC in an oven for 3 hours. This was done to avoid the contamination.

3.11.2 Determination of biological contamination using coli form count

100 ml of each water sample was measured and put in a plastic container. 1 ml was drawn from each sample using 1 ml pipette and carefully spread on the 3M *E. coli* kit, and incubated in the incubator model DNP 9022 A for 24 hrs at 37 ºC. For vegetables and soils, 1 g of vegetable or soil samples was weighed into 100 ml of distilled water rinsed and vigorously shaken. 1 ml of the solution was pipetted and transferred onto 3M *E. Coli* kit and incubated as described for water above.

3.12 Determination of physico-chemical parameters of irrigation water

3.12.1 pH

This was measured and recorded at the field using pH meter model IQ 150. The meter was calibrated using buffers of pH 10.0, 7.0, and 4.0 before use then measurements were done and all readings were recorded.

3.12.2 Total Suspended Solids (TSS)

The water sample was shaken thoroughly to homogenize and 100 ml of the sample was filtered through a pre-weighed Whatman filter paper No.42. The residue retained on the Whatman filter paper was dried to a constant weight at 105 ºC for 1 hr in an oven. The increase in weight of the Whatman filter paper was that one for the total suspended solids and it was expressed in mg/L.

$$TSS\ (mg/L) = \frac{(A-B) \times 1000}{\text{Volume of the Sample (ml)}}$$

Where A is the weight of Whatman filter paper plus the dried residue (mg). B is the weight of Whatman filter paper (mg).

3.12.3 Total Dissolved Solids (TDS) and Conductivity

TDS and conductivity were both measured in-situ using Martin instruments model Mi 306.

3.13 Moisture Content of vegetables and Soil

Moisture content of the soil and vegetable was considered by heating 10 g of each sample in a watch glass whose weight had been taken before and after oven drying until a constant weight was obtained. The weight difference between the wet sample and the dry sample was calculated and the value that was obtained was the moisture content of the samples.

3.14 Quality Assurance and Quality Control

Quality assurance and quality control was achieved by adding internal standard (isodrin) before extraction to monitor effectiveness of the method. Anhydrous Na_2SO_4 and di-ionised water were carried along at every field trip to track field pollution and were then treated as a sample. Extraction and analysis was carried out in triplicate.

3.15 Statistical Data Analysis

Data analysis was done using Microsoft excel and the results obtained were expressed as mean ± standard deviation and percentage. Correlations were done using Statistical Package for Social Sciences tools (SPSS). Results obtained were discussed and represented by use of graphs, tables and pie charts.

CHAPTER FOUR

4. RESULTS AND DISCUSSION

4.1 Inventory of Pesticides used in Nairobi Metropolitan

4.1.1 Gender of the respondents

Most of the vegetable farmers in Nairobi metropolitan were female who accounted for 81% while the male accounted for 19% (Table 4.1). This findings agreed with study conducted by Havork and coworkers who reported that 80% of urban farmers in Uganda were female while 20% were male (Hovorka *et al.,* 2009).

4.1.2 Age brackets of the respondents

Most of the farmers in Nairobi metropolitan aged between 35 - 40 years (50 %), followed by 45 years and above (34%), 30-34 years (10%), 25-29 years (4%) and 2% was below 25 years of age (Table 4.1). In general 84% of the farmers were above the age of 35 years. Table 4.1 below shows the gender and age of the respondents.

Table 4. 1: Gender and Age of the Respondents

	Frequency	**Percentage**
Gender		
Male	57	81%
Female	13	19%
Total	70	100%
Age brackets		
Above 45 years	**24**	34%
35-40 years	**35**	50
30-34 years	**7**	10
25-29 years	**3**	4
below 24 years	**1**	2
Totals	70	100

4.1.3 Education level of the respondents

Vegetable farmers in Nairobi metropolitan have not attended school, according to the finding 53% of the farmers in Nairobi metropolitan have not attended school, 30% have secondary school, 14% primary school, whereas respondents with college qualification accounted for 3%. There were no farmers with university education as shown in Figure 4.1.

The result shows that farmers in Nairobi metropolitan have different levels of education with majority having no formal education. This is very dangerous as most of the farmers could not understand the instructions and warnings on pesticide containers. The findings correspond to study conducted by Danso and coworkers (2002) who reported about the composition of farmers doing urban and peri-urban agriculture. They found that 6% of the farmer interviewed had tertiary education, 33% had primary education, 37 % had secondary education while 23% lacked formal education. Figure 4.1 below shows the level of education of the farmers.

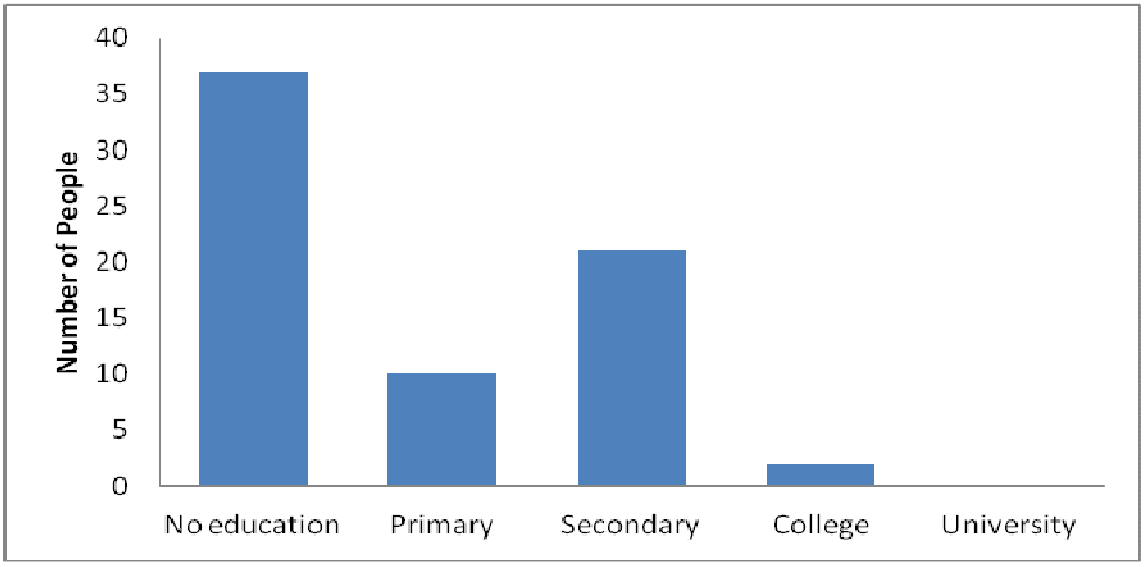


Figure 4. 1: Level of education of farmers

4.1.4 Classes of Pesticides used in Nairobi Metropolitan

The frequently used pesticides in Nairobi metropolitan were pyrethroids, organophosphates, organosulfur and carbamates. All of the pesticides are allowed to be used in Kenya by the Pest Control Products Board (PCPB, 2004). Figure 4.2 below shows summary of pesticide available in Mlolongo, Kitengela and Mavoko.

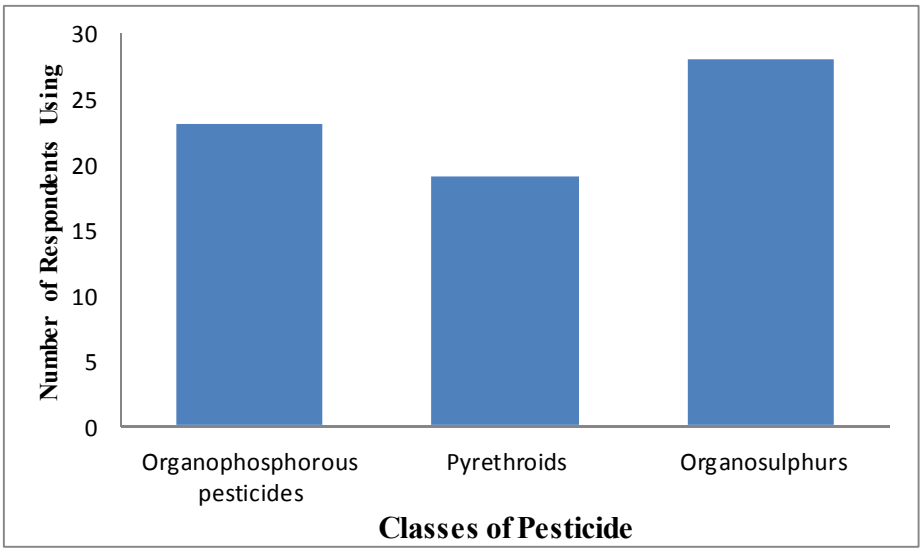


Figure 4. 2: Types of pesticides used by farmers

4.1.5 Pesticide Training and Knowledge by Farmers

All the respondents were a ware of the use of pesticides, but only 86 % had basic training , while 14 % had no training. Nevertheless, none of the respondents had advanced traning about the use of pesticides. The training was conducted by Agriculture Extension Officer, Agro-Chemical Dealers and Industries. Figure 4.3 shows the level of training of the farmers.

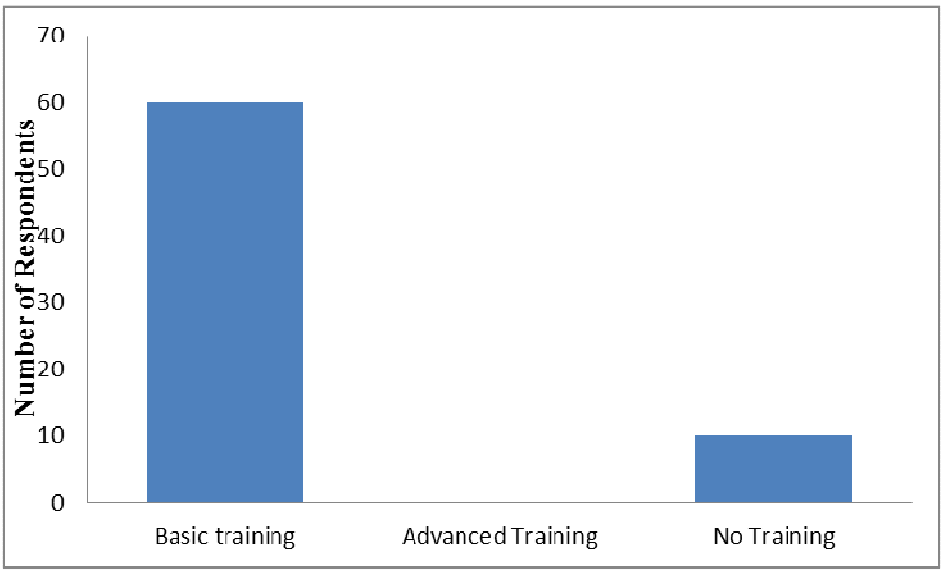


Figure 4. 3: Training of farmers

4.1.6 The frequency of pesticides application

The findings indicated in Table 4.2 shows that 13% of the respondents used pesticides on weekly basis, 25% used pesticides every two weeks, 40% applied pesticides monthly, whereas 22% did not apply pesticides to their vegetables instead they used other methods to control pest and weeds. In general, 78% of the respondents applied pesticides and only 22% did not apply any pesticides on their vegetable farms.

Table 4. 2: The frequency of pesticides application

Using interval	Frequency	Percentage
Weekly	8	13
After 2 weeks	15	25
Monthly	24	40
None	13	22
Total	60	100

All the respondents used other methods apart from pesticides to control weeds, pest and diseases. Weeds were controlled mechanically by removing them from the field by hands and weeding tools such as machetes and fork hoe. Plant diseases were controlled by methods such as uprooting and destroying infected plants to prevent the disease from spreading to the healthy ones. Pruning of the infected parts of plant and growing disease resistant varieties was also applied. Comparing the harvest for other methods alone, 65% of farmers reported that harvests were almost the same as when one used pesticides, whereas 22% reported lower harvest, and only 13% reported higher yields. The results suggest that farmers in Nairobi metropolitan used other methods to complement pesticide use.

4.2 Physico-chemical parameters

4.2.1 Physico-chemical parameters of water

Physico-chemical parameters of irrigation water analyzed were pH, TDS, Conductivity and TSS.

4.2.1.1 pH

The pH of irrigation water ranged between 7.21±0.38 - 8.96±0.54 as shown in Figure 4.4. The highest pH was recorded at Mlolongo farm in the month of February, while lowest was recorded at Kitengela farm in the month of December. During the month of July, Mavoko farm had the highest pH (8.42±0.60), while Kitengela farm had the lowest pH (7.84±0.07). The month of December, Mlolongo market had the highest pH (8.41±0.27), while Kitengela farm had the lowest pH (7.21±0.07). The month of February, Mlolongo farm had the highest pH (8.96±0.52), while Kitengela market had the lowest pH (7.72±0.84). The pH of water samples from all the six sampling sites was within the WHO guideline limits range of 6.5 - 8.5 for irrigation water except for Mlolongo and Mavoko farms that recorded higher pH than the maximum guideline (WHO, 2007 and EMC, 2006). Samples collected in dry season had high pH values than the wet season.

This could be attributed to dilution by the rain water. In addition, the changes observed from one site to the other could be partly attributed to the wide range of human activities in the area. Mlolongo and Mavoko is near factories hence high rate of release of effluent from the factories.

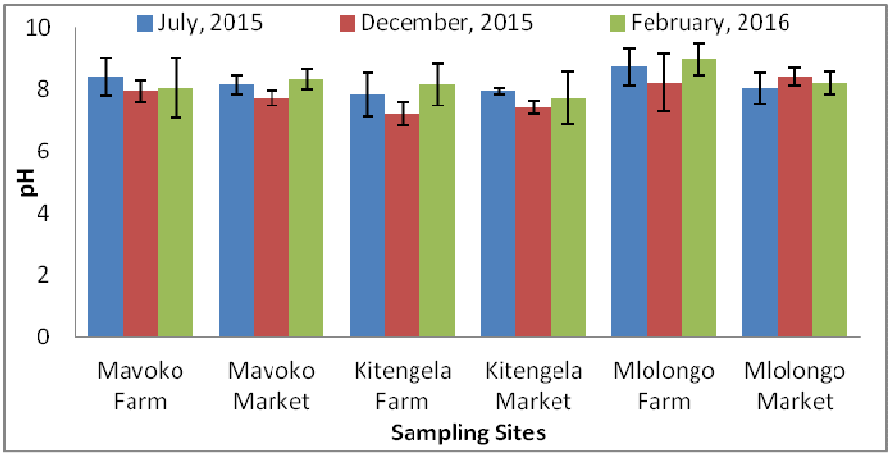


Figure 4. 4: Mean pH values of irrigation water samples

4.2.1.2 Total Suspended Solids (TSS) in Irrigation Water samples

Total Suspended Solids (TSS) comprises of organic and mineral particles that are transported in water column and cannot pass through a sieve of two micrometers. TSS of irrigation water ranged between 22.15±1.38 - 225.96±10.54 mg/L as shown in Figure 4.5. The highest TSS was recorded at Mlolongo farm during the month of February and the lowest was recorded in Kitengela market in the month of February. In the month of July, Mlolongo farm had the highest TSS (203.56±15.84), while Mlolongo market had the lowest TSS (42.58±2.34). In December, Mlolongo farm recorded the highest TSS (110.99±10.32), while Mlolongo market had the lowest TSS (62.58±2.34). The month of February 2016, Mlolongo farm had the highest TSS (225.56±15.84), while Mlolongo market had the lowest TSS (38.96±0.1). TSS of irrigation water samples from all the six sampling site was above the maximum WHO acceptable TSS concentration of 30 mg/L for irrigation water (WHO, 2007).

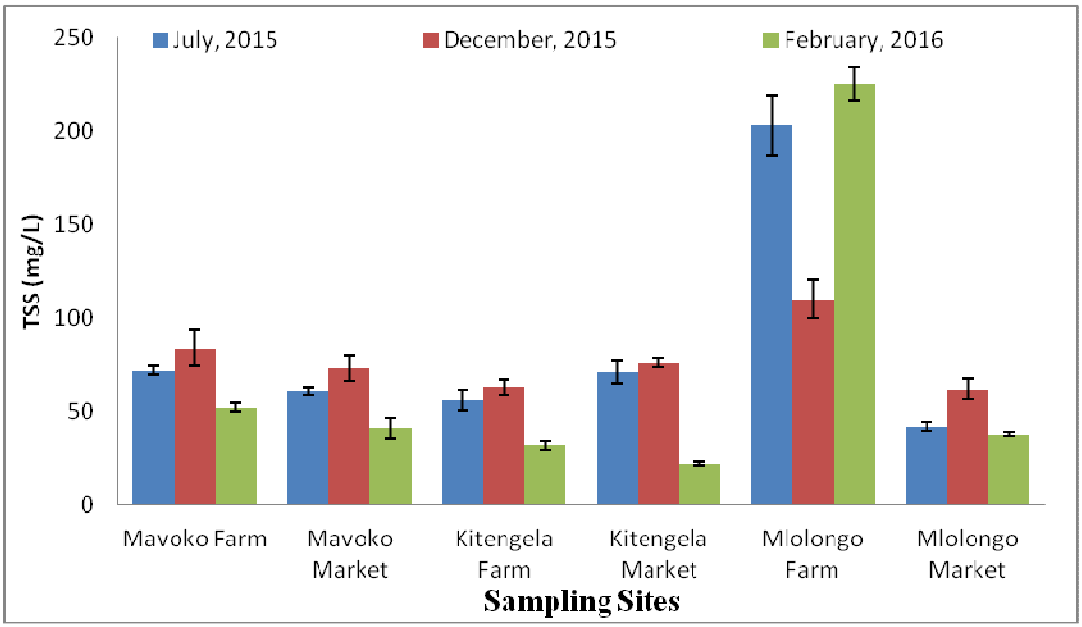


Figure 4. 5: Mean Total suspended solids of irrigation water samples

4.2.1.3 Total dissolved Solids (TDS) in Water

Total dissolved solid (TDS) of irrigation water ranged between 78.22±2.38 - 485±25.32 mg/L as shown in Figure 4.6. The highest TDS was recorded at Mlolongo farm during the month of December and the lowest was recorded at Mavoko market in December. In July, Mlolongo farm had the highest TDS (306.92±22.35 mg/L), while Mavoko market had the lowest TDS (96.54±2.34 mg/L). In December, Mlolongo farm had the highest TDS (485±25.32 mg/L) while Mavoko market had the lowest TDS (78.22±2.38 mg/L). The month of February, Mlolongo farm had the highest TDS (398.56±15.84 mg/L), while Mlolongo market had the lowest TDS (95.96±3.6 mg/L). All the irrigation water samples from the six sampling sites TDS was within the maximum EMC acceptable TDS concentration of 1200 mg/L for irrigation water (EMC, 2006).

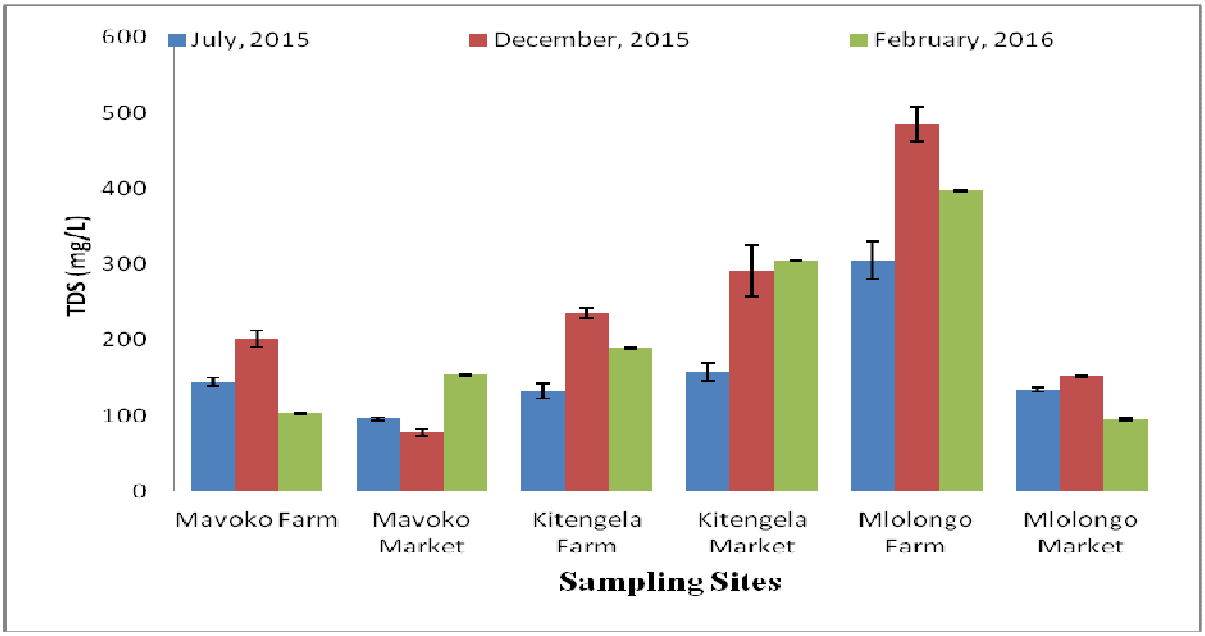


Figure 4. 6: Mean TDS of irrigation water samples

4.2.1.4 Conductivity of Water

Conductivity of irrigation water ranged between 190.35±10.25 - 970.87±14.58 µS/cm as shown in Figure 4.7. The highest conductivity was recorded at Mlolongo farm during the month of December and the lowest was recorded at Mavoko market in December. During the Month of July, Mlolongo farm had the highest conductivity (613.58±40.32 µS/cm), while Mavoko market had the lowest conductivity (193.28±11.56 µS/cm). The month of December, Mlolongo farm had the highest conductivity (970.83±14.58 µS/cm) while Mavoko market had the lowest conductivity (156.72±5.73 µS/cm). The month of February, Mlolongo farm had the highest conductivity (796.86±55.23 µS/cm), while Mlolongo market had the lowest conductivity (190.44±10.36 µS/cm).

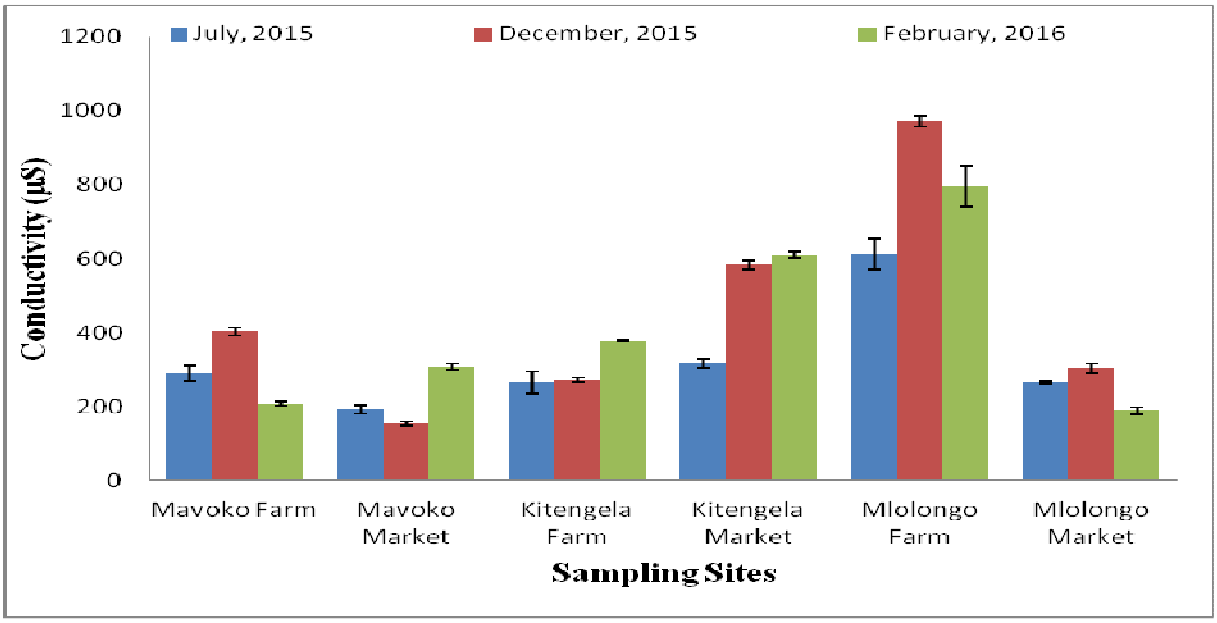


Figure 4. 7: Mean Conductivity in Irrigation Water

4.2.2 Physico- Chemical Properties of Soil

Table 4.3 shows the physico-chemical parameters of soil in Nairobi metropolitan. Soil pH ranged between 6.01 and 7.96. The highest pH was recorded in soil from Kitengela farm while the lowest pH was recorded in soil from Kitengela market. The acidic pH at Kitengela market can be attributed to the formation of carbonic acid as a result of dissolving carbonates with water. Low total nitrogen and phosphorus levels were measured in all soils. The % organic carbon ranged 2.87-4.84 %, highest % organic carbon (4.84%) was recorded at Mlolongo farm followed by Mavoko farm (4.26%) and Kitengela market (2.87%). The high % organic carbon at Mlolongo farm and Mavoko farm may possibly be a result of the use of waste that is loaded in organic materials to the soils. The percentage total nitrogen ranged between 0.16 - 0.89%. The highest % total nitrogen (0.89%) was recorded at Kitengela farm followed by Mavoko farm (0.78%), while Kitengela market recorded the lowest (0.16%). Phosphorous concentration ranged between 17-55 mg/kg. The highest concentration of phosphorous (55 mg/kg) was recorded at Mlolongo

market followed by kitengela farm (46 mg/kg), while Mavoko market recorded the lowest concentration (17 mg/kg). The metal concentration were relatively adequate, whereby copper ranged between 0.06-1.94 mg/kg, Potassium ranged between 0.99-2.98 me%, calcium the concentration ranged between 18.2=31.0 me%, Manganase ranged between 1.23 – 2.11me%, iron ranged between (216 -496 mg/kg), Zinc ranged between 3.99 - 5.85 mg/kg and Sodium between 3.99-5.85 me%.

