ASSESSMENT OF PESTICIDE EXPOSURE PATHWAYS ON HUMANS IN MANG'OLA WARD, KARATU DISTRICT-ARUSHA, TANZANIA

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A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN PUBLIC HEALTH AND FOOD SAFETY OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

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ABSTRACT

A cross-sectional study was carried out in Mang'ola area in Lake Eyasi basin from October 2012 to February 2013 to assess pesticide exposure pathways to vegetable growers and consumers. A total sample size of 263 respondents was selected for the study. Baseline data for exposure pathway scenario, eating habits and quantities of vegetables consumed were collected using structured questionnaires, In-depth interview, Focus group discussion and observations. Health risk characterization was estimated based on FAO/WHO guidelines. Results showed an indiscriminate use of pesticides with limited knowledge on environmental contaminants and public health risks. About 61% of vegetable growers who applied pesticides once pests appeared on their grown vegetables, only 4.9% consulted the Agriculture Extension Officers. Up to 75.6% of vegetable growers mixed more than two types of pesticides and did not abide to basic safety procedures for pesticide application. Also 73.2% of pesticide applicators were not used personal protection devices. Ingestion of contaminated vegetables as the route of pesticide exposure to consumers had 53.7% and most consumed vegetables were onions and tomatoes (97.6%). Among the identified exposure pathways from pesticide contaminated fields were "take-home pathway", "residential proximity pathway" and "contaminated wind spray drift exposure pathway" associated with direct dermal contact (68%) and inhalation (54%). Secondary retrieved pesticide residue concentrations data ranged from <0.01 to 18.10 mg/kg, those were organophosphates, organochlorines, pyrethroids, triazole and Triadimefonog-menol. The highest health indices were found for pyrethroids (0.96 ≈1) and organophosphate (5.9). Therefore, health hazards were by organophosphate since their Hazard Risk Index level exceeded 1, while pyrethroids level was likely to cause risk to exposed consumers. Most of the previous studies ended up with hazard identification and characterization but this study addressed exposure assessment leading to risk characterization. According to this study, pesticide safety education programme on exposure pathways is important against human health risks.

DECLARATION

I, Arthur Bernard Mhauka do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

___________________________ ___________________

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The above declaration is confirmed;

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Prof. Mdegela, R. H. Date

(Supervisor)

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Dr. Nonga, H. E. Date

(Supervisor)

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DEDICATION

This work is dedicated to my beloved wife Shukrani Mdegela, my daughter Rebecca John Mhauka and my Mother Ganeth Dennis Mhagama for their prayers, patience and inspiration during the period of my MSc. Public Health and Food Safety study.

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LIST OF ABBREVIATIONS AND SYMBOLS

AAPCC	American Association of Poison Control Centers
ADI	Acceptable Daily Intake
ANOVA	Analysis of Variance
ARfD	Acute Reference dose
ATSDR	Agency for Toxic Substances and Disease Registry, USA
BW	Body weight
CAC	Codex Alimentarious Commission
CI	Confidence interval
CPPAES	Children's Post-Pesticide Application Exposure Study
DDT	Dichlorodiphenyltrichloroethane
DED	District Executive director
EDI	Estimated daily intake
EFSA	European Food Safety Authority
EP	Edible portion
EPA	Environmental Protection Agency
EU	European Union
FAO	Food and Agriculture Organization
FGD	Focus group discussion
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FSA	Food Standards Agency
GAP	Good agricultural practice
gm	Gram
HH	Household
HRI	Hazard Risk Index

IDI	In-Depth Interviews
ILSI	International Life Sciences Institute
IPM	Integrated pest management
kg	Kilogram
LFEO	Livestock/agriculture field extension officer
LOEL	Low observed effect level
MHC	Maternal and Health Care nurse
MLs	Maximum levels
MORATANZ	Monitoring and risk assessment of contaminants in southern Africa project: Arusha in Tanzania.
MRL	Maximum Residual Limits
NBS	National Bureau of Statistics
NFI	Nutrition Foundation of India
NGOs	Non-Governmental Organizations
NIMR	National Institute for Medical Research
NOAEL	No observed adverse effect level
NRC	National Research Council
OC	Organochlorine
OECD	Organization for Economic Co-operation and Development
OP	Organophosphate
PF	Processing factor for the specific food commodity
PHI	Pre-harvest interval
PPE	Personal protection equipments
PSU	Primary sampling unit
®	Registered trade mark
SBuChE	Serum Butyl cholinesterase

