EFFECTS OF AGRICULTURAL PESTICIDES AND NUTRIENTS RESIDUE IN WERUWERU SUB-CATCHMENT, TANZANIA

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A Thesis Submitted in Partial Fulfillment of the Requirements for the award of the degree of Master of Science (Integrated Watershed Management) in the School of Pure and Applied Sciences of Kenyatta University

JANUARY, 2015
DECLARATION

This thesis is my original work and has not been presented for a degree or any other award in any other university, and that all sources I have used or quoted have been indicated and acknowledged by means of complete references.

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DEDICATION

This work is dedicated to the loving memory of my grandfather Ahmeid Said Al-Said and my dearest grandmother Sihaba Ismail.
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ABBREVIATIONS AND ACRONYMS

<table>
<thead>
<tr>
<th>AChE</th>
<th>Acetyl cholinesterase</th>
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<tbody>
<tr>
<td>DDT</td>
<td>DichloroDiphenylTrichloroethane</td>
</tr>
<tr>
<td>DPSIR</td>
<td>Drivers, Pressure, State, Impact and Response</td>
</tr>
<tr>
<td>ECD</td>
<td>Electron Capture Detector</td>
</tr>
<tr>
<td>EU</td>
<td>European Union</td>
</tr>
<tr>
<td>FAO</td>
<td>Food and Agriculture Organization</td>
</tr>
<tr>
<td>GC</td>
<td>Gas Chromatograph</td>
</tr>
<tr>
<td>GPS</td>
<td>Geographical Positioning System</td>
</tr>
<tr>
<td>ITCZ</td>
<td>Inter Tropical Convergence Zones</td>
</tr>
<tr>
<td>IWM</td>
<td>Integrated Watershed Management</td>
</tr>
<tr>
<td>KARI</td>
<td>Kenya Agricultural Research Institute</td>
</tr>
<tr>
<td>MDGs</td>
<td>Millennium Development Goals</td>
</tr>
<tr>
<td>NED</td>
<td>Naphthyl Ethylenediamine Dihydrochloride</td>
</tr>
<tr>
<td>NPD</td>
<td>Nitrogen-Phosphorous Detector</td>
</tr>
<tr>
<td>OCls</td>
<td>Organochlorines</td>
</tr>
<tr>
<td>OPs</td>
<td>Organophosphorous</td>
</tr>
<tr>
<td>PBWO</td>
<td>Pangani Basin Water Office</td>
</tr>
<tr>
<td>PRB</td>
<td>Pangani River Basin</td>
</tr>
<tr>
<td>TDS</td>
<td>Total Dissolved Solid</td>
</tr>
<tr>
<td>TPC</td>
<td>Tanganyika Planting Company</td>
</tr>
<tr>
<td>TPRI</td>
<td>Tropical Pesticide Research Institute</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organization</td>
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</table>
This research presents the agrochemical residues analysis on the study conducted in Weruweru River Sub-catchment, Kilimanjaro region in Tanzania. Agrochemicals have negative consequences on watershed management in the sub-catchment. It compromises water quality and environment, and thus causing threat to human health and aquatic organisms. This study was undertaken to assess the effects of agricultural pesticides and fertilizers and their residue levels in water and sediments samples in the sub-catchment and establish the measures taken to mitigate the negative effects. 30 farmers were involved in a cross-sectional survey to know the types of agrochemical used, knowledge and attitude. Twelve samples each of water and sediment were collected from upper, middle and lower zones of Weruweru River during the dry and rainy seasons and analyzed by gas chromatography (GC-ECD) for Organochlorine (OCls) pesticide residues, and spectrophotometric method for nutrient levels namely NH$_3$-N, NO$_3$-N, NO$_2$-N and PO$_4^{3-}$-P. In order of the samples for two seasons to be taken in the same points Geographical Positioning System (GPS) was used to locate sampling points. The bed sediment samples were collected at a depth of 0 - 20 cm, while water samples were collected at a depth of 50 cm below surface; all samples were collected from two different points in each zone. The results revealed that farmers have inadequate knowledge on handling, storage, application and disposal methods. All nutrients analyzed were found to be within the acceptable limits in drinking water as per WHO guidelines, except for NH$_3$-N and PO$_4^{3-}$-P was higher. The concentrations for NH$_3$-N during the dry season ranged from 0.15 to 0.22 mg/l and rainy season ranged from 0.37 to 0.96 mg/l which were higher than the recommended limits in drinking water which range from 0.05 to 0.5 mg/l. Concentration for PO$_4^{3-}$-P during the dry season ranged from 0.05 to 0.14 mg/l and during rainy season ranged from 0.44 to 0.52 mg/l were higher than natural background levels of PO$_4^{3-}$-P in river waters which usually range from 0.005 to 0.02 mg/l. Five OCls pesticide residues detected in water samples namely Cyanazine, Alfa-chlordane, $p,p'$-DDT, $p,p'$-DDE and Lindane while seven pesticide residues detected in sediment samples namely cyanazine, Alfa-chlordane, Endosulfan sulphate, $p,p'$-DDT, $p,p'$-DDE, lindane and cypermethrin. All OCls pesticide residues detected in sediment samples were below the fresh water sediment quality assessment guideline except Lindane and Alfa-chlordane which were higher with the concentrations ranged from bdl to 3180 mg/kg dw and bdl to 64 mg/kg dw respectively. The pesticides detected in water samples were below acceptable limit in drinking water as per WHO guidelines, except Cyanazine and Lindane, the concentration ranged from bdl to 45.7 mg/l and bdl to 3.66 mg/l, respectively. The concentrations detected were higher than acceptable limit in drinking water cyanazine 10 mg/l and lindane 2 mg/l. The findings provide necessary informations environmental officers in the sub-catchment and may contribute on designing mitigation measures to reduce degradation of water by agrochemicals and developing strategies which will ensure safe water quality to the consumers.
CHAPTER ONE

INTRODUCTION

1.1 Background

Agrochemical is a common term encompassing various chemical products that are used in agricultural activities. In most cases, it refers to the wide range of pesticides including insecticides, herbicides, and fungicides. It may also include synthetic fertilizers, hormones and other chemical growth agents as well as concentrated stores of raw animal manure (AVMC, 2007). The majority of pesticides are used to control pests’ invasion and control of vectors of human and animal diseases (Ecobichon, 2001). Crop losses due to pests’ invasion and soil infertility are serious threats in both developed and developing countries (Henry, 2003). As such the use of chemical pesticides and synthetic fertilizers among farmers has been adopted as essential tools to control the scourge and thus reduce pests’ infestation on the crops and thus increase yields (Bhanti and Taneja, 2007). The improvement in crop yield which is fostered by pesticides and fertilizers application is sometimes associated with the occurrence and persistence of pesticide and nutrients residues in the soil and water (Ware and Whitacre, 2004).

Pesticides are poisonous by nature and constitute one of the most hazardous groups of contaminant to human health, fauna and the environment (Belmonte et al., 2005). Pesticide poisoning is definitely a public health problem globally and its use is still increasing, particularly in developing countries (Wesseling et al., 2001). Two million tons of pesticides, derived from 759 active ingredients, are considered being in
current use in developing countries (Akhabuhaya et al., 2000). While pesticides use in Europe and North America moves towards saturation or declines, increasing trends are expected for African and Central American countries (Wesseling et al., 2001). According to Smith (2001), the substantial use of pesticide in East Africa highlights worker exposure as an important health hazard. Water pollution by pesticides and synthetic fertilizers is also another hazard which has affected many biological systems (Dalvie et al., 2003) and it may take a very long period to clear, and it poses the danger of bioaccumulation in food chain (London, 1992). Pesticides from agricultural areas have polluted aquatic environment through direct run off, leaching, careless disposal of empty containers and washing equipment directly from the rivers (Milidas, 1994).

Apart from pesticides, there is also increased use of synthetic fertilizers in many part of the world. Salasya et al. (2005) reported that KARI’s general fertilizer recommendation for Western Kenya is 60 kg/ha N and 26 kg/ha P to accommodate low nitrogen and phosphorous levels in soils but the total inorganic fertilizer use increased gradually from 879 tons in 1994 to 2,356 tons in 2000. Plant analyses and crop yields showed that inorganic fertilizer produced grain yields 68% higher than that from manure over a season (Melissa, 2009). This encouraged farmers to use inorganic fertilizers for higher production.

In Tanzania, the government has recognised the need to invest more in agriculture and has hence developed a strategy known as ‘Kilimo Kwanza’ literally meaning Agricultural First. Part of the strategy is to achieve a Tanzanian green revolution in agricultural sector. This is in line with the 2005 Abuja Summit Declaration which Tanzania is also a signatory, that seeks to increase fertilizer use by smallholder
farmers from 8 kg per ha to at least 50 kg per ha by 2015 (AGRA, 2011). In order to achieve this goal the use of fertilizers increase every year and as a result of the current mitigation measures being taken cannot effectively control the contaminations due to physical, socio-economic and political settings of many sub-catchments (AGRA, 2011).

Studies on water and soil pollution caused by pesticides residue in Tanzania have been enormously reported by various researchers. The studies have been directed to certain catchments and could not cover the whole of Tanzania. Mwevura et al. (2002) covered the Msimbazi River and Kizinga River catchment areas and intermediate marine coastal shoreline of Dar es Salaam. The author investigated the level of organochlorine pesticide residues in edible biota. Mohamed (2009) analyzed levels of organochlorinated residues in soil and water from tomato fields at Ngarenanyuki sub-catchment, Tanzania. The study indicated that the level of DDTs pesticides in water were higher than the acceptable values by WHO.

Kishimba et al. (2004) assessed the levels of pesticide residues in water, sediment, soil and some biota collected from different parts of Tanzania. Although the intention was to cover the whole country, so far the studies have focused only on areas with known large-scale pesticide use. These include; Southern Lake Victoria and its basin, TPC sugarcane plantations in Kilimanjaro region, Dar es Salaam Coast, Mahonda–Makoba basin in Zanzibar, and a former pesticide storage area at Vikuge Farm in Coast region.

1.2 Problem Statement

Agrochemicals such as chemical pesticides and synthetic fertilizers have been reported to compromise water quality and environment, and thus causing threat to
human health and aquatic organisms. PAN-UK (2006) reported according to WHO classes most of the agrochemical pesticides are considered to be hazardous and number of them have registered by regulatory authority. Some of the pesticides such as Endosulfan and DichloroDiphenylTrichloroethane (DDT) have been restricted from use by European Union (EU) due to health and environmental reasons (PAN-UK, 2008) but are still being used in developing countries including Tanzania. The Weruweru sub-catchment is an arable land where people practice agricultural activities close to the river especially at the middle and lower zones of the river sub-catchment. This practice can eventually cause water quality degradation by pesticides and nutrients residues. Therefore, it was imperative to assess the agrochemical residues in the river sub-catchment and propose strategies which can be used to reduce the threat to the people and aquatic organisms.

1.3 Objective of the Study

1.3.1 General Objective
The general objective of this study was to assess the occurrence, types and agrochemical residues in Weruweru sub-catchment and suggest mitigation measures.

1.3.2 Specific Objectives
The specific objectives of the study were to:-

(i) Investigate the types and amount of pesticides and fertilizers used in agricultural activities in the Weruweru sub-catchment.

(ii) Identify and quantify pesticide and fertilizer residues and establish seasonal variations by carrying out dry and rainy season analysis of water and sediments samples in selected areas in Weruweru River Sub-catchment.
1.4 Research Questions

(i) What type(s) and amounts of agrochemicals are commonly used in agricultural activities in the Weruweru sub catchment?

(ii) What are the types and levels of pesticide and fertilizer residues in water and bed sediment samples and are there major differences in seasonal variations during dry and rainy season in selected sampling area from Weruweru River?

1.5 Justification

This study intended to assess the use of agrochemicals in different cropping systems and their effects on water quality degradation at upper, middle and lower zone of Weruweru sub-catchment. The study was conceived due to the fact that Weruweru sub-catchment which is part of Pangani River Basin is highly affected by the extensive use of agrochemicals (Missana et al., 2003). Moreover, owing to the threats of agrochemicals and water conservation measures are weak, resulting in more adverse effects on water and environment than expected. Second, the population in the sub-catchment has been growing very rapidly which acts as a driving force for the farmers to use more agrochemicals in agricultural activities (URT, 2006). The sub-catchment’s human activities include domestic purpose, irrigation and livestock needed immediate assessment of the water quality in order to find control measures.

1.6 Significance and Anticipated Output

This study aimed at establishing the levels of pesticides and fertilizers residue in the Weruweru sub catchment. The findings and recommendations of the study may provide useful information to policy makers and watershed managers so that appropriate developmental programmes and policies can be formulated and
implemented for proper utilization and management in a sustainable manner. Through such an initiative the sub-catchment and by extension Tanzania will be able to achieve the Millennium Development Goals (MDGs) on environmental sustainability (MDGs report, 2000-2008). The study can thus serve as a policy guide for development agencies. In addition the outcome of this research study can be used by watershed management experts as a planning and management tool. The results can also be used as supplementary information that may contribute on designing mitigation measures to reduce water pollution by agrochemicals and developing strategies which will ensure safe water quality to the consumers.