Table 4. 3: Composition of different soil properties of Nairobi Metropolitan

SITES	PH	TOTAL N %	TOTAL ORG C %	P Mg/Kg	K me%	C me%	Mg me%	Mn me%	Cu ppm	Fe ppm	Zn ppm	Na me%
Mlolongo Market	7.43	0.23	3.65	55	1.03	31	1.65	1.23	0.99	432	5.85	2.65
Mlolongo Farm	6.45	0.18	4.84	26	2.98	28	2.58	1.66	0.06	336	4.61	3.92
Mavoko Market	7.57	0.22	3.91	17	0.99	32	3.65	1.75	1.05	276	4.32	2.47
Mavoko Farm	8.41	0.78	4.26	29	2.18	23	1.98	1.65	0.77	496	3.99	3.69
Kitengela market	6.01	0.16	2.37	32	2.61	18.2	2.35	2.11	0.42	438	4.05	3.64
Kitengela Farm	7.96	0.89	3.98	46	2.22	26.6	1.99	1.67	1.94	398	4.22	3.13

4.3 Results for microbial contaminants in water, soil and kales

4.3.1 Results for microbial contaminants in water

The results shows the level of microbiological contaminants that were measured in irrigation water samples from three farms and markets during the month of July, December and February.

4.3.1.1 Microbial Contaminants in water during the Months of July, December 2015 and February 2016

The analysis of water samples from the six sites showed existence of total coliforms ranging from 81±4 – 3,797±119 cfu/ml and *E-coli* from 2±0 - 89±5 cfu/ml. The highest number of

coliform was recorded at Mlolongo farm in the month of February, while the highest number of *E. Coli* was recorded at Mlolongo farm during the month of December.

In the month of July, the number of total coliforms ranged between 81±4 -1500±22 cfu/ml, while *E-coli* ranged between 2±0 - 78±3 cfu/ml. In December, the number of total coliforms increased the range between 95±19 – 3,214±284 cfu/ml, while *E-coli* concentration was between 7±1 - 89±5 cfu/ml. Higher total coliforms concentration was also observed in February with levels from 179±1 – 3,797±119 cfu/ml, as *E-coli* recorded lower values between 15±1 - 66±6 cfu/ml. The results show high prevalence of microbial contaminants in irrigation water used in the urban agriculture farms, and agree with previous reports that recorded low quality of water used in urban vegetable farming (Sonou, 2001).

4.3.1.2 Comparison of microbial contaminants in irrigation water from different sites in July 2015

Mlolongo market water samples recorded the highest number of total coliforms (1,500±22cfu/ml) while the farm recorded the highest number of *E. Coli* (78±3 cfu/ml). Mavoko farm on the other hand had total coliforms concentration at 81±4 cfu/ml, while *E.Coli level was* 23±4 cfu/ml (Figure 4.8). The market recorded total coliforms at 108±6 cfu/ml and *E. Coli* concentration of 4±0.0 cfu/ml. In Kitengela, the farm site recorded total coliforms concentration of 345±29 cfu/ml and *E. Coli* levels at 2±0 cfu/ml. The market had total coliforms at 331±26 cfu/ml, while *E. Coli* was 7±1 cfu/ml. Mlolongo, the farm recorded total coliforms count of 1,292±265 cfu/ml and *E. Coli* level of 78±3 cfu/ml while the market had total coliforms levels of 1,500±22 cfu/ml and *E. Coli* concentration of 18±1 cfu/ml.

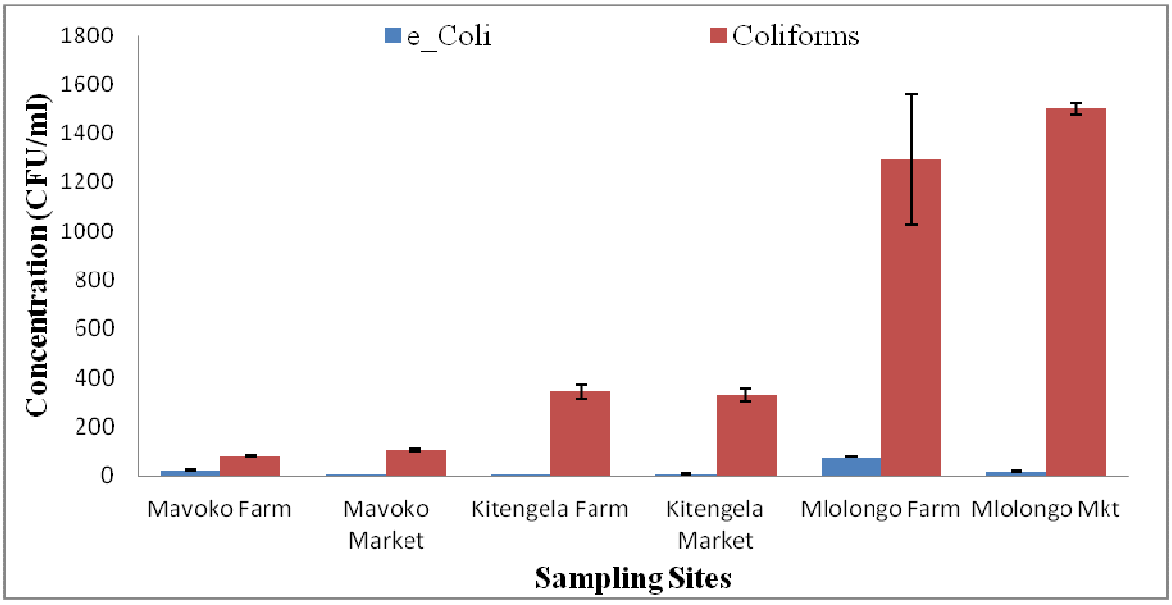


Figure 4. 8: Coli form and *E-coli* in water in during Month of July, 2015

4.3.1.3 Comparison of microbial contaminants in water in December, 2015

Mlolongo farm irrigation water samples recorded the highest number of total coliforms (3,214±284 cfu/ml) and the highest number of *E. Coli* (89±5 cfu/ml) in December, 2015. Mavoko farm recorded total coliforms concentration of 95±19cfu/ml and *E. Coli* levels of 27±1cfu/ml, the market recorded total coliforms concentration of 124±6 cfu/ml and *E. Coli* levels of 7±1 cfu/ml. Kitengela farm had total Coliforms levels of 934±20cfu/ml and *E. Coli* concentration of 11±2 cfu/ml. The levels of total coliforms in Kitengela market was 316±34 cfu/ml and *E. Coli* level of 10±1 cfu/ml, while Mlolongo market registered total coliforms count of 1,606±74 cfu/ml and *E. Coli* count of 25±1 cfu/ml (Figure 4.9).

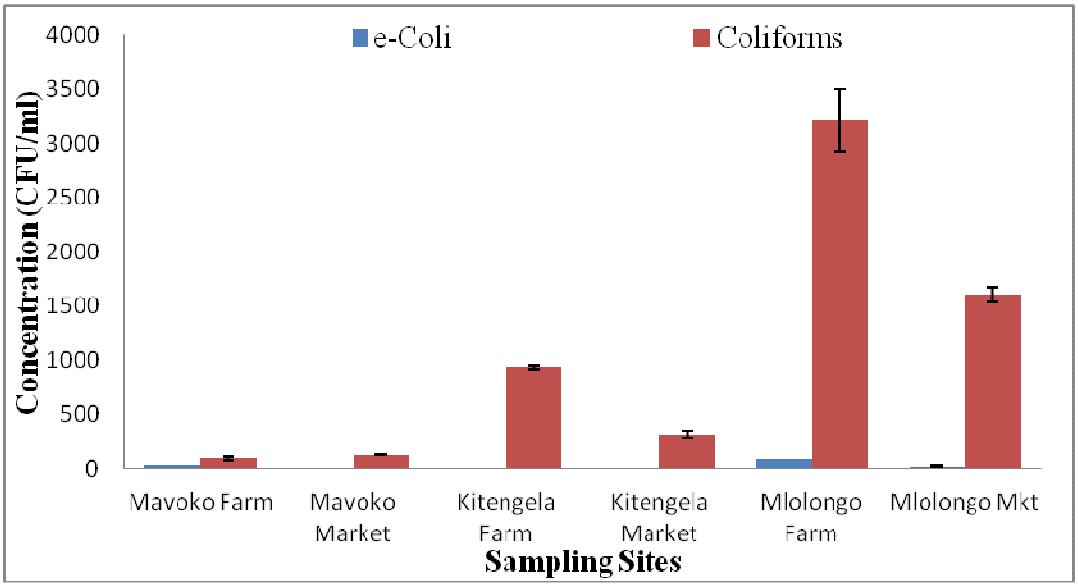


Figure 4. 9: Coli form and *E-coli* in irrigation water in December, 2015

4.3.1.4 Comparison of microbial contaminants in irrigation water in February, 2016

Mlolongo farm irrigation water samples recorded the highest number of total coliforms with 3,797±119 cfu/ml and the highest number of *E. Coli* counts at 66±6 cfu/mL during the month of February, 2016. The total coli-forms count in Mavoko farm water was 179±1 cfu/ml while *E. Coli* count was 23±3 cfu/ml. Mavoko market recorded total coliform count of 225±8 cfu/ml and *E. Coli* concentration of 19±1 cfu/ml. Kitengela farm recorded higher total coliforms count of 521±31cfu/ml and *E. Coli* count of 37±1cfu/ml, while the market recorded total coliforms count of 335±37cfu/ml and *E. Coli* count of 18±2 cfu/ml. Mlolongo market water had the highest total coliforms count of 911±20 cfu/ml and *E. Coli* count of 15±1 cfu/ml (Figure 4.10).

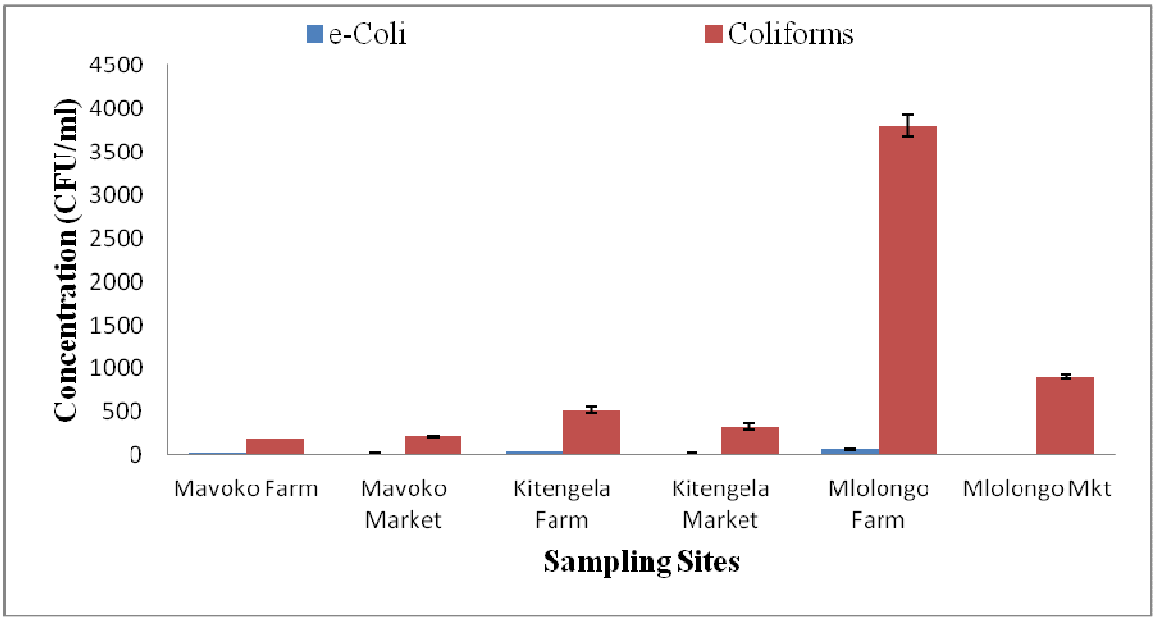


Figure 4. 10: Coli form and E-coli in irrigation water during the month of February, 2016

4.3.2 Results for microbial contaminants in Soil

The results of microbiological contaminants in soil samples from the three farms and three markets in the months of July, December, 2015 and February, 2016 are discussed below.

4.3.2.1 Microbial Contaminants in Soil in July, December, 2015 and February, 2016

The analysis of soil samples from the six sites showed existence of microbial counts of coliforms in the range of 1±0 – 3,214±284 cfu/g and *E. Coli* count from 0 - 145±8 cfu/g. The highest number of coliform was recorded at Mlolongo farm soil, while the highest number of *E. Coli* was recorded at Kitengela farm soil. In July 2015, the number of total coliforms ranged between 120±1- 1225±33 cfu/g while *E. Coli* count was between 0 - 85±5cfu/g. In December 2015, the number of total coliforms ranged between 95±19 - 3214±284 cfu/g while the *E-coli* count was between 1±0 - 145±8 cfu/g. February recorded total coliforms between 1±0 - 52±3 cfu/ml and *E. Coli* between 6±1 - 37±3 cf u/g.

4.3.2.2 Comparison of Microbial Contaminants in Soil from Different Sites in July, 2015

Mlolongo farm soil recorded the highest total coliforms count of 1,225±33 cfu/g, while the highest number of *E. Coli* (89±5 cfu/g) was recorded in soil from Mavoko market. Mavoko farm recorded total coliforms count of 285±7 cfu/g and *E. Coli* concentration of 31±1 cfu/g, while the market recorded total coliforms concentration of 120±1 cfu/g and *E. Coli* counts of 89±5 cfu/g. On the other hand, Kitengela farm recorded total coliforms count of 130±0 cfu/ml and zero *E. Coli* counts, while the market recorded total coliforms count of 224±7 cfu/g and zero *E. Coli* counts. Mlolongo market had total coliforms count of 1,036±28 cfu/g and *E. Coli* count of 15±2 cfu/g (Figure 4.11).

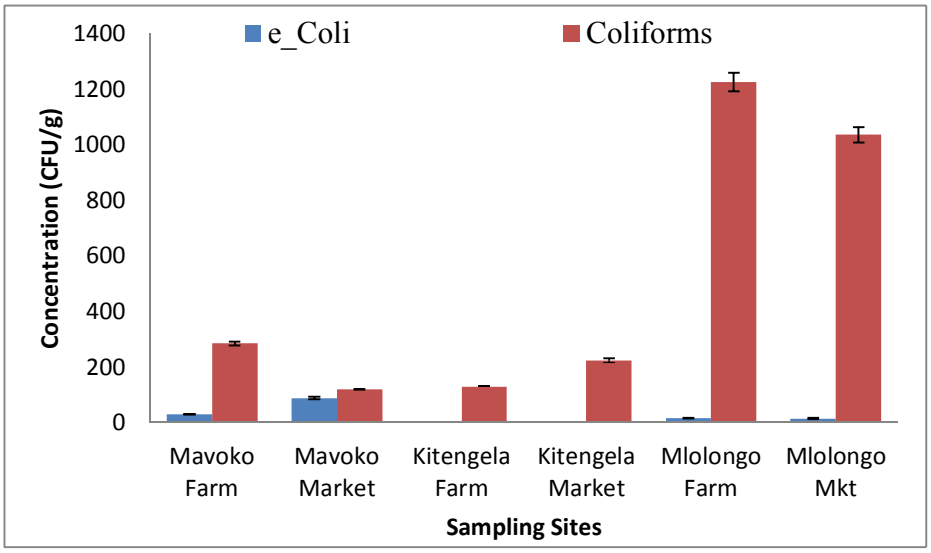


Figure 4. 11: Coli form and E-coli in Soil in July, 2015

4.3.2.3 Comparison of microbial contaminants in Soil from different sites during the Month of December, 2015

Mlolongo farm soil samples recorded the highest number of total coliforms (3,214±284 cfu/g), while the highest number of *E. Coli* (145±8 cfu/g) was recorded at Kitengela farm during the

month of December, 2015. Mavoko farm recorded total coli-form (95±19 cfu/g) and *E. Coli* (4±0 cfu/g), Mavoko market recorded total coliform count of 124±2 cfu/g and *E. Coli* count of 40±5 cfu/g. Kitengela farm on the other hand recorded higher total coliforms count at 934±204 cfu/g and *E. Coli* count of 145±80 cfu/g, whereas the market soil recorded total coliforms count of 316±34 cfu/g and *E. Coli* 12±2 cfu/g. For Mlolongo market, the number of total coliforms count in soil was 1,606±74 cfu/g, while the *E. Coli* was 19±2 cfu/g (Figure 4.12).

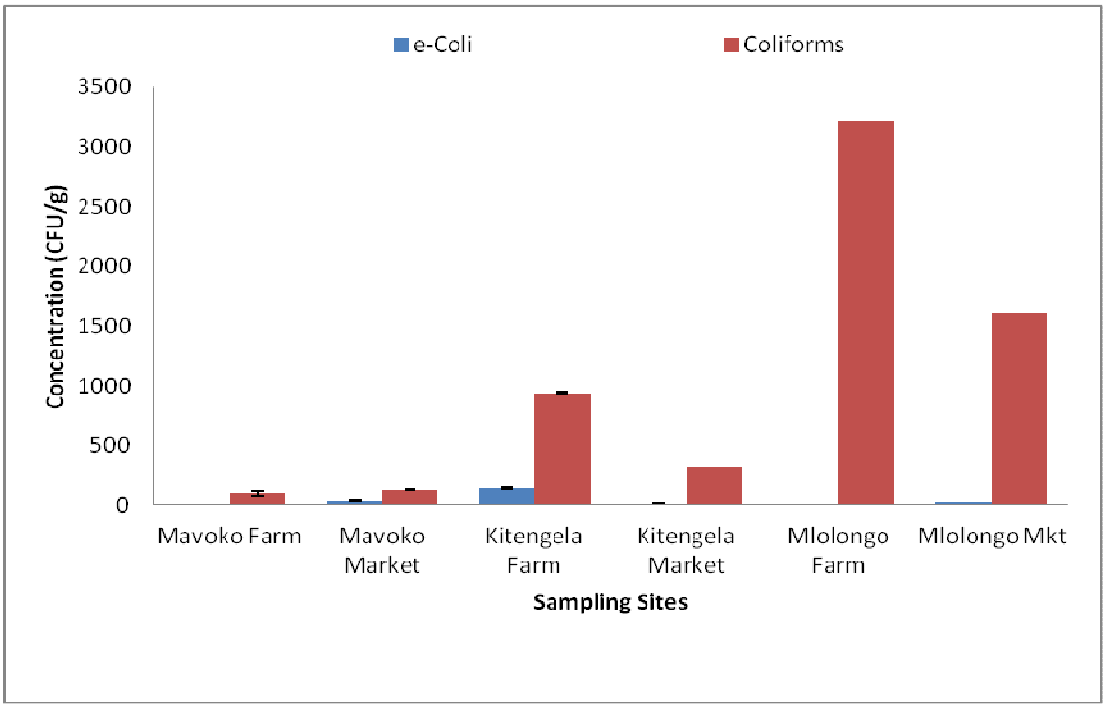


Figure 4. 12: Coliform and *E. Coli* in Soil in December, 2015

4.3.2.4 Comparison of microbial contaminants in Soil from different sites in February, 2016

Mlolongo farm soil samples recorded the highest number of total coliforms and *E. Coli* at 3797±119 cfu/g and 66±6 cfu/g. Mavoko farm recorded total coli-form (179 ±1 cfu/g and *E. Coli* count of 23 ±3 cfu/g, while the market recorded total coliforms count of 225 ±3 cfu/g and *E. Coli* count of 19 ±2 cfu/g. Kitengela farm recorded total coliforms as 521 ±13 cfu/g and *E. Coli* count of 37 ±3 cfu/g, while the market recorded total coliforms count of 335 ±37cfu/g and *E.*

Coli count of 18 ±1 cfu/g. Mlolongo market recorded total coliforms count of 911 ±22 cfu/g and *E. Coli* count of 15 ±4 cfu/g (Figure 4.13).

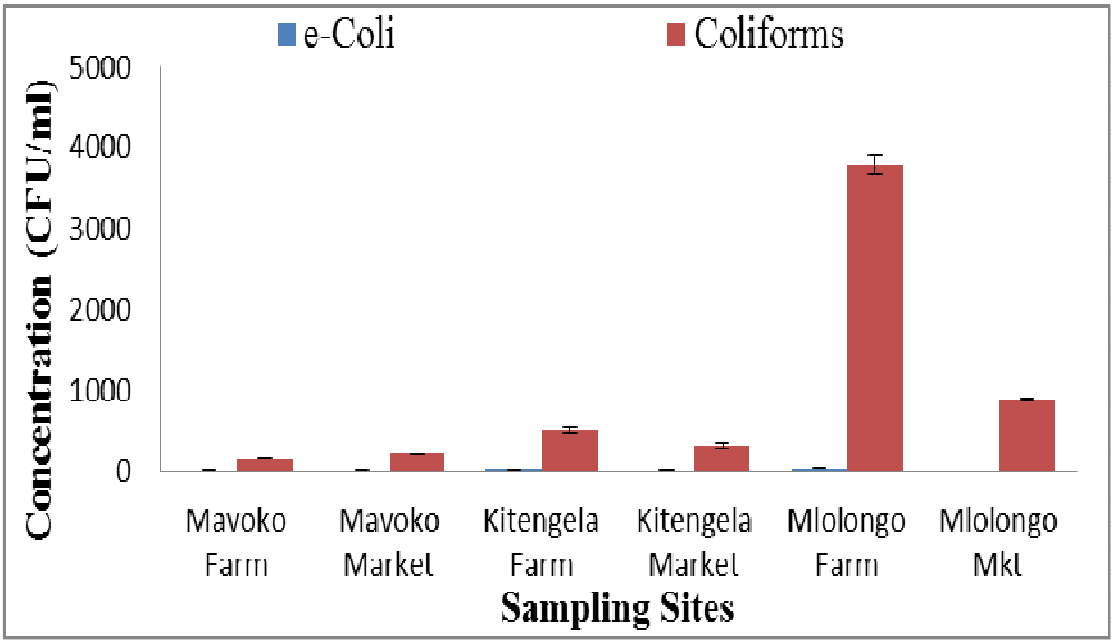


Figure 4. 13: Total coliforms and *E. Coli* in Soil in February, 2016

4.3.3 Results for microbial contaminants in Kales

Microbiological contaminants in Kale samples from the three farms and three markets were determinened in July and December, 2015 and February, 2016.

4.3.3.1 Microbial Contaminants in Kales in July, December, 2015 and February, 2016

The analysis of Kale samples from the six sites showed existence of microbial counts with total coliforms ranging from not-detected – 353±19 cfu/g, while *E. Coli* ranged from not detected - 13±2 cfu/g. The highest levels of coliforms and *E. Coli* were recorded at Mlolongo market in December 2015.

In July the number of total coliforms ranged between 12±1 - 230±20 cfu/g while *E. Coli* ranged from 0 - 5±1 cfu/g. while in February, total coliforms ranged between 43±3 - 273±36 cfu/g and *E-coli* 1±0 - 52±3 cfu/g.

4.3.3.2 Comparison of microbial contaminants in Kales from different sites in July, 2015

Mlolongo market vegetable samples recorded the highest number of total coliforms at 230±20 cfu/g, while the highest count of *E. Coli* 5±1 cfu/g was recorded at Mavoko market. Mavoko farm recorded total coliform count of 12± cfu/g and *E. Coli* count of 4±1 cfu/g, while the market recorded total coliforms count of 25±2 cfu/g and *E. Coli* count of 5±1 cfu/g. Kitengela farm recorded total coliforms count of 37±4 cfu/g and zero *E. Coli* count, while the market recorded total coliforms count of 15±3 cfu/g and *E. Coli* concentration of 2±1 cfu/g. In Mlolongo market, number of total coliforms count was 230±20 cfu/g and zero *E. Coli* count, while for the farm the number of total coliforms count was 27±4 cfu/g and zero *E. Coli* contamination (Figure 4.14).