SD	Standard Deviations
SPSS	Statistical Package for Social Sciences Software.
SUA	Sokoine University of Agriculture
TAPP	Tanzania Agriculture Productivity Program
TFDA	Tanzania Foods, Drugs and cosmetics Authority
UNEP	United Nations Environment Programme
US EPA	United States Environmental Protection Agency
USAID	United States Agency of International Development
VEO	Village executive officer
WEC	Ward Education Coordinator
WEO	Ward executive officer
WHO	World Health Organization
WRI	World Research Institute

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Pesticides are chemical substances with harmful effects on both the human beings and the environment (Wilson and Tisdell, 2001). These chemical substances are purposely manufactured to prevent, repel, or destroy pests that compete for food supply (FIFRA, 2003). Ideally, a pesticide should effectively control the target pests for a critical period of time during its growth and then be degraded to products harmless to man and other organisms (IUPAC, 1980). Practically, this situation rarely occurs and some application may lead to the continued existence of the parent compound or biologically active metabolites over a prolonged periods. These unwanted residues or contaminants may directly or indirectly endanger some phase of life. However, the persistence of pesticides in the environment depends on their chemical and physical properties, dose and formulation; type of soil, its moisture content, temperature, physical properties of the soil, composition of the soil micro flora and species present. For example organochlorine pesticides persist in the environment for more than 18 months and some may persist for over 10 years (Boca-Raton and Day, 2001; Goncalves and Alpendurada, 2005).

Pesticides are generally categorized according to the type of pest for which they have been shown to be efficacious. The primary categories are insecticides, herbicides and fungicides. Many other categories, such as fungicides, termiticides, rodenticides, algaecides, repellents and miticides, are also in use (Ware, 1994). The use of pesticides have increased because they have rapid action, decrease toxins produced by food infecting organisms and are less labour intensive than other pest control methods (Keikotlhaile and Spanoghe, 2011). However, the use of pesticides may lead to the presence of pesticide residues in harvested food which was a concern to consumers because pesticides are known to have potential harmful effects to other non-targeted organisms. Major concerns are their toxic effects that obstruct the reproductive systems and foetal development as well as their capacity to cause cancer and asthma (Gilden *et al.,* 2010). The direct contact effects through their skin, mouth, eyes and nose results to mild symptoms like skin and eyes redness and itchy, dizziness, faintness, blurry vision, vomiting, coughing, headache, wheezing, drooling from mouth or nose and small pupils of the eyes. Severe symptoms include cold, flu or heat exhaustion and allergic reaction (DPH, 2008).

Since 1950, the use of pesticides has increased 50 folds and over 2.5 million tons of industrial pesticides are worldwide used annually (Farag *et al*., 2011). Pests contribute significantly to food losses and their control is very central to the attainment of food security at all spatial scales (Al-Eed *et al*., 2006; Iya and Kwaghe, 2007). Pesticides are extensively used in agricultural production to prevent and control pests, diseases, weeds and other plant pathogens as efforts to reduce or eliminate yield losses to get high product quality (Sanborn *et al*., 2004; Eskenazi *et al.,* 2008). In addition to the high quantity of pesticides applied, farmers use high concentrations with increased frequency of applications and mix several pesticides together to combat resistance by pests (Wilson and Tisdell, 2001).

Although pesticides are manufactured under very strict regulation processes to function with logical certainty and minimal impact on human health and environment, serious concerns have been raised about health risks resulting from residues in food (Eskenazi *et al*., 2008; Damalas and Eleftherohorinos, 2011). By their nature, most pesticides show a high degree of toxicity intended to kill certain organisms and thus create some risk of harm to human health (Zidan, 2009; Abdelgadirand and Adam, 2011). Within this framework, pesticide use has evoked grave concerns not only of potential effects on human health but also impacts on domestic animals, wildlife and sensitive ecosystem (Power, 2010).

In developing countries such as Ghana, farmers face immense risks of exposure owing to the use of toxic chemicals that are banned or restricted in other countries (Al-Eed *et al*., 2006; Nasr *et al.*, 2007; Adhikari, 2010). Wrong application techniques, badly maintained or totally unsuitable spraying equipment and inadequate storage practices exacerbate their risks (Al-Wabel *et al*., 2011). Often the reuses of old pesticide containers for food and water storage also contribute to the risk of exposure (Ecobichon, 2001; Damalas and Eleftherohorinos, 2011). Pesticide residues in or on plants may be unavoidable even when pesticides are used in accordance with good agriculture practices (GAP) (Uysal-Paha and Bilisli, 2006). This is evidenced by a number of studies which have reported presence of pesticide residues in a number of food items including strawberries, onions, cucumber, lettuce, cabbage, okra, pepper, tomatoes, beans, oranges and lemons (Hussain *et al.*, 2002; El-Nahhal, 2004 and Hanson *et al.*, 2007).