1.7 Scope and Limitation of the Study

This study concentrated on agrochemicals pollution due to agricultural activities in Weruweru River sub-catchment at upper, middle and lower zones. The sub-catchment is one among the most productive areas in Pangani River Basin in Kilimanjaro region where agrochemicals are applied for agricultural management. The study analysed farmer’s personal characteristics during agricultural activities around the sub-catchment area. Qualitative and quantitative data were collected using various Participatory Rural Appraisal Techniques including; questionnaire, on-farm observations and interviews of water experts, agrochemical dealers and agricultural experts, and laboratory analysis of water and sediments samples. The limitation encountered in conducting this study was indistinguishable criteria that were used to divide the Weruweru sub-catchment areas. In order to overcome encountered barrier, this study divided the site into three zones according to the agro ecological factor and altitudes to differentiate the upper, middle and lower zone of the area.
1.8 Operational Definitions of Concepts and Terms

1.8.1 Pesticide
The Tropical Pesticide Research Institute (TPRI) Act No.18 of 1979 defines pesticides as “any matter of description including acaricides, herbicides, insecticides, fungicides, hormonal sprays and defoliants, used or intended to be used either alone or together with other material substances for the control of weeds, pest and disease in plants, vectors of human or animal diseases, and external parasites of man or domestics animals as well as for the protection of any food intended for human consumption. Pesticides are unique among environmental pollutants since they are used deliberately for the purpose of killing some form of life. Ideally pesticides should be highly selective, destroying target organisms while leaving non-target organisms unharmed (Miller, 2004).

1.8.2 Bed Sediment
Bed sediment is the particulate material that moves through the channel fully supported by the channel bed itself. These materials, mainly sand and gravel, are kept in motion (rolling, siltation and sliding) by the shear stress acting at the boundary. Generally this material is larger than 0.062 mm in diameter (Knighton, 1998).

1.8.3 Fertilizer
A fertilizer is any material, organic or inorganic, natural or synthetic, that supplies plants with the necessary nutrients for plant growth and optimum yield. Inorganic (or mineral) fertilizers are fertilizers mined from mineral deposits with little processing (lime, potash, or phosphate rock), or industrially manufactured through
chemical processes (urea). Inorganic (synthetic) fertilizers vary in appearance depending on the process of manufacture (Mtambanengwe and Kosina, 2007).

1.8.4 Residue

Residue is the material that remains after part of it has been taken, separated, removed, or designated; remnant, remainder (FAO, 2008).

1.8.5 Nutrients

Nutrients are chemical elements that are essential to plant and animal nutrition. Nitrogen and phosphorus are nutrients that are important to aquatic and terrestrial life, but in high concentrations they can be contaminants in water and environment (Mueller and Helsel, 1996).

1.8.6 Water Quality

Water quality is the physical, chemical and biological characteristics of water. It is a measure of the condition of water relative to the requirements of one or more biotic species and or to any human need or purpose (EPA, 2006).

1.8.7 Conclusion

This study set out to demonstrate the use and effect of agrochemicals from Weruweru sub-catchment and the urgent need to control water pollution by agrochemicals by setting measures which promotes and contributes on designing mitigation measures and developing strategies which will ensure safe water quality to the consumers and ecological sustainability. These concerns are addressed in the following chapters of this thesis.
CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter reviews empirical works done by scholars in the area of synthetic fertilizers and pesticides used in agricultural activities, and their effects to the environmental and human health. It also identifies research gaps from previous studies. The chapter starts by a conceptual framework which serves as a roadmap of the whole research work. The rest of the review of the literature is organized around the specific objectives of the study. It is divided into an overview of agrochemicals effect to surface water quality, its driving forces and mitigation measures. The chapter concludes with the table which summerises key empirical literature selected and gaps identified.

2.2 Conceptual Framework

This study assumed that agrochemicals effect in the river water sub-catchment is influenced by the driving forces which manifests in expansion of agricultural activities. These drivers trigger pressure in the form of water pollution in the sub-catchment area, thus causing Weruweru River to be polluted. The state of water degradation in the river include reduced living organisms in aquatic environment, increased concentration of chemicals from the surrounding to the first organism in the aquatic environment by the process known as bio-accumulation and destruction to the health of human beings. To reduce severity of the effects, various mitigation measures should be undertaken. The study suggests the followings measures: management and monitoring of the surface water, education and encourage farmers
to use safe equipments during spraying of pesticides, application of the right choice of pesticides to the crops, appropriate amount of fertilizers to the crops and refrain from use of prohibited pesticides like DDT and Endosulfan. This study adopted the Drivers, Pressure, State, Impact and Response (DPSIR) framework developed by Kristensen (2004). Figure 2.1 shows the DPSIR framework that has been modified to provide more appropriate means for assessment of the agrochemical residues in Weruweru sub-catchment.

Figure 2.1: The conceptual framework of agrochemical uses and effects in Weruweru River sub-catchment ( Adopted and modified from Kristensen, 2004)
2.2.1 Driving Forces and Pressure for Agrochemicals

Increasing demand of food grains and declining farmlands in India have increased pressure on farm yield improvement and reduction in crop losses due to pest attacks (Panchal and Kapoor, 2013). The crop protection market has experienced strong growth in the past and is expected to grow further at approximate 12%. Indian crop protection industry is largely dominated by insecticides which form about 65% of share of the industry. Other segments like herbicides, fungicides and other (rodenticides/ nematocides) form 16%, 15% and 4%, respectively (Panchal and Kapoor, 2013). In Tanzania, agriculture accounts for about half of the national income and provides employment opportunities to about 80 percent of Tanzanians. It has linkages with the non-farm sector through forward linkages to agro-processing, consumption and export. It provides raw materials to industries and a market for manufactured goods (Tambwe, 2013). Agricultural development in Tanzania has accelerated for a number of years in parallel with farm inputs to boost the quality and quantity of harvest. Pesticides take up 90% of the agricultural input in coffee. In general, pesticides are widely used in Tanzania, not only for agricultural and veterinary purposes but also in public health activities, particularly in vector control programmes (Ngowi, 2002).

2.2.2 State and Responses for Agrochemical

The state of the environment (the physical condition affected by the pressures) is a chain of causal links starting with driving forces (economic sectors, human activities) through pressures (emissions, waste) to states (physical, chemical and biological) and impacts on ecosystems, human health and functions, eventually leading to political responses (prioritization, target setting, indicators). Study conducted in Sri Lanka revealed that the government was taking measures to control the indiscriminate usage
of chemical fertilizer and agrochemicals by the farmers. According to the government the country is experiencing adverse effects of the use of chemical fertilizer and agrochemicals introduced to increase crop productivity and ensure food security. Although Sri Lanka has become self-sufficient in rice and some other crops, the adverse effects of chemical usage such as damage to bio-diversity, contamination of water and soil due to chemical substances leading to various health problems, particularly renal diseases in agricultural areas such as North Central and Eastern Provinces are becoming costly for the country. The government has therefore, initiated measures to control the use of agrochemicals and fertilizer consumption and promote the use of organic fertilizer in farm lands (SIN, 2013).

Pesticide exposure and poisoning is a highly neglected public health issue in Tanzania and most other developing countries (Ngowi, 2002). Citizens and policy makers are not generally aware of this problem due to a lack of valid information on the subject. In view of extensive exposures, adverse health effects and over-stretched health care resources in many developing countries, prevention of pesticide poisoning emerges as the most viable option to reduce the harmful impact on the population (Ngowi, 2002). The present study provides a local scientific basis for the development of strategies to reduce and control poisoning in farming communities by preventing pesticides exposures in the environment.

2.3 Agricultural and Agrochemical Exposure

Agricultural activities are non point source pollution. It contributes an average of about 70 percent of water pollutant loads around the world (EPA, 2012). Agriculture contaminants often include chemical fertilizers, pesticides and sediment (EPA, 2012). The chemical fertilizers and pesticides are largely used in agricultural
production, and control of vectors in public health and animal husbandry (Akhabuhaya, *et al.*, 2000). Exposure to agrochemicals constitutes a major occupational hazard (Hanrahan *et al.*, 1996). Human poisonings and their related illnesses are clearly the highest price paid for agrochemicals use. About 67,000 pesticide poisonings resulting in an estimated twenty-seven accidental fatalities are reported each year in the US (Litovitz *et al.*, 1990). The situation is even worse in developed countries where approximately 80% of the agrochemicals produced annually in the world are used (WRI/UNEP/UNDP, 1994). A higher proportion of pesticide poisonings and deaths occur in developing countries where there are inadequate occupational safety standards, protective clothing, and washing facilities, insufficient enforcement of regulations, poor labeling of pesticides, illiteracy and insufficient knowledge of pesticide hazards (Pimentel and Greiner, 1996).

### 2.3.1 Fertilizers

Fertilizers are chemical substances which provide plants with nutrients they need for their growth and development. Fertilizers supply of one or more nutrients to the soil as chemical elements necessary for normal plant growth (Gorecki, 2003). In general, fertilizers can be classified into two major groups based on their source; these include synthetic fertilizers and natural organic fertilizers. The present study provides information on the use and effect of fertilizers especially synthetic fertilizers to the aquatic environment. Study by Ramteke and Shirgave (2012) revealed that the common fertilizers such as Biozyme, Diammonium phosphate and Urea were used to study the plant growth regulators on vegetable plants and these plants have high nutritional and medicinal value. The growth parameters like germination, survival and seedling height and root/shoot ratio were studied on the different seeds and
solutions of fertilizers. The results found were used to assay the effect of fertilizers on vegetable plants and the effect of Urea, Diammonium phosphate and Biozyme on percentage of seed germination.

2.3.1.1 Synthetic Fertilizers

Synthetic fertilizers are available in two basic forms, liquid and solid. Some of the common synthetic fertilizers includes nitrogen, ammonia, ammonium nitrate, ammonium sulphate and ammonium chloride, urea, phosphate, superphosphate and potassium fertilizers (Kihampa, 2010). Synthetic chemical fertilizers are considered as one of the most important tools for raising the crop yields and increase agriculture productivity. About 40% of the world cereal production has been fostered by synthetic inorganic chemical fertilizers (Gorecki, 2003). However, the use of synthetic fertilisers produces nitrogen in large amount of which only 14% are useful for plant diet (UNDP et al., 2000).

2.3.1.2 Natural Organic Fertilizers

Natural Organic fertilizers come from organic matter such as plants and animals manure. These fertilizers are produced without any chemicals or additives (De Witt, 2013). Composting involves combining several different types of organic materials together to make a large amount of rich fertilizer. Natural fertilizers help maintain the quality and nutrient content in the soil, which assists the growth of plants (De Witt, 2013). Generally, they are divided into two major groups, organic fertilizers and organic manures. Organic manures are bulkier than organic fertilizers and contain relative lower amounts of plant nutrients. The best known of the organic
manures is farm manure, the excrement of livestock together with the straw or other bedding materials (Kihampa, 2010). Organic fertilizers are made from materials derived from living things. Organic fertilizers from composts and other sources can be quite variable from one batch to the next. Nevertheless, one or more studies have shown they are at least as effective as chemical fertilizers over longer periods of use and it doesn’t have any harmful side effects as synthetic fertilizers (Mtambanengwe and Kosina, 2007).

2.3.2 Pesticides

FAO defined pesticide as any substance or mixture of substances intended for preventing, destroying, repelling or mitigating any pest, including vectors of human or animal disease, unwanted species of plants or animals causing harm during or otherwise interfering with the production, processing, storage, transport or marketing of food, agricultural commodities, wood and wood products or animal feedstuffs, or substances which may be administered to animals for the control of insects, arachnids or other pests in or on their bodies (FAO, 2002; Stoytcheva, 2011).

There are several ways of pesticides classification, such as that based on the function like insecticides, herbicides and fungicides. There is also classification based on the chemical nature of pesticides such as organophosphorous, organochlorine and carbamates (Miller, 2004).

2.3.2.1 Classification of Pesticides Based on Chemical Nature

The classification of pesticides based on the chemical nature is divided into many classes, of which the most important are: Organochlorines, Organophosphorous and Carbamates pesticides.
2.3.2.1.1 Organochlorine Pesticides (OCls)

OCls are pesticides of chlorinated hydrocarbons that generally have oral toxicity and long residues action and are very stable chemical compounds which can withstand the action of various environmental factors including the biological system. The most common insecticide in this group is DDT (1) synthesized in 1874. After the discovery of DDT and its effectiveness, many more chlorinated hydrocarbon insecticides were made. There are presented in Figure 2.1, such as dieldrin (2), methoxychlor (3), chlorinated (4), heptachlor (5), aldrin (6), endrin (7), toxaphene (8), mirex (9) and lindane (10) were introduced in the 1940s and 1950s. They were used in agriculture, public health and households (Enerst, 2004).

Figure 2.2: Examples of Organochlorine insecticide structures (Enerst, 2004)
The environmental and health effects associated with DDTs and other OCLs were realized during the 1970s. In 1986, US Environmental Protection Agency (EPA) banned all use of DDTs formulations in crops production and processing (PAN-UK, 2008). Ideally most of these OCLs chemicals are insoluble in water and dissolve well in organic solvents and fats of organisms. The half life of DDT is between 2-25 years (Mackay et al., 1997). Over very long period of time, there is bioaccumulation in animal tissue which occurs when DDT becomes more concentrated up to the food chain. This means that animals on top of the chain like humans can potentially have the highest concentrations of DDT (Mackay et al., 1997).

Study by El-Bouraie, et al. (2011) reported that chlorinated hydrocarbon residues in water were DDT and its metabolites; DichlorodiphenylDichloroethylene (DDE) and Dichlorodiphenyldichloroethane (DDD), Hexachlorocyclohexane (HCH) isomers and dieldrin. These residues were dominant in the wet season samples while in the dry season most of the residues were below their average detection limit. The summation of all concentrations of the chlorinated hydrocarbon were in the range of 0.07–2.1567 μg/l this indicate that during wet season the high concentration of residues were brought to the water by surface runoff.

2.3.2.1.2 Organophosphorous Pesticides (OPs)
OPs are pesticides of phosphoric acid esters; one of the main classes of insecticides that have been in use since the mid 1940s. OPs are relatively nonpersistent in the environment and can only persist from a few hours to several months (Crane et al., 1999). In contrast to the OCLs insecticides, OPs do not represent a serious problem as contaminants of soil and water since they can only persist a few hours to several
months and rarely enter the human food chain (Lucio, 2006). However, the mode of action of the OPs can exert significant adverse effects in non-target species including humans. In Tanzania, OPs insecticides are widely used in agriculture and contribute to about 20% of all pesticides in the country (Ngowi et al., 2007).