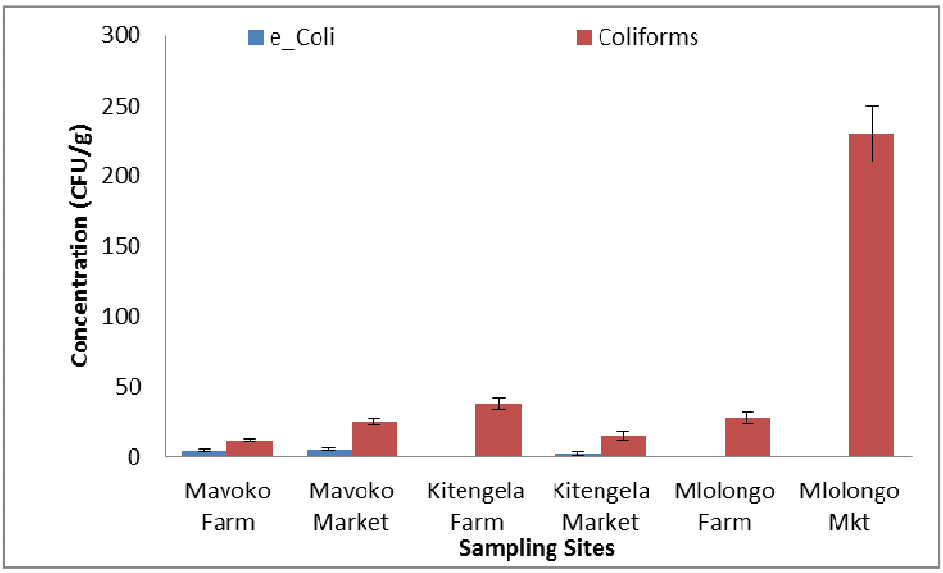


Figure 4. 14: Total coliforms and *E. Coli* in Kales in July, 2015

4.3.3.3 Comparison of microbial contaminants in Kales from different sites in December, 2015

Mlolongo market kales samples recorded the highest number of total coliforms at 353±19 cfu/g and the highest number of *E. Coli* count of 13±2 cfu/g. Mavoko farm recorded total coliforms count of 8±14 cfu/g and E. Coli concentration of 3±1 cfu/g, while the market recorded total coliforms counts of 27±4 cfu/g and *E. Coli* count of 5±1 cfu/g. Kitengela farm recorded total coliforms counts of 40±2 cfu/g and *E. Coli* 1±0 cfu/g, while the market recorded total coliforms count of 22±3 cfu/g and *E. Coli* concentration of 2±0 cfu/g. In Mlolongo farm, the number of total coli-form count was 55±7 cfu/g and *E. Coli* count of 2±0 cfu/g, while the market recorded total coliforms count of 353±19 cfu/g and *E. Coli* count of 13±2 cfu/g (Figure 4.15).

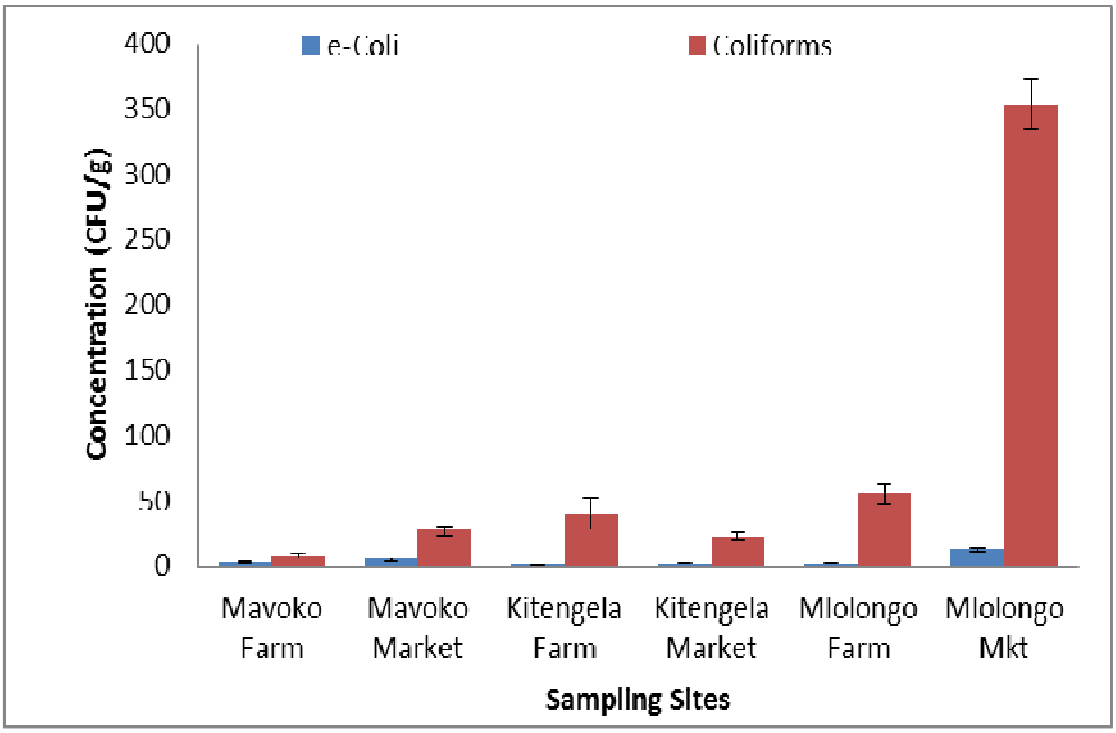


Figure 4. 15: Coliforms and *E. Coli* in Kales in December, 2015

4.3.3.4 Comparison of microbial contaminants in Kales from different sites in February, 2016

Mlolongo farm soil samples recorded the highest number of total coliforms at 31±2 cfu/g while the highest number of *E. Coli* 10±3 cfu/g was recorded at Mavoko market. Mavoko farm recorded total coliforms count of 8±1 cfu/g and E. Coli count of 1±0 cfu/g, while the market recorded total coliforms count of 25±5 cfu/g and *E. Coli* count of 10±3 cfu/g. Kitengela farm recorded total coliforms count of 25±1 cfu/g and E. Coli count of 3±1 cfu/g, while the market recorded total coliforms count of 8±2 cfu/g and E. Coli count of 2±1 cfu/g. Mlolongo market number of total coliforms count of 54±7 cfu/g and E. Coli concentration of 25±3 cfu/g as shown in Figure 4.16.

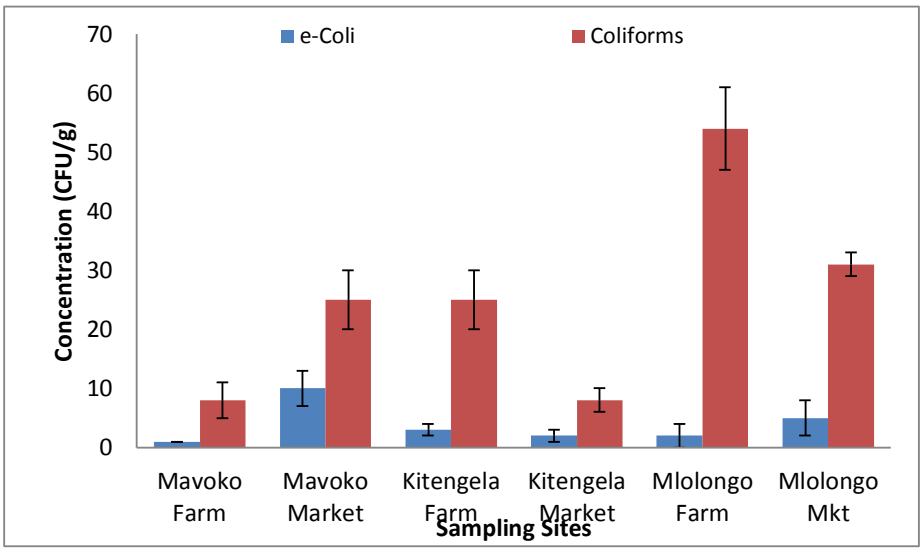


Figure 4. 16: Coli form and *E-coli* in Kales in February, 2016

4.4 Results for heavy metal analysis

4.4.1 Results for heavy metal analysis in water (µg/L)

Heavy metals analysed in irrigation water samples included Zn, Cu, Pb and Cd in the months of July 2015, December 2015 and February 2016.

4.4.1.1 Mean concentration of Heavy Metals in irrigation water samples in July 2015

The analysis of water samples from the three markets and three farms showed existence of heavy metal residues at varying concentrations. The levels of Cu ranged between 13.72±0.00 µg/L - 98.50±10.47 µg/L, Pb ranged between ND- 8.60±0.00 µg/L, while Zn varied between 34.50±2.74 - 302.87±11.24 µg/L. Cd was below the detection limits of 0.60 µg/L. The magnitude of heavy metals concentration was in the order of Zn > Cu> Pb> Cd.

4.4.1.2 Comparison of heavy metals in irrigation water from the six sites in July 2015

Zinc recorded the highest concentration in all the sampling sites. This could be attributed to the use of zinc based fertilizer by farmers, which is afterwards washed into the water bodies. Cu was detected in all the water samples with the highest concentration recorded in irrigation water samples collected from Mlolongo market (98.50±10.47 µg/L), whereas the lowest concentration was recorded in water samples from Mavoko farm (13.72±0.00 µg/L). The highest concentration of lead was recorded in water samples from Kitengela farm (8.60±0.00 µg/L), however lead was not detected in Mavoko farm water. Zn concentration ranged from (34.50±2.74 - 302.87±11.24 µg/L). Mlolongo market recorded the highest concentration of Zn. Cd was below the detection limit in all the water samples. The concentration of all the four metals analysed were within the WHO guideline as shown in Figure 4.17.

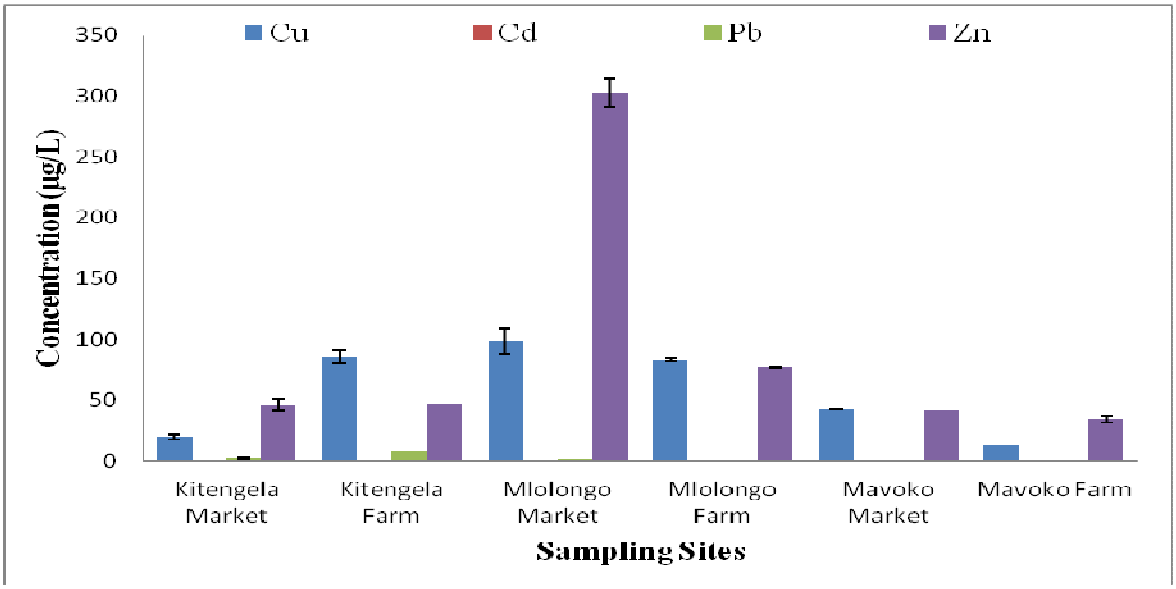


Figure 4. 17: Mean Concentration Heavy Metals in Irrigation Water in July, 2015

4.4.1.3 Mean concentration of Heavy Metal in water samples during the December, 2015

The analysis of water samples from the three markets and three farms showed existence of heavy metal residues at varying concentrations. The concentration of Cu ranged between 4.08±0.00 µg/L - 160.55±2.22 µg/L, Pb between ND- 1.65±0.00 µg/L and Zn between 6.00±0.01-41.28±2.78 µg/L. Cd was below the detection limits of 0.60 µg/L, The magnitude of heavy metals concentration was in the order of Cu > Zn> Pb> Cd.

4.4.1.4 Comparison of heavy metals in water from the six sites in December, 2015

Copper recorded the highest concentration in all the sampling sites. This can be attributed to the use of fertilizer containing Cu by farmers which are then washed to the water bodies. Cu was detected in all the water samples with the highest concentration recorded in irrigation water samples collected from Kitengela farm (160.55±2.22µg/L) and the lowest concentration was recorded in water samples from Mlolongo farm (4.08±0.00µg/L). The highest concentration of Pb was recorded in water samples from Mavoko farm (1.65±0.00µg/L) and it was not detected in

Mavoko market, Mlolongo market, Kitengela market, Kitengela farm and Mlolongo farm. The concentration of Zn ranged from 6.00±0.01- 41.28±2.78µg/L (Figure 4.18). Mavoko farm recorded the highest concentration of Zn, whereas Cd was below the detection limit in all the water samples. The concentration of all the four metals analysed were within the WHO guideline as shown in Figure 4.17.

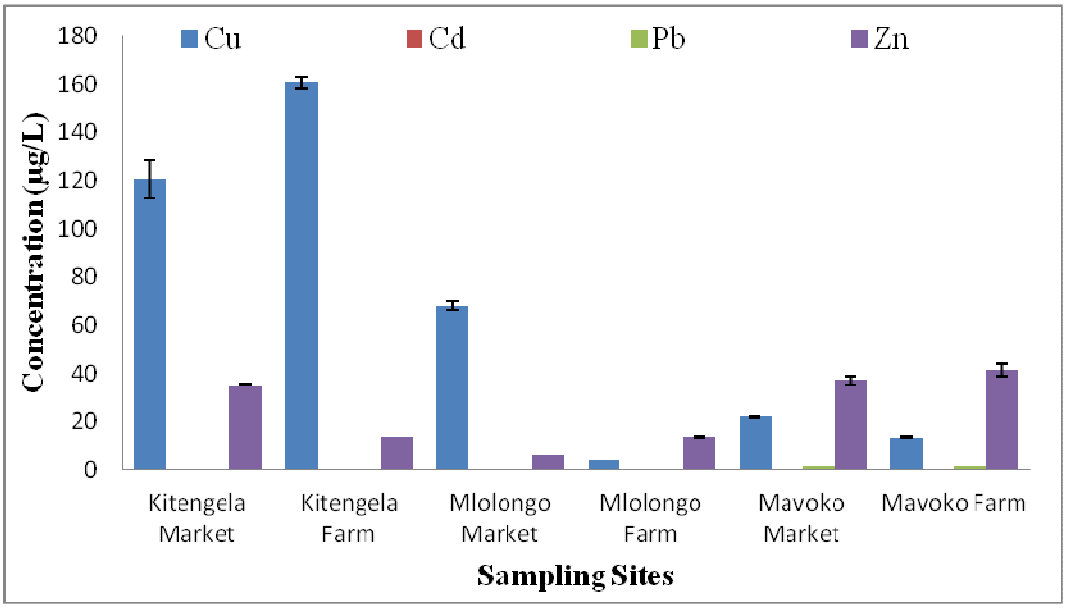


Figure 4. 18: Mean Concentration Heavy Metals in Water during month of December, 2015

4.4.1.5 Concentrations of Heavy Metals in irrigation water samples during February, 2016

The concentration of Cu ranged between 23.98±0.12 - 108.69±11.52 µg/L and the concentration of Zn was between 48.84±7.82- 201.00±22.54 µg/L. Cd and Pb were below the detection limits of 0.60 µg/L and 20 µg/L respectively, The magnitude of heavy metals concentration was in the order of Zn > Cu> Pb> Cd.

4.4.1.6 Comparison of heavy metal in irrigation water from Six sites during the Month of February 2016

Zinc metal recorded the highest concentration in all the sampling sites. This can be attributed to the use of fertilizer containing Zn by farmer which is then washed to the water bodies. Cu was detected in all the water samples with the highest concentration recorded in irrigation water samples collected from Mavoko farm (108.69±11.52 µg/L) and the lowest concentration was recorded in water samples from Kitengela farm (23.98±0.12 µg/L). The highest concentration of Zinc was recorded in water samples from Kitengela market (201.00±22.54 µg/L) and the lowest concentration was recorded in water samples from Mavoko farm (48.84±7.82 µg/L). Cd and Pb was below the detection limit in all the water samples As shown in Figure 4.19. The concentration of all the four metals analysed were within the WHO guideline.

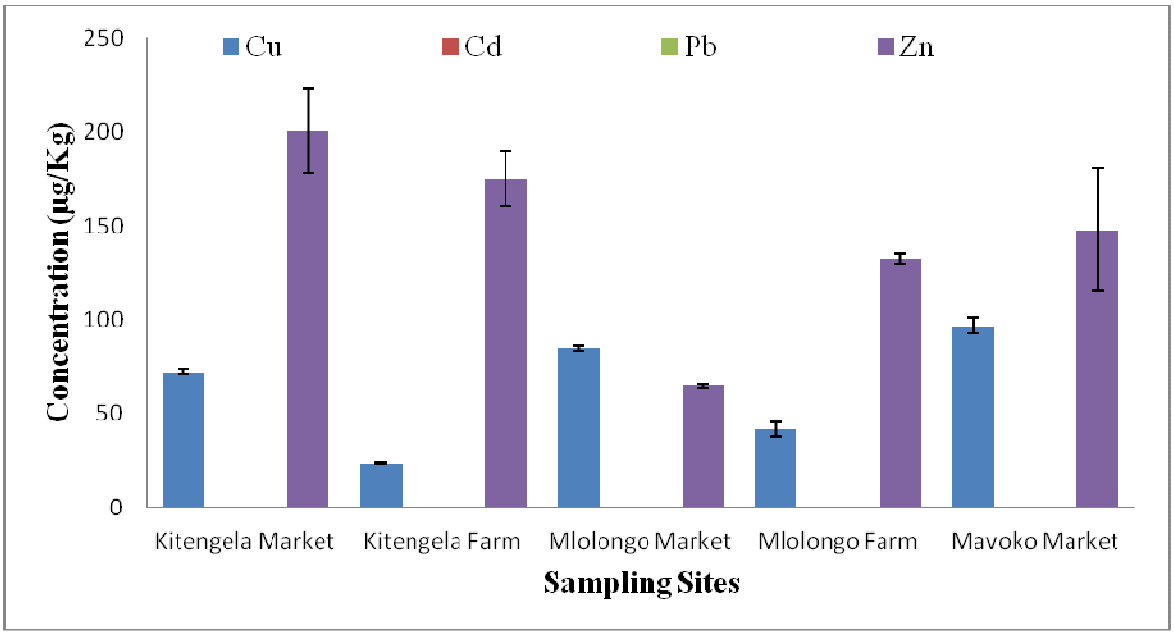


Figure 4. 19: Mean Concentration Heavy Metals in Irrigation Water in February, 2016

4.4.2 Concentration of Heavy metals in soil samples (µg/kg)

The subsections that follow show the mean concentration of each heavy metal analysed in soil samples from the six sampling sites during the month of July 2015, December 2015 and February 2016.

4.4.2.1 Concentration of Heavy metals in soil samples during the Month of July 2015

The analysis of soil samples from the three markets and three farms showed existence of heavy metals at varying concentrations. The concentration of Cu ranged between 10.11±0.07-239.56±16.25 µg/Kg, while Zn ranged between 186.77±12.77-1,025.15±80.57 µg/Kg. The concentration of Pb ranged between ND -121.93±21.72 µg/Kg while Cd levels were below the detection limits of 0.60 µg/L. The magnitude of heavy metals concentration was in the order of Zn > Cu> Pb> Cd. All the metal analysed in the six sampling sites were within the maximum permitted levels by WHO (WHO, 2007).

4.4.2.2 Comparison of heavy metal in Soil from six sites during the Month of July, 2015

Zinc recorded the highest concentration in all the sampling sites. Cu was detected in all the soil samples with the highest concentration recorded in soil samples collected from Kitengela Market (239.56±16.25 µg/Kg) and the lowest concentration was recorded in soil samples from Mavoko farm (10.11±0.07 µg/Kg). The highest concentration of Zn was recorded in soil from Kitengela market (1,025.15±80.57 µg/Kg) and the lowest concentration was recorded in soil samples from Mavoko market (186.77±12.77 µg/Kg). The highest concentration of Pb was recorded in soil samples from Mavoko market at a concentration of 121.93±21.72 µg/Kg, while the levels of lead in soil from Kitengela farm was below the detection limit in. Cd was not detected in all the soil samples (Figure 4.20).

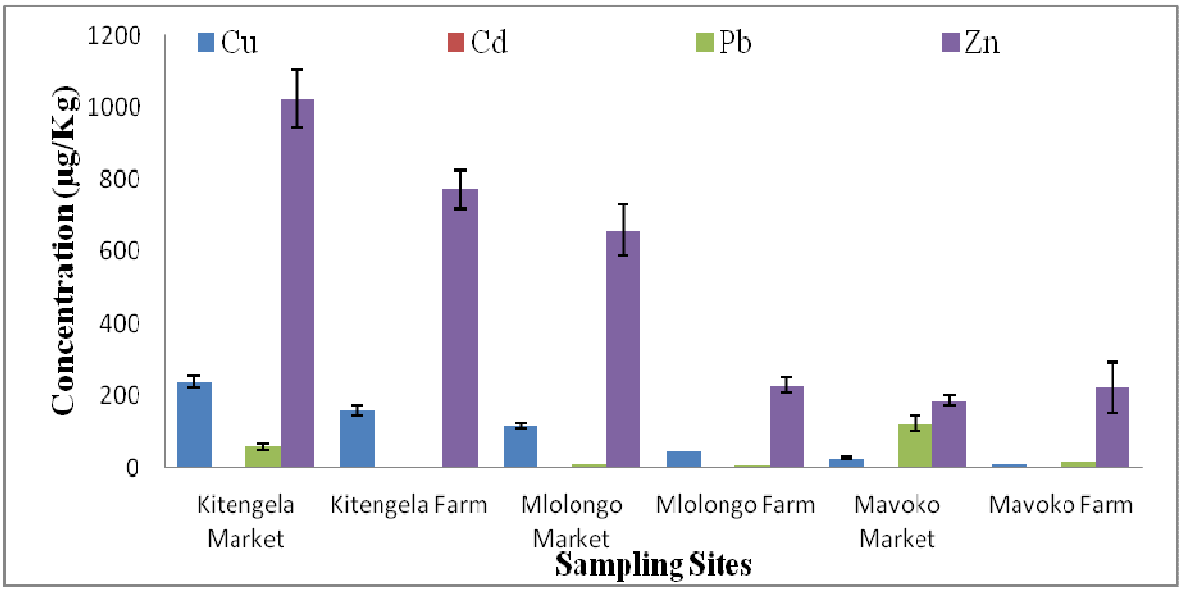


Figure 4. 20: Mean Concentration Heavy Metals in Soil in July, 2015

4.4.2.3 Concentration of Heavy metals in soil samples in December 2015

The concentration of Cu ranged between 120.85±6.67- 561.45±32.68 µg/Kg, the concentration of Zn ranged between 475.25±19.97-950.05±74.16 µg/Kg and Pb the concentration ranged between ND - 45.80±0.1 µg/Kg while Cd levels were below the detection limit of 0.60 µg/L. The magnitude of heavy metals concentration was in the order of Zn > Cu> Pb> Cd. All the metal analysed in all the six sampling sites were within the range of permitted levels by WHO (WHO, 2007).

4.4.2.4 Comparison of heavy metal in Soil from the six sites in December, 2015

Zinc had the highest concentration in all the sampling sites. This can be attributed to the use of inorganic fertilizer containing Zn by farmers. Cu was detected in all the soil samples with the highest concentration recorded in soil samples from Mavoko market (561.45±32.68 µg/Kg), while the lowest levels were recorded in soil from Kitengela market (120.85±6.67 µg/Kg). The highest concentration of Zn was recorded in soil samples from Mlolongo farm (950.05±74.16

µg/Kg) while the lowest concentration was recorded in soil from Kitengela market (475.25±19.97 µg/Kg). The highest concentration of Pb was recorded in soil samples from Kitengela market (45.80±0.1 µg/Kg) but the same was below the detection limit in Mavoko farm. Cd was not detected all soil samples (Figure 4.21).

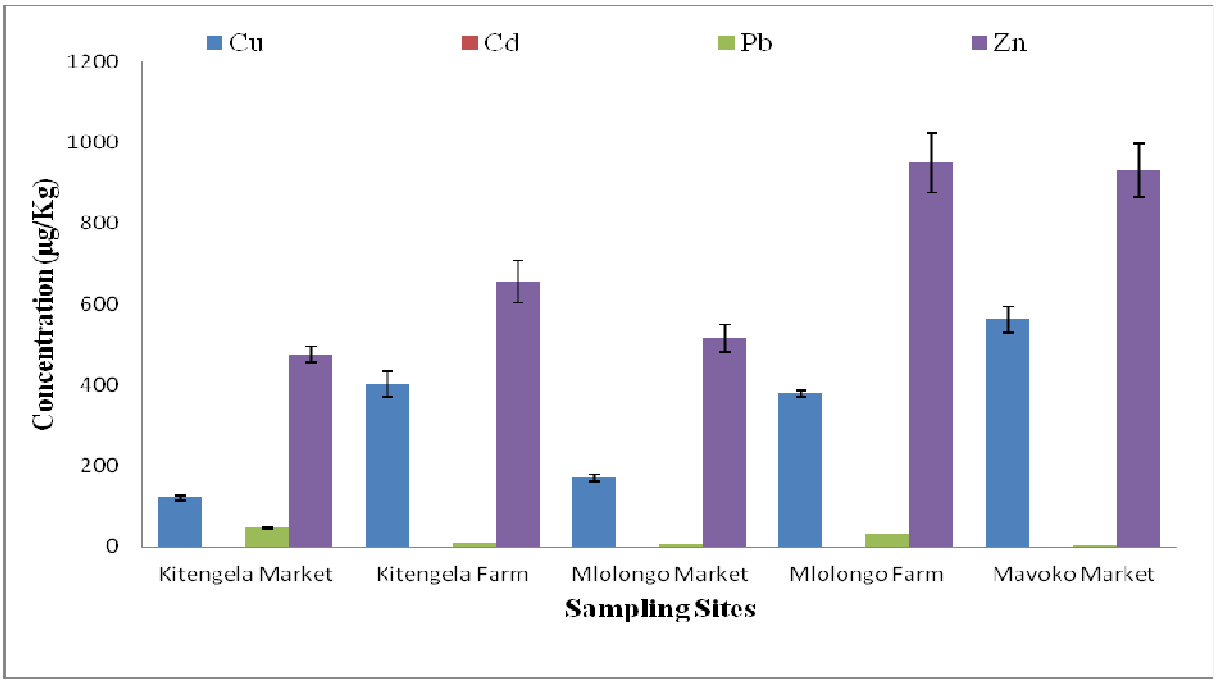


Figure 4. 21: Mean Concentration Heavy Metals in Soil in December, 2015

4.4.2.5 Concentration of Heavy metals in soil samples in February 2016

The analysis of soil samples from the three markets and three farms showed existence of heavy metal residues at varying concentrations. The concentration of Cu ranged between 7.23±0.89 - 323.18±6.52 µg/Kg, Zn ranged between 88.27±13.47- 997.28±51.76 µg/Kg, Pb ranged between 1.56±0.08-96.36±10.27 µg/Kg, while Cd was below the detection limits of 0.60 µg/L. The magnitude of heavy metals concentration was in the order of Zn > Cu> Pb> Cd. All the metal analysed in all the six sampling sites were within the maximum permitted levels by WHO (WHO, 2007).