In Tanzania pesticides are highly used in areas where coffee, fruits and vegetable farming are practiced. Arusha is one of the leading regions in pesticide trading and utilization because of its favourable climate for agriculture (Pesticide and poverty, 2006). Both small and large scale farmers indiscriminately use large quantities of different pesticides (Ngowi *et al*., 2007). For instance, in a preliminary survey made in January 2010 in Mang'ola area in Arusha, pesticides costs for large scale farmers was estimated about 12 000 US$ per household per year (Nonga *et al*., 2011).

High uses of pesticides may be associated with undesirable effects to humans, animals and the environment (ENVIROCARE, 2000). Exposure to agricultural pesticides can pose significant health risks to farmers and the public at large. According to Ngowi (2002), about 62 people in the coffee growing areas in Tanzania were dying annually from pesticides poisoning, and many others suffer from different poisoning signs. However, little attention on pesticide contaminations has been received from the general population in Tanzania.

Exposure to pesticide residues through food consumption is assumed to be higher in magnitude than other exposure routes, such as inhalation and dermal absorption (Juraske *et al.*, 2009). It has been reported that most frequently consumed raw or semi-processed food types which inevitably use pesticides during growing are fruits and vegetables (WHO, 2003). But the amount of pesticide residues consumed will depend on the process conditions and physicochemical properties of the pesticide (EFSA, 2007; Keikotlhaile *et al.,* 2010). Pesticide residues on vegetables are scrutinized with reference to Maximum Residue Limits (MRLs) and are based on analysis of quantity of a given residue remaining on food product samples. The MRLs is not a health-based exposure limit and thus exposure to residue in excess of MRLs does not necessarily imply a risk to health (Boobis *et al*., 2008). This is because the use of a pesticide would not be allowed if the proposed MRL resulted in long-term and short-term exposure of pesticide residue and the human diet is above safety limit. Given the potential risk of pesticides to the public; the use of pesticides in agriculture need to be subjected to constant monitoring on the proper use of pesticides in terms of authorization, registration, application rates, pre-harvested intervals, compliance with the use of maximum levels (MLs) and maximum residue limits (MRLs).

To evaluate the safety of consumed agricultural products from pesticide residues, the warranted exposure need to be assessed and compared to health safety limits or toxicological endpoint values such as the Acceptable Daily Intake (ADI) (Wendie *et al.*, 2011). Nevertheless, there is limited information to link the status of human exposure to pesticides and their pathways in developing countries like Tanzania. Understanding pesticide exposure pathways is essential for drawing firm conclusions about the health effects of pesticides to exposed community. What are the pesticides contaminant pathways that depict the exposure scenario on humans? Are there sources of pesticide contaminations? Does pesticide contaminant reach an exposure points e.g. soil, air, water, or vegetable fields? Are there possible routes of human exposure to pesticide contaminants? Those were the questions that estimated people's potential exposure to chemical contaminants through ingestion, inhalation or dermal absorption (Hanne *et al*., 2002).

Humans may be exposed to pesticides through different pathways and some of the pesticides are not biodegradable. They accumulate in their body through occupational activity, accidental or consumption of contaminated foods. Some of the used chemicals in particular organochlorines (OC) accumulate and persist in human tissues due to their lipid solubility and resistance to metabolism (Jandacek and Tso, 2001). This study therefore, was carried out to assess the pesticide exposure pathways in human population in Mang'ola ward where pesticide are applied in high quantities.

1.2 Objectives

1.2.1 Main objective

To assess pesticide exposure pathways to the vegetable consumers and farm workers in Mang'ola area where pesticides are applied in high quantities.

1.2.2 Specific objectives

1. To establish baseline data about pesticide exposure pathway scenarios in the study area
2. To assess the eating habits and quantities of various types of vegetables consumed in the study area
3. To characterize the risk of the identified pesticide hazards based on FAO/WHO guidelines.