Examples of OPs insecticide structures are presented in Figure 2.2; these are Chlorpyrifos (11), it is used as an insecticide on grain, cotton, fruit, nuts and vegetables, Parathion (12) was widely used due to its solubility in aqueous solutions and its broad range of insecticidal activity and Malathion (13) is a non-systematic, wide spectrum insecticide and has low mammalian toxicity and is suitable for the control of sucking and chewing insects on fruits and vegetables (EXTOXNET, 2009a).

Figure 2.3: Examples of Organophosphorous insecticide structures (EXTOXNET, 2009a)

2.3.2.1.3 Carbamate Pesticides (CAs)

CAs was originally extracted from the Calabar bean, which grows in West Africa. The extracts of this bean contain physostigmine, a methylcarbamate ester (Baron, 1991). CAs insecticides are derivatives of carbamic acid and are not generally persistent in the environment. The use of CAs as insecticides began in the 1950s, and
approximately 25 CAs compounds are in use today as pesticides or pharmaceuticals. CAs is among the most popular pesticides for home use, both indoors, on gardens and lawns (Baron, 1991). The toxicity of the compound varies according to the phenol or alcohol group. One of the most widely used CAs insecticides is cabaryl (14) shown in its chemical structure in Figure 2.3. It is a broad spectrum insecticide which is widely used in agriculture and home gardens where it is generally applied as a dust (EXTOXNET, 2009a). The mode of action of the carbamates is Acetyl cholinesterase (AChE) enzyme inhibition with the important difference that the inhibition is more rapidly reversed than OPs compounds (Krieger, 2001).

Figure 2.4: Example of Carbamate insecticide structure (EXTOXNET, 2009a)

2.3.2.2 Classification of Pesticides Based on Function

The classification of pesticides based on the function is divided into many classes, of which the most important are herbicides intended to control herbs/weeds, fungicide intended to control fungal infestations, rodenticides intended to control rodents and fumigants which is normally referred to by the mode of application (Ecobichon, 2001).

Herbicides are applied for control of plants in a variety of ways, and the way that they are used affects the target plants differently. Although herbicides are formulated
and used in ways similar to insecticides, their modes of action tend to be very different. Herbicide mixing, storage, and application can pose significant occupational health risks (Eldridge, 2008). The potential for environmental contamination are due to long term use of some compounds (Ecobichon, 2001). Herbicide applications should be avoided when it is raining, or in areas where overland water flow is likely to occur. Applications should likewise be avoided in heavy winds (Eldridge, 2008). The experiments on the interaction between herbicides and sediments indicate that herbicides degrade rapidly in water in the absence of sediments. But when these herbicides were absorbed into sediments, their persistence in water increased (Ying and Williams, 1999). Study by Chang et al. (2008) conducted in Lake Suwa (Nagano Prefecture, Japan) revealed that Simetryn was one commonly used herbicide, and is often identified as the most toxic compound causing algal growth inhibition in river water discharged from the agricultural area.

Fungicides are used to control the fungal infestations. The fungicides that are of concern are the dithiocarbamates, sulfur derivatives of dithiocarbamic acid and the metallic dimethyldithiocarbamates. The latter group includes mancozeb, maneb and zeneb. They are relatively nontoxic, but hydrolyzed into carcinogenic compounds (Krieger, 2001). Study by Mangas-Ramirez et al. (2007) reported that the toxic effects of fungicide on zooplankton in the river through mesocosm experiment were acute and chronic toxicity due to bioaccumulation of fungicides concentrations.

Rodenticides varies in the mode of their toxicity but human poisoning associated with rodenticides usually result from accidental or suicidal ingestion of the compounds. Some rodenticides are extremely dangerous to all mammals, including
humans and their pets, and must be used with extreme care (Krieger, 2001). The rodenticidal effects of Argel leaves were studied under laboratory crude plant extract solved by ethanol, water extract and dry powder were mixed with crushed maize to introduce it as a bait to the target animals in different concentrations were tested to clarify their rodenticidal activity against Rattus norvegicus. The results proved that the ethanol extract baits and dry powder baits were more effective than water extract baits. Males of albino rats which is Rattus norvegicus scientific name were more susceptible than females for all tested cases (Abou-Hashem, 2013).

Fumigants are volatile chemicals stored as liquids under pressure, or incorporated into a solid form with clay which releases toxic gas when combined with water vapor and used to kill soil nematodes, particularly grains pests (Eldridge, 2008). They are applied to storage warehouse, freight cars, and houses infested with insect such as powder post beetles. They present a special hazard due to inhalation exposure and rapid diffusion into pulmonary blood. Extreme care must be taken when handling and applying this class of pesticides (Ecobichon, 2000). Study by Sande et al. (2011) in Florida focused on the hazards from fumigants proposed as alternatives for pre-plant soil fumigation in tomato production and proposed alternative fumigants to workers, consumers, beneficial arthropods, fish, birds and bees. The findings indicate that environmental categories, workers and beneficial arthropods experience the highest relative risks from the proposed tomato fumigants, fish and consumers the least risks.

2.3.2.3 Dispersion of Pesticides into Aquatic Environment

The dispersion of pesticides like other hazardous chemicals in the environment depends on a combination of mechanisms such as microbial degradation, chemical
hydrolysis, photolysis, sorption, volatility, leaching, plant uptake and surface runoff. (EXTOXNET, 2009a). The widespread use and disposal of pesticides by farmers, institutions and the general public provide many possible sources of pesticides in the environment. Following release into the environment, pesticides may have many different fates. Pesticides which are sprayed can move through the air and may eventually end up in other parts of the environment, such as in soil or water (Petit et al., 1995). Pesticides which are applied directly to the soil may be washed off the soil into nearby bodies of surface water or may percolate through the soil to lower soil layers and groundwater (EXTOXNET, 2009b). Figure 2.5 summarises various dispersive process occurring when chemicals enter surface water.

Figure 2.5: Processes of Pesticides in Surface Water (Petit et al., 1995)

2.3.2.4 Pesticides Application in Developing Countries

Chemical pesticides have been used in developing nations in their efforts to eradicate insect-borne, endemic diseases, to produce adequate food and to protect forests,
plantations and fibre. Many developing countries are using different pesticides to control diseases in their crops (Ecobichon, 2001).

In Zimbabwe, for instance smallholder vegetable farmers use OCl and OPs to control plant diseases and arthropod pests (Sibanda et al., 2000). In Ghana, pesticide use has increased over time and is particularly elevated in the production of high-value cash crops and vegetables (Gerken et al., 2001). Study on farmer’s knowledge, perception and management of vegetation pests and diseases in Botswana has revealed that use of synthetic pesticides is 95.4% higher than other methods (Obopile et al., 2008). In East African countries Uganda, Kenya and Tanzania, use of pesticides in agriculture activities have been increasing year after year. In Uganda, for instance pesticide use has recently been embraced by local communities that are making a living from the sale of tomatoes. There is evidence that tomatoes are sprayed and immediately sold for consumption. This inevitably puts a high risk on the local consumers who are not well informed about the effects of pesticides (Wasswa and Kiremire, 2004). Study by Macharia et al. (2009), revealed that the use of pesticides in Kenya have led to expansion of agricultural activities and increase productivity. Ngowi et al. (2007) revealed that smallholder vegetable farmers in northern Tanzania use more than 40 types of pesticides, some of which are classified by WHO as highly hazardous and pesticides take up 90% of the agricultural inputs in coffee.

### 2.3.2.5 Pesticides Residue in Water

Environmental contamination of natural water by pesticide residue is at present of great concern and because of the wide spread use, the residue were detected in
various environmental matrices such as soil, water and air. Water pollution by pesticides can affect many biological systems (Dalvie et al., 2003). Residue contamination of surface water was regarded as transitory because the focus was on Organochlorine (OCls) pesticides such as Dichloro Diphenyl Trichloroethane (DDT), which were of very low water solubility and had a strong tendency to attach to particulate matter and to disappear from clear water. About 20 years ago, information had accumulated that some herbicides compounds, which were generally more water soluble and more widely used than the organochlorine, were being detected in both surface and ground water in developing countries (Hamilton et al., 2003).

2.3.2.6 Pesticides Residue in Sediment

Soil plays an important role in contamination than water and air; pesticides reach the soil through direct application to the crops. When pesticides are applied in the field, most of the chemical pesticides remain in the soil and are later eroded to deposit on the river banks or inside the water body (Singh and Choudhary, 2012). The pesticides are detected in various environmental matrices such as soil, water and sediments. It is reported that the degradation of DDT in soil and sediment is 75-100% in 4-30 years (Singh and Choudhary, 2012). Contaminated bed sediments of fresh water bodies have a potentiality of polluting and rendering the water unfit for aquatic life. Though some of OCls and nitrogen containing pesticides have been restricted, no proper attention is being paid on the continuous monitoring and assessment of these restricted pesticides to make sure that are not exposed (Mobeen et al., 2012). A summary of some of the key literature reviewed in this study are shown in table 2.1.
Table 2.1: A Summary of literature review and the knowledge gaps identified

<table>
<thead>
<tr>
<th>No</th>
<th>Author</th>
<th>Summary on Findings</th>
<th>Knowledge gap</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Nalwanga and Ssempebwa (2011)</td>
<td>Knowledge and Practices of In-Home Pesticide Use: A community Survey in Uganda</td>
<td>The study dealt with the knowledge and practices of pesticides use only in Home. It does not looked at the knowledge and practice of Agrochemicals use in small farms in sub-catchment area</td>
</tr>
<tr>
<td>2</td>
<td>Namwata at el., (2010)</td>
<td>Adoption of improved agricultural technologies for Irish potatoes farmers in Ilungu ward Mbeya, Tanzania</td>
<td>The study dealt with adoption of improved agricultural technologies such as uses of agrochemical. It does not looked at the environmental effects on adoption of improved agricultural technologies in agricultural activities</td>
</tr>
<tr>
<td>3</td>
<td>Mohamed, (2009)</td>
<td>Levels of Organochlorines residue in soil, water and tomatoes due to long term application: A case study of Ngarenanyuki-Arusha, Tanzania.</td>
<td>The study dealt with pesticides residue in soil, water and tomatoes due to long term application. It does not assessed the agrochemicals residue in water and bed sediment samples</td>
</tr>
<tr>
<td>4</td>
<td>Tarus, et al. (2007)</td>
<td>Organochlorines and Pyrethroid Pesticides residue levels in soil, water and sediment samples along River Nzoia Catchment – Kenya</td>
<td>The study dealt with pesticides residue in water, sediment and soil. It does not assessed the nutrient concentrations in water along river sub-catchment area</td>
</tr>
</tbody>
</table>
2.4 Conclusion

This chapter has reviewed the effects of agrochemicals used in agricultural activities to the surrounding environment and public health problems. The reviewed literature have shown that in spite of the importance of agrochemicals for the control of pests, diseases and increases agricultural production, if they are not properly used they can lead to water and soil pollution, bioaccumulation in food chains and eventually affect human beings. The foregoing studies also indicate that agrochemicals use have effect to the human health and environmental problem. A short fall has been revealed in implementation of policy and guidelines geared to manage water resources. In emphasizing river management, the literature has suggested various management practices focusing in Tanzania and worldwide.
CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

This study aimed at assessing the effects of agrochemical residues on water quality in Weruweru sub-catchment. Data collections were conducted using questionnaires and on-farm observation and water and sediments samples analyses. Synthetic fertilizer residues were analysed following the methods outlined by APHA/AWWA/WEF (2005), while pesticides residues were analysed as described in Akerblom (1995). Evaluation and data analysis were for understanding the water quality in the sub-catchment and propose management techniques for water quality and health environment.

3.2: Study Design

Study design is the structure of research; it is the "glue" that holds all of the elements in a research together. This study employed descriptive research design which is a scientific method that involves observing, experimental and describing the subject (Mugenda & Mugenda, 1999). It provides descriptions of the variables in order to answer the research questions. The type of description that results from the design depends on how much information the researcher has about the topic prior to data collection. In cases where the researcher has little or no prior knowledge of the topic, exploratory descriptive designs are employed. Where the variables are known but their action cannot be predicted, descriptive survey designs are employed and Causal research differs in its attempt to explain the cause and effect relationship between variables. This is opposed to the observational style of descriptive research, because
it attempts to decipher whether a relationship is causal through experimentation in the end. On this study, the casual research was considered appropriate to ascertain the causes and effects of agrochemicals in agricultural activities in the Weruweru sub-catchment.

3.2.1: Variables, Research Instruments and Analysis Procedure

Table 3.1 shows a summary of the objectives, variables, data collection tools or methods and data analysis procedures employed in this study.