4.4.2.6 Comparison of heavy metals in Soil from the Six sites in February 2016

Cu was detected in all the soil samples with the highest concentration recorded in soil from Kitengela market (323.18±6.52 µg/Kg), while the lowest concentration was recorded in soil from Mlolongo farm (7.23±0.89 µg/Kg). Zinc recorded the highest concentration in all the sampling sites, with the highest levels recorded in soil samples from Mlolongo farm (997.28±51.76 µg/Kg), while the lowest was recorded in soil from Mavoko market (88.27±13.47µg/Kg). The highest concentration of Pb was recorded in soil from Mavoko market (96.36±10.27 µg/Kg), while the lowest concentration was recorded in soil from Mlolongo farm (1.56±0.08 µg/Kg). Cd was below the detection limit in all the soil samples as shown in Figure 4.22.

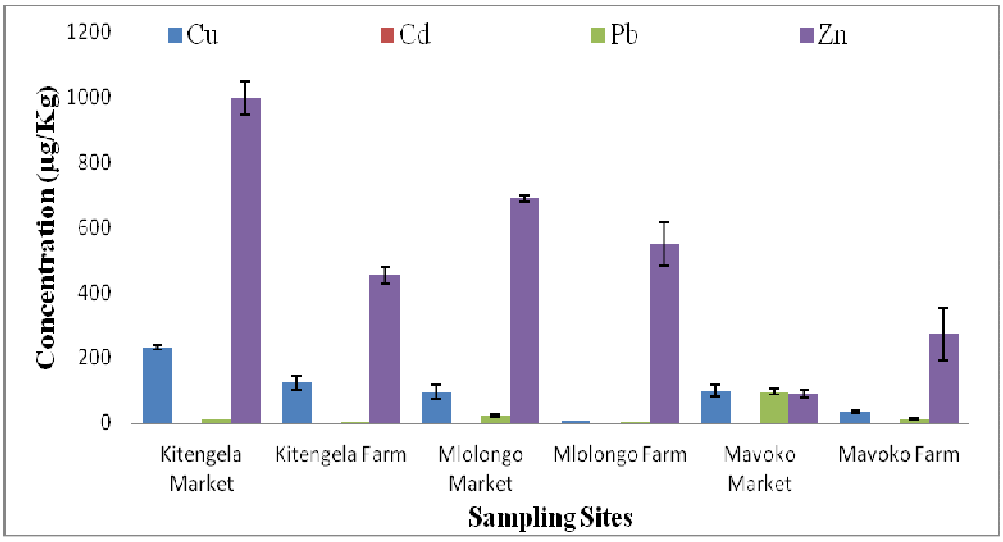


Figure 4. 22: Mean Concentration Heavy Metals in Soil in February, 2016

4.4.3 Concentration of Heavy metal in Kale samples (µg/kg)

The concentration of heavy metals in kale was analysed in samples from six sites during the months of July 2015, December 2015 and February 2016.

4.4.3.1 Concentration of Heavy metal in Kale Samples during Month of July, 2015

The analysis of kale samples from the three markets and three farms showed existence of heavy metals at varying concentrations. The concentration of Zn ranged between 8.26±0.99-225.91±10.81 µg/Kg, Pb ranged between ≤0.20-0.74±0.00 µg/Kg, while Cd and Cu were below the detection limits. The magnitude of heavy metals concentration was in the order of Zn > Pb> Cu = Cd. All the metal analysed in all the six sampling sites were within the permitted levels by WHO (WHO, 2007).

4.4.3.2 Comparison of heavy metal in Kales from the Six sites in July, 2015

Zinc recorded the highest concentration in kale from all the six sampling sites. The highest concentration was recorded in kale samples from Mavoko farm (225.91±10.81 µg/Kg), while the lowest concentration was recorded in kale samples from Mavoko market (8.26±0.99 µg/Kg). Pb was detected in kale from Mlolongo farm at concentration of 0.74±0.00 µg/Kg, while the rest of the sites recorded levels below the detection limit. Cd and Cu were below the detection limit in all the kale samples as shown in Figure 4.23.

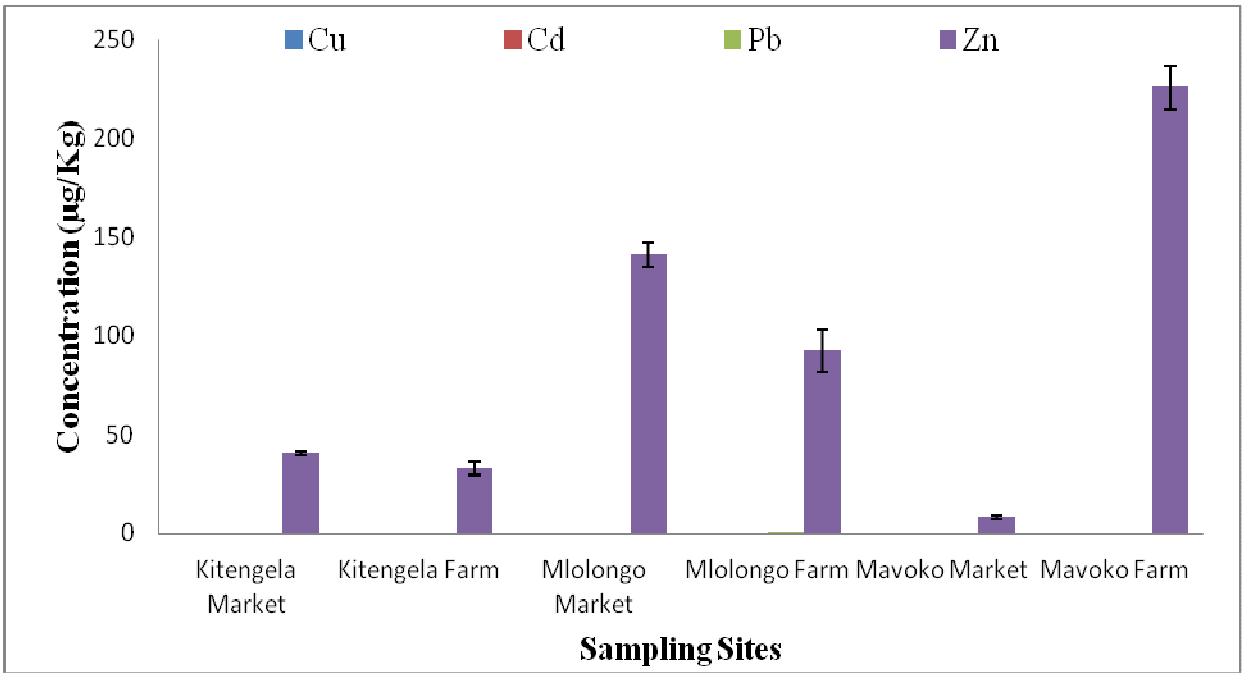


Figure 4. 23: Mean Concentration Heavy Metals in Kales in July, 2015

4.4.3.3 Concentration of Heavy metals in Kale samples in December, 2015

The concentration of Zn ranged between 138.07±22.97-627.15±56.10 µg/Kg, while Pb ranged between ≤0.20 - 87.28±10.57 µg/Kg. Cd and Cu were only detected at Mlolongo farm with cncentrations of 0.02±0.00 µg/Kg and 122.50±2.17 µg/Kg, respectively. The magnitude of heavy metals concentration was in the order of Zn > Pb> Cu> Cd. All the metal analysed in samples from all the six sites were within the permitted levels by WHO (WHO, 2007).

4.4.3.4 Comparison of heavy metal in Kales from the Six sites in December, 2015

Zinc metal recorded the highest concentration in all the sampling sites with the highest concentration recorded in kale from Kitengela market (627.15±56.10 µg/Kg), while the lowest was recorded in samples from Kitengela Farm (138.07±22.97 µg/Kg). The highest concentration of Pb was recorded at Mavoko farm (87.28±10.57 µg/Kg), but it was not detected in Mlolongo

farm samples. Cd and Cu were only detected in Mlolongo farm with concentration of 0.023±0.00 µg/Kg and 122.50±2.17 µg/Kg, respectively as shown in Figure 4.24.

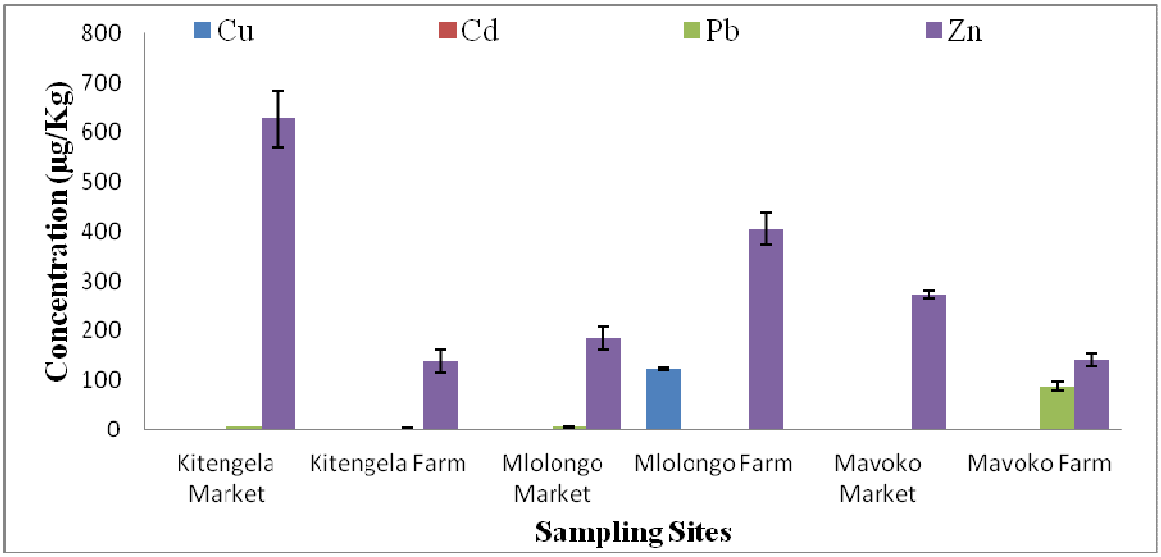


Figure 4. 24: Mean Concentration Heavy Metals in Kales in December, 2015

4.4.3.5 Concentration of Heavy metals in Kale samples in February, 2016

The concentration of Zn ranged between 19.30±0.08-716.09±56.10 µg/Kg, Pb ranged between 0.05±0.00-7.19±1.13 µg/Kg, while Cd and Cu were below detected limit in all the samples. However, the levels of heavy metals analysed in all the six sampling sites were within the permitted levels by WHO (WHO, 2007).

4.4.3.6 Comparison of heavy metal in Kales from the Six sites in February, 2016

Zn was detected in all the kale samples with the highest concentration recorded samples from Kitengela market (716.09±56.10 µg/Kg), while the lowest concentration was recorded in kale samples from Kitengela farm (14.37±0.17 µg/Kg). The highest concentration of Pb was recorded in samples from Mavoko farm (7.19±1.13 µg/Kg). lead was not detected in Mlolongo farm samples, while Cd and Cu were not detected at all samples from the six sites (Figure 4.25).

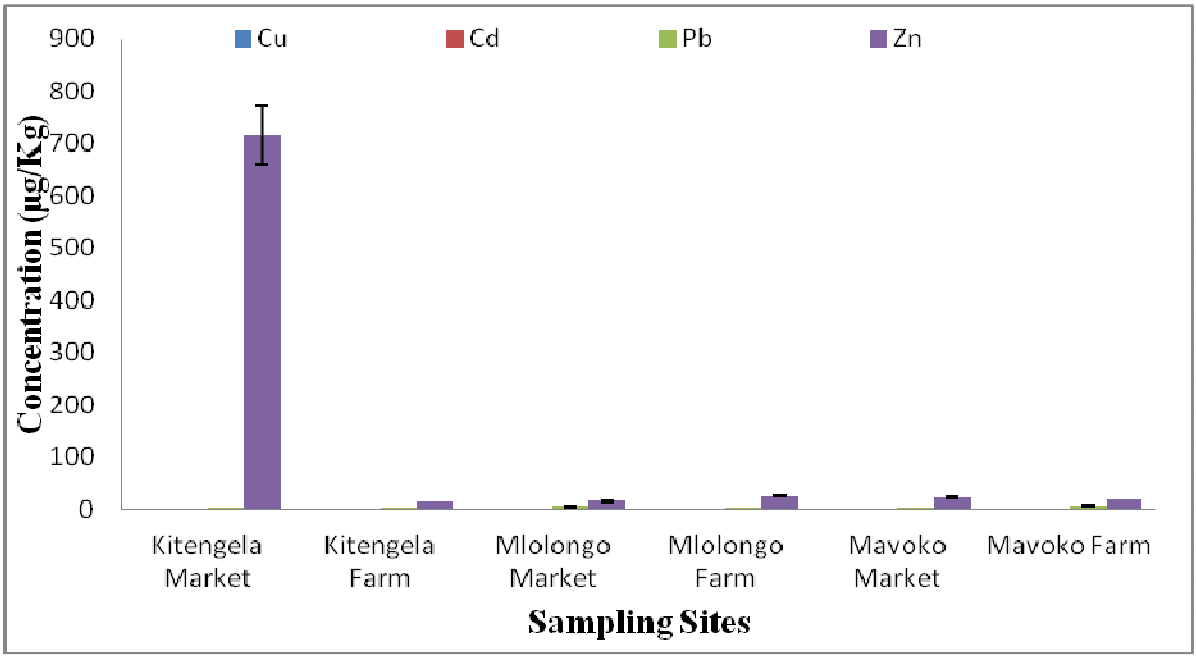


Figure 4. 25: Mean Concentration Heavy Metals in Kales in February, 2016

4.5 Pesticide residues

4.5.1 Quality Assurance and Quality Control

4.5.1.1 Instrument Calibration and Optimisation

The calibration curve of pesticides were developed based on concentrations ranging from 3.92 ng/ml to 94.60 ng/ml. All the calibration curves had a straight line with correlation factor (R^2) above 0.99. Calibration curves are shown in the appendix II Figures II. Sample 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=Analyte concentration, m=Gradient, and c= Constant.

4.5.1.2 Limits of Detection

Table 4.4 below shows the Limit of Detection (LOD) of the gas chromatography for various pesticides. The LOD of a compound is the lowest concentration of the analytes that the analytical process can reliably detect, but not necessarily quantitated as an exact value. It may be described as the concentration which gives a peak (Y) on the instrument which is different from the blank or background signal (Miller, 2004). The LOD of each of the OC Pesticides was calculated based on the lowest concentration of the calibration standards injected and the corresponding noise signals using the equation:

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

The limits of detection for OC Pesticides ranged from 0.001 µg/L for α HCH to 0.004 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 4.4: 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±0.0004		

Average= Mean ± S.D

4.5.1.3 OC Pesticide Recovery Levels

The average percetage recoveries of the 17 pesticides ranged from 70.01±4.21% for endrin to 114.83± 3.33% for dieldrin, respectively. The recoveries for the rest of the pesticides had values as summarised in Table 4.5.

Table 4.5: Average Percentage Recovery Tests for Selected Pesticides

Pesticide	Recovery(%±S.D)	Pesticide	Recovery(%±S.D)
α-HCH	94.82±8.31	Endosulfan sulfate	78.25± 6.00
β-HCH	87.52±4.09	Aldrin	94.26±5.23
γ-HCH	92.06±9.58	Dieldrin	114.83±3.33
δ-HCH	82.54±6.95	Endrin	70.01±4.21
p,p'-DDT	99.89±3.41	Endrin aldehde.	77.81±8.63
p,p'-DDE	78.35± 5.12	Heptachlor	92.08±4.56
p,p'-DDD	99.31±2.84	Heptachlor epoxide	98.35±2.45
α- endosulfan	102.58±4.95	Methoxychlor.	88.23±6.86
β-endosulfan	93.23±7.13		

Average= mean± S.D

4.5.2 Levels of Organochlorine Pesticides in Water

4.5.2.1 OC Pesticide in Water during Month of July, 2015

Organochlorine pesticide residues detected ranged between 0.0011±0.00 to 0.74±0.09 µg/L. DDT was the highest detected in water from Kitengela Farm. The mean concentration of ranged between 0.0011±0.00 - 0.02±0.00 µg/L for α-HCH, β-HCH (0.0016±0.00 - 0.01±0.00 µg/L), γ-HCH (0.0016±0.00 - 0.01±0.00 µg/L) and δ- HCH (BDL - 0.11±0.01 µg/L).

The Mean concentration of heptachlor ranged from 0.0011±0.00 -0.05±0.00 µg/L, aldrin (0.0036±0.00 - 0.02±0.00 µg/L), heptachlor epoxide (0.0011± 0.00 - 0.14±0.00 µg/L), α-endosulfan (0.0011± 0.00 - 0.03±0.00 µg/L), β-endosulfan (0.00016± 0.00-0.02±0.00 µg/L), dieldrin (0.0031±0.00 - 0.02±0.00 µg/L), endrin (0.0022±0.00 - 0.01±0.00 µg/L), endrin aldehyde (0.0022±0.00 - 0.20±0.05 µg/L), endosulphan sulfate (0.0021±0.00 - 0.04±0.00 µg/L) and methoxychlor (0.0016±0.00 - 0.11±0.00 µg/L).

Mean concentration of *p,p'*-DDT ranged between 0.0017±0.00-0.74±0.09 µg/L, while the mean concentration of its analogues isomers *p,p'*-DDE ranged between 0.0018±0.00 - 0.04±0.00 µg/L and *p,p'*-DDD was not detected.

4.5.2.2 Comparison of OCPs levels in water from different study sites in July 2015

p,p'-DDT (0.74±0.09 µg/L) was the highest pesticide residue detected at Kitengela farm, followed by heptachlor epoxide (0.15±0.00 µg/L), endrin aldehyde (0.20±0.05 µg/L), endosulfan sulfate (0.04±0.00 µg/L) and methoxychlor (0.11±0.00 µg/L). The rest had relatively low values. Water from Mavoko farm recorded the lowest levels of pesticide residues (Figure 4.26).

Presence of *p,p'*-DDT in the water samples could be majorly due to its persistence in the environment while the detection of *p,p'*-DDD suggested degradation of *p,p'*-DDT to *p,p'*-DDD. On the other hand, the isomers of HCH have high levels of biodegradability, high vapour pressures, high solubility in water and lesser particle attraction and lipophilicity than *p,p'*-DDT and its metabolites(Yang *et al.,* 2005).Therefore, these could quickly dissipate, leaving very little residues in water (Yang *et al.,* 2005).

High levels of methoxychlor in irrigation water (Figure 4.26) could be explained by the fact that some of the farms are located just a few metres from the river which they use its water to irrigate the vegetables. The waste water might eventually get back into the river causing pesticide contamination (ATSDR, 2002).

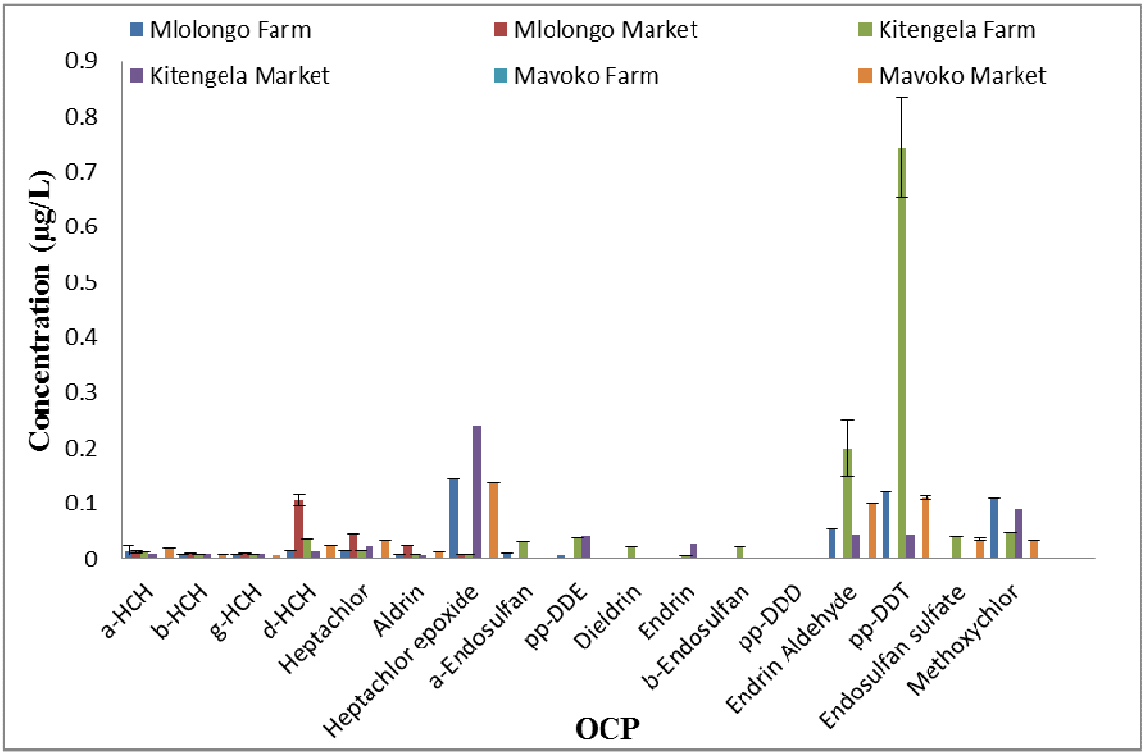


Figure 4. 26: Mean Concentrations of OC Pesticide in Irrigation Water During the month of July, 2015

4.5.2.3 OC Pesticide in Water during Month of December 2015

Organochlorine pesticide residues detected in water during the month of December ranged between <0.0011±0.00 to 2.26±0.02 µg/L. Aldrin was the highest detected at Mlolongo Farm. The mean concentration of Hexachlorocyclohexanes (HCH) isomers ranged between <0.0011±0.00 - 0.32±0.05 µg/L for α-HCH, β-HCH (<0.0016±0.00 -0.49±0.00 µg/L), γ-HCH (<0.0016±0.00 -1.51±0.06 µg/L), δ-HCH (BDL - 0.86±0.00 µg/L).

The Mean concentration of heptachlor ranged (<0.0011±0.00 -0.39±0.0 1µg/L), aldrin (<0.0036±0.00 - 2.26±0.02 µg/L), heptachlor epoxide (<0.0011±0.00 -0.01±0.00 µg/L), α-endosulfan (<0.0011±0.00 -0.15±0.00µg/L), β-endosulfan (<0.0011±0.00 - 0.21±0.00 µg/L), endrin (<0.0022±0.00 -0.08±0.00 µg/L), endrin aldehyde (<0.0022±0.00 - 0.62±0.06 µg/L),

endosulphan sulfate (<0.0022±0.00 -0.65±0.00 µg/L) and methoxychlor (<0.0016±0.00 - 0.92±0.00 µg/L) while dieldrin was not detected in all the samples.

Mean concentration of *p,p'*-DDT ranged between <0.0016±0.00 -0.46±0.00 µg/L and mean concentration of its analogues *p,p'*-DDD ranged between <0.0018±0.00 -0.06±0.00 µg/L and *p,p'*-DDE was not detected.

4.5.2.3 Comparison of OCPs concentration in Water samples from different sampling sites during the Month of December 2015

Aldrin (2.26±0.02 µg/L) at Mlolongo farm was the highest pesticide residue detected followed by γ-HCH (1.51±0.06 µg/L), methoxychlor (0.92±0.00 µg/L), endosulfan sulfate (0.65±0.00 µg/L) at Mlolongo farm site followed by endrin aldehyde (0.62±0.06 µg/L) at Mlolongo market, β-HCH (0.49±0.00 µg/L). The rest were relatively low (Figure 4.27).

From Figure 4.27 below, it can be observed that generally higher concentrations of OCPs were detected in December as compared to those detected in July and February. This could be explained by the fact that during the rainy season, pesticides are washed off from the farms into the water bodies by the rain. The presence of high amounts of aldrin in the environment that its degradation metabolite product dieldrin suggests current use of the insecticide.