1.2.3 Research questions

1.2.3.1 Research questions for specific objective 1

Are there any pesticides contaminant pathways that depict the exposure scenario on humans living in Mang'ola area?

a. What are the sources of pesticide contaminations?
b. Does pesticide contaminant reach an exposure points e.g. soil, air, water, or vegetable fields?
c. What are the possible routes of pesticide contaminants to exposed humans?

1.2.3.2 Research questions for specific objective 2

Is there any vegetable eating habit that exposes consumers to pesticide residue contaminants?

a. What is a daily vegetable intake history of a household and their usual meal pattern?
b. What are the frequency estimates of vegetable consumption at household level?
c. What are the quantities of vegetables prepared for a meal before eating and their leftovers?

1.2.3.2 Research questions for specific objective 3

i. What dose of pesticide residuals are vegetable consumers exposed to?

ii. At what exposure levels increase the health risk or adverse effects are likely to occur?

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Definition of Pesticide Exposure Pathway

An exposure pathway must, by definition, have five components: (a) a contamination source or release such as pesticide treated vegetable fields which release contaminants into various media; (b) an environmental fate and transport mechanism in which once released to the environment, contaminants move through and across different media and some degrade altogether; (c) a point or area of exposure that refers to specific locations where people might come into contact with a contaminated medium such as hands, cloth and the personal protective equipments - PPE); (d) an exposure route that refers to the means by which people physically become in contact with environmental contaminants at point of exposure such as ingestion, inhalation and dermal contact and (e) potentially exposed population that refers to identified and characterized population that may come or may have come in contact with contaminants, such as vegetable growers and laborers, pesticide applicators as well as vegetable consumers. When all five components are present, the exposure pathway is termed a complete exposure pathway (WHO, 2010).

These five elements of exposure pathway largely determine to what extent exposures may have occurred, may be occurring, or may occur in the future at and around the site. Some elements may require more detailed assessment to identify exposure situations that may require further investigation for a public health assessment. A combination of facts, assumptions, and inferences that defines a discrete situation or activity where potential exposures to two or more pesticides may occur is called exposure scenario. The cumulative exposure framework for estimating combined exposures is based on exposure to individuals, which represent differing attributes of the population (e.g., human activity patterns, place of residence, age) that link route of exposure through scenario building) (USEPA, 2002).

The key word in the definition of exposure is contact; people are in contact with potentially harmful chemical, physical and biological agents in air, food, water, soil, dust and products among others. Exposure does not result only from the presence of a harmful agent in the environment; there must be contact between the agent and the outer boundary of the human body, such as the airways, skin and the mouth. It is events that occur when there is contact at the boundary between a human and the environment with a contaminant of a specific concentration for an interval of time (Berglund *et al.*, 2001). Hence exposure assessment is the qualitative and/or quantitative evaluation of the likely intake of biological, chemical, and physical agents via food as well as exposures from other sources if relevant (FAO/WHO, 2008).

In a risk assessment, exposure pathways are means by which hazardous substances move through the environment from a source to a point of contact with people. Routes of entry can be eating or drinking contaminated materials, breathing contaminated air, or absorbing contaminants through the skin. The studies conducted by Jaga and Dharmani (2003) and Hamilton *et al.* (2004) found that the actual sources of human exposure pathway are variable, may be higher than that anticipated due to certain food preferences, residue variability between individual food items and the greater than average consumption of a particular food item.

Risks can be assessed when exposure pathway is complete. If any part of exposure pathway is absent, the pathway is said to be incomplete and no exposure or risk is possible. In some cases, although a pathway is complete, the likelihood that significant exposure will occur is very small. Risk assessments include a "pathways analysis" to identify pathways that are complete and most likely to produce significant exposure (ATSDR, 2005). On the other hand, duration and the frequency of exposure are both important determinants of total exposure. The minimum duration of exposure causing a disease is often not known. Therefore, it can be important to evaluate exposure over both long and short periods. When health effects from long-term exposure (months, years) are to be evaluated, exposure and dose are usually integrated over the time period of interest. For shorter periods, such as minutes, hours, or days, exposure is usually averaged over the specific time period (Berglund *et al.*, 2001).