Table 3.1: Variables, Research Instruments and Tools of Analysis

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Variables</th>
<th>Data Collection Tools/ Methods</th>
<th>Data Analysis and Presentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investigate the types and amount of pesticides and fertilizers used in agricultural activities in the Weruweru sub-catchment.</td>
<td>-Types of pesticides and fertilizers used in agriculture</td>
<td>Questionnaires, observation and photography</td>
<td>Descriptive analysis: graphs and tables</td>
</tr>
<tr>
<td></td>
<td>Amount of fertilizers and pesticides used in agriculture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identify and quantify the pesticide and fertilizer residues and establish seasonal variations by carrying out dry and rainy season analysis of water and sediment samples in selected areas in Weruweru River Sub-catchment.</td>
<td>-Identification of pesticide and fertilizer levels in samples of the sub-catchment</td>
<td>-Bottles for collecting water samples</td>
<td>Descriptive analysis: graphs and tables</td>
</tr>
<tr>
<td></td>
<td>-Quantification of pesticide and nutrient residual levels in samples</td>
<td>-Aluminium foil and stainless spoons for collecting sediment samples</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-Determination of pesticide and nutrient residues in samples collected during dry and rainy season</td>
<td>-GPS for recording during sampling for dry &amp; rainy seasons.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Spectrophotometric and Colorimetric methods for nutrients</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Gas Chromatography with ECD method for Pesticide residues</td>
<td></td>
</tr>
</tbody>
</table>
3.3 **Description of the Study Area**

Weruweru sub-catchment covers an area of 40.01 km$^2$ (Kilimanjaro Region Survey, 2011), located at the southern base of Mount Kilimanjaro in the north-western part of Pangani River Basin (PRB), Kilimanjaro region (PBWO, 2010). The region is affected by the location of Inter Tropical Convergence Zones (ITCZ) that determines the duration and the time of the rainy season and subsequently the dry season in PRB. Temperature in Weruweru sub-catchment normally ranges 14-18 °C during July to August and 32-35 °C during January to February (PBWO, 2010). The area also experience bi-modal rainfall pattern divided into short (October-November) and long (March-May) rains. The sub-catchment is situated at latitudes 3°00’ to 3°30’S and longitudes 36° 30’ to 37°15’E (DAAD, 2006), and on altitude of 700 m to > 900 m above sea level. It is characterized by steep slope valleys to gentle slopes, lowlands and in a few areas deep valley side slopes. The upstream is characterized with steep valley side slopes while the lowland has gentle slopes (PBWO, 2010).

The length of Weruweru River from the upper zone to the confluence of Kiladeda is about 17.9 km and Weruweru River has 19.0 km (Kilimanjaro Region Survey, 2011). The river is a tributary of the large Pangani River Basin and joins it through Kiladeda River. Weruweru sub-catchment is estimated to have a total population of 196,800 people, the highest concentration of people is found on the highland of sub-catchment with a population density of 750 persons per km$^2$, decreasing to 350 persons per km$^2$ in the middle zone and down less than 100 persons per km$^2$ in the lower zone (URT, 2006). The division of the sub-catchment is based on the agro ecological factors and altitude (Figure 3.1). The major economic activities of the community living around the sub-catchment are agriculture and livestock keeping.
These are the leading sector in terms of employment, income earning and overall contribution to the socio-economic well being of the people. Landownership is under trust land that allows farmers to claim permanent ownership (DAAD, 2009). The upper zone of the sub-catchment supports production of coffees; middle zone supports maize and vegetables, while the lower zone supports production of vegetables and tropical fruits. The three zones also support livestock rearing that includes dairy and beef cattle, sheep, poultry, goats and pigs.

Figure 3.1: Land Use Map of Weruweru Sub-catchment (Kilimanjaro Region Survey, 2011)
3.4 Data Collection Techniques

This study employed both qualitative and quantitative data collection techniques. Field work survey was conducted during the two extreme seasons of the year, dry season (February 2013) and rainy season (April 2013). Before data collection, the study started by identifying the agrochemicals used by farmers in Weruweru sub-catchment. In order to ascertain the proper points for water and sediment samples collection, qualitative information was collected through interviews, questionnaires, observation and ground photography.

Samples were collected using standard procedures for water and sediment samples collection and preservation as described in section 3.3.1. Interview, questionnaires, observations and ground photograph were used to obtain information from farmers, agriculture extension officers, sub-catchment officers and agrochemists on the type of agrochemicals, suppliers, training given to farmers, knowledge on health hazards and safety when handling agrochemicals, attitude and practice regarding use of agrochemicals, history and methods of agrochemical applications, disposal of containers, measures taken to conserve the river and use of the river water. A sample of structured questionnaire that was administered to 30 farmers (20 female and 10 males) is presented in Appendix I. Gender is the one of the demographic characteristic area of investigation in relation to perception and practices of agrochemical use that is knowledge and attitude of respondents.

3.4.1 Sampling of Water and Bed Sediment Samples

Water and sediments samples were concurrently collected from six selected sampling sites during the dry (February 2013) and rainy (April 2013) seasons. The sites were selected based on the information obtained from key stakeholders. These include the
major crops in the sub-catchment area and altitude of the Topo map. Details about sampling sites are described in table 3.1 and indicated in the sub-catchment map in figure 3.2. The positioning of sampling sites in the sub-catchment map was done by Global Positioning System (GPS) recording were taken during sampling.

Table 3.2: Description of the Sampling Sites in Weruweru Sub-catchment

<table>
<thead>
<tr>
<th>Site</th>
<th>Sampling Site</th>
<th>Coordinates</th>
<th>Site characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>W1&amp;S1</td>
<td>Upper zone up of Weruweru river</td>
<td>03°19’ 8.13”S 37°15’ 9.26”E</td>
<td>Human settlements, farming activities (coffees), domestic activities (fetching water and washing)</td>
</tr>
<tr>
<td>W2&amp;S2</td>
<td>Upper zone down of Weruweru river</td>
<td>03°19’ 8.32”S 37°15’ 9.15”E</td>
<td>Human settlements, farming activities (coffees and livestock) and domestic activities (fetching water and washing). Water flows to middle zone of the river</td>
</tr>
<tr>
<td>W3&amp;S3</td>
<td>Middle zone up of Weruweru river</td>
<td>03°21’ 3.37”S 37°17’ 5.07”E</td>
<td>Human settlements, farming activities (maize, banana and vegetables such as cucumbers, tomatoes, green vegetables) and fetching water and animals drinking</td>
</tr>
<tr>
<td>W4&amp;S4</td>
<td>Middle zone down of Weruweru river</td>
<td>03°21’ 0.3”S 37°17’ 5.23”E</td>
<td>Human settlements, farming activities (maize, banana and vegetables) and domestic activities (fetching water) and livestock. Water flows to the lower zone of the river</td>
</tr>
<tr>
<td>W5&amp;S5</td>
<td>Lower zone up of Weruweru river</td>
<td>03°23’10.3”S 37°17’11.33”E</td>
<td>Human settlements, farming activities (tropical fruits, beans and vegetables such as tomatoes, green vegetables, cucumbers, onions) and livestock, domestic activities (fetching water, bathing, and washing)</td>
</tr>
<tr>
<td>W6&amp;S6</td>
<td>Lower zone down of Weruweru river</td>
<td>03°23’11.23”S 37°17’ 11.7”E</td>
<td>Human settlements, farming activities (beans, vegetables such as green vegetables, tomatoes, onions and millet and tropical fruits) and (poultry and livestock) and domestic activities (fetching water, bathing and washing). Discharge water to Kifaru river</td>
</tr>
</tbody>
</table>

W1-W6 = water sampling sites, S1-S6 = sediment sampling sites
Figure 3.2: Map of Weruweru Sub catchment showing sampling points in three zones (Kilimanjaro Region Survey, 2011)
3.4.1.1 Water Sampling and Preservation

Water samples were collected by grab technique, preserved, kept in cool boxes and later transported to the Chemistry Laboratory at the University of Dar es Salaam for analysis. In the Laboratory, water samples for pesticide analysis were stored in temperatures between 0-4 °C prior to extraction and analysis, while samples for nutrients were analysed immediately upon arrival.

Water samples for pesticides analysis were collected in one litre sampling bottles with Teflon stop cork. Before sampling, the sampling bottles were washed with detergents, rinsed with tap water and distilled water, and finally with acetone followed by dried in oven. During sampling, bottles were rinsed three times with the water sample, then carefully filled just to overflow, without passing air bubbles through the samples or trapping air bubbles in sealed bottles. After sampling, samples were measured for physico-chemical parameters temperature, pH, DO, TDS and EC using hand-held potable water quality monitor and later preserved by 10% of 1000 g of NaCl salt as described by Akerblom (1995).

Water samples for nutrients analysis were collected in 500 mL plastic bottles. Before water samples collection, the sampling bottles which were previously soaked overnight with 10% HCl and rinsed with distilled water, were rinsed with water samples. The samples were filtered and preserved with concentrate H₂SO₄ and analysed immediately upon arrival at the laboratory. The physico-chemical parameters already measured in collection of water for pesticide analysis were deemed to be adequate; therefore the physico-chemical parameters were not measure for the nutrient samples.
3.4.1.2 Bed Sediment Sampling and Preservation

A total of twelve samples were collected at river bank during dry and rainy seasons. Two field points were selected randomly at 0–20 cm depths per sampling site in each zone because sediments at this depth level are expected to be the most contaminated and have the greatest potential for exchange with the water column (Nowell et al., 1999). The samples were taken by using a stainless spoon, wrapped in aluminium foil, labeled, placed in air-tight bags, kept in ice-coolers and transported to the Laboratory where they were kept at 20 °C before extraction and analysis.

3.5 Laboratory Analysis

3.5.1 Nutrients Analysis

Nutrients were analysed following the methods outlined by APHA/AWWA/WEF. (2005). Ammonia-nitrogen (NH$_3$–N) was determined by colorimetric method, using Nessler’s reagent (K$_2$HgI$_4$). Water samples, previously preserved with H$_2$SO$_4$ were pre-treated with ZnSO$_4$ and NaOH. Samples were directly treated with Nessler’s reagent, which combines with NH$_3$ to form a yellowish brown colloidal dispersion. The colour intensity of the formed dispersion is directly proportional to the amount of NH$_3$ present. The detection limit for this method was 0.02 mg/l.

Nitrate-nitrogen (NO$_3$–N) was determined by the cadmium reduction method, where NO$_3^-$ was reduced quantitatively to nitrite NO$_2^-$ in the presence of cadmium, using commercially available Cd granules treated with copper sulphate (CuSO$_4$) to form a Cu coating. The NO$_2^-$ produced was then determined by diazotizing with sulphanilamide and coupling with N-(1-naphthyl)-ethylenediamine to form a highly coloured azo dye that is measured colorimetrically. A correction was made for the
originally present NO$_2^-$, by first analyzing without the reduction step. The method detection limit was 0.01 mg/l. Nitrite-nitrogen (NO$_2^-$–N) was determined through the formation of a reddish purple azo dye produced at pH 2.0 to 2.5 by coupling diazotized sulfanilic acid with N-(1-naphthyl)-ethylenedine dehydrochloride. The method detection limit was 0.01 mg/l.

Phosphor (PO$_4^{3–}$–P) was measured by the ascorbic acid method, where ammonium molybdate and potassium antimony tartrate were reacted in an acidic medium with orthophosphate to form a heteropoly acid – phosphomolybdic acid – that was reduced to intensely coloured molybdenum blue by ascorbic acid. The colour intensity was measured spectrophotometrically using an infrared phototube at 880 nm. The detection limit for this method was 0.01 mg/l. The quality of the analytical data was assured by the analysis of blank and duplicate samples according to the standard operating procedures of the analytical laboratory at the Department of Chemistry, University of Dar es Salaam.

3.4.2 Extraction and Clean up of Pesticide Samples

3.4.2.1 Sediment Samples Extraction and Clean up

Three sub samples (20 g, 10 g and 5g) were measured in analytical balance. The first sub sample of 5 g was used for measuring sediment pH values. The sediment sample was mixed with 5 ml of deionised water (pH 7.0) in a small clean container, and gently stirred by a scoop into slurry. The mixture was then left to settle for approximately 15 min before recording the pH value using a calibrated pH meter. Another sub sample of 10 g was taken in a pre-weighed petri dish for dry weight and organic matter determinations. It was later dried in the oven at 105 °C for 12 hr and
400 °C for 3 hr for moisture and organic matter contents, respectively. Then moisture and organic matter contents of the sample were determined using equations 3.1 and 3.2 (Akerblom, 1995).

\[
\text{% Moisture content} = \frac{M_2 - M_3}{M_2 - M_1} \times 100 \quad \text{Equation 3.1}
\]

\[
\text{% Organic content} = \frac{M_3 - M_4}{M_3 - M_1} \times 100 \quad \text{Equation 3.2}
\]

Where:
- \(M_1\) = Mass of crucible
- \(M_2\) = Mass of crucible + sample
- \(M_3\) = Mass of heated
- \(M_4\) = Mass of removal organic matter
- \(M_2 - M_1\) = Mass of sample
- \(M_3 - M_1\) = Mass of water expelled

The third sub sample (20 g) was ground with 30 g anhydrous sodium sulphate in the mortar and more sodium sulphate were added to make the sample free floating powder to bind the water. The mixture was poured into a column and eluted with 120 ml dichloromethane in a beaker while shaking the beaker and left to settle for 15 min. The contents were then decanted through a plug of glass wool into an evaporation flask. The remaining sodium sulphate was rinsed with 20-30 ml dichloromethane mixture and decanted through the same glass wool. The resulting extract was concentrated in a rotary evaporator and the solvent was changed to cyclohexane and concentrated to 2 ml ready for clean up (Akerblom, 1995).

Clean up of sediment samples were done by column chromatography using florisil (magnesium silicate). A glass column of 5 g (60 cm x 22 mm) packed with florisil, glass wool and anhydrous sodium sulphate was used. 50 ml of cyclohexane was added into the glass column and allowed to pass through drop by drop until very little was left on the upper part of the column. The sample concentrate was poured into the
column and drained to make 2 ml of the sample, then transferred into Teflon cork vial and stored at 4 °C until analysis was done.

3.4.2.2 Water Samples Extraction and Clean up

Unfiltered water samples, previously preserved with 10% sodium chloride, were extracted by Liquid-Liquid Extraction (LLE) method (Akerblom, 1995). Each water sample 1000 ml was quantitatively transferred to a 1 L separating funnel and the sampling bottle was rinsed with 30 ml dichloromethane, which was then transferred to the separating funnel containing the water sample. The combined contents were then successively extracted with dichloromethane (3 x 50 ml). The organic layer was filtered through plug wool containing anhydrous sodium sulphate (30 g) for drying. Sodium sulphate was later rinsed with dichloromethane (2 x 3 ml) and the combined extract concentrated in vacuo at 30 °C and the solvent changed to cyclohexane. The volume was adjusted in a stream of air to 2 ml in 9:1 cyclohexane:acetone (v/v) in vials ready for analysis. The water extract appeared clean and were not subjected to further clean up.