Presence of higher levels of heptachlor epoxide as compared to heptachlor in water suggests degradation product of heptachlor. Similarly, the detection of higher amounts of endrin aldehyde as compared to endrin suggested decomposition of endrin to endrin aldehyde and its transportation from the farms to the water bodies.

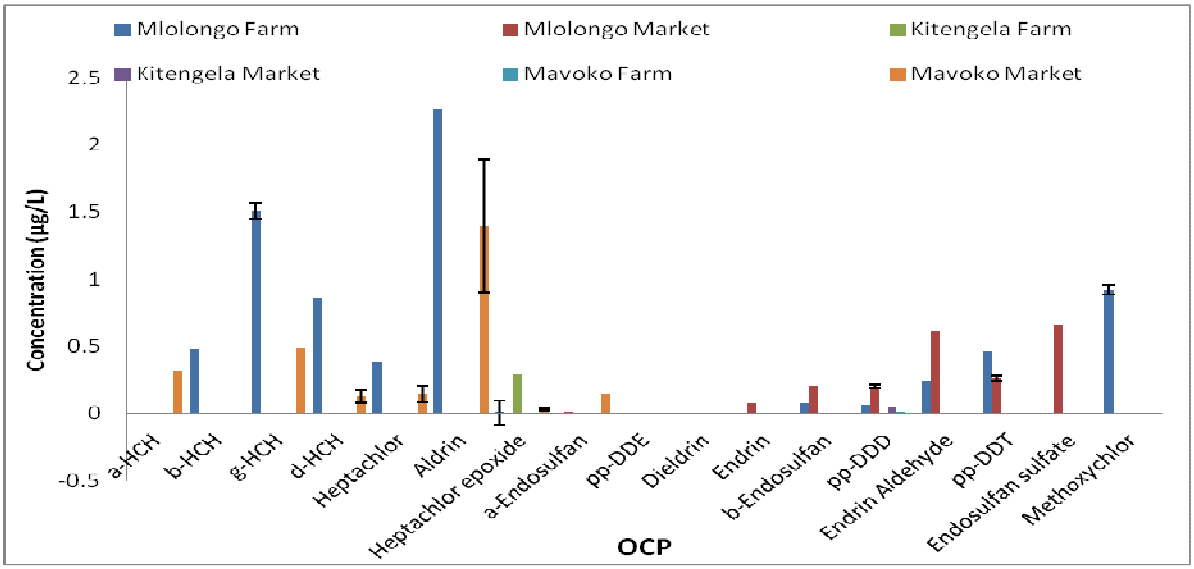


Figure 4. 27: Mean Concentrations of OC Pesticide in Irrigation Water in December, 2015

4.5.2.2 OC Pesticide in Water during Month of February 2016

Organochlorine pesticide residues detected in water in December ranged between <0.0011±0.00 to 3.53±0.99 µg/L. Aldrin was the highest detected in water at Mlolongo Farm. The mean concentration of Hexachlorocyclohexanes (HCH) isomers ranged between <0.0011±0.00 - 0.76±0.00 µg/L for α-HCH, β-HCH (<0.0016±0.00 -0.38±0.00 µg/L), γ-HCH (<0.0016±0.00 - 1.57±0.01 µg/L), δ- HCH (BDL - 0.26±0.00µg/L).

The Mean concentration of heptachlor ranged from <0.0011±0.00 - 0.302±0.00 µg/L, aldrin (<0.0036±0.00 - 3.53±0.99 µg/L), heptachlor epoxide (<0.0011±0.00 -1.08±0.07µg/L), α-endosulfan (<0.0011±0.00 - 0.71±0.00 µg/L), β-endosulfan (<0.0015±0.00 -0.21±0.06 µg/L) endrin (<0.0022±0.00 -0.08±0.00 µg/L), endrin aldehyde (<0.0022±0.00 - 1.47±0.00 µg/L), endosulphan sulfate (<0.0021±0.00 -0.05±0.00 µg/L) and methoxychlor (<0.0016±0.00 - 0.67±0.01 µg/L), while dieldrin was not detected in all the sites.

The mean concentration of *p,p'*-DDT ranged between <0.0017±0.00 -0.48±0.00 µg/L, while the mean concentration of its analogues *p,p'*-DDD ranged between BDL-<0.0018±0.00 ±0.00 µg/L. *p,p'*-DDE was not detected.

4.5.2.3 Comparison of OCPs levels in Water from different sampling sites in February 2016

Aldrin had the highest pesticide residue levels (3.53±0.99 µg/L) detected in water from Mlolongo farm, followed by γ-HCH (1.57±0.01 µg/L), methoxychlor (0.92±0.00 µg/L) and endosulfan sulfate (0.65±0.00 µg/L) in Mlolongo farm water, followed by endrin aldehyde at 0.62±0.06 µg/L in Mlolongo market water and β-HCH (0.49±0.00 µg/L). The rest of the pesticides were below detection limit (Figure 4.28).

The presence of high amounts of aldrin in the environment than its degradation metabolite product dieldrin suggests current use of the insect side. Presence of higher levels of heptachlor epoxide as compared to heptachlor in water suggests degradation product of heptachlor. Similarly, the detection of higher amounts of endrin aldehyde as compared to endrin suggested decomposition of endrin to endrin aldehyde and its transportation from the farms to the water bodies.

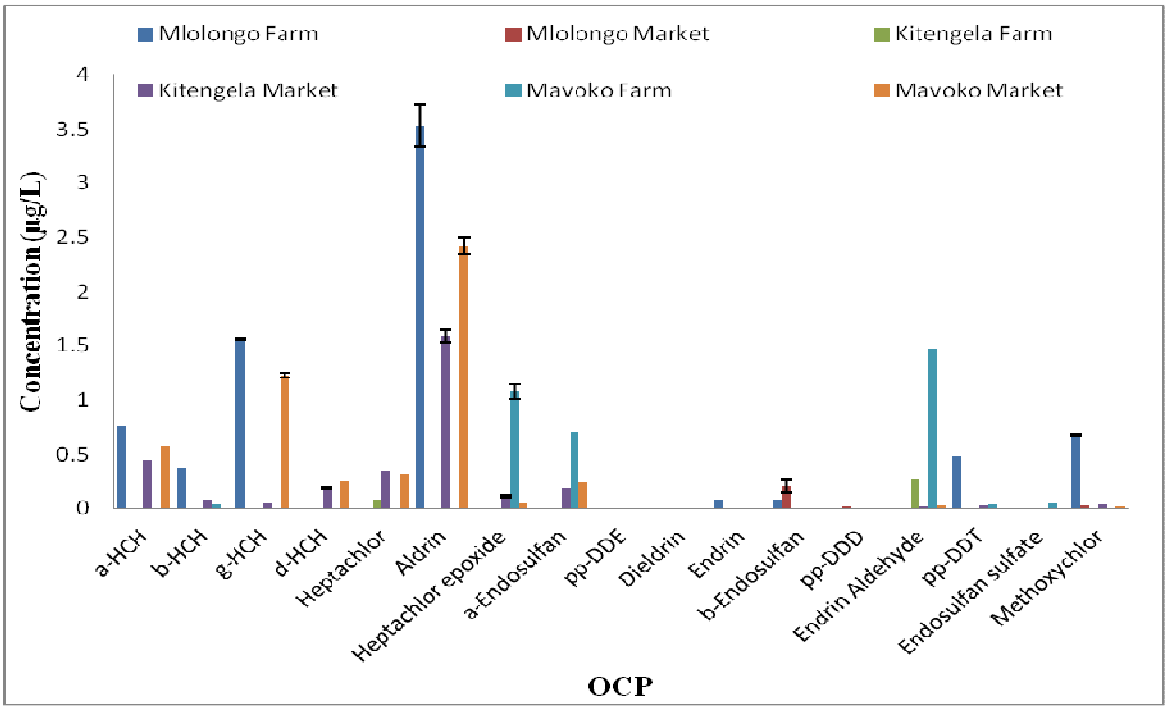


Figure 4. 28: Mean Concentrations of OC Pesticide in irrigation Water in February, 2016

4.5.2.4 Seasonal variation of OCPs concentration in water samples from the three sampling sites

December recorded the highest mean concentration of OCPs followed by July and February. 63.25% of OCPs analysed had higher concentrations in December compared to July. High concentration of OCPs in December (wet season) could be attributed to soil erosion and surface runoff.

The high levels of OCPs detected in the irrigation water during wet season could have been attributed to runoff, desorption from sediments and wet deposition. In the environment, aldrin breaks down slowly by oxidation to dieldrin with the metabolite having equally slow degradation rate. This explains the large amount of aldrin in water compared to its metabolite.

However, OCPs residues in water in both dry and wet seasons were below the World Health Organization (WHO) permissible limits for drinking water in all samples signifying low risks to the end users (IUPAC, 2003).

4.5.2.5 Spatial Distribution of OCPs in water samples from the three sampling sites.

Figure 4.29 shows the average OC Pesticides in irrigation water sampled from the three farms. It was notable that the highest detected OC Pesticides level in water samples was aldrin in water from Mlolongo farm while dieldrin was below the detection limit in all the sampling points except Kitengela farm (Figure 4.29).

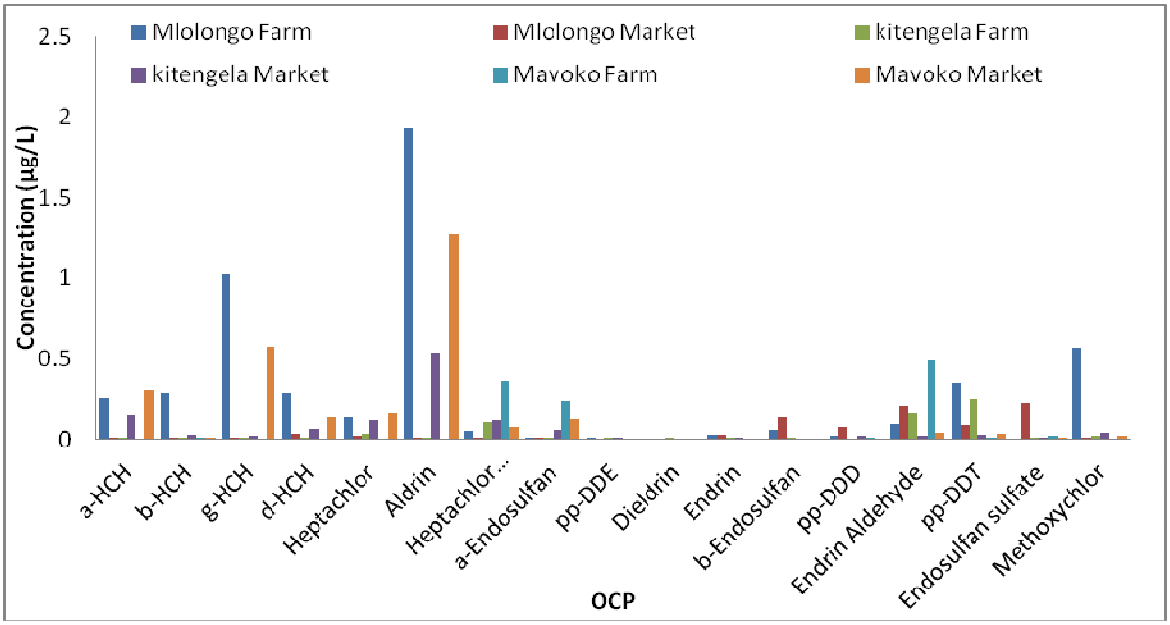


Figure 4.29: Average OCPs in irrigation water samples from the six sampling sites.

4.5.3 Levels of Organochlorine Pesticides in Soil

The average pesticides levels ranged from below detection limits (<0.0011±0.00) to 170.53±3.25 µg/Kg. The highest concentration was recorded in soil samples collected during the month of February from Mavoko market site.

4.5.3.1 OC Pesticide in Soil during Month of July, 2015

OCPs residues detected in soil in July ranged between <0.0011±0.00 to 137.63±7.57 µg/Kg. Heptachlor epoxide was the highest detected at Mavoko market. The mean concentration of Hexachlorocyclohexanes (HCH) isomers ranged between 2.20±0.26- 114.84±28.49 µg/Kg for α-HCH, β-HCH (1.82±0.29-68.25±17.81µg/Kg), γ-HCH (1.57±0.22- 4.81±1.83 µg/Kg), δ-HCH (1.93± 4.83±0.35 µg/Kg).

The Mean concentration of heptachlor ranged from 2.53±0.57-59.95±5.91 µg/Kg, aldrin (1.47±0.04-4.71±0.71µg/Kg), heptachlor epoxide (1.71±0.03-137.63±7.57 µg/Kg), α-endosulfan (<0.0017±0.00 -22.346±0.06µg/Kg), β-endosulfan (<0.0018±0.00 -3.56±0.03 µg/Kg), endrin (<0.0022±0.00 - 36.46±0.95 µg/Kg), endrin aldehyde (<0.0022±0.00 -11.37±3.67 µg/L), endosulphan sulfate (2.71±0.63-17.93±1.60 µg/Kg), dieldrin (<0.0011±0.00 -12.76±3.30 µg/Kg) and methoxychlor (<0.0016±0.00 - 33.05±1.45 µg/Kg). The mean concentration of *p,p'*-DDT ranged between <0.0017±0.00 -30.10±2.44 µg/Kg, while the mean concentration of its analogues *p,p'*-DDE ranged between <0.0018±0.00 -46.19±6.90 µg/Kg and *p,p'*-DDD was not detected.

4.5.3.2 Comparison of OCPs concentration in Soil samples from different sampling sites in July 2015

Heptachlor epoxide had the highest concentration with 137.63±7.57 µg/Kg soil from Mavoko market followed by a-HCH (114.84±28.49 µg/Kg) at Mavoko market, β- HCH (68.25±17.81 µg/Kg), heptachlor (59.95±5.91 µg/Kg), *p,p'*-DDE (46.19±6.90 µg/Kg), endrin (36.46±0.95 µg/Kg), methoxychlor (33.05±1.45 µg/Kg) (Figure 4.31).

The observed residue levels of the three isomers of HCH could be associated with the use of lindane in the area. In some of the sites, higher levels of heptachlor were detected as compared to those of its metabolic product heptachlor epoxide suggesting illegal application on the farms.

The existence of isomeric residue of endosulfan in the collected soil samples relates to use of the technical products in the area

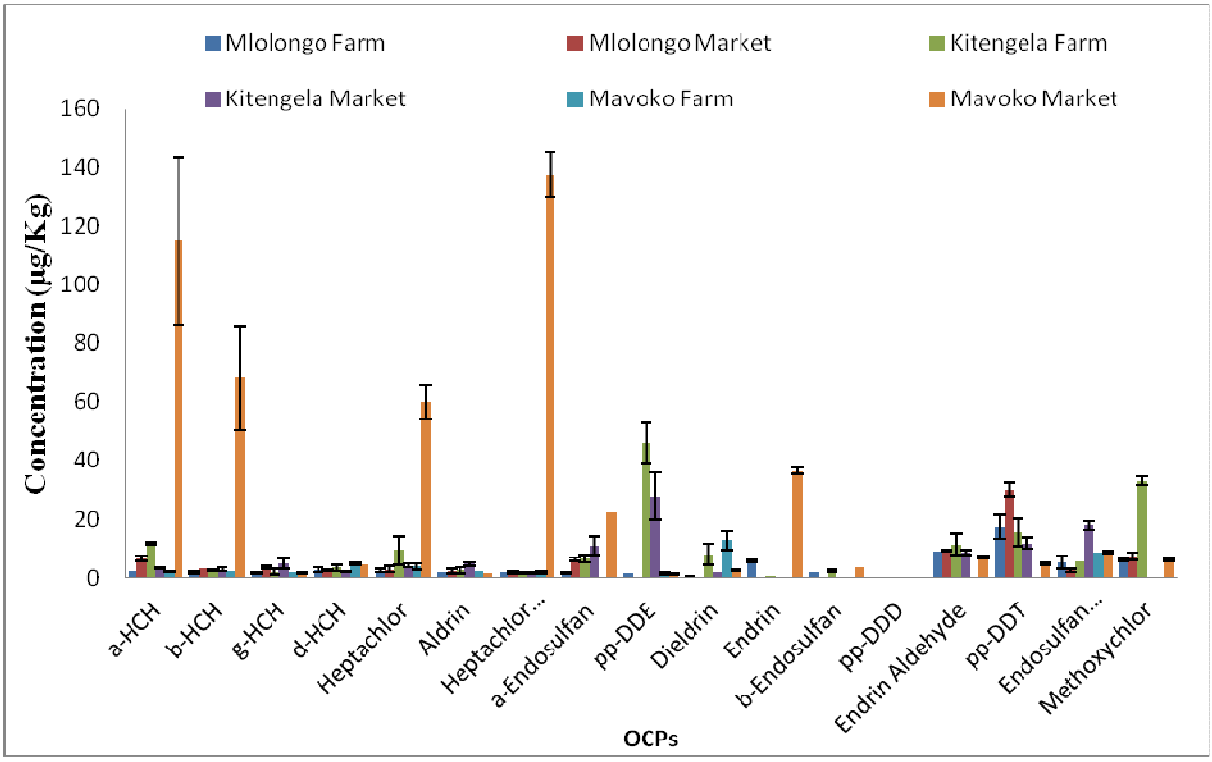


Figure 4. 30: Mean Concentration of OC pesticides in soil in July, 2015

4.5.3.3 OC Pesticide in Soil during Month of December 2015

Organochlorine pesticide residues ranged between BDL and 119.46±3.41µg/Kg. Aldrin was the highest detected at Mavoko market. The total OCPs in soil from the six sampling sites are presented in table 4.21. The mean concentration of Hexachlorocyclohexanes (HCH) isomers ranged between α-HCH (BDL - 9.29±0.02 µg/Kg), β-HCH (BDL- 12.59±0.16 µg/Kg), g-HCH (BDL - 12.63±0.46 µg/Kg), d- HCH (BDL- 2.59±0.02 µg/Kg).

The Mean concentration of heptachlor ranged (0.42±0.00- 1.91±0.04 µg/Kg), aldrin (BDL-119.46±3.41 µg/Kg), heptachlor epoxide (BDL-4.10±0.00 µg/Kg), α-endosulfan (BDL-

47.31±3.24 µg/Kg), β-endosulfan (BDL-12.13±1.02 µg/Kg), endrin (BDL-10.09±0.81µg/Kg), endrin aldehyde (BDL-19.65±0.55 µg/Kg), endosulphan sulfate (BDL-22.78±3.18 µg/Kg), dieldrin (BDL- 2.01±0.00 µg/Kg) and methoxychlor (BDL- 55.81±1.65 µg/Kg).

The mean concentration of *p,p'*-DDT ranged between BDL-59.49±2.98 µg/Kg, while the concentration of its analogues *p,p'*-DDE ranged between BDL - 15.63±0.94 µg/Kg) and *p,p'*-DDD between BDL-20.31±2.34 µg/Kg.

4.5.3.4 Comparison of OCPs Concentration in soil from different sampling sites in December 2015

Aldrin registered the highest mean concentration with 119.46±3.41 µg/Kg at Mavoko market followed by *p,p'*-DDT (59.49±2.98 µg/Kg) at Mavoko farm, methoxychlor (55.81±1.65 µg/Kg), heptachlor (59.95±5.91 µg/Kg), *p,p'*-DDE (46.19±6.90 µg/Kg), α-endosulphan (47.31±3.24 µg/Kg) and endosulphan sulphate (22.78±3.18 µg/Kg) (Figure 4.32).

High levels of aldrin detected in some sites as compared to dieldrin levels suggested potential illegal use or transportation by runoff during the rainy season also high levels of *p,p'*–DDT detected in some sites as compared to its metabolites DDD and DDE levels suggested potential illegal use or transportation by runoff during the rainy season. The presence of the three isomers of HCH measured were attributed to previous use of γ-HCH. Higher levels of heptachlor epoxide were detected as compared to those heptachlor suggesting degradation of heptachlor to the metabolite heptachlor epoxide. The existence of isomeric remains of endosulfan in the soil samples suggested use of the technical products in that area. On the other hand, higher residues of dieldrin were detected in most of the sampling sites as compared to aldrin suggesting decomposition of aldrin to dieldrin.

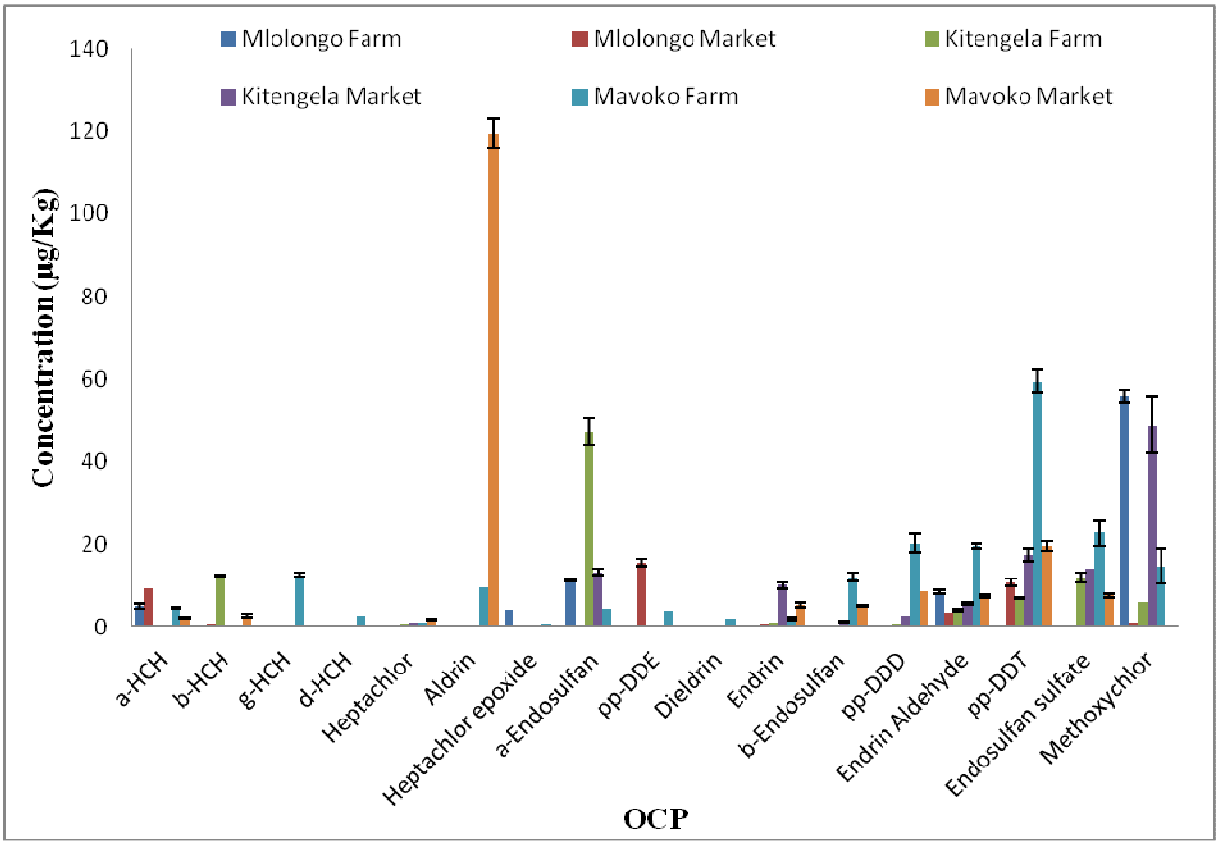


Figure 4. 31: Mean Concentration of OC pesticides in soil during the Month of December, 2015

4.5.3.5 OC Pesticide in Soil during Month of February 2016

Organochlorine pesticide residues detected in soil during the month of February ranged between BDL to 170.53±3.25 µg/Kg. α-endosulphan was the highest detected at Mavoko market. Hexachlorocyclohexanes (HCH) isomers ranged between <0.0011±0.00 -1.82±0.03 µg/Kg for α-HCH, β-HCH (<0.0011±0.00 -2.81±0.02 µg/Kg), γ-HCH (<0.0011±0.00 -14.37±0.33 µg/Kg), δ-HCH (BDL- 12.35±1.13 µg/Kg).

The Mean concentration of heptachlor ranged between <0.0011±0.00 -15.06±0.86 µg/Kg, aldrin (<0.0036±0.00 - 158.67±8.94 µg/Kg), heptachlor epoxide (<0.0011±0.00 -0.47±0.08 µg/Kg), α-

endosulfan (<0.0018±0.00 -170.53±3.25 µg/Kg), β-endosulfan (<0.0017±0.00 -12.13±1.31 µg/Kg), endrin (<0.0022±0.00 -12.62±1.46 µg/Kg), endrin aldehyde (<0.0022±0.00 -25.63±0.65 µg/Kg), endosulphan sulfate (<0.0021±0.00 -75.47±6.53 µg/Kg), dieldrin (<0.0032±0.00 -2.01±0.05 µg/Kg) and methoxychlor (<0.0016±0.00 -42.63±2.58 µg/Kg). Mean concentration of *p,p'*-DDT ranged between (<0.0018±0.00 -43.04±9.01 µg/Kg) and mean concentration of its analogues *p,p'*-DDE ranged between (<0.0017±0.00 -2.01±0.05 µg/Kg) and *p,p'*-DDD (<0.0018±0.00 -27.47±6.64 µg/Kg).