2.2 The Origin of Human Exposure Assessment

Exposure assessment has been a natural part of human history and civilization. Different kinds of exposure and various types of foods and environments were encountered by the humans who soon learnt what could be eaten or not, and what kinds of environments should be avoided (Berglund *et al.*, 2001). Early professionals in the field of exposure assessment were the testers at the court of the Roman Emperors. They had to consume part of the food to be served to the Emperor in order to reveal if the meal was poisonous or not. If they survived, the meal was obviously considered not poisoned and that was safe for the emperor to eat (Berglund *et al.*, 2001). Bernardino Ramazzini (1714) was the first Italian physician to realize and report that there was an association between occupational exposure and particular diseases. Ramazzini realized that specific exposure occurring in different occupations may cause the disease. For example smoke and white glowing iron gave the blacksmith sore and inflamed eyes and well potters became anemic and suffered from palsies from exposure to lead salts used for glazing (Berglund *et al.*, 2001).

It was also experienced that human senses were not always sufficient to predict what could be eaten, or what environment could be met without risks of health effects. Food sometimes had proved to contain poisonous substances and in some environments, human could not survive long due to prevailed condition. From harsh experiences, human was required to know that certain types of foods and environments should be avoided if possible. Therefore, Berglund *et al*. (2001) reported that, at the end of the 19th and beginning of the 20th century some of the health professionals raised considerable interest in the associations between environmental factors and diseases.

2.3 Exposure Pathways and Routes

The physical course a contaminant takes from the source of an agent to the organism exposed is often referred to as an *exposure pathway*. The way a chemical, physical or biological agent enters an organism is referred to as an exposure route. The major three pesticide exposure routes to humans include inhalation, ingestion and dermal contact as summarized in Fig.1 (ATSDR, 2005).

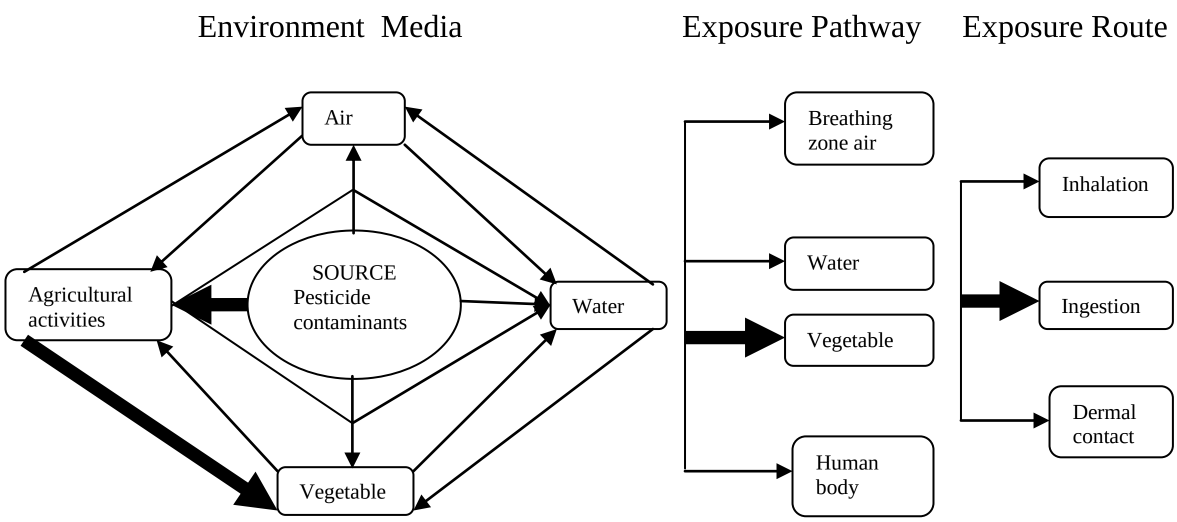


Figure 1: **The relationship between the environmental exposure media, exposure pathways and routes (Modified from ATSDR, 2005).**

Note: The bold arrows are examples of exposure pathways due to vegetable consumption

The major predictors of health risk from pesticide exposure are the pathway, quantity and toxicity of pesticides reaching end-users, field workers, and persons with casual and indirect exposures to field and food residues, drift, and contaminated water. One pathway by which people may be exposed to higher levels of agricultural chemicals is take-home exposure. This pathway involves the transport of contaminants from the workplace to the residence by agricultural raw produce, air, water, or via workers clothing or body. Pesticides likely to stick to and difficult to remove from clothing, shoes, skin, or hair become potential take-home contaminants and take-home pathway has been well documented (Fenske and Day, 2005).