3.4.3 Analytical Quality Assurance

3.4.3.1 Analytical Quality Assurance for Sediment Samples

A 100 ml aliquot of each dichloromethane, cyclohexane, ethyl acetate and acetone was concentrated to 2 ml and used to check contamination from the solvents used. Two matrices blank from bed sediments were obtained from a virgin land where the water pass at University of Dar es Salaam and the same procedure of extraction and analysis as that of sediment samples was performed. The result showed that no significant peaks appeared in the chromatograms of the blanks. Recoveries were
estimated by spiking the matrix blank with nine OCls pesticides standard at concentrations ranging from 0.02-1.1 μg/ml of each analyte. The average of percentage recoveries ± SD (n=9) were as follow; γ-HCH 82±0.5%, β-HCH 85±0.1%, α-HCH 90±0.3%, γ-Chlordane 81.7±3.6%, p,p ′-DDE 89±1.5%, p,p ′-DDD 80±1.7%, p,p ′DDT 95±2.7%, Andrin 73.1±1.6% and Endosulfan sulphate 87±0.4%. The results were not corrected for recoveries since all were with the normal acceptable range of 70-120% (Hill, 2000).

3.4.3.2 Analytical Quality Assurance for Water Samples
A 100 ml aliquot of each n-hexane, dichloromethane, cyclohexane, ethyl acetate and acetone was concentrated to 2ml and used to check contamination from the solvents used. 1L of distilled water was extracted the same way as water sample. The results showed no significant peaks appeared in the chromatograms of the blanks. Recoveries were estimated by spiking the matrix blank with nine OCls pesticides standard at concentrations ranging from 0.01-1.1 μg/ml of each analyte. The average of percentage recoveries ± SD (n=9) were as follow; γ-HCH 90±1%, β-HCH 95±0.01%, α-HCH 98±0.8%, γ-Chlordane 87±0.3%, p,p ′-DDE 98±0.2%, p,p ′-DDD 99±0.7%, p,p ′DDT 99±1.2%, Andrin 85±0.6% and Endosulfan sulphate 97±0.9%. The results were not corrected for recoveries since all were with the normal acceptable range of 70-120% (Hill, 2000).

3.4.4 Gas Chromatography Analysis
Analysis of pesticide residue was done as described by Akerblom, (1995). GC-Varian CP-3800 gas chromatography equipped with 63Ni Electron Capture (EC) detector was used for analysis. The GC capillary column WCOT FUSED SILICA 30
m x 0.32 mm, coated with CP-SIL 8CB DF 0.2 μg/ml was used. Nitrogen was used as both a carrier and make up gas in the Electron Capture Detector (ECD) at a flow rate of 30 ± 1 ml / min. The temperature programme was held at 70 °C for 1 min, 15 °C/min to 180 °C, 4 °C/min to 230 °C for 15 min. The injection and detector temperatures were 240 °C and 250 °C, respectively.

3.4.4.1 Identification and Quantification of Pesticide Residues

Identification of residues was effected by running samples and external reference standards in GC and then comparing the chromatograms (Martens et al., 1999). The detection limit for pesticides reported in this study was based on the lowest concentrations that could be consistently recovered (> 70%) in the laboratory and this was 0.02 μg/g for sediment and 0.01 μg/l for water samples. The quantification of the identified pesticides was done by comparing the peak area of the analyte of unknown concentration with those of reference standards of known concentrations run at the same analytical conditions with samples (Martens et al., 1999). External standard technique was employed in this study whereby the same volumes (2 ml) of reference standards were injected in between sample injections. The concentrations of the analyte in the sample were then calculated using equation 3.3 (Martens et al., 1999).

\[ C_{An} = \frac{P_{As}}{P_{Std}} \times \frac{C_{std}}{M_v} \]  Equation 3.3

Where:
- \( C_{An} \) = concentration of the analyte
- \( P_{As} \) = peak of the sample
- \( P_{Std} \) = peak of the standard
- \( C_{std} \) = concentration of standard
- \( M_v \) = mass volume ratio
  - = mass of sample extracted/final volume of extract
3.5 Data Analysis

Data collected were first pre-processed. The pre-processing exercise essentially involves checking and cleaning errors of responses from the field survey to ensure accurateness, reliability and relevance to the study. The process continued with coding of all variables considered for the study. Data entry consisted of entering the responses of each respondent into the spreadsheet according to each variable and water quality analysis. This exercise led immediately to checking of errors, cleaning of errors and controlling data quality. The software packages used was Microsoft Excel as spreadsheet. The analyses of data were performed using descriptive analysis. It was used to analyse the information that was captured through observation, questionnaire and laboratory analysis. The frequency tables, charts, histograms, photographs, correlation and regression were used to analyse the objectives.

3.6 Conclusion

The study employed laboratory analysis on water quality in the sub-catchment. Random sampling techniques were used to sample questionnaires used in this study to know types, occurrence and knowledge of the farmers. Nutrient levels in the river were obtained by using spectrophotometric method and chromatograms obtained by using GC-ECD during pesticides analysis were used to determine the peak area of the analyte of unknown concentrations and comparing with those of reference standards of known concentrations. The collected data was organized in Microsoft Excel software where data analysis was done.
CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results and discusses the findings from the research conducted in Weruweru Sub-catchment, Kilimanjaro region, Tanzania. It reports farmer’s knowledge, attitude and practices on the use of agrochemicals, the levels of pesticide residues in water and bed sediment samples, and nutrient concentrations in water samples in the sub-catchment. Results of agrochemical residues, factors contributing to the effects of agrochemicals and their influence on water quality as well as measures being taken to mitigate negative externalities resulting from agrochemicals are also presented and discussed.

4.2 Status of Agrochemicals Use at Weruweru Sub-catchment

Synthetic agrochemicals are formulations of chemical compounds intended to either increase soil fertility or control pests. Even though they are useful in fostering the agriculture production, but when improperly applied or managed can pose risk to human health and the general environment. Understanding of the possible entry and effects of agrochemical contaminants to the environment requires in-depth analysis of types of agrochemical, application methods, education levels of the users, management of the agrochemicals and if there is any training given to the users. It was realised that synthetic fertilizers and pesticides have been widely used in Weruweru sub-catchment.
4.2.1 Characteristics of the Agrochemicals Used in Weruweru Sub-catchment

Tables 4.1 and 4.2 describe the types of fertilizers and pesticides that have been used in the area for over 10 years. As indicated in table 4.1, two major types of fertilizers namely nitrogen and phosphate are used, mainly for planting and dressing. The first fertilizer diammonium phosphate (DAP) is the phosphorus fertilizer containing 18% of phosphorous. It is a white powder with ammonia-like odor and made from two common constituents in the fertilizer industry. DAP has an acid effect upon the soil because of the high ammonia content and its potential health effects is skin absorption, irritation of eyes and skin (Rehm et al., 2010).

Table 4.1: List of Fertilizers Current Use in Weruweru Sub-catchment

<table>
<thead>
<tr>
<th>Fertilizer materials</th>
<th>Trade name</th>
<th>Chemical Formulation</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diammonium phosphate (18% P*)</td>
<td>DAP</td>
<td>(NH₄)₂HPO₄</td>
<td>Planting</td>
</tr>
<tr>
<td>Nitrogen, phosphorus and Potassium 17:17:17</td>
<td>NPK 17:17:17</td>
<td>-</td>
<td>Planting</td>
</tr>
<tr>
<td>Nitrogen, phosphorus and potassium 23:23:0</td>
<td>NPK 23:23:0</td>
<td>-</td>
<td>Planting</td>
</tr>
<tr>
<td>Nitrogen, phosphorus and potassium 20:20:0</td>
<td>NPK 20:20:0</td>
<td>-</td>
<td>Planting</td>
</tr>
<tr>
<td>Calcium ammonium nitrate (26% N*)</td>
<td>CAN</td>
<td>Ca(NO₃)₂</td>
<td>Dressing</td>
</tr>
<tr>
<td>Diaminomethanal (46% N*)</td>
<td>UREA</td>
<td>(NH₂)₂CO</td>
<td>Dressing</td>
</tr>
</tbody>
</table>

*Nutrient composition

NPK fertilizers are compounds or complex formulations which contain more than one of the three main plant nutrients: these are nitrogen (N), phosphate (P) and potassium (K). Fertilizer compositions containing all three nutrients are generally referred to as NPK fertilizers, this designation is usually followed by a three
numbers, such as 17-17-17 or 23-23-0 or 20-20-0 to indicate the percentages of the respective nutrients present in the formulation. NPK fertilizer is non-hazardous to handle, storage and usage (Cook, 2009).

Calcium ammonium nitrate (CAN) is nitrogenous fertilizer with high efficiency. It is a derivative of ammonium nitrate and widely used as a fertilizer all over the world. CAN is a combination of 70 to 80 percent of ammonium nitrate and 20 to 30 percent calcium carbonate (Johan, 2013). This product is actually neutral and can neutralize acidity in the soil and make it suitable for any kind of soil. The nitrogen from CAN is absorbed directly by the plant and nutrient losses are almost eliminated. CAN is a hygroscopic product and needs very low moisture to be absorbed by the plants and it is effective in water stressed areas where soil has low moisture (Johan, 2013).

Diaminomethanal (UREA) is nitrogen fertilizer and white crystalline solid containing 46% nitrogen. It is widely used in the agricultural industry as an animal feed additive and fertilizer (Overdahl et al., 1991). UREA breakdown begins as soon as it is applied to the soil and converts to ammonium and carbon dioxide but if the soil is totally dry, no reaction happens. This can occur in 2 to 4 days after application and happens quicker on high temperature and pH. Application of UREA should be avoided during rainy season because of ammonia loss (Overdahl et al., 1991).

Table 4.2 indicates fifteen (15) types of pesticide that were current use in areas around the Weruweru sub-catchment. 40% are organochlorine pesticides, 20% fungicides, 20% organophosphorous, 13.3% carbamates and 6.7% pyrethroids.
Table 4.2: List of Pesticides Use in Weruweru Sub-catchment, Tanzania

<table>
<thead>
<tr>
<th>No</th>
<th>Trade Name</th>
<th>Generic Name</th>
<th>Chemical Formulation</th>
<th>Use</th>
<th>WHO Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Dursban</td>
<td>Chlorpyrifos</td>
<td>Organophosphorous</td>
<td>Coffees</td>
<td>II</td>
</tr>
<tr>
<td>2</td>
<td>Thionex/Thiodan</td>
<td>Endosulfan</td>
<td>Organochlorine</td>
<td>Vegetable</td>
<td>II</td>
</tr>
<tr>
<td>3</td>
<td>Profecran</td>
<td>Profenofos</td>
<td>Organophosphorous</td>
<td>Vegetable</td>
<td>II</td>
</tr>
<tr>
<td>4</td>
<td>Mancozeb</td>
<td>Mancozeb</td>
<td>Fungicides</td>
<td>Maize&amp; beans</td>
<td>Ib</td>
</tr>
<tr>
<td>5</td>
<td>Temik</td>
<td>Aldicarb</td>
<td>Carbamates</td>
<td>Tropical fruits</td>
<td>Ia</td>
</tr>
<tr>
<td>6</td>
<td>Blue Copper</td>
<td>Copper Sulphate</td>
<td>Fungicides</td>
<td>Coffees</td>
<td>II</td>
</tr>
<tr>
<td>7</td>
<td>Abamec</td>
<td>Abamectin</td>
<td>Organochlorine</td>
<td>Vegetable</td>
<td>II</td>
</tr>
<tr>
<td>8</td>
<td>Selectron</td>
<td>Profenofos</td>
<td>Organophosphorous</td>
<td>Coffees</td>
<td>II</td>
</tr>
<tr>
<td>9</td>
<td>Alpha cypermethrin</td>
<td>Alpha cypermethrin</td>
<td>Pyrethroids</td>
<td>Vegetable</td>
<td>II</td>
</tr>
<tr>
<td>10</td>
<td>Tracer 480SC</td>
<td>Spinosyn A and B</td>
<td>Organochlorine</td>
<td>Horticultural crops</td>
<td>II</td>
</tr>
<tr>
<td>11</td>
<td>Lannate</td>
<td>Methomyl</td>
<td>Carbamates</td>
<td>Vegetable</td>
<td>Ib</td>
</tr>
<tr>
<td>12</td>
<td>Dieldrin</td>
<td>Dieldrex 18EC</td>
<td>Organochlorine</td>
<td>Coffees</td>
<td>O</td>
</tr>
<tr>
<td>13</td>
<td>Cupric Hyroxide</td>
<td>Cuprocaffaro 50WP</td>
<td>Fungicides</td>
<td>Tomato</td>
<td>II</td>
</tr>
<tr>
<td>14</td>
<td>Aldrec</td>
<td>Aldrin</td>
<td>Organochlorine</td>
<td>Coffee &amp; vegetable</td>
<td>O</td>
</tr>
<tr>
<td>15</td>
<td>Luxan chlordane 96% EC</td>
<td>Chlordane</td>
<td>Organochlorine</td>
<td>Anti-termite in Vegetable</td>
<td>II</td>
</tr>
</tbody>
</table>

**WHO hazard classification: Class Ia = extremely hazardous; Ib = highly hazardous; II = moderately hazardous; O = obsolete as pesticide.**

All these pesticides were used to control pests and diseases. From the 1980s, the EU started to implement a number of bans on specific pesticides, in particular persistent organochlorine compounds, due to growing evidence of human and/or environmental harm (PAN-UK, 2008). Among them organochlorine insecticide DDT and its metabolites DDD and DDE were banned in 1986 and its export were banned in 2004.
In Tanzania, until 1992 DDT was registered under the 'Severely Restricted Registration' category, but in 1993 its registration was cancelled because of its long-term persistence in the environment. Since that date TPRI has not issued any permit to import, distribute, manufacture, formulate, repack, handle, sell or use DDT under any trade name (Mackay et al., 1997). Thus, of 15 synthetic chemical pesticides that farmers revealed to use in different formulations, 33.3% (5) of the pesticides are restricted for use and export in the EU but are still used in developing countries including Tanzania. These include: aldicarb, chlordane, dieldrin, endosulfan and aldrin.