4.5.3.6 Comparison of OCPs Concentration in Soil samples from different sampling sites in February 2016

The mean concentration of α-endosulfan (170.53±3.25 µg/Kg) at Mavoko market was the highest pesticide residue detected followed by aldrin (158.67±8.94 µg/Kg) at Mlolongo market, endosulphan sulphate (75.47±6.53 µg/Kg) and methoxychlor (42.63±2.58 µg/Kg) (Figure 4.33).

The existence of isomeric remains of endosulfan in the soil samples suggested use of the technical products in that area also the metabolite endosulfan sulphate shows the degradation of endosulfan. Higher *p,p'*-DDT residue levels were noted in most of the sites as compared to those of p,p'-DDD this could be attributed to illegal use of *p,p'*-DTT. For endrin and endrin aldehyde residues, a similar situation as that observed in December. Endrin aldehyde was more pre-dominant suggesting degradation of endrin.

The observed residue levels of the three isomers of HCH could be associated with the use of lindane in the area. In some of the sites, higher levels of heptachlor were detected as compared to those of its metabolic product heptachlor epoxide suggesting illegal application on the farms.

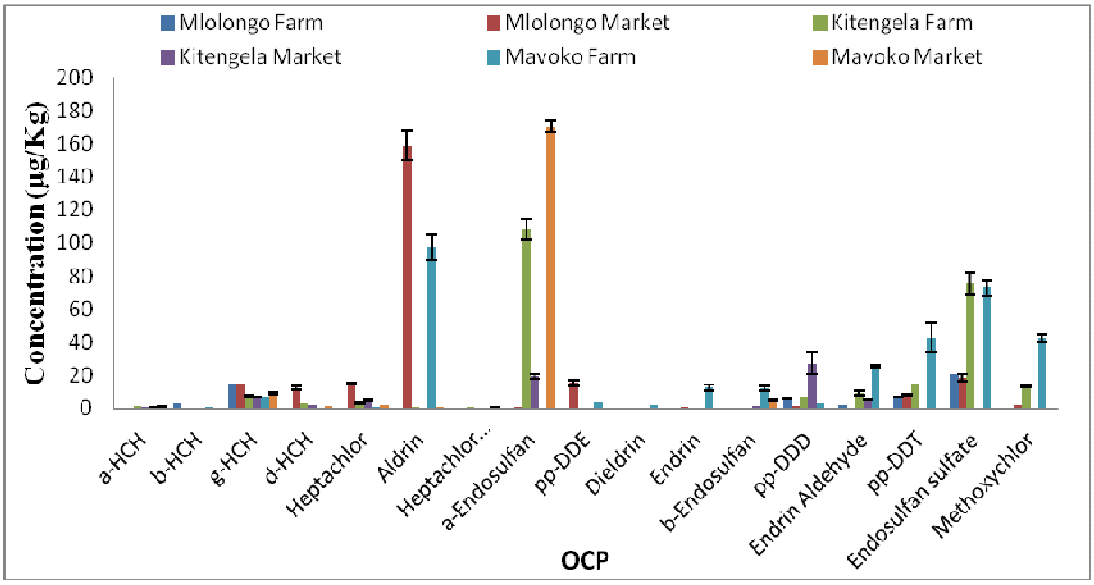


Figure 4. 32: Mean Concentration of OC pesticides in soil in February, 2016

4.5.4 Levels of Organochlorine Pesticides in Vegetables

The average pesticides levels in kales ranged from below detection limits (<0.0011±0.00) to 322.55±8.84 µg/Kg. The highest concentration was recorded in vegetable samples collected from Mavoko market in February 2016.

4.5.4.1 OC Pesticide residues in kale during Month of July, 2015

OCPs residues in vegetabes in July ranged between <0.0011±0.00 to 58.01±3.34 µg/Kg. Heptachlor epoxide was the highest detected at Mavoko farm. The mean concentration of Hexachlorocyclohexanes (HCH) isomers ranged between 2.20±0.26- 114.84±28.49 µg/Kg for α-HCH, β-HCH (1.82±0.29-68.25±17.81 µg/Kg), γ-HCH (1.57±0.22- 4.81±1.83 µg/Kg), δ-HCH (1.93± 0.01 - 4.83±0.35 µg/Kg).

The Mean concentration of heptachlor ranged from 2.53±0.57-59.95±5.91 µg/Kg), aldrin (1.47±0.04-4.71±0.71 µg/Kg), heptachlor epoxide (1.71±0.03-137.63±7.57 µg/Kg), α-endosulfan (<0.0011±0.00 -22.35±0.06 µg/Kg), β-endosulfan (<0.0015±0.00 -3.56±0.03 µg/Kg), endrin (<0.0022±0.00 -36.46±0.95 µg/Kg), endrin aldehyde (<0.0022±0.00 -11.37±3.67 µg/L), endosulphan sulfate (2.71±0.63-17.93±1.60 µg/Kg), dieldrin (<0.0031±0.00 -12.76±3.30 µg/Kg) and methoxychlor (<0.0016±0.00 - 33.05±1.45 µg/Kg).

The mean concentration of *p,p'*-DDT ranged between <0.0017±0.00 -30.10±2.44 µg/Kg, while concentration of its analogues *p,p'*-DDE ranged between <0.0018±0.00 -46.19±6.90 µg/Kg and *p,p'*-DDD was not detected.

4.5.4.2 Comparison of OCPs Concentration in Vegetable samples from different sampling sites in July 2015

The mean concentration of endosulphan sulphate was the highest at 82.57±0.00 µg/Kg detected in vegetables from Mavoko farm, followed by methoxychlor (64.36±6.96 µg/Kg), heptachlor epoxide (58.01±3.34 µg/Kg), endrin aldehyde (17.05±1.42 µg/Kg), *p,p'*-DDE (16.38±1.81 µg/Kg) and *p,p'*-DDT (13.03±0.71 µg/Kg) (Figure 4.34).

The high concentration of α-HCH detected in the vegetables was much higher than the set maximum limits of 0.01µg/kg (Codex, 2009). The high concentration of α-HCH could be an indication of more HCHs originating from atmospheric deposition and long-term degradation of γ-HCH and α-HCH which is also a known metabolite under environmental conditions.

The occurrence of *p,p'*-DDT and *p,p'*-DDD in the kales may indicate the slow break down of *p,p'*-DDT in the environment or illegal recent use (Yuan *et al.,* 2001). The presence of *p,p'*-DDD

in some of the vegetable samples suggest environmental degradation of *p,p'*- DDT to p,p'-DDD. The high concentration of methoxychlor was detected in kale samples, the source of these compounds could not be immediately established, but its presence could be attributed to long range transport and atmospheric deposition. Methoxychlor is documented to undergo slow breakdown in soil, water and air by microscopic organisms and sunlight (Wauchope *et al.,* 1992), which can take several months.

The predominance of endrin aldehyde is an indication of the degradation of endrin to endrin aldehyde. Similarly, the predominance of dieldrin suggests the degradation of aldrin to dieldrin. All the isomers of endosulfan (endosulfan 1 and endosulfan 2) were detected. A high concentration of endosulfan 2 was detected in kale this could be attributed to longer persistence of endosulphan 2 and endosulphan sulphate. Endosulphan I readily decompose and does not build up in the environment the way other organochlorine pesticides do (Cremlyn, 1991).

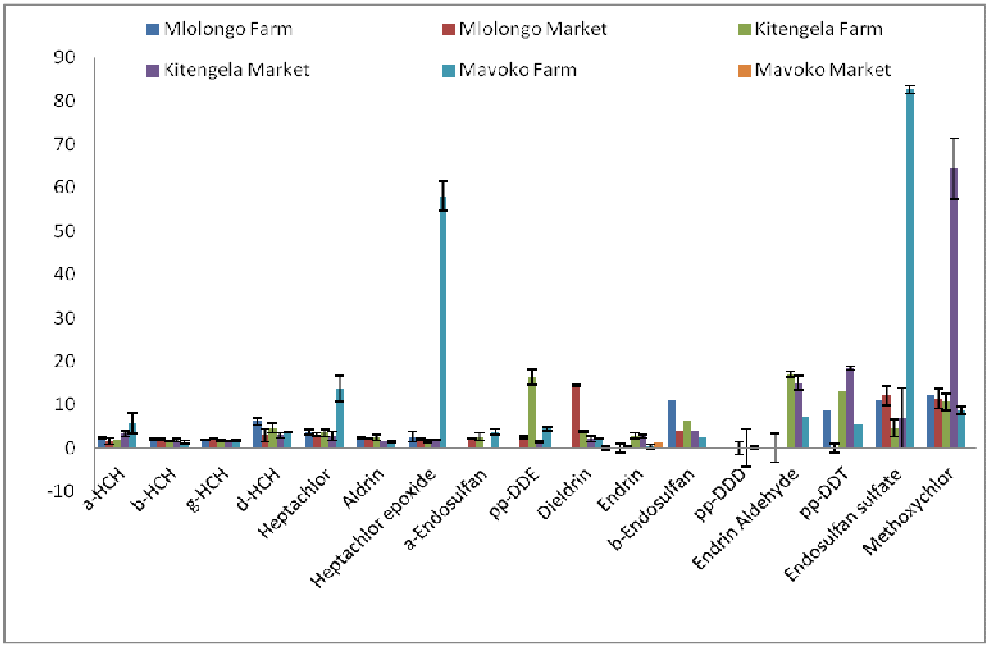


Figure 4. 33: Mean Concentration of OCPs in Kales in July, 2015

4.5.4.3 OC Pesticide in Vegetable in December 2015

OCPs residues detected in vegetabes in December ranged between BDL to 202.37±7.69 µg/Kg. Methoxychlor was the highest detected in kales from Mavoko farm. The mean concentration of methoxychlor highest measured (202.37±7.69 µg/Kg) in kales from Mavoko farm followed by δ-HCH (158.02±6.92 µg/Kg), γ-HCH (143.04±8.81 µg/Kg), α-HCH (115.30±2.25 µg/Kg), endosulphan sulphate (111.65±10.49 µg/Kg), endrin aldehyde (78.42±8.28 µg/Kg) and p,p'-DDT (76.43±2.91 µg/Kg). *p,p'*-DDE, dieldrin and β-endosulphan were not detected (Figure 4.35).

4.5.4.4 Comparison of OCPs concentrations in kales from different sampling sites in December, 2015

The presence of Methoxychlor in the kale samples (Figure 4.35) is explained by the fact that it slowly breaks down in soil, water and air and it may take several months. This explains its

presence in the kales. It's presence in the kale samples from Kihoto market suggests recent use. For the two conformational isomers of endosulphan (endosulphan 1 and endosulphan 2), the same scenario is seen as that observed during the first sampling (July). This gives an indication of recent use in farms where these vegetables had been grown because endosulfan readily degrades and does not have a tendency to build up in the environment the way other organochlorines do (Cremlyn, 1991).

From Figure 4.35, it can be observed that α-BHC, β-BHC and δ-BHC, were found in kales from some of the sites. DDT was found in kales collected from each of the sampling sites. The presence of DDT is an indication that it degrades slowly in the environment or there has been a recent illegal use (Yuan *et al.,* 2001). The presence of *p,p'*-DDD in some of the kale samples suggests environmental degradation of *p,p'*- DDT to *p,p'*-DDD and thus its occurrence in the kales. A similar scenario is seen in the vegetable samples collected in July as well as in February where *p,p'*-DDE was below detection limit in vegetables from all the sites suggesting slow degradation of *p,p'*-DDD to *p,p'*-DDE. While endrin aldehyde was detected in some of the sites, endrin was not detected in all the sites.

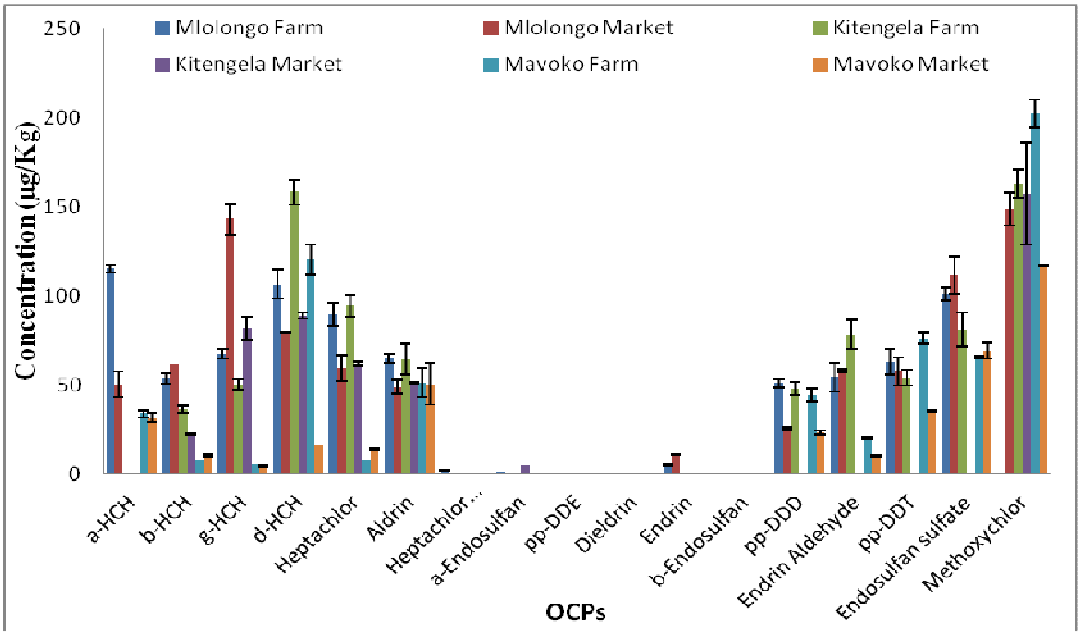


Figure 4. 34: Mean Concentration of OC pesticides in Kales in December, 2015

4.5.4.5 OC Pesticide in kales during Month of February, 2016

Organochlorine pesticide residues detected in vegetabes during the month of February ranged between <0.0011±0.00 to 322.55±8.84 µg/Kg. *p,p'*-DDD was the highest detected in kales from Kitengela market.

4.5.4.6 Comparison of OCPs Concentration in Vegetable samples from different sampling sites in February 2016

The mean concentration of *p'p'*-DDD was 322.55±8.80 µg/Kg in kales from Kitengela market followed by methoxychlor (312.20±34.07 µg/Kg), heptachlor (291.94±24.17 µg/Kg), endosulphan sulphate (276.58±5.73 µg/Kg), endrin aldehyde (255.98±15.81 µg/Kg), β-HCH (250.31±22.75 µg/Kg) and *p,p'*-DDT (219.20±5.47 µg/Kg). *p,p'*-DDE, dieldrin and endrin were not detected (Figure 4.36).

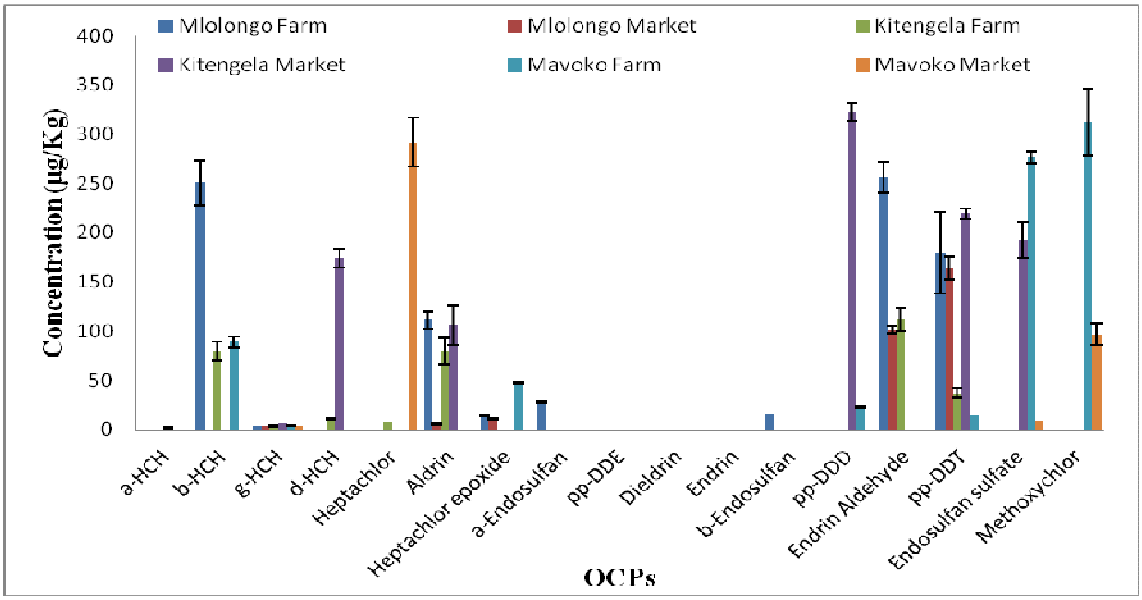


Figure 4. 35: Mean Concentration of OC pesticides in Kales in February, 2016

4.6 Correlations

Correlation analysis was carried out for organochlorine pesticides, heavy metal, microbial contaminants and physico-chemical parameters in water, soil and kales. SPSS was applied for determination of Pearson's correlation coefficients which have numerical values (r) ranging between -1.00 to +1.00 (APA, 2001).

4.6.1. Correlation of Heavy Metal in Water, Soil and Kales

There was a weak positive correlation of heavy metals in soil and water as indicated by positive Pearson r values of 0.12. Heavy metal in water and kales showed positive correlation r values of 0.17, while the heavy metals in soil were negatively correlated with the heavy metal in kales as indicated by negative Pearson r values of -0.41. Table 4.6 6shows a correlation of levels of heavy metals in water, kales and soil samples

Table 4.6: Correlation of levels of Heavy Metal in water, Kales and soil

		Heavy Metal in Water	Heavy Metal in Soil	Heavy Metal in Kales
Heavy Metal in Water	Pearson Correlation	1	.123	.170
	Sig. (2-tailed)		.817	.748
	N	6	6	6
	Sig. (2-tailed)	.266	.310	.074
	N	6	6	6
Heavy Metal in Soil	Pearson Correlation	.123	1	-.405
	Sig. (2-tailed)	.817		.426
	N	6	6	6
	Sig. (2-tailed)	.670	.017	.650
	N	6	6	6
Heavy Metal in Kales	Pearson Correlation	.170	-.405	1
	Sig. (2-tailed)	.748	.426	
	N	6	6	6
	N	6	6	6

4.6.2 Correlation of Heavy Metal in Water with OCPs

During the month of July, 2015, there was a direct relationship between the heavy metal concentrations in water with organochlorine pesticide concentration as indicated by a positive r value of 0.80 for July, 0.65 for December and 0.57 for February 2016. Table 4.7 below shows a correlation of levels of heavy metals in water and levels of organochlorine pesticides.

Table 4.7: Correlation of levels of heavy metals in water and levels of organochlorine pesticides

		Heavy Metal in water in July	Heavy Metal in water in December	Heavy Metal in water in February	OCPs in water in July	OCPs in water in December	OCPs in water in February
Heavy Metal in water in July	Pearson Correlation	1	-.139	-.543	.801	-.450	-.687
	Sig. (2-tailed)		.793	.266	.056	.370	.132
	N	6	6	6	6	6	6
Heavy Metal in water in December	Pearson Correlation	-.139	1	.491	-.193	.645	.025
	Sig. (2-tailed)	.793		.323	.714	.167	.963
	N	6	6	6	6	6	6
Heavy Metal in water in February	Pearson Correlation	-.543	.491	1	-.582	.585	.567
	Sig. (2-tailed)	.266	.323		.226	.223	.241
	N	6	6	6	6	6	6
OCPs in water in July	Pearson Correlation	.801	-.193	-.582	1	-.052	-.217
	Sig. (2-tailed)	.056	.714	.226		.923	.679
	N	6	6	6	6	6	6
OCPs in water in December	Pearson Correlation	-.450	.645	.585	-.052	1	.736
	Sig. (2-tailed)	.370	.167	.223	.923		.095
	N	6	6	6	6	6	6
OCPs in water in February	Pearson Correlation	-.687	.025	.567	-.217	.736	1
	Sig. (2-tailed)	.132	.963	.241	.679	.095	
	N	6	6	6	6	6	6

4.6.3 Correlation of Heavy Metal in Water with Microbial Contamination

In February, 2015, the correlation between heavy metals in water and *E. Coli* was positive with r value of 0.35, while there was a weak negative correlation between heavy metals and *E. Coli* in water was observed in July and December, 2015 (r values of -0.45 and -0.21, respectively). Table 4.8 shows the correlation of heavy metal concentration with *E. Coli* in water.

Table 4.8: Correlation of heavy metal concentration with *E. Coli* in water

		Heavy Metal in water in July	Heavy Metal in water in December	Heavy Metal in water in February	E-Coli in water in July	E-Coli in water in December	E-Coli in water in February
Heavy Metal in water in July	Pearson Correlation	1	-.139	-.543	-.450	-.392	.116
	Sig. (2-tailed)		.793	.266	.371	.442	.827
	N	6	6	6	6	6	6
Heavy Metal in water in December	Pearson Correlation	-.139	1	.491	-.176	-.205	-.198
	Sig. (2-tailed)	.793		.323	.738	.697	.707
	N	6	6	6	6	6	6
Heavy Metal in water in February	Pearson Correlation	-.543	.491	1	.583	.535	.351
	Sig. (2-tailed)	.266	.323		.224	.274	.496
	N	6	6	6	6	6	6
E-Coli in water in July	Pearson Correlation	-.450	-.176	.583	1	.997**	.830*
	Sig. (2-tailed)	.371	.738	.224		.000	.041
	N	6	6	6	6	6	6
	Sig. (2-tailed)	.447	.272	.760	.217	.191	.480
	N	6	6	6	6	6	6
E-Coli in water in December	Pearson Correlation	-.392	-.205	.535	.997**	1	.858*
	Sig. (2-tailed)	.442	.697	.274	.000		.029
	N	6	6	6	6	6	6
	Sig. (2-tailed)	.719	.368	.858	.030	.018	.054
	N	6	6	6	6	6	6
E-Coli in water in February	Pearson Correlation	.116	-.198	.351	.830*	.858*	1
	Sig. (2-tailed)	.827	.707	.496	.041	.029	
	N	6	6	6	6	6	6
	Sig. (2-tailed)	.632	.521	.540	.004	.002	.017
	N	6	6	6	6	6	6

February 2016 experienced a positive correlation between heavy metals and coliforms with r value of 0.32 while negative correlation was observed in July and December, 2015 with r values of -0.39 and -0.45, respectively. Table 4.9 shows the correlation of heavy metals and coliform in water.

Table 4.9: Correlation of heavy metal concentration with the number of coliform in water

		Heavy Metal in water in July	Heavy Metal in water in December	Heavy Metal in water in February	Coliform in Water in July	Coliform in Water in December	Coliform in Water in February
Heavy Metal in water in July	Pearson Correlation	1	-.139	-.543	-.388	-.190	-.251
	Sig. (2-tailed)		.793	.266	.447	.719	.632
	N	6	6	6	6	6	6
Heavy Metal in water in December	Pearson Correlation	-.139	1	.491	-.537	-.452	-.332
	Sig. (2-tailed)	.793		.323	.272	.368	.521
	N	6	6	6	6	6	6
Heavy Metal in water in February	Pearson Correlation	-.543	.491	1	-.161	.095	.317
	Sig. (2-tailed)	.266	.323		.760	.858	.540
	N	6	6	6	6	6	6
	Sig. (2-tailed)	.371	.738	.224	.217	.030	.004
	N	6	6	6	6	6	6
Coliform in Water in July	Pearson Correlation	-.388	-.537	-.161	1	.844*	.681
	Sig. (2-tailed)	.447	.272	.760		.035	.136
	N	6	6	6	6	6	6
	Sig. (2-tailed)	.442	.697	.274	.191	.018	.002
	N	6	6	6	6	6	6
Coliform in Water in December	Pearson Correlation	-.190	-.452	.095	.844*	1	.952**
	Sig. (2-tailed)	.719	.368	.858	.035		.003
	N	6	6	6	6	6	6
	Sig. (2-tailed)	.827	.707	.496	.480	.054	.017
	N	6	6	6	6	6	6
Coliform in Water in February	Pearson Correlation	-.251	-.332	.317	.681	.952**	1
	Sig. (2-tailed)	.632	.521	.540	.136	.003	
	N	6	6	6	6	6	6

4.6.4 Correlation of Heavy Metals with physico-chemical parameters

In July 2015, heavy metals were negatively correlated with pH, TSS, conductivity and TDS as indicated by negative Pearson coefficient value of -0.15, -0.54, -0.25 and -0.25, respectively. Table 4.10 shows the correlation of heavy metal concentration with physico-chemical parameters of water in July, 2015.

Table 4.10: Correlation of heavy metals with physico-chemical parameters of water in July, 2015

		Heavy Metal in water in July	TDS of Water in July	Conductivity in Water in July	pH of Water in July	TSS of Water in July
Heavy Metal in water in July	Pearson Correlation	1	-.248	-.252	-.598	-.143
	Sig. (2-tailed)		.635	.631	.210	.786
	N	6	6	6	6	6
TDS of Water in July	Pearson Correlation	-.248	1	1.000**	.745	.909*
	Sig. (2-tailed)	.635		.000	.089	.012
	N	6	6	6	6	6
Conductivity in Water in July	Pearson Correlation	-.252	1.000**	1	.749	.911*
	Sig. (2-tailed)	.631	.000		.087	.012
	N	6	6	6	6	6
pH of Water in July	Pearson Correlation	-.598	.745	.749	1	.803
	Sig. (2-tailed)	.210	.089	.087		.054
	N	6	6	6	6	6
TSS of Water in July	Pearson Correlation	-.143	.909*	.911*	.803	1
	Sig. (2-tailed)	.786	.012	.012	.054	
	N	6	6	6	6	6

The correlation between heavy metals and water pH was positive with r value of 0.05, while TSS, conductivity and TDS showed negative correlation of -0.01,-0.56 and -0.50 respectively. At high pH some metals like cadmium and lead precipitate forming complexation products which influence metal toxicity by chemical speciation in water and sediment. During dry season, heavy metal concentrations are reduced from water to sediment through precipitation and sedimentation (Rashed, 2001).Table 4.11 below shows the correlation of heavy metal concentration with physico-chemical parameters of water in December, 2015.