According to Lu *et al*. (2004) study on different pesticide exposure pathways for children living in agricultural and non-agricultural regions. Environmental measurements of organophosphates pesticides (OP) were conducted in the homes of 13 children living in the agricultural region of Washington State to ascertain exposure through multiple pathways. At least one OP pesticide (chlorpyrifos) was found in each of the matrices sampled. Half of the indoor air samples contained detectable levels of chlorpyrifos or diazinon.

2.4 Adverse Health Effects of Exposure to Pesticides on Humans

Pesticide poisoning is very common in developing countries particularly rural areas where pesticides application is highly practiced (Yassin *et al*., 2002). Mourad (2005) reported that families of farmers have increased risks of neuroblastoma, nervous system tumours, Hodgkin disease, bone and brain cancer due to long-term exposure to pesticide and pesticide residues. In a study by Meuling *et al.* (2004) reported that daily occupational exposure of an individual to chlorpyrifos may result to its accumulation and/or its metabolites in tissues resulting in adverse effects like deaths. According to WHO (2004) report, most pesticide related deaths involve acute poisonings rather than chronic exposure

In Tanzania, pesticide poisoning was considered a major problem in the community by 63% of the health care providers. A total of 736 pesticide-poisoning cases were reported in-patient district hospital medical records with more women than men poisoned. However, the medical records were inadequate as they failed to show the cause or type of poisoning (Ngowi, 2002). Acute health effects assessment of the extent and intensity of organophosphate exposure showed that erythrocyte acetylcholinesterase activities during spraying and non-spraying period were comparable. Similarly, the prevalence of cough, headache, abdominal pain, excessive sweating, nausea, diarrhoea, and vomiting did not differ significantly between spraying and non-spraying periods (Ngowi, 2002).

The study conducted by Christos and Ilias (2011) also reported that, exposure originating from pesticide residues in food, air and drinking water generally involves low doses which may cause chronic or semi-chronic effects to humans. Dose refers to the amount of chemical to which individuals are exposed to and crosses the external boundary. Dose that cause damage and influence the likelihood or frequency of the adverse effects is estimated through calculating pesticide concentration in food per Maximum Levels (MLs) or Maximum Residual Limits (MRLs). MRL is a limit amount of chemicals present in food acceptable or tolerable for human health compared to the Acceptable Daily Intake (ADI). ADI is an estimated amount of pesticide residues in food (mg/kg body weight/day) that can be ingested daily over a lifetime without appreciable health risk to the consumer (FAO/WHO (2008).

2.5 Eating Habit

Rodriguez (2009) states that eating habits refers to why and how people eat, which foods they eat, and with whom they eat, as well as the ways people obtain, store, use, and discard food. People eat according to learned behaviuor regarding good manners, meal and snack patterns, acceptable foods, food combinations, and portion sizes. The components of a meal vary across cultures, but generally include grains, such as rice; meat or a meat substitute, such as fish; or beans and accompaniments, such as vegetables. Various food guides provide suggestions on foods to eat, portion sizes, and daily intake (WHO, 2003). However, personal preferences, habits, family customs, social setting, and other factors largely determine what a person consumes (Loureiro *et al.,* 2001). Eating habits are generally formed right from childhood through to the adolescent years (Moreno *et al.*, 2007). The study by Wood-Wright (2009) examined dietary intakes and patterns among U.S. families and found the resemblance between children and their parents' eating habits were weak and that factors other than family and parental eating behaviours played an important role in affecting dietary intakes. Some previous studies showed that 80% of the children exposed to television food advertisement preferred more confectionery, beverages and food products which contain large amounts of fat and sugar that increase the risk of obesity (Salmon *et al.*, 2005). Some people eat or do not eat certain foods based on religious, political, or social beliefs reflecting their food choices (Rea, 2007).

Vegetable eating habit was a component of the study conducted to assess pesticide exposure pathways to people living and/or engaged on vegetable growing where pesticides were used to control pests. The aim was to establish a baseline data, scenario of pesticide exposure pathways and to carryout risk characterization that reveal health status of the community in target area.

CHAPTRE THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

This study was conducted at Mang'ola ward in Karatu district, Arusha Region, located in Northern Zone of Tanzania. The district has three physiographic zones of uplands, midlands and lowlands, with altitude ranging from 1000 to 1900 meters. Mang'ola ward geographically coordinates are 3° 20' South, 35° 40' East. Rainfall in the district is bimodal; the short rains fall between October and December and the long rains between March and June. Annual rainfall may range from less than 400 mm in Eyasi Basin to over 1000 mm in the highlands with rain zones classified as semi-arid (300-700 mm/year) and sub humid (700-1200 mm/year) (Owenya *et al.,* 2012). Mang'ola ward falls in a semiarid region with sparse vegetation, characterized by low, erratic rainfall. It has a mean annual rainfall of 374 mm and high daily temperatures range between 25^{o} to 30°C (Magoggo *et al.,* 1994).