PAN-UK, (2008) has detailed a total of 109 active ingredients and hazardous formulations either banned or severely restricted in the EU for agricultural use (plant protection products) and/or for biocide and other uses. In some cases the ban was phased in four active ingredients aldicarb, atrazine, simazine and endosulfan. Endosulfan was banned in 2006 as plant protection due to long term persistent, aldicarb was restricted as plant protection production in 2003 and also banned on other uses in 2006, chlordane was banned in 1981 and export banned in 2004. Aldrin was banned in 1991 and export banned in 2004, and dieldrin was banned in 1981 and export banned in 2004 (PAN-UK, 2008). With exception to aldicarb which is a carbamate, the other three restricted pesticides are in the group of organochlorine pesticides which accumulate in the environment, they are very persistent and move long distances in surface runoff or groundwater (DHSS, 2010). Aldicarb is restricted because is an extremely toxic insecticide and it leaches to groundwater from soil in sufficient quantities potentially harmful to human health (EXTOXNET, 1993).
The WHO classification distinguishes between the more and less hazardous forms of each pesticide and based on the toxicity of the technical compound and its formulations (WHO, 2009). WHO classes are as follows: Ia = Extremely hazardous; Ib = Highly hazardous, II = Moderately hazardous, III = slightly hazardous; U = Unlikely to present acute hazard in normal use and O = Obsolete as pesticide, not classified (WHO, 2009). FAO recommends in its Pesticide Code of Conduct that WHO Ia and Ib pesticides should not be used in developing countries and if possible class II should also be avoided (PAN-UK, 2009).

4.2.2 Management of Agrochemicals and Anticipated Public Health and Environmental Problems in Weruweru Sub-catchment

Plate 4.1 shows agrochemicals that were kept by farmers during site visit. 70% of the farmers buy additional pesticides from small shops within sub-catchment and others do obtain from Kilimanjaro town. 50% of the farmers store inside the house, 10% in food store and 40% in separate room. The survey revealed that most of the farmers do use agrochemical immediately after buying (within two weeks). Similar observation on mishandling of pesticides in term of storage, application and health was reported in Northern Tanzania by Ngowi (2003). The farmers were also asked where they obtained information and direction on application of agrochemicals; about 70% of the farmers receive instructions on pesticide use primarily through written materials, informal talks, past experience and training from agricultural officers.
All the farmers use one established procedure during application of pesticides, which is mixing, loading and spraying. Mixing normally is done inside the farm and followed by spraying of pesticides to the crops. In the procedure of application about 90% of the farmers do not use any safety equipments neither on mixing nor on spraying (Plate 4.2) and (Plate 4.3) respectively and the rest use either masks face or gumboots. About 90% reported that no need to use any protective equipments during spraying of pesticides and application of other agrochemical because they don’t know and never heard about side effects of them on practical use. During application, 50% of the farmers spray pesticide against the wind direction and 43.3% of the farmers applied agrochemicals at least once in a growing season in their crops while 56.7% indicated that they used agrochemical more than twice in a season.
There were no proper disposal methods of the empty pesticide containers and plastic bags of fertilizers. The containers and plastic bags were either thrown in the pit latrines, thrown away in the environment, left around the farms or open burned (Table 4.3). This observation correlates with a study in Brazil to assess exposure to pesticides in which most respondents above 50% reported to leave empty pesticide containers within the field (Araujo et al., 1999).
Table 4.3: Method of Disposal of Agrochemical containers

<table>
<thead>
<tr>
<th>Method of Disposal</th>
<th>Response (n=30)</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Put inside pit latrine</td>
<td>12</td>
<td>40</td>
</tr>
<tr>
<td>Just throw away</td>
<td>9</td>
<td>20</td>
</tr>
<tr>
<td>Disposing within the farm</td>
<td>6</td>
<td>30</td>
</tr>
<tr>
<td>Open burning</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
<td>30</td>
<td>100</td>
</tr>
</tbody>
</table>

The farmers were asked if they were aware of pesticides on managing pests and crops diseases and fertilizers for increasing the crops production. Farmers expressed awareness and even knowledge of a variety of pesticides approaches for reducing pest problems. There was a general agreement among the farmers that traditional based pesticides were not expensive, could be easily obtained, and would have minimal negative effects on the environment and the health of farmers. Awareness and knowledge of traditional methods of pest management, however, should not be interpreted as adoption. The farmers indicated that although traditional methods of pest management were safe, inexpensive, and somewhat readily available, they were not used because of timing and labour consuming. The farmers were also of the view that the effectiveness of traditional methods was not guaranteed for pest’s reduction. Additionally, other method was plant-based pesticides were difficult to measure or calibrate and could easily result in destruction of the crops if incorrect quantities were applied. Another response said that agrochemicals of pest management and increases crops production are the easiest to use if one has money to purchase them.” These responses were given in spite of the farmers expressing their awareness of using chemical pesticides and having negative views of traditional method means of pest management.
4.3 Physico-chemical Characteristics of the Water

The results of the physicochemical parameters measured at upper, middle and lower zones of rivers within Weruweru sub-catchment are presented in figure 4.1.

![Bar charts showing pH, Temperature, Electrical Conductivity, DO, and TDS levels at different sampling stations.](chart_image)

Figure 4.1: Levels of physicochemical parameters measured in water samples in Weruweru sub-catchment

The pH range during the dry and rainy season show that the river water was near neutral 7.3 to 8.6. The pH values during dry season were higher than rainy season (pH\text{dry} > pH\text{rainy}) and it ranged from 7.6-8.6 and during rainy season was 7.3-7.6
The decrease in pH during the rainy season may be attributed to increase in organic matter and pesticide residues in the river. In general pH values in this study were within permissible values for potable water range from 6.5 to 9.2 for pH as recommended by WHO (WHO, 2004). The pH values in surface water are very important for aquatic organisms because their metabolic activities are pH dependent.

The measurement of DO provides a broad indicator of water quality (DFID, 1999). These were possibly brought by overland flow or surface runoff which resulted in decrease in dissolved oxygen (DO) through breaking down of organic matter by microorganisms in the water (DeZuane, 1997). In this study, DO during dry season ranged from 8.6 to 9.8 mg/l and rainy season was 6.5 to 7.6 mg/l. These ranges were within range of DO concentrations in unpolluted water which are normally about 8.0 to 10 mg/l (DFID, 1999). Concentrations below 5.0 mg/l adversely affect aquatic life. The concentrations of DO in the Weruweru River were above 5.0 mg/l and therefore, the river water is suitable for use by the aquatic ecosystem.

Water temperature of the Weruweru river for all sampling sites were lower during the rainy season ($T_{\text{dry}} > T_{\text{rainy}}$). The temperature ranged from 19.4 to 23.7 °C during the rainy season and 21 to 27.4 °C during the dry season (Figure 4.1). The lowest temperature of water samples were recorded in the upper zone (high altitude > 900 m) of the river for both seasons. The levels of conductivity measured range 105 to 163 μs/cm and 57.0 to 78.7 μs/cm during dry and rainy seasons respectively. The high conductivity during the dry season is related to the higher concentration of total dissolved solids (TDS) that results in increase of concentration of salts, organic and inorganic materials (Islam et al., 2012).
TDS levels ranged from 51 to 80 mg/l during the dry season and the value decreased in rainy season from 28.5 to 39.4 mg/l. The increase of concentration of TDS during the dry season could be due to evaporation and decrease sources of water to the river and thus increase concentrations of salts, organic and inorganic materials. The EC and TDS values of water samples from all the sampling stations and in both seasons were within the allowable limits for potable water quality as per WHO guidelines (2000 μs/cm) and Tanzania standards (1500 mg/l) (WHO, 2004; TBS, 2005).

4.4 Nutrient Concentrations in Weruweru River

Nutrients are chemical elements and compounds in the environment from which living things synthesize living matter, their body cells and tissues, their genetic material, their energy-bearing molecules, and their reproductive cells (Antweiler et al., 1995). In this study, four nutrients compounds nitrate (NO$_3^-$), nitrite (NO$_2^-$), ammonia (NH$_3$), and orthophosphate (PO$_4^{3-}$) were analysed in water samples collected from Weruweru sub catchment. These are the most significant inorganic forms of two elements; nitrogen and phosphorus that commonly limit the productivity of plants (Antweiler et al., 1995).

Nitrogen nutrient occur in many forms of both organic and inorganic compounds. Inorganic nitrogen NO$_3^-$-N, NO$_2^-$-N and NH$_3$-N are of particular importance in water contamination due to its toxicity. Depending on the amount of nitrification which occurs, in most cases the water may contain either ammonia or nitrate-nitrogen. Under normal circumstances, the nitrite form of nitrogen does not present in large quantities due to its rapid oxidation or conversion to nitrate. The presence of large concentrations of ammonia in a river or lake can create a high oxygen demand. This demand is caused by the conversion of ammonia to nitrate.
Figure 4.2: Concentration (Mean ± SD) of the Nutrients in Weruweru water samples measured at six sampling sites

The results in figure 4.2a show that NH$_3$-N was low during dry season (range 0.15 – 0.22 mg/l) than during the rainy season (range 0.37 – 0.96 mg/l). NH$_3$-N is pH and temperature dependents, at high pH and temperature high values of NH$_3$-N are expected (Antweiler et al., 1995). But (Figure 4.1) shows that pH and temperature were high during the dry season than rainy season. Both sampling stations are located close to farmlands where extensive agriculture are conducted, therefore possible source of high NH$_3$-N contamination during rainy season is runoffs
containing fertilizers from upstream. High nitrite concentrations in water are indicative of poor microbiological quality of water. Determination of nitrite and nitrate in surface waters gives a general indication of the nutrient status and level of organic pollution.

The results in figure 4.2c show that the concentrations of NO₂⁻-N during the dry and rainy seasons range from 0.005 to 0.008 mg/l and from 0.08 to 0.13 mg/l, respectively. Both concentrations were below the maximum limits in drinking water quality of 1 mg/l per Tanzania standards (TBS, 2005). The concentration for NO₃⁻-N during the dry season ranged from 0.15 to 0.454 mg/l and rainy season range from 0.17 to 0.37 mg/l. The normal background range of nitrate concentration in natural waters is normally below 5 mg/l, any value above this level is an indication of man-made nitrate pollution (Kihampa and Wenaty, 2013). The World Health Organization has set limits of 10 mg/l for NO₃⁻-N concentration in potable water (WHO, 2004). Therefore in this study concentrations of NO₃⁻-N in all sampling station and in both seasons were within the allowable limits for WHO potable water quality and normal range of natural water.

Phosphorus from agricultural practices tend to attach soil particles and thus, moves into surface-water bodies from runoff, when there is too much of it in water, it can speed up eutrophication in the river (Perlman, 2013). In figure 4.2b, the concentration for PO₄³⁻-P during the dry season range from 0.05 to 0.14 mg/l and during rainy season range from 0.44 to 0.52 mg/l. These concentrations were higher than the natural background levels of PO₄³⁻-P in river waters which usually range from 0.005 to 0.02 mg/l (Chapman, 1992). High values of phosphorous in river can speed up eutrophication and reduction of dissolved oxygen of the river water due to
increase of mineral and organic nutrients. Thus, the low level of DO during the rainy season (Figure 4.1) could partly be associated with high level of phosphorous.

4.5 Physicochemical Characteristics of the Sediments

The rate of chemical degradation is influenced by physico-chemical properties of the sediments (such as pH and organic matter content), biological properties (activity and distribution of microorganisms) and environmental conditions that control soil temperature and moisture content. In this study, organic matter content in the middle zone during the dry season ranged from 3.3 to 4.7% and during rainy season were 9.9 to 10.8% (Figure 4.3c) and the temperature during dry season were higher 22.3 °C to 27.4 °C than rainy season 19.4 °C to 23.7 °C, these means that the rate of degradation and photodegradation were higher during the dry season than rainy season. In lower zone of the river, organic content were found in the range of 8.6 to 11.6% during the dry season and 6.6 to 11.6% during rainy season. High organic matter content increases the expectation that the sediment will tend to accumulate more chemical species.

Sediment pH is a measurement of the acidity or alkalinity of a soil. On the pH scale, 7.0 are neutral, below 7.0 are acid, and above 7.0 are basic or alkaline. A pH range of 6.8 to 7.2 is termed near neutral. Areas of the world with limited rainfall typically have alkaline soils while areas with higher rainfall typically have acid soils (VRO, 2009). In this report, the sediment pH was measured in all sediment samples (Figure 3.1; S1-S6).
Figure 4.3: pH, Moisture content and Organic matter content of the Sediment Samples from Weruweru sub-catchment

The results presented in Figure 4.3a showed that the sediment pH in upper zone of the sub-catchment were neutral, within the range of 6.8-7.2, while the pH in the middle zone of the sub-catchment during the dry season in all samples were alkaline and in the lower zone during rainy season were acidic for all samples measured. Sediment pH may influence the degradation of pesticides; the degradation was proceeding faster at high pH than in low pH means that during dry season the degradation are faster than in rainy season.
4.6 Pesticide Residue in Sediment Samples

Seven different types of pesticide residues were detected in varying concentrations from twelve sediment samples analysed during the dry and rainy seasons in the lower and middle zone of the river. Table 4.4 presents results of the pesticides residues measured during dry and rainy seasons. OCls pesticide residues were below detection limits for all the sediment samples collected from the upper zone of the river. This could be explained by the use of OPs in coffee plantation where OCls are inappropriate. Endosulfan sulphate, a metabolite of endosulfan was the most detected pesticide residue. It was detected in about 33% of the sediment samples analysed during the dry and rainy season. The concentration of endosulfan sulphate ranged from 12 to 12.7 µg/kg dw during the dry season and 0.433 to 13 µg/kg dw in rainy season and is susceptible to photolysis in the environment. It is expected to have a high occurrence in cultivated areas (Manirakiza et al., 2003).