Table 4. 11: Correlation of heavy metals with physico-chemical parameters of water in December, 2015

		Heavy Metal in water in December	TDS of Water in December	Conductivity in Water in December	pH of Water in December	TSS of Water in December
Heavy Metal in water in December	Pearson Correlation	1	-.559	-.499	.055	-.008
	Sig. (2-tailed)		.249	.313	.917	.989
	N	6	6	6	6	6
TDS of Water in December	Pearson Correlation	-.559	1	.961**	.119	.788
	Sig. (2-tailed)	.249		.002	.822	.063
	N	6	6	6	6	6
Conductivity in Water in December	Pearson Correlation	-.499	.961**	1	.294	.869*
	Sig. (2-tailed)	.313	.002		.572	.025
	N	6	6	6	6	6
pH of Water in December	Pearson Correlation	.055	.119	.294	1	.357
	Sig. (2-tailed)	.917	.822	.572		.487
	N	6	6	6	6	6
TSS of Water in December	Pearson Correlation	-.008	.788	.869*	.357	1
	Sig. (2-tailed)	.989	.063	.025	.487	
	N	6	6	6	6	6

In February, 2016 heavy metals concentration in water had a positive correlation with pH, TSS, TDS and conductivity with r values of 0.37, 0.53, 0.14 and 0.14, respectively. Table 4.12 shows the correlation of heavy metals with physico-chemical parameters of water in February, 2016.

Table 4.12: Correlation of heavy metals with physico-chemical parameters of water in February, 2016

		Heavy Metal in water in February	TDS of Water in February	Conductivity in Water in February	pH of Water in February	TSS of Water in February
Heavy Metal in water in February	Pearson Correlation	1	.137	.139	.368	.526
	Sig. (2-tailed)		.796	.793	.473	.284
	N	6	6	6	6	6
TDS of Water in February	Pearson Correlation	.137	1	1.000**	.427	.699
	Sig. (2-tailed)	.796		.000	.398	.122
	N	6	6	6	6	6
Conductivity in Water in February	Pearson Correlation	.139	1.000**	1	.426	.699
	Sig. (2-tailed)	.793	.000		.400	.123
	N	6	6	6	6	6
pH of Water in February	Pearson Correlation	.368	.427	.426	1	.892*
	Sig. (2-tailed)	.473	.398	.400		.017
	N	6	6	6	6	6
TSS of Water in February	Pearson Correlation	.526	.699	.699	.892*	1
	Sig. (2-tailed)	.284	.122	.123	.017	
	N	6	6	6	6	6

4.6.5 Correlation of OCPs across matrices

OCPs in water had a positive correlation with those in soil (0.25) and negative correlation with those in kales (-0.69). Pesticides are washed off the soil to the water bodies hence the positive correlation. Table 4.13 illustrates the correlation of OCPs concentration in water, kales and soil. A positive correlation of OCPs during wet season indicates that at high concentration, OCPs are released from the soil to sediment by leaching and surface runoff. They are also released from sediment to water by desorption, redistribution and resuspension.

Table 4.13: correlation of OCPs concentration in water, kales and soil

		OCPs in Soil	OCPs in water	OCPs in Kales
OCPs in Soil	Pearson Correlation	1	.249	-.693
	Sig. (2-tailed)		.635	.127
	N	6	6	6
	Sig. (2-tailed)	.995	.662	.522
	N	6	6	6
OCPs in water	Pearson Correlation	.249	1	-.313
	Sig. (2-tailed)	.635		.545
	N	6	6	6
	Sig. (2-tailed)	.733	.679	.688
	N	6	6	6
OCPs in Kales	Pearson Correlation	-.693	-.313	1
	Sig. (2-tailed)	.127	.545	
	N	6	6	6
	Sig. (2-tailed)	.404	.618	.308
	N	6	6	6

4.6.5 Correlation of OCPs with Microbial

OCPs in kales had a negative correlation with the number of coliforms (-0.63) and negative correlation with *E. Coli* in kales (-0.24). Table 4.14 illustrates the correlation of OCPs concentration in kales with the number of *E. Coli* and coliforms in kales.

Table 4. 14: Correlation of OCPs in kales with E. Coli and coliforms in kales

		OCP in Kales in	E-coli in Kales	Coliform in Kales
OCP in Kales	Pearson Correlation	1	-.238	-.632
	Sig. (2-tailed)		.650	.178
	N	6	6	6
	Sig. (2-tailed)	.308	.862	.426
	N	6	6	6
E-coli in Kales	Pearson Correlation	-.238	1	-.467
	Sig. (2-tailed)	.650		.350
	N	6	6	6
Coliform in Kales	Pearson Correlation	-.632	-.467	1
	Sig. (2-tailed)	.178	.350	
	N	6	6	6

There was a direct relationship of the concentration of OCPs in soil with the number of coliform in soil as indicated by positive Pearson r value 0.133 while the OCPs concentration in Soil had no relationship with the number of E-coli as indicated by a negative Pearson r value of -0.24. Table 4.15 illustrates the correlation of OCPs concentration in soil with the number of *E. Coli* and coliforms in soil.

Table 4.15: correlation of OCPs with the *E-coli* and coliforms in soil

		OCP in Soil	E-coli in soil	Coliform in soil
OCP in Soil	Pearson Correlation	1	-.242	.133
	Sig. (2-tailed)		.644	.801
	N	6	6	6
E-coli in soil	Pearson Correlation	-.242	1	-.331
	Sig. (2-tailed)	.644		.522
	N	6	6	6
Coliform in soil	Pearson Correlation	.133	-.331	1
	Sig. (2-tailed)	.801	.522	
	N	6	6	6

The OCPs correlation with *E. Coli* and coliform showed a negative r value of -0.64 and -0.31, respectively suggesting that increase in OCPs levels had a negative effect on coliforms. Table 4.16 shows the correlation of OCPs with *E. Coli* and coliforms.

Table 4.16: Correlation of OCPs with the number of *E.Coli* and coliforms in water

		OCPs in Water	E-coli in water	Coliform in Water
OCPs in Water	Pearson Correlation	1	-.643	-.306
	Sig. (2-tailed)		.168	.555
	N	6	6	6
E-coli in water	Pearson Correlation	-.643	1	.590
	Sig. (2-tailed)	.168		.217
	N	6	6	6
Coliform in Water	Pearson Correlation	-.306	.590	1
	Sig. (2-tailed)	.555	.217	
	N	6	6	6

4.6.6 Correlation between OCPs and physico-chemical parameters

OCPs concentration in water negatively correlated with pH, TSS, conductivity and TDS as with r values of -0.77, -0.61, -0.49 and -0.49, respectively, for July, 2015 samples. Table 4.17 illustrates the correlation of OCPs concentration in water with the physico-chemical parameters in July, 2015.

Table 4.17: Correlation of OCPs concentration in water with the physic-chemical parameters during the month of July, 2015

		OCPs in Water in July	pH of water in July	TDS of Water in July	Conductivity in water in July	TSS of Water in July
OCPs in Water in July	Pearson Correlation	1	-.770	-.491	-.494	-.607
	Sig. (2-tailed)		.073	.322	.320	.201
	N	6	6	6	6	6
pH of water in July	Pearson Correlation	-.770	1	.745	.749	.830*
	Sig. (2-tailed)	.073		.089	.087	.041
	N	6	6	6	6	6
TDS of Water in July	Pearson Correlation	-.491	.745	1	1.000**	.960**
	Sig. (2-tailed)	.322	.089		.000	.002
	N	6	6	6	6	6
Conductivity in water in July	Pearson Correlation	-.494	.749	1.000**	1	.960**
	Sig. (2-tailed)	.320	.087	.000		.002
	N	6	6	6	6	6
TSS of Water in July	Pearson Correlation	-.607	.830*	.960**	.960**	1
	Sig. (2-tailed)	.201	.041	.002	.002	
	N	6	6	6	6	6

In December, 2015 OCPs residues negatively correlated with TSS, conductivity and TDS with r values of -0.06, -0.33 and -0.43, respectively. However, pH positively correlated with the OCPs in water with r value of 0.33. Table 4.18 illustrates the correlation of OCPs with the physico-chemical parameters in water in December, 2015.

Table 4.18: Correlation of OCPs in water with the physico-chemical parameters in December, 2015

		OCPs in Water in December	pH of water in December	TDS of Water in December	Conductivity of water in December	TSS of Water in December
OCPs in Water in December	Pearson Correlation	1	.332	-.433	-.328	-.055
	Sig. (2-tailed)		.520	.391	.525	.918
	N	6	6	6	6	6
pH of water in December	Pearson Correlation	.332	1	.119	.294	.357
	Sig. (2-tailed)	.520		.822	.572	.487
	N	6	6	6	6	6
TDS of Water in December	Pearson Correlation	-.433	.119	1	.961**	.788
	Sig. (2-tailed)	.391	.822		.002	.063
	N	6	6	6	6	6
Conductivity in water in December	Pearson Correlation	-.328	.294	.961**	1	.869*
	Sig. (2-tailed)	.525	.572	.002		.025
	N	6	6	6	6	6
TSS of Water in December	Pearson Correlation	-.055	.357	.788	.869*	1
	Sig. (2-tailed)	.918	.487	.063	.025	
	N	6	6	6	6	6

In February 2016, OCPs in water negatively correlated with pH, conductivity and TDS with values of -0.12, -0.26 and -0.26, respectively. TSS was positively correlated with OCPs in water with r values of 0.08. Table 4.19 illustrates the correlation of OCPs with the physico-chemical parameters in February, 2016.

Table 4.19: Correlation of OCPs concentration in water with the physic-chemical parameters during the month of February, 2016

		OCPs in Water in December	pH of water in December	TDS of Water in December	Conductivity in water in December	TSS of Water in December
OCPs in Water in December	Pearson Correlation	1	-.119	-.258	-.256	.082
	Sig. (2-tailed)		.822	.622	.625	.878
	N	6	6	6	6	6
pH of water in December	Pearson Correlation	-.119	1	.427	.426	.892*
	Sig. (2-tailed)	.822		.398	.400	.017
	N	6	6	6	6	6
TDS of Water in December	Pearson Correlation	-.258	.427	1	1.000**	.699
	Sig. (2-tailed)	.622	.398		.000	.122
	N	6	6	6	6	6
Conductivity in water in December	Pearson Correlation	-.256	.426	1.000**	1	.699
	Sig. (2-tailed)	.625	.400	.000		.123
	N	6	6	6	6	6
TSS of Water in December	Pearson Correlation	.082	.892*	.699	.699	1
	Sig. (2-tailed)	.878	.017	.122	.123	
	N	6	6	6	6	6

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Majority of urban farmers in Nairobi metropolitan area are female and are illiterate or semi-literate with only basic primary education. The frequently used class of pesticides in Nairobi Metropolitan is pyrethroids, organophosphates, organosulfur and carbamates, all are registered by PCPB. The farmers have basic training on the use of pesticide which they have been trained by agricultural extension officers, agrochemical dealers and the agrochemical industries workers.

Microbial contaminants in water, kales and soil were high. Water samples the highest number of total coliforms was 3,797±119 cfu/ml recorded at Mlolongo farm in February and E-coli the highest number was 89±5 cfu/ml recorded at Mlolongo farm in December. Soil samples the highest number of total coliforms was 3,214±284 cfu/g recorded at Mlolongo farm and E-coli the highest number was 145±8 cfu/g recorded at Kitengela farm. Kale samples the highest number of total coliforms was 353±19 cfu/g recorded at Mlolongo market in December and E-coli the highest number was 13±2 cfu/g recorded at Mlolongo farm in December.

Significant amount of heavy metals (cadmium, copper, zinc and lead) in water, vegetable and soil samples were detected in Nairobi metropolitan. Water samples the highest concentration of Cu, Pb, Zn and Cd was 98.50±10.47 µg/L, 8.60±0.00 µg/L, 302.87±11.24 µg/L and ≤0.60 µg/L respectively. Soil samples the highest concentration of Cu, Pb, Zn and Cd was 239.56±16.25 µg/Kg, 121.93±21.72 µg/Kg, 1,025.15±80.57 µg/Kg and ≤0.60 µg/Kg respectively. Kales samples the highest concentration of Cu, Pb, Zn and Cd was ≤0.60 µg/Kg, 0.74±0.00 µg/Kg,

225.91±10.81 µg/Kg and ≤0.60 µg/Kg respectively All the heavy metals analysed were within the WHO guideline in water, soil and vegetables.

Organochlorine pesticide residues of heptachlor epoxide, *p,p'*-DDE, *p,p'*-DDT, γ-HCH, *p,p'*-DDD, aldrin, δ-HCH, dieldrin, α-endosulphan, β-endosulphan, α-HCH, methoxychlor β-HCH, heptachlor, endrin and endrin aldehyde were detected at varying concentrations in water, kale and soil samples from Nairobi Metropolitan area. In water samples Aldrin was the detected in February with concentration levels of 3.528±0.99µg/L at Mlolongo farm. In soil samples Aldrin was the highest detected pesticide in the month of February with concentration level of 158.667±8.94 µg/Kg at Mlolongo market. Vegetable samples, Aldrin was the highest detected pesticide in the month of February with concentration level of 322.554±8.84 µg/Kg Kitengela market. The OCPs residues were all below the IUPAC maximum limits.

5.2 Recommendations

5.2.1 Policy Recommendations

High level of illiteracy was detected amongst the farmers during this study hence awareness campaigns should be conducted to educate the farmers on safe use of pesticides and their adverse environmental and human health impacts. These should be done with the help of the agrochemical industries, government and NGOs.

Farmers and vegetable sellers should be trained on safe handling of vegetables to prevent microbial contaminations.

Policy makers should put in place a regular environmental monitoring program and mitigation strategies of reducing the pollutants especially from water, and general management of water quality status within the Nairobi metropolitan.

There should be a follow up on the compounds banned or restricted to ensure that they are not illegally used.

5.2.2 Research Recommendations

Further research should be carried out to determine point and nonpoint sources of OCP in aquatic environment.

Additional study should be carried out to determine amounts and fate of pesticides that are commonly used in the area.

Further research should be conducted on human beings and animal to determine the levels of pesticides exposure.

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APPENDICES

Appendix I: QUESTIONNAIRE

The following questionnaire was prepared by a student from University of Nairobi to identify the type of pesticides used by the farmers in the vegetable farms and the frequency of application in Kitengela, Mlolongo, Athi River area. Your co-operation in completing this study by responding to the following questions will be greatly appreciated.

SECTION A

Personal Information about the farmers

- What is your gender?

  Male ☐ Female ☐

- What is your age? (Optional)

  24-29 ☐ 30-34 ☐ 35-40 ☐ Above 45 ☐

  Below 23

- What is your educational level?

  Primary ☐ Secondary ☐ College ☐

  University ☐

- Which is your highest professional qualification?

  Certificate ☐ Diploma ☐ Degree ☐

  Masters ☐ PhD ☐

- For how long have you been cultivating vegetables in your farms?

SECTION B

Types of pesticides used by the farmer

1. Which type of pesticides do you normally use in your farm?

   a)……..

   b)…….

   c)……

   d)……

2. How many times do you apply pesticides in your farm?

……..

……..

……..

3. Have you been trained on the safe handling of the agrochemicals such as pesticides?

YES ☐ NO ☐

If yes, when was it and it was conducted by who?

……

……

4. Do you follow re-entry period and Pre-harvest intervals after the chemical application?

YES NO ☐

If no give a reason

……..

……..

5. Which type of fertilizers and chemicals do you apply?

……

……

6. Do you follow fertilizer and chemicals application as recommended?

YES ☐ NO ☐

If no explain or give a reason.

SECTION C

Market and the effects of consuming the vegetables

1. Where do you supply or sell your vegetables to?

……

……..

2. What are effects of consuming the vegetables?

a)……

b)……..

c)……

SECTION D

Source of water for Irrigation

1. Where do you get the water for irrigating your farm?

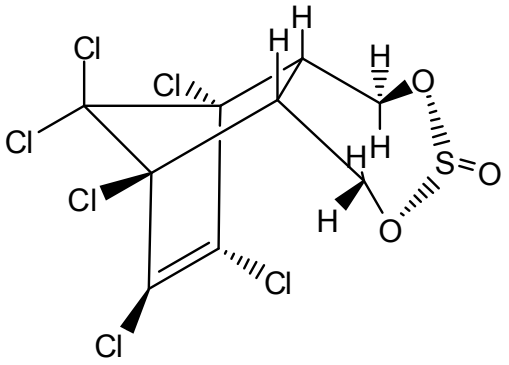
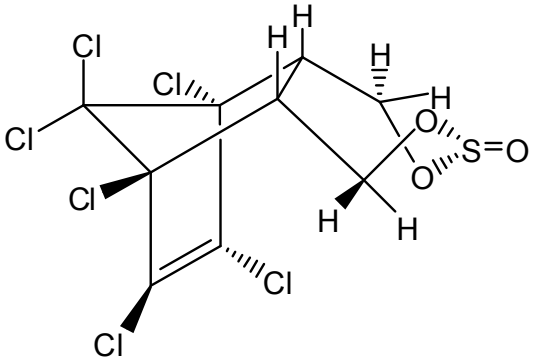
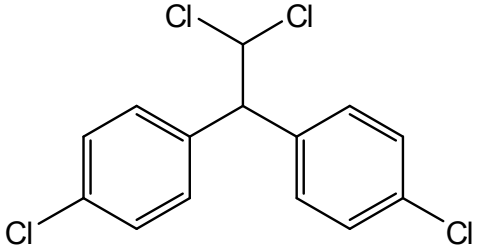
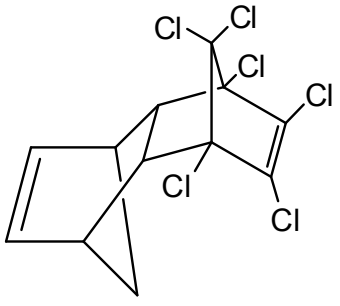
……

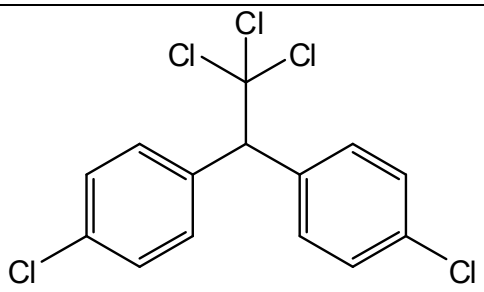
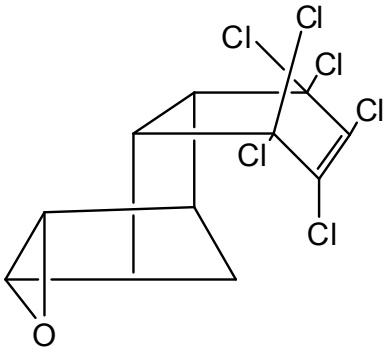
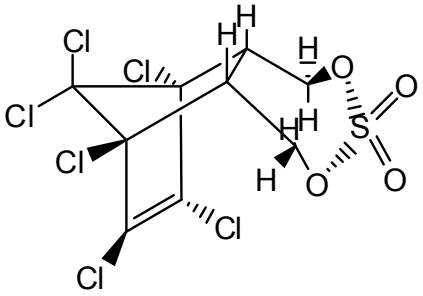
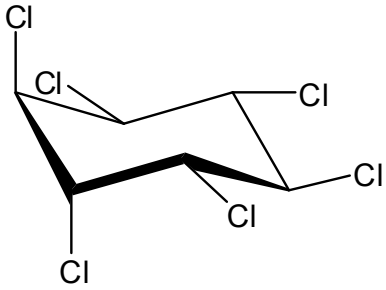
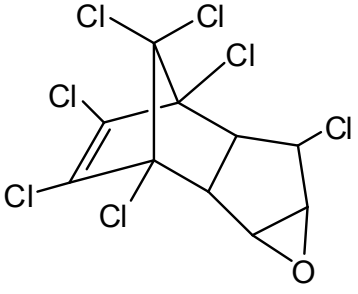
2. How many times do you irrigate in a day?

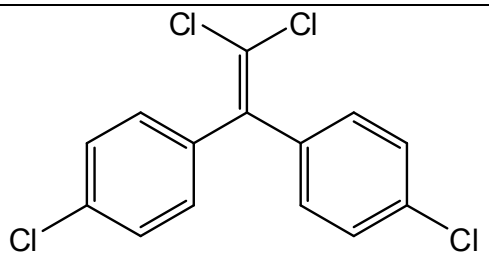
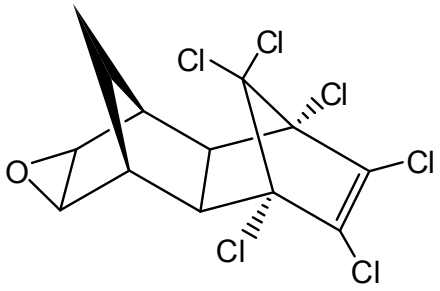
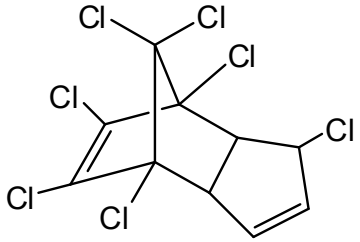
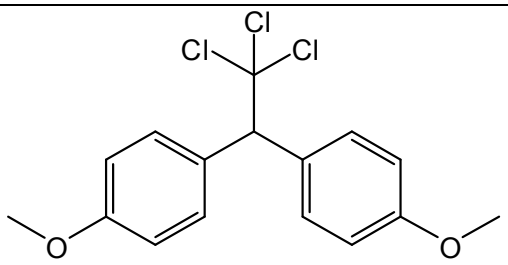
……

……

Appendix II: Structures of Organochlorine Pesticides

SN	Name	Structures
	α−Endosulphan	
	β−Endosulphan	
	(1,1-dichloro-2,2-bis (4-chlorophenyl) ethane) *p,p* DDD	
	Aldrin	

	dichloro-diphenyl-trichloro-ethane (*pp* '-DDT)	
	Dieldrin	
	EndosulphanSulfate	
	hexachlorocyclohexane (HCH),	
	Heptachlor epoxide	

	2,2-bis p-chlorophenyl1, 1-dichloroethylene- p,p'-DDE	
	Endrin	
	Heptachlor	
	Methoxychlor	

APPENDIX 3

Table A1: Mean Coli form and E. coli in irrigation water in July & December, 2015 and February, 2016

Months	**July, 2015**		**December, 2015**		**February, 2016**	
Site/Microbial	**E_Coli**	**Coli forms**	**E-Coli**	**Coli forms**	**E-Coli**	**Coli forms**
Mavoko Farm	23±4	81±4	27±1	95±19	23±3	179±1
Mavoko Market	4±0.0	108±6	7±1	124±6	19±1	225±8
Kitengela Farm	2±0	345±29	11±2	934±20	37±1	521±31
Kitengela Market	7±1	331±26	10±1	316±34	18±2	335±37
Mlolongo Farm	78±3	1292±265	89±5	3214±284	66±6	3797±119
Mlolongo Market	18±1	1500±22	25±1	1606±74	15±1	911±20

Table A2: Mean Coli form and E. coli in Soil in July & December, 2015 and February, 2016

	July-15		**December, 2015**		**February, 2016**	
Site/Microbial	**e_Coli**	**Coliforms**	**e-Coli**	**Coliforms**	**e-Coli**	**Coliforms**
Mavoko Farm	31±1	285±7	4±0	95±19	37±3	1±0
Mavoko Market	89±5	120±1	40±5	124±2	36±2	52±3
Kitengela Farm	0±0	130±0	145±8	934±204	6±1	3±1
Kitengela Market	0±0	224±7	12±2	316±34	17±1	13±1
Mlolongo Farm	17±1	1225±33	1±0	3214±284	8±1	11±1
Mlolongo Mkt	15±2	1036±28	19±1	1606±74	36±4	25±2

Table A3: Mean Concentration of E-Coli and Coli forms in Kales in July & December, 2015 and February, 2016

	Jul-15		December, 2015		February, 2016	
Site/Microbial	**e_Coli**	**Coliforms**	**e-Coli**	**Coliforms**	**e-Coli**	**Coliforms**
Mavoko Farm	21±1	60±5	17±1	40±14	1±0	43±3
Mavoko Market	25±1	126±10	29±8	137±4	52±3	132±28
Kitengela Farm	0±0	186±19	2±0	200±12	3±1	142±5
Kitengela Market	11±1	78±3	14±2	90±3	13±1	91±2
Mlolongo Farm	0±0	139±22	10±1	295±7	11±2	273±36
Mlolongo Mkt	0±0	1152±203	70±12	1766±190	25±3	156.97±10