Administratively, the ward comprises three villages Mang'ola Barazani, Maleckchand and Laqreri. The Ward population counted 13 570 people among them 6917 was males and 6653 females living in 3330 households with average of 4 people per household before the 2012 Population and Housing Census of National Bureau of Statistics (NBS, 2013). Economically Mang'ola ward is prospering with the expansion of small scale farmers, agricultural merchants' together with Agrovet and craftsmen businesses. The area has a suitable environment for the production of a range of vegetables and cereal crops like maize, rice and beans practicing crop rotation system. Because pests were a problem in the study areas, the farmers used pesticides indiscriminately as the control measures. The choice of pesticide depended on the efficacy, price and availability from the local Agrovet dealers. Therefore, the area was famous for production of onions and economically named as the "onion belt" (Kramm and Wirkus, 2010). Population growth is as a result of water availability which encourages rotational cultivation of varied types of crops throughout the year. The agricultural activities also generate a labour demand which attracts young men and women from other regions for permanent or casual labour.

3.2 Study Design

Exploratory cross sectional study design was employed using both descriptive qualitative and quantitative methods to determine pesticide exposure pathways on human. The study focused on exposure pathway scenarios, eating habit and quantities of various types of vegetables consumed per household in relation to the risk of pesticide contaminants. Methods for data collection were based on structured questionnaires, interviews with key informants, focus group discussion, participants' observation and direct measurements of consumed food items at household level.

3.3 Sampling Design and Techniques

In this study, mixed sampling designs were involved (random, stratified and purposive sampling). According to Kothari (2004) three villages (Mang'ola Barazani, Maleckchand and Laqreri) located in Mang'ola ward were considered as different strata, and the total number of primary sampling unit (PSU) was allocated proportionately across all strata. Each village was divided into smaller clusters administratively known as hamlet which on average had 167 households. At first stage (Ward level), the representative sample from strata (villages) were computed using the proportional allocation technique, under which the sizes of samples (in terms of geographical allocation) from different strata were kept proportional to the population size of that strata. At second stage (village level), the representative respondents were selected using a table of random numbers and probability proportional size techniques. In this technique regardless of the cluster individuals the village executive officer indicated which clusters (hamlet) and how many from the cluster are to be selected randomly. This method was less cumbersome and relatively inexpensive. The agrovet dealers together with key informant respondents for in-depth interview were purposively sampled as described by Bryman (2008).

3.4 Sample Size

The sample size was estimated using Yamane’s (1967) formula which practically provides simple way of estimating sample required given the known population of study area.

Yamane’s (1967) formula:

$$n = \frac{N}{1+N(e)^2} \qquad \text{……………………………………………………..……………… (1)}$$

Where: n = sample size

N = Population size

e = level of precision which is equal to 0.05

Using the actual population before the 2012 National population and housing census, Mang’ola ward had 13 570 people among them 6917 were males and 6653 were females, and each house hold had average of 4 people (Tanzania Population and Housing Census, 2013).

$$n = \frac{13,570}{1+13,570\,(0.05)^2} \qquad \text{……………………...………………..……………….. (2)}$$

Then, the sample size: n = 389

In most cases the decision about the sample size is affected by consideration of time and cost. Therefore, invariably decisions about sample size represent a compromise between the constraints of time and cost, the need for precision, and a variety of further considerations that will now be addressed (Bryman, 2008). For that matter then, a total sample size of 263 was suitable for this study.

The sample size was further computed using the method of proportionality allocation under which the sizes of the representative samples from the different three villages were kept proportional to the sizes of the village (Kothari, 2004). That was $P_í$ represented the proportion of the population included in stratum í and n represented the total sample size, the number of respondents selected from stratum í was therefore, equals to n. $P_{i.}$ Where $P = N_1/N_{t.}$ (N_1 = strata population and N_t = Total ward population).

Using this formula therefore, the sample size for:

i) Eating habit study was 60, calculated from a total ward population size N_t= 13570 which was divided into three villages of size N_1 =9015 (Mang'ola barazani); N_2 = 3086 (Maleckchand) and N_3 = 1469 (Laqreri).