Dem at el. (2007) also reported high occurrence of endosulfan sulphate in 15 soil samples from Sikasso areas in Mali, West Africa, which were 11 (74%) of the sample analysed. Endosulphate is a major degradation product of endosulfan and is known to be as toxic as parent compound (Jiang et al., 2009). Because of their high toxicity, technical endosulfan was restricted in many countries including Tanzania but was found being used in the study area (Plate 4.1). This is also confirmed by 90% of farmers who revealed to have been using endosulfan under trade name thionex/thiodan (Table 4.2). In 1998, fish exports from Lake Victoria to the European Union were temporarily banned following observations of tainted fish, which were later proved to have been harvested using endosulfan sulphate (European Commission, 1999).
*p,p’*-DDT was detected during the dry season of the sediment samples analysed with concentration ranged from 5.63 to 19.0 μg/kg dw (Table 4.4) and its metabolites *p,p’*-DDE was detected with concentration of 81 μg/kg dw during rainy season. DDT can be degraded into DDD under anaerobic conditions and into DDE in aerobic environments. DDE generally resist further chemical and biological degradation and normally, \((p,p’\text{-DDT})/(\text{DDT metabolite})\) ratios > 0.5 indicate recent DDT usage (Montgomery, 2000). However, ratios of *p,p’*-DDT to *p,p’*-DDE in this study was 0.23 below the ratio of 0.5 and suggested past inputs of DDT into Weruweru river sediments.

The occurrence of *p,p’*-DDE in sediment samples correlates with the finding from farmers survey who claimed to have used DDT till late 1990s. DDE may last in the sediment for a very long time, potentially for hundreds of years (ATSDR, 2002) sticking strongly to sediment and thus remain in the sediment surface. The persistence in the environment of this organochlorine has also been reported in others areas, for instance DDE have been reported to be widely distributed in soil in China despite of their discontinued use since 1983 (Wu et al., 2007). Dem et al. (2007) also reported the presence of *p,p’*-DDE in sediment and water from four cotton growing areas of Mali, West Africa and also Tarus et al. (2007) reported the presence of *p,p’*-DDE in sediment samples at Pan-paper were detected but within acceptable standards. High toxicity of DDT technical was restricted in many countries including Tanzania but are still found in sediment samples in the study area for very low concentrations after has been restricted usage in Tanzania since 1993 (Mackay et al., 1997).
Table 4.4: Types and Levels of Pesticides Detected in Sediment Samples for Dry and Rainy Seasons

<table>
<thead>
<tr>
<th>Sampling</th>
<th>Site Position</th>
<th>Cyazine</th>
<th>Alfa-Chlordane</th>
<th>Endosulfan Sulphate</th>
<th>p,p'-DDT</th>
<th>p,p'-DDE</th>
<th>Lindane</th>
<th>Cypermethrin</th>
<th>Cyanazine</th>
<th>Alfa-Chlordane</th>
<th>Endosulfan Sulphate</th>
<th>p,p'-DDT</th>
<th>p,p'-DDE</th>
<th>Lindane</th>
<th>Cypermethrin</th>
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bdl = below detection limit
Lindane, a gamma-hexachlorocyclohexane (γ-HCH) was also detected in sediments samples (Table 4.4), use of lindane was restricted by EPA due to concerns over its potential to cause cancer and birth defects in animals but soil concentration of lindane depend on the method of application, soil composition and climatic condition (Gandhi and Snedeker, 2010). Lindane like other organochlorine is highly persistent in most soils and sediment, with a field half life of approximately 15 months. In this study, lindane was detected in middle zone during rainy season (Table 4.4) with the concentration ranged from bdl to 3180 μg/kg dw which was above the fresh water sediment quality assessment guideline of 2.37 μg/kg dw (MacDonald et al., 2000). The percentage detected in sediment samples were 16.7% (Figure 4.4) for both seasons. This lindane was not mentioned during questionnaire with farmers but the detection of lindane in sediment samples indicated past usage in the sub-catchment where by the contaminated soil was eroded from one place to another by surface runoff.

![Figure 4.4: Percentage Occurrence of Pesticide Residue in Sediment Samples during the Dry and Rainy Season](image)
Cyanazine is classified by EPA as a Restricted Use Pesticide (RUP) because of its teratogenicity and because it has been found not only in surface water but also in groundwater (EXTOXNET, 1996). Cyanazine has a low to moderate persistence in soil and it quickly degrades in many soil types mostly due to the action of microbes. Cyanazine has a half-life of 2 to 14 weeks depending on the nature of soil structure (EXTOXNET, 2009a). In this study, cyanazine was detected in the middle and lower zones of the river only during the dry season (Table 4.4) with the concentrations ranged from 0.115 to 7945 μg/kg dw, and percentage detection was 33% (Figure 4.4) of the sediment samples analysed during the dry season.

Cypermethrin is not soluble in water and has a strong tendency to adsorb into soil particles and is unlikely to cause surface and groundwater contamination, and it photodegrades rapidly with a half-life of 8 to 16 days in the soil (EXTOXNET, 1996). This is a major photodegradation products and also subject to microbial degradation under aerobic conditions. EXTOXNET (1996) reported that, when cypermethrin was applied to wheat at 28g of active ingredient/ ha, residues on the wheat were 4 ppm immediately after spraying and declined to 0.2 ppm in 27 days later. In another study with cypermethrin applied to wheat at 0.25 to 1.5 kg/ha, its half-life was 4.8 days. In this study, cypermethrin was found in dry season with the concentration ranging from bdl to 157 μg/kg dw in lower zone of the river and during rainy season was detected in the middle zone of the river ranged from bdl to 5.2 μg/kg dw and the percentage detection was about 16.7% for the sediments samples analysed in both seasons (Figure 4.4). In this study, cypermethrin pesticide was the one which has highest photodegradation of equal or less than 2 weeks followed by cyanazine.
Alfa-chlordane is highly persistent in soils with a half-life of about 4 years. Several studies have found chlordane residues in excess of 10% of the initially applied amount 10 years or more after application. Alfa-chlordane does not chemically degrade and is not subject to biodegradation in soils (EXTOXNET, 1996). Chlordane has been detected in surface water, groundwater and sediments. Concentrations detected in surface water have been very low, while those found in suspended solids and sediments are always higher <0.03 to 580 µg/l (EXTOXNET, 1996). Ouyang *et al.* (2005) reported that the Cedar River area and Ortega river area were contaminated with maximum concentration of alpha-chlordane was 26.3 µg/kg dw in sediments and comparison of total chlordane concentration with Florida Sediment Assessment Guidelines (FSAG) showed that these rivers had total chlordane concentrations above the probable effect level 4.79 µg/kg dw which could pose a potential risk to aquatic life. In this study, alfa-chlordane was detected only during the dry season in lower zone of the river with the concentration ranged from bdl to 64 µg/kg dw which was above the fresh water sediment quality assessment guideline for alfa-chlordane 4.5 µg/kg dw (MacDonald *et al.*, 2000). The percentage detection of alfa-chlordane was 16.7% of the sediments samples analysed in both seasons.

### 4.7 Pesticide Residue in Water Samples

During study visit, water used for irrigation and domestic purpose was found to come from Weruweru river and Shiri springs. But communities in Weruweru sub-catchment received water supplied from Shiri springs 3days/week, which are not sufficient for irrigation and domestic use. In this case people use water from Weruweru river as alternative water source in their daily life (Plate 4.4 & 4.5).
Plate 4.4: Community members wash their clothes directly in the river water (Author, 2013)

Plate 4.5: Children fetch water from Weruweru River for domestic uses (Author, 2013)

Results for water analysis shows diverse concentrations of pesticide residues Lindane, $p,p'$-DDE, $p,p'$-DDD, Alfa-chlordane and Cyanazine. The concentrations of OCls pesticide residues for all water collected from the upper zone of the river were below instrument detection limits. As explained under section 4.6, farmers in this zone use OPs for their coffee plantations.
Table 4.5: Pesticide Residue Concentration (μg/l) Detected in Water Samples

<table>
<thead>
<tr>
<th>Site</th>
<th>Position</th>
<th>Cyanazine</th>
<th>Alfa Chlordane</th>
<th>p,p’-DDD</th>
<th>p,p’-DDE</th>
<th>Lindane</th>
<th>Cyanazine</th>
<th>Alfa Chlordane</th>
<th>p,p’-DDD</th>
<th>p,p’-DDE</th>
<th>Lindane</th>
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<td>0.816</td>
<td>0.481</td>
<td>0.74</td>
<td>bdl</td>
<td>bdl</td>
<td>0.23</td>
<td>0.506</td>
<td>bdl</td>
<td>bdl</td>
</tr>
</tbody>
</table>

% Detected 16.7 33 16.7 16.7 16.7 - 50.1 16.7 - -

bdl = below detection limit
The samples collected from the middle and lower zones displayed all other pesticide residues detected in sediments samples with exception to endosulfan and cypermethrin which their concentrations were below instrument detection limits. Percentage detection of DDT metabolites in water samples were 33.4% during the dry season and 16.7% during rainy season. \( p,p' \)-DDD was detected in lower zone of the river for both seasons and the concentration range from 0.481 to 0.506 \( \mu \)g/l (Table 4.5). \( p,p' \)-DDE was only detected in the lower zone of the river during the dry season with the concentration range from bdl to 0.74 \( \mu \)g/l. The concentrations of the DDT metabolites were within the acceptable limits in water 2 \( \mu \)g/l as per WHO guidelines (WHO, 1993).

Lindane was detected in 16.7% of the water samples analysed during the dry season (Figure 4.5) with concentration range from bdl to 3.66 \( \mu \)g/l, this concentration was above the acceptable limits for drinking water 2 \( \mu \)g/l as per WHO guidelines (WHO, 1993). Lindane was not detected in water during rainy season (Figure 4.5).

![Figure 4.5: Percentage Occurance of Pesticide Residue in Water Samples during the Dry and Rainy Season](image)
This observation was less than that reported by Kihampa et al. (2010) where 40 % lindane was detected from the water sample with the concentration of 2800 µg/l and Manirakiza et al. (2003) reported that 90 % of lindane was detected from the water samples collected from West African City farms (Banjul and Dakar). The small percentage detected of lindane indicates past usage, the concept can also be confirmed by the interview and site observations where farmers did not mention or found to use lindane in any name.

Cyanazine was detected in lower zone of the river during the dry season only with the concentration range from bdl to 45.7 µg/l (Table 4.5), which was higher than acceptable limit in drinking water 10 µg/l as per WHO guidelines (WHO, 1993). Concentrations of cyanazine during rainy season were below detection limits, this could be due to the fact that cyanazine takes 2 to 14 weeks to complete disappearing but could also have been washed away by runoff from one point to another (EXTOXNET, 1996). This results of high concentration of cyanazine during dry season correlate with the study in USA, cyanazine was detected in surface water and groundwater at maximum concentrations of 1300 µg/l and 3500 µg/l, respectively (EXTOXNET, 1996).

The EPA banned all uses of chlordane in 1998. The EPA recommends that children should not drink water with more than 60 µg/l of chlordane for longer than 1 day. EPA has set a limit in drinking water of 2 µg/l (PBCR, 1998). In this study, alfa-chlordane was detected in 33% (Figure 4.5) of the water sample analysed during the dry season and 50% during rainy season with concentration range from 0.0281 to 0.816 µg/l and mean concentration of 0.24 µg/l which was below the acceptable limit in drinking water of 2 µg/l as per WHO guidelines (WHO, 1993). This is the
highest percentage detection in water samples for both seasons followed by \textit{p,p‘}-DDD because of their long persistent in water, the rest of the pesticides were detected only during the dry season (Figure 4.5).

4.8 Conclusion

This chapter presented of the results as analyzed and interpreted, and the discussion of the presented results was finally made. Discussion was made through comparisons with the results from related similar studies to show how better were the presented results, as compared to earlier works in similar or related field on water quality. This gave an understanding of the use and effect of agrochemical in Weruweru sub-catchment.
CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary of Key Findings

The study identified the farmer’s attitude, knowledge and practices on the use of pesticides, levels of nutrients in water samples and pesticide residues detected in water and sediment samples during the dry and rainy seasons in Weruweru subcatchment. It was evident that, some of pesticides which were being used in the study area are already restricted in the European Union (Plate 4.1 & Table 4.2). Handling and application of agrochemicals which include storage, mixing, spraying and disposal are among the problems discovered. Four plant nutrients include NO$_3^-$, NO$_2^-$, NH$_3$ and PO$_4^{3-}$ were analysed in water samples for both seasons and all were found below maximum limits in drinking water except NH$_3$, which was above WHO (0.05-0.5 mg/l) maximum limits in both seasons, during the dry season it ranged from 0.15 to 0.22 mg/l while in the during rainy season the range was 0.37 - 0.96 mg/l (WHO, 2004). The concentrations of PO$_4^{3-}$ in both seasons, dry (0.05-0.14 mg/l) and rainy (0.44-0.52 mg/l) were higher than the natural background levels of PO$_4^{3-}$ in river waters, which usually range from 0.005 to 0.02 mg/l (Chapman, 1992).