Table A4: Mean Concentration of Heavy Metal in Irrigation Water in July, 2015

Site/Heavy Metal	**Cu**	**Cd**	**Pb**	**Zn**
Kitengela Market	20.04±1.67	ND	2.24±0.99	46.00±4.87
Kitengela Farm	85.58±5.19	ND	8.6±0.00	47.5±0.00
Mlolongo Market	98.5±10.47	ND	1.54±0.00	302.87±11.24
Mlolongo Farm	83.19±1.33	ND	0.83±0.00	77.12±0.99
Mavoko Market	42.5±0.27	ND	0.48±0.00	41.5±0.00
Mavoko Farm	13.72±0.00	ND	ND	34.5±2.74
WHO Limits	200	10	500	2000

Table A5: Mean Concentration of Heavy Metal in Irrigation Water in December, 2015

Site/Heavy Metal	**Cu**	**Cd**	**Pb**	**Zn**
Kitengela Market	120.35±7.81	ND	ND	35.25±0.09
Kitengela Farm	160.55±2.22	ND	ND	13.5±0.00
Mlolongo Market	67.67±1.81	ND	ND	6.00±0.01
Mlolongo Farm	4.08±0.00	ND	ND	13.16±0.24
Mavoko Market	21.97±0.35	ND	1.35±0.00	36.97±1.87
Mavoko Farm	13.00±0.15	ND	1.65±0.00	41.28±2.78
WHO Limits	200	10	500	2000

Table A6: Mean Concentration of Heavy Metal in Irrigation Water in February, 2016

Site/Heavy Metal	**Cu**	**Cd**	**Pb**	**Zn**
Kitengela Market	72.41±1.91	ND	ND	201.00±22.54
Kitengela Farm	23.98±0.12	ND	ND	174.89±14.83
Mlolongo Market	84.64±1.33	ND	ND	64.71±0.99
Mlolongo Farm	41.87±3.96	ND	ND	132.46±2.4
Mavoko Market	96.81±4.22	ND	ND	147.83±32.76
Mavoko Farm	108.69±11.52	ND	ND	48.84±7.82
WHO Limits	200	10	500	2000

Table A7: Mean Concentration of Heavy Metal in Soil in July, 2015

Site/Heavy Metal	Cu	Cd	Pb	Zn
Kitengela Market	239.56±16.25	ND	59.24±9.15	1025.15±80.57
Kitengela Farm	159.15±14.22	ND	ND	773.86±52.87
Mlolongo Market	118.65±7.14	ND	11.44±0.80	659.33±70.41
Mlolongo Farm	43.97±0.00	ND	8.01±0.06	229.25±22.38
Mavoko Market	26.25±1.870	ND	121.93±21.72	186.77±12.77
Mavoko Farm	10.11±0.07	ND	17.74±0.99	223.25±70.01
limit WHO *	I35 $x10^3$	$0.1x10^3$	$0.3 x10^3$	$300 x10^3$

Table A8: Mean Concentration of Heavy Metal in Soil in December, 2015

Site/Heavy Metals	Cu	Cd	Pb	Zn
Kitengela Market	120.85±6.67	ND	45.80±0.1	475.25±19.97
Kitengela Farm	402.11±32.15	ND	7.98±0.02	655.78±51.21
Mlolongo Market	170.92±9.43	ND	5.77±0.27	514.95±33.87
Mlolongo Farm	377.71±7.81	ND	32.52±0.02	950.05±74.16
Mavoko Market	561.45±32.68	ND	3.08±0.02	931.13±66.25
Mavoko Farm	411.97±21.31	ND	ND	901.45±25.68
limit WHO *	I35 $x10^3$	$0.1x10^3$	$0.3 x10^3$	$300 x10^3$

Table A9: Mean Concentration of Heavy Metal in Soil in February, 2016

Site/Heavy Metal	Cu	Cd	Pb	Zn
Kitengela Market	323.18±6.52	ND	10.33±0.81	997.28±51.76
Kitengela Farm	123.73±22.86	ND	3.65±0.00	453.71±26.13
Mlolongo Market	96.43±21.34	ND	22.27±3.68	689.46±10.41
Mlolongo Farm	7.23±0.89	ND	1.56±0.08	549.65±66.38
Mavoko Market	98.17±17.82	ND	96.36±10.27	88.27±13.47
Mavoko Farm	32.95±2.82	ND	11.66±1.83	272.23±78.01
limit WHO *	I35 $x10^3$	$0.1x10^3$	$0.3 x10^3$	$300 x10^3$

Table A10: Mean Concentration of Heavy Metal in Kales in July, 2015

Site/Heavy Metal	Cu	Cd	Pb	Zn
Kitengela Market	ND	ND	ND	40.36±1.24
Kitengela Farm	ND	ND	ND	32.87±3.66
Mlolongo Market	ND	ND	ND	141.39±5.97
Mlolongo Farm	ND	ND	0.742±0.00	92.67±10.43
Mavoko Market	ND	ND	ND	8.26±0.99
Mavoko Farm	ND	ND	ND	225.91±10.81
Safe limit WHO*	-	$1.5x10^3$	$0.3x10^3$	$50x10^3$

Table A11: Mean Concentration of Heavy Metal in Kales in December, 2015

Site	Cu	Cd	Pb	Zn
Kitengela Market	ND	ND	8.15±0.08	627.15±56.10
Kitengela Farm	ND	ND	3.28±0.95	138.07±22.97
Mlolongo Market	ND	ND	5.95±1.01	185.23±29.71
Mlolongo Farm	122.5±2.17	0.023±0.00	ND	404.89±31.99
Mavoko Market	ND	ND	0.115±0.01	272.91±8.16
Mavoko Farm	ND	ND	87.28±10.57	139.67±12.84

Table A12: Mean Concentration of Heavy Metal in Kales in February, 2016

Site/Heavy Metal	**Cu**	**Cd**	**Pb**	**Zn**
Kitengela Market	ND	ND	0.15±0.08	716.09±56.10
Kitengela Farm	ND	ND	1.31±0.05	14.37±0.17
Mlolongo Market	ND	ND	5.24±1.01	15.03±0.71
Mlolongo Farm	ND	ND	0.05±0.00	24.81±1.07
Mavoko Market	ND	ND	1.26±0.26	22.46±1.16
Mavoko Farm	ND	ND	7.19±1.13	19.30±0.08

Table A13: Mean Concentrations of OC Pesticide in Irrigation Water in July, 2015 (µg/L±s.d)

Pesticide/Site	Mlolongo Farm	Mlolongo Market	Kitengela Farm	Kitengela Market	Mavoko Farm	Mavoko Market
a-HCH	0.015±0.009	0.015±0.002	0.012±0.00	0.010±0.00	BDL	0.02±0.00
b-HCH	0.009±0.00	0.010±0.00	0.009±0.00	0.009±0.00	BDL	0.009±0.00
g-HCH	0.008±0.00	0.010±0.00	0.01±0.00	0.01±0.00	BDL	0.007±0.00
d-HCH	0.015±0.00	0.107±0.01	0.035±0.00	0.014±0.00	BDL	0.024±0.00
Heptachlor	0.017±0.00	0.046±0.00	0.016±0.00	0.023±0.00	BDL	0.033±0.00
Aldrin	0.008±0.00	0.025±0.00	0.008±0.00	0.008±0.00	BDL	0.013±0.00
Heptachlor epoxide	0.145±0.00	0.008±0.00	0.009±0.00	0.239±0.02	BDL	0.136±0.01
a-Endosulfan	0.011±0.00	BDL	0.031±0.00	BDL	BDL	BDL
pp-DDE	0.006±0.00	BDL	0.038±0.00	0.042±0.00	BDL	BDL
Dieldrin	BDL	BDL	0.021±0.00	BDL	BDL	BDL
Endrin	BDL	BDL	0.004±0.00	0.027±0.00	BDL	BDL
b-Endosulfan	BDL	BDL	0.021±0.00	BDL	BDL	BDL
pp-DDD	BDL	BDL	BDL	BDL	BDL	BDL
Endrin Aldehyde	0.053±0.00	BDL	0.198±0.05	0.044±0.00	BDL	0.102±0.04
pp-DDT	0.12±0.00	BDL	0.743±0.09	0.043±0.00	BDL	0.111±0.03
Endosulfan sulfate	BDL	BDL	0.041±0.00	BDL	BDL	0.035±0.00
Methoxychlor	0.109±0.00	BDL	0.047±0.00	0.091±0.00	BDL	0.033±0.00
∑ OCP	0.515403695	0.218613556	1.245184312	0.560358832	BDL	0.522744392

Table A14: Mean Concentrations of OC Pesticide in Irrigation Water in December, 2015 (µg/L±s.d)

Pesticides/Sites	Mlolongo Farm	Mlolongo Market	Kitengela Farm	Kitengela Market	Mavoko Farm	Mavoko Market
a-HCH	BDL	BDL	BDL	BDL	BDL	0.319±0.05
b-HCH	0.486±0.00	BDL	BDL	BDL	BDL	BDL
g-HCH	1.505±0.06	BDL	BDL	BDL	BDL	0.489±0.00
d-HCH	0.862±0.00	BDL	BDL	BDL	BDL	0.129±0.00
Heptachlor	0.386±0.01	BDL	BDL	BDL	BDL	0.146±0.00
Aldrin	2.259±0.02	BDL	BDL	BDL	BDL	1.396±0.07
Heptachlor epoxide	0.005±0.00	BDL	0.292±0.00	BDL	BDL	0.03±0.00
a-Endosulfan	BDL	0.002±0.00	BDL	BDL	BDL	0.145±0.00
pp-DDE	BDL	BDL	BDL	BDL	BDL	BDL
Dieldrin	BDL	BDL	BDL	BDL	BDL	BDL
Endrin	BDL	0.0792±0.00	BDL	BDL	BDL	BDL
b-Endosulfan	0.081±0.00	0.206±0.00	BDL	BDL	BDL	BDL
pp-DDD	0.063±0.00	0.20±0.01	BDL	0.0568±0.00	0.001±0.00	BDL
Endrin Aldehyde	0.241±0.05	0.616±0.06	BDL	BDL	BDL	BDL
pp-DDT	0.462±0.00	0.262±0.00	BDL	BDL	BDL	BDL
Endosulfan sulfate	BDL	0.654±0.00	BDL	BDL	BDL	BDL
Methoxychlor	0.921±0.00	BDL	BDL	BDL	BDL	BDL
∑ OCP	7.271	2.02	0.292	0.056	0.001	2.658

Table A15: Mean Concentrations of OC Pesticide in Irrigation Water in February, 2016 (µg/L±s.d)

Pesticides/Sites	Mlolongo Farm	Mlolongo Market	Kitengela Farm	Kitengela Market	Mavoko Farm	Mavoko Market
a-HCH	0.758±0.00	BDL	BDL	0.444±0.00	BDL	0.577±0.00
b-HCH	0.3752±0.00	BDL	BDL	0.078±0.00	0.042±0.00	BDL
g-HCH	1.565±0.01	BDL	BDL	0.055±0.00	BDL	1.222±0.02
d-HCH	BDL	BDL	0.006±0.00	0.186±0.01	BDL	0.261±0.00
Heptachlor	BDL	BDL	0.077±0.00	0.346±0.00	BDL	0.302±0.00
Aldrin	3.528±0.99	BDL	BDL	1.591±0.06	BDL	2.416±0.08
Heptachlor epoxide	BDL	BDL	BDL	0.108±0.01	1.079±0.07	0.049±0.00
a-Endosulfan	BDL	BDL	BDL	0.175±0.00	0.705±0.00	0.243±0.00
pp-DDE	BDL	BDL	BDL	BDL	BDL	BDL
Dieldrin	BDL	BDL	BDL	BDL	BDL	BDL
Endrin	0.084±0.00	BDL	BDL	BDL	BDL	BDL
b-Endosulfan	0.081±0.00	0.205±0.06	BDL	BDL	BDL	BDL
pp-DDD	BDL	0.021±0.00	BDL	BDL	BDL	BDL
Endrin Aldehyde	BDL	BDL	0.268±0.00	0.022±0.00	1.47±0.00	0.03±0.00
pp-DDT	0.476±0.00	BDL	0.005±0.00	0.026±0.00	0.037±0.00	BDL
Endosulfan sulfate	BDL	BDL	BDL	0.009±0.00	0.049±0.00	BDL
Methoxychlor	0.6732±0.01	0.0291±0.00	BDL	0.043±0.00	BDL	0.019±0.00
∑ OCP	7.541	0.2559	0.3559	3.085	3.384	5.121

Table A16: Mean Concentration of OC pesticides in soil in July, 2015 (µg/Kg ± SD)

Pesticide/Site	Mlolongo Farm	Mlolongo Market	Kitengela Farm	Kitengela Market	Mavoko Farm	Mavoko Market
a-HCH	2.295±0.11	6.547±0.76	11.554±0.41	3.327±0.165	2.196±0.26	114.839±28.49
b-HCH	1.82±0.29	3.056±0.01	2.56±0.22	2.789±0.68	2.305±0.01	68.246±17.81
g-HCH	1.706±0.39	3.741±0.44	2.105±0.96	4.812±1.83	1.993±0.02	1.574±0.22
d-HCH	2.631±0.83	2.582±0.30	3.45±0.94	1.932±0.19	4.834±0.35	4.538±0.00
Heptachlor	2.532±0.57	2.957±1.05	9.463±4.82	4.143±0.74	3.835±0.88	59.952±5.91
Aldrin	1.864±0.00	2.335±0.81	2.563±1.19	4.713±0.71	2.296±0.11	1.465±0.04
Heptachlor epoxide	1.792±0.07	2.041±0.40	1.707±0.03	1.758±0.33	1.868±0.37	137.626±7.57
a-Endosulfan	1.794±0.19	6.279±0.57	6.528±1.16	10.894±3.19	BDL	22.346±0.06
pp-DDE	1.425±0.16	BDL	46.188±6.90	27.704±8.03	1.507±0.51	1.23±0.18
Dieldrin	0.352±0.09	BDL	8.037±3.77	1.753±0.0	12.76±3.30	2.592±0.16
Endrin	5.536±0.40	BDL	0.684±0.00	BDL	BDL	36.464±0.95
b-Endosulfan	1.963±0.13	BDL	2.457±0.40	BDL	BDL	3.559±0.03
pp-DDD	BDL	BDL	BDL	BDL	BDL	BDL
Endrin Aldehyde	9.237±0.03	9.326±0.38	11.369±3.67	8.729±0.77	BDL	6.87±0.40
pp-DDT	17.335±3.98	30.101±2.44	15.481±4.55	11.821±1.99	BDL	4.804±0.39
Endosulfan sulfate	5.169±2.13	2.71±0.63	5.78±0.0	17.925±1.60	8.851±0.0	8.847±0.44
Methoxychlor	6.157±0.43	7.498±1.31	33.046±1.45	BDL	BDL	6.021±0.36
∑ OCP	63.608	79.173	162.972	102.3	42.445	480.973

Table A17: Mean Concentration of OC pesticides in soil in December, 2015 (µg/Kg ± SD)

Pesticide/Site	Mlolongo Farm	Mlolongo Market	Kitengela Farm	Kitengela Market	Mavoko Farm	Mavoko Market
a-HCH	5.121±0.6	9.289±0.02	0.457±0.00	BDL	4.559±0.08	2.214±0.05
b-HCH	0.082±0.00	0.847±0.09	12.589±0.16	BDL	BDL	2.746±0.49
g-HCH	BDL	BDL	BDL	BDL	12.633±0.46	BDL
d-HCH	BDL	BDL	BDL	BDL	2.593±0.02	BDL
Heptachlor	0.676±0.04	0.423±0.00	0.721±0.00	1.132±0.01	1.068±0.00	1.910±0.04
Aldrin	BDL	BDL	BDL	BDL	9.603±0.03	119.458±3.41
Heptachlor epoxide	4.104±0.00	BDL	BDL	BDL	0.747±0.00	BDL
a-Endosulfan	11.351±0.36	BDL	47.311±3.24	13.309±0.72	4.412±0.00	BDL
pp-DDE	BDL	15.626±0.94	BDL	BDL	3.922±0.00	BDL
Dieldrin	BDL	BDL	BDL	BDL	2.006±0.00	BDL
Endrin	BDL	0.825±	1.143±0.00	10.090±0.81	2.108±0.39	5.321±0.57
b-Endosulfan	BDL	BDL	BDL	1.377±0.08	12.133±1.02	5.278±0.09
pp-DDD	BDL	BDL	0.791±0.00	2.672±0.00	20.311±2.34	8.698±0.01
Endrin Aldehyde	8.551±0.4	3.517±0.04	4.074±0.31	5.806±0.31	19.648±0.55	7.535±0.24
pp-DDT	BDL	10.792±0.9	7.032±0.22	17.496±1.55	59.493±2.98	19.585±1.14
Endosulfan sulfate	BDL	BDL	12.089±1.17	14.039±0.04	22.779±3.18	7.702±0.49
Methoxychlor	55.809±1.65	1.124±0.06	5.928±00.00	48.906±6.87	14.747±4.23	BDL
OCP	85.694	42.444	92.136	114.827	192.763	180.448

Table A18: Mean Concentration of OC pesticides in soil in February, 2016 (µg/Kg ± SD)

Pesticides/Sites	Mlolongo Farm	Mlolongo Market	Kitengela Farm	Kitengela Market	Mavoko Farm	Mavoko Market
a-HCH	BDL	BDL	1.817±0.03	0.245±0.06	0.483±0.05	1.264±0.05
b-HCH	2.812±0.023	BDL	BDL	BDL	0.030±0.00	BDL
g-HCH	14.343±0.21	14.365±0.33	7.467±0.17	6.831±0.09	7.261±0.05	9.434±0.71
d-HCH	BDL	12.346±1.13	3.025±0.09	1.993±0.00	BDL	1.728±0.05
Heptachlor	BDL	15.056±0.86	3.426±0.14	4.766±0.05	0.504±0.04	2.025±0.08
Aldrin	BDL	158.667±8.94	0.330±0.00	BDL	97.338±7.54	0.261±0.08
Heptachlor epoxide	BDL	BDL	0.262±0.09	BDL	BDL	0.4723±0.08
a-Endosulfan	BDL	1.01±0.01	108.285±6.11	19.132±1.38	BDL	170.526±3.25
pp-DDE	BDL	15.626±1.69	BDL	BDL	3.922±0.03	BDL
Dieldrin	BDL	BDL	BDL	BDL	2.006±0.05	BDL
Endrin	BDL	0.329±0.00	BDL	BDL	12.619±1.46	BDL
b-Endosulfan	BDL	BDL	BDL	1.377±0.01	12.133±1.31	5.278±0.64
pp-DDD	6.291±0.11	1.358±0.09	7.095±0.10	27.470±6.64	2.789±0.02	BDL
Endrin Aldehyde	2.487±0.03	BDL	9.485±1.24	5.387±0.17	25.629±0.65	BDL
pp-DDT	6.837±0.27	8.339±0.27	14.684±0.02	BDL	43.035±9.01	BDL
Endosulfan sulfate	20.717±0.04	18.725±2.29	75.469±6.53	BDL	72.9815±4.57	BDL
Methoxychlor	BDL	2.478±0.01	13.012±0.32	BDL	42.629±2.58	BDL

Table A19: Mean Concentration of OC pesticides in Kales in July, 2015 (µg/Kg ± SD)

Pesticides/Site	Mlolongo Farm	Mlolongo Market	Kitengela Farm	Kitengela Market	Mavoko Farm	Mavoko Market
a-HCH	2.422±0.24	1.5765±0.72	1.963±0.05	3.239±0.73	5.691±0.39	BDL
b-HCH	2.149±0.21	2.1±0.27	1.645±0.21	1.807±0.07	1.361±0.33	BDL
g-HCH	1.798±0.18	2.212±0.12	1.624±0.24	1.687±0.11	1.63±0.26	BDL
d-HCH	6.144±0.77	2.967±1.50	4.606±1.13	2.949±0.48	3.713±0.09	BDL
Heptachlor	3.511±0.55	3.119±0.31	3.394±0.74	2.722±0.99	13.691±2.95	BDL
Aldrin	2.406±0.26	2.282±0.09	2.39±0.69	1.683±0.04	1.418±0.19	BDL
Heptachlor epoxide	2.544±1.13	1.964±0.30	1.615±0.34	1.785±0.09	58.01±3.34	BDL
a-Endosulfan	BDL	2.26±0.18	2.679±0.91	BDL	3.715±0.64	BDL
pp-DDE	BDL	2.539±0.34	16.379±1.81	1.487±0.21	4.453±0.45	BDL
Dieldrin	BDL	14.262±	3.715±	2.087±	2.226±	BDL
Endrin	0	0.409±0.28	2.789±0.32	2.725±0.71	0.321±0.15	1.331±0.46
b-Endosulfan	11.089±0.91	3.898±0.08	6.456±0.60	3.949±0.31	2.381±0.54	BDL
pp-DDD	BDL	BDL	BDL	BDL	BDL	BDL
Endrin Aldehyde	BDL	BDL	17.045±1.42	14.994±4.45	7.203±0.41	BDL
pp-DDT	8.683±3.28	BDL	13.031±0.71	18.375±1.52	5.405±0.01	BDL
Endosulfan sulfate	11.046±0.0	12.024±0.95	4.623±0.36	6.852±0.42	82.568±0.00	BDL
Methoxychlor	11.985±0.0	11.447±2.24	10.674±1.95	64.355±6.96	8.714±0.83	BDL
OCP	63.778461	63.060714	94.62938	130.69904	202.50074	1.331074

Table A20: Mean Concentration of OC pesticides in Kales in December, 2015 (µg/Kg ± SD)

Pesticides/Sites	Mlolongo Farm	Mlolongo Market	Kitengela Farm	Kitengela Market	Mavoko Farm	Mavoko Market
a-HCH	115.295±2.25	50.358±7.25	BDL	BDL	33.977±2.05	31.745±2.27
b-HCH	53.488±3.17	61.270±5.06	36.355±1.95	22.433±0.55	7.774±0.14	10.591±0.55
g-HCH	67.573±2.80	143.042±8.81	50.296±2.85	81.724±6.51	5.344±0.07	4.361±0.59
d-HCH	106.689±7.93	79.541±0.33	158.020±6.92	88.993±1.72	120.261±8.64	16.095±0.23
Heptachlor	89.554±6.87	59.254±7.17	94.615±6.08	61.893±1.43	7.714±0.00	14.225±0.25
Aldrin	65.039±2.51	48.829±3.82	64.315±8.76	51.218±0.25	51.091±8.16	50.474±11.74
Heptachlor epoxide	2.028±0.41	BDL	BDL	BDL	BDL	BDL
a-Endosulfan	0.844±0.02	BDL	BDL	4.855±0.04	BDL	BDL
pp-DDE	BDL	BDL	BDL	BDL	BDL	BDL
Dieldrin	BDL	BDL	BDL	BDL	BDL	BDL
Endrin	5.321±0.57	10.929±0.23	BDL	BDL	BDL	BDL
b-Endosulfan	BDL	BDL	BDL	BDL	BDL	BDL
pp-DDD	50.989±2.36	25.734±0.74	48.226±3.71	BDL	44.240±3.68	23.039±1.20
Endrin Aldehyde	54.575±8.14	57.958±1.05	78.415±8.28	BDL	20.135±0.65	10.345±0.11
pp-DDT	63.072±7.32	57.622±8.04	54.109±4.05	BDL	76.433±2.91	35.523±0.67
Endosulfan sulfate	100.978±3.77	111.649±10.49	81.138±9.83	BDL	65.315±0.66	69.218±8.49
Methoxychlor	BDL	148.445±8.99	163.037±8.08	157.305±28.62	202.373±7.69	117.108±0.33
OCP	775.44808	854.63586	828.52686	468.4212	634.65949	382.7262

Table A21: Mean Concentration of OC pesticides in Kales in February, 2016 (µg/Kg ± SD)

Pesticides/Sites	Mlolongo Farm	Mlolongo Market	Kitengela Farm	Kitengela Market	Mavoko Farm	Mavoko Market
a-HCH	BDL	BDL	BDL	1.704±0.51	BDL	BDL
b-HCH	250.305±22.75	BDL	80.216±9.23	BDL	88.883±6.04	BDL
g-HCH	4.157±0.06	4.665±0.09	3.606±0.89	6.124±0.01	3.723±0.46	3.363±0.31
d-HCH	BDL	BDL	11.476±0.78	174.021±9.71	BDL	BDL
Heptachlor	BDL	BDL	7.435±0.14	BDL	BDL	291.936±24.17
Aldrin	111.091±8.73	6.006±0.16	79.625±13.69	106.295±19.65	BDL	BDL
Heptachlor epoxide	14.119±0.42	11.298±0.87	BDL	BDL	47.428±0.78	BDL
a-Endosulfan	28.106±0.55	BDL	BDL	BDL	BDL	BDL
pp-DDE	BDL	BDL	BDL	BDL	BDL	BDL
Dieldrin	BDL	BDL	BDL	BDL	BDL	BDL
Endrin	BDL	BDL	BDL	BDL	BDL	BDL
b-Endosulfan	15.957±0.02	BDL	BDL	BDL	BDL	BDL
pp-DDD	BDL	BDL	BDL	322.554±8.84	23.159±0.72	BDL
Endrin Aldehyde	255.982±15.81	101.476±3.79	111.849±11.58	BDL	BDL	BDL
pp-DDT	179.607±41.54	163.628±11.09	37.326±4.48	219.199±5.47	14.016±0.13	BDL
Endosulfan sulfate	BDL	BDL	BDL	192.627±18.49	276.578±5.73	8.335±0.02
Methoxychlor	BDL	BDL	BDL	BDL	312.199±34.07	97.006±10.76
OCP	859.32428	287.07253	331.53344	1022.5255	765.9862	400.6403