Five Organochlorine pesticide residues namely cyanazine, alfa-chlordane, $p,p'$-DDT, $p,p'$-DDE and lindane were detected in water samples while in sediments samples seven pesticide residues, which include cyanazine, alfa-chlordane, endosulfan sulphate, $p,p'$-DDT, $p,p'$-DDE, lindane and cypermethrin were detected. All OCls pesticide residues in sediment samples were within the requirements of the fresh
water sediment quality assessment guideline except lindane and alfa-chlordane, which were higher than assessment guideline, the lindane concentrations ranged from bdl to 3180 µg/kgdw and acceptable limit for lindane is 2.37 µg/kg dw while for alfa-chloradn was ranged from bdl to 64 µg/kgdw and the acceptable limit is 4.5 µg/kg dw. All the pesticides detected in water samples were within the acceptable limit in drinking water as per WHO except cyanazine and lindane, the concentration range from bdl to 45.7 µg/l and bdl to 3.66 µg/l respectively. These concentrations were higher than acceptable limit in drinking water for cyanazine 10 µg/l and lindane 2 µg/l (WHO, 1993).

5.2 Conclusions
The study revealed that agrochemicals normally represent the major health problems in farming areas, but little information is available on the serious and chronic effects on human health in Weruweru sub-catchment. As noted on this study, Weruweru sub-catchment faces problems of handling and application of agrochemicals, which results into various nutrients concentration in water and pesticide residues levels in water and sediment samples, not only that but also lacking the fundamental skills, knowledge and safety equipment necessary for handling of pesticides, these agricultural labourers are causing substantial harm to themselves, their communities and their environment in their attempt to grow different crops in the sub-catchment.

The results showed that there’s danger of pollution of the drinking water of Weruweru river from some OCls pesticides (lindane and cyanazine) and effect of ammonia concentration to aquatic organisms specifically at the lower zone of the river.
There was a general increasing trend of the concentrations of the pollutants from middle to lower zone of the river. The increasing use of pesticides especially those which were already restricted in Tanzania, demands a worldwide control of residue levels in water and environment and especially when the residue level concentrations are higher than the required minimum levels. The compositional analysis of DDT indicated that past usage of DDT was degraded significantly to $p,p'\text{-DDD}$ and $p,p'\text{-DDE}$ in water and sediment samples. Although the use of agrochemicals has supported the development of agriculture and generated broad health benefits through the management of pests and disease, there are serious risks to human health and environmental sustainability. The contamination of water and sediment pose risks of bioaccumulation into food chains. The global nature of agrochemical issues requires a comprehensive and global approach that brings together all stakeholders.

5.3 **Recommendations**

From the study findings, the following recommendations will help environmental managers in the area to manage the Weruweru Sub-catchment sustainably:

(i) In order to achieve water quality standard and the management in charge of the sub-catchment (especially the local government) should immediately adopt Integrated Water Resources Management and Integrated Watershed Management throughout the sub-catchment.

(ii) Extension services in the sub-catchment should be improved. This will serve as a source of information and training forum for farmers on safe application of agrochemical and safety of equipments during mixing and spraying pesticides.

(iii) Since watershed development is considered to be the focal point for rural development with the aim of increasing agriculture production by using
agrochemical to control diseases and reducing poverty, farmers should be trained and assisted in their agricultural activities including use of agrochemicals and water resources conservation.

(iv) Pesticides products which fall into WHO classes Ia and Ib, or formulations of products in Class II such as endosulfan should not be used.

(v) Raise awareness of the problems linked to agrochemical in agricultural activities, and how they can be avoided through extensive training programmes to the farmers and use of integrated agrochemicals management such as crop rotation should be encouraged.

(vi) Regular monitoring of agrochemicals residues is required in order to control the pollution.

5.4 Further Research in the Study Area

This study was mainly based on assessing the agrochemical residues on water quality in Weruweru sub-catchment for watershed management and planning. Different data collection methods (for instance, taking data at different time of the year) and results compared. For strategic planning purposes in the sub-catchment, further studies should be carried out to carefully monitor and assess how farmers continue to use the agrochemical in agricultural activities in the study area. This will enhance enforcement to stop using restricted pesticides, proper use of agrochemicals which are environmental friendly, safety use of protective equipment during the application of agrochemicals and training to farmers. Potential areas for research and development in the sub-catchment include:-

(i) Assessment of the study area for organophosphorous pesticide residues in especially in upper zone of the river where coffee plantation are major crops.
(ii) Evaluation of chronic human health effects that may be associated with water consumers from Weruweru sub-catchment.

(iii) Evaluation of possible bioaccumulation of pesticide residues in the aquatic organisms, plants and the environment.

(iv) Monitoring and modelling pesticide fate and nutrient levels in surface water at the sub-catchment scale

(v) Health impact associated with exposure to agrochemicals in agricultural activities in Weruweru sub-catchment.
REFERENCES


APPENDICES

Appendix I: Questionnaire

Preamble

Good morning/afternoon: My name is Jokha Mohamed, am studying MSc. in Integrated Watershed Management at Kenyatta University. I am conducting a research on assessment of agrochemical residues influence on water quality degradation in Weruweru sub-catchment, Tanzania. I would like to ask you some few questions in relation to this study. The information you provide will be kept confidential and will be used sorely for research on finding solutions to agrochemical problems.

1. Name of interviewee/household head
   ………………………………...Sex……………Age………………..Date……………………

2. District/Ward/Village ………………………………………………………………………

3. What is your main source of income? (Tick)
   Farming □   Self employed in business □   Government employed □
   Other □ (Specify)…………………………………………………………………………

4. Your Education:  None □   Primary □   Secondary □   University □

5. Your Farm size (in acres):
   0-1 □   1-3 □   3-5 □   5-7 □   7-9 □   above 10 □

6. What is the source of water for your household? (Tick)
   (a). Tape water
   (b). Weruweru-Kiladeda River / any river near by
   (c). Shallow wells/Boreholes
   (d). Other (Specify)……………………………………………………………………
Uses of Agrochemicals

1. Have you ever used pesticides for your crops? Yes…No…

2. If yes, when did you start using pesticides?
   - 0-3 yrs
   - 3-6 yrs
   - 6-9 yrs
   - >10 yrs

3. What common type(s) of pests/disease(s) do you control by using pesticides?

4. What type(s) of pesticides have you ever used/continue using?

5. What type of pesticides commonly used in Weruweru-Kiladeda sub-catchment?

6. Where did you buy pesticides?
   - Small shops in Kilimanjaro town
   - Vendors
   - Other
   Specify

7. Where do you store the stock of pesticides?
   - Inside house
   - In food store
   - In separate room/store
   - Other
   Specify

8. How far long do you store pesticides before application?
   - 0-1yr
   - 1-2 yrs
   - 2-3 yrs
   - Use immediately

9. Where do you dispose your used containers and obsolete of pesticides?
   - Leave at the field/Shamba
   - Just throw away
   - Burning deep in the soil
   - Other
   Specify

10. How many times do you spray in the field for one crop type in a year?

11. When was the last spray in the field?
12. What techniques/ safe equipments do you use during applying pesticides?

…………………………………………………………………………………………

13. How do you get information on safe use of pesticides?
   Pesticide dealers  □  Agriculture officer  □ Read instruction by yourself  □
   Other  □  Specify…………………………………………………………………………

14. What common problem(s) do you know or heard relating to the application of pesticides?
…………………………………………………………………………………………

15. Have you heard of any case(s) reported relating to the use of pesticides in Kilimanjaro region?

16. Do you use manure fertilizers and / fertilizers?
   Specify with reason(s) for use one or both of them ..............................
   …………………………………………………………………………………………………

17. If you use fertilizers, what type(s) do you commonly use?
   Phosphate fertilizer  □  Nitrogen fertilizer  □  Other  □
   Specify…………………………………………………………………………………

18. Where do you buy fertilizers?
   Small shops in Kilimanjaro town  □  Vendors  □  Other  □
   Specify………………………………………………………………………………

19. How many times do you use fertilizers in the field in a year?
   Once a year  □  twice a year  □  Other  □
   Specify……………………………………………………………………………….

20. What is your opinion towards application of pesticides and fertilizers in cropping systems in the Weruweru sub-catchment?
   Comment(s)………………………………………………………………………………
   ……………………………………………………………………………………………

Thank you very much for your cooperation!
## DATA ANALYSIS RESULTS SHEETS

Table 4.6: Mean Concentration of Nutrients in Surface Water

<table>
<thead>
<tr>
<th>Sampling Code</th>
<th>Dry season</th>
<th>Rainy season</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NH$_3$-N</td>
<td>NO$_2$-N</td>
</tr>
<tr>
<td>W1</td>
<td>0.18±0.005</td>
<td>0.005±0.001</td>
</tr>
<tr>
<td>W2</td>
<td>0.15±0.021</td>
<td>0.005±0.001</td>
</tr>
<tr>
<td>W3</td>
<td>0.16±0.003</td>
<td>0.006±0.001</td>
</tr>
<tr>
<td>W4</td>
<td>0.19±0.055</td>
<td>0.006±0.001</td>
</tr>
<tr>
<td>W5</td>
<td>0.17±0.038</td>
<td>0.008±0.005</td>
</tr>
<tr>
<td>W6</td>
<td>0.22±0.04</td>
<td>0.008±0</td>
</tr>
</tbody>
</table>

Table 4.7: Physicochemical Parameters of the Sediment Samples

<table>
<thead>
<tr>
<th>Sampling Sites</th>
<th>pH</th>
<th>Moisture Content (%)</th>
<th>Organic Content (%)</th>
<th>pH</th>
<th>Moisture Content (%)</th>
<th>Organic Content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>7.20</td>
<td>17.2</td>
<td>1.77</td>
<td>6.8</td>
<td>25.4</td>
<td>17.8</td>
</tr>
<tr>
<td>S2</td>
<td>7.28</td>
<td>19.2</td>
<td>12.5</td>
<td>6.95</td>
<td>25.9</td>
<td>10.8</td>
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<tr>
<td>S3</td>
<td>7.35</td>
<td>26.5</td>
<td>3.3</td>
<td>6.0</td>
<td>20.4</td>
<td>9.9</td>
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<tr>
<td>S4</td>
<td>7.44</td>
<td>27.2</td>
<td>4.7</td>
<td>5.9</td>
<td>25.8</td>
<td>12.0</td>
</tr>
<tr>
<td>S5</td>
<td>7.46</td>
<td>34.5</td>
<td>8.9</td>
<td>5.5</td>
<td>28.5</td>
<td>11.6</td>
</tr>
<tr>
<td>S6</td>
<td>7.49</td>
<td>38.8</td>
<td>11.6</td>
<td>5.8</td>
<td>15.1</td>
<td>6.6</td>
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### Appendix II: Physicochemical and Nutrient Results

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<tr>
<th>Date</th>
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<th>COD</th>
<th>BOD</th>
<th>CO2</th>
<th>DO</th>
<th>NH3-N</th>
<th>NO2-N</th>
<th>NO3-N</th>
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<tbody>
<tr>
<td>1/21/2019</td>
<td>Sample 1</td>
<td>7.5</td>
<td>80</td>
<td>60</td>
<td>10</td>
<td>8</td>
<td>2</td>
<td>1</td>
<td>3</td>
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<tr>
<td>1/21/2019</td>
<td>Sample 2</td>
<td>7.8</td>
<td>90</td>
<td>80</td>
<td>15</td>
<td>9</td>
<td>3</td>
<td>2</td>
<td>4</td>
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<tr>
<td>1/21/2019</td>
<td>Sample 3</td>
<td>8.0</td>
<td>100</td>
<td>90</td>
<td>20</td>
<td>12</td>
<td>4</td>
<td>3</td>
<td>5</td>
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*Note:* Water analysis results include physical and chemical parameters.
<table>
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<tr>
<th>Parameter</th>
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<th>EC (mS/cm)</th>
<th>pH</th>
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<tbody>
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<td>Fe II</td>
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<td></td>
</tr>
<tr>
<td>Fe III</td>
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<td>Ca</td>
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</tr>
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</tr>
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<td>PO4</td>
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April 2013

Water sample collected by: JOHNNY MOHAMMED

E-mail: info@waterresearch.com
P.O. Box 482 LASHERA ARISHA
NATIONAL DEPARTMENT OF WATER RESEARCH WATER LABORATORIES

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41.314837, 13.788257

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Water analysis results: Physical and Chemical parameters
### Table 12.1 Gas chromatographic retention times of pesticides

<table>
<thead>
<tr>
<th>Substance</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>ECD</th>
<th>NPD</th>
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<tbody>
<tr>
<td>Melaminophos</td>
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<tr>
<td>Dichlorvos</td>
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<td>0.08</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Diazinon</td>
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</tr>
<tr>
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</tr>
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</tr>
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<td>Paraoxon</td>
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</tbody>
</table>

Retention times are related to parathion (A-D adapted from Zwol, 1972; E and F from Anderson and Chirm, 1966).
<table>
<thead>
<tr>
<th>Substance</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>ECD</th>
<th>NPD</th>
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<tbody>
<tr>
<td>diethylidion</td>
<td>0.59</td>
<td>0.55</td>
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<td></td>
<td>0.79</td>
<td>0.69</td>
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<td>x</td>
</tr>
<tr>
<td>fenthion (2)</td>
<td>0.80</td>
<td>0.61</td>
<td></td>
<td></td>
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<td>0.80</td>
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<td>x</td>
</tr>
<tr>
<td>alachlor</td>
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<td>0.27</td>
<td></td>
<td></td>
<td>0.86</td>
<td>0.60</td>
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<td>x</td>
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<td>oxadiazon</td>
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<td>0.80</td>
<td>0.70</td>
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<td>terbutryl</td>
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<td>0.76</td>
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<td>0.76</td>
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<td>fenothiocarb</td>
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<td>0.85</td>
<td></td>
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Appendix IV: Chromatograms of Pesticide Residues in Water and Sediment Samples
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