Where: $n_1 = n.P_1 = 60(9015/13570) = 40$; $n_2 = n.P_2 = 60(3086/13570) = 14$ and $n_3 = n.P_3 = 60(1469/13570) = 6$.

ii) Household for daily dietary analysis record was 9

Where: $n_1 = n.P_1 = 9(9015/13570) = 6$, $n_2 = n.P_2 = 9(3086/13570) = 2$ and $n_3 = n.P_3 = 9(1469/13570) = 1$

iii) Baseline data survey respondents was 123

Where: $n_1 = n.P_1 = 123(9015/13570) = 82$; $n_2 = n.P_2 = 123(3086/13570) = 28$

$n_3 = n.P_3 = 123(1469/13570) = 13$

iv) Focus group discussion respondents was 50

Where: $n_1 = n.P1 = 50(9015/13570) = 33$; $n2 = n.P_2 = 50(3086/13570) = 11$ and

$n_3 = n.P_3 = 50(1469/13570) = 6$

Thus the total sample size from different strata (Barazani, Maleckchand and Laqreri) was 161, 55 and 26, which was proportion to sizes of the strata population viz., 9015:3086:1469 respectively. In-depth interviews were conducted to key informants and the sample size was 12. Also the sample size for agrovet dealers was 9 (Table 1).

Table 1: Sample size from the three villages in the study area (N=263)

S/N	Questionnaire /Interview	Barazani	Maleckchand	Laqreri	Total male	Total female	Grand Total
1	Eating habit	40	14	6	32	28	60
2	Daily dietary record	6	2	1	-	-	9
3	Vegetable growers	27	9	5	21	20	41
4	Pesticide applicators	27	9	5	38	3	41
5	Vegetable consumers	27	9	5	17	24	41
6	Agrovet dealers	6	2	1	6	3	9
7	FGD	33	11	6	24	26	50
8	Key Informants	6	3	3	9	3	12
Total		172	59	32	147	107	263

3.5 Selection of Study Households and Respondents

The qualitative study was conducted to explore eating habit and establish baseline data on pesticide exposure pathway scenario. Households and respondents that participated in this study were randomly selected from the three villages of the Mang'ola ward. The study villages had 20 hamlets with an average of 167 household and 679 people. The community of this area was engaged in agricultural activities like livestock keeping, cereal crop and vegetable growing. The eligibility criteria for the household and the respondent to be selected for study were vegetable grower, pesticide applicator or consumer of the vegetables available within the study area.

Using a table of random numbers and ward population information, a total of nine households and 254 respondents were randomly selected from all 20 hamlets within the study area. The selected respondents comprised:

i. Sixty respondents involved on eating habit to study vegetable consumer awareness on pesticide and pesticide contaminants in vegetables and pesticide residues exposure pathway through vegetable consumptions.

ii. Nine household recruited on the daily dietary record analysis aimed to quantify and determine the amount of vegetables consumed on daily basis and finally to carryout risk characterization for identified hazards.

iii. A total of 132 respondents participated in the study to establish baseline data about exposure pathway scenario. The questions asked were seeking to understand respondent’s knowledge, perceptions and practices about vegetable growing, pesticide application and exposure pathways. The participants were vegetable growers, pesticide applicators, Agrovet dealers and vegetable consumers.

iv. Fifty respondents were involved on focus group discussion and 12 respondents participated on in-depth interview. These respondents were important to provide detailed and deeper understanding of the community’s knowledge, perceptions and practices related to pesticide and pesticide residues exposure pathways on human. Key informants were purposively selected based on researcher need to interview professional and/or influential people with specific information relevant to the research questions as described by Bryman (2008).

3.6 Studies on Communities' Knowledge, Perceptions and Practices related to Pesticide Exposure Pathways in Mang'ola Ward

3.6.1 Field observation

Direct observation was done in the vicinity of study area to determine pesticide application practice by farmers and pesticide applicators with regard to pesticide exposure pathways from October 2012 to February 2013. The study area has a suitable environment for the production of a range of vegetables and cereal crops like maize, rice and beans practicing crop rotation system. Because pests were a problem in the study areas, the farmers used pesticides indiscriminately as control measures. The choice of pesticide depended on the efficacy, price and availability from the local Agrovet dealers. Therefore, observation study concentrated mainly on vegetable fields so as to study the farming and pesticide application practices and identify the possible pesticide exposure pathway on human.

The observation also helped to study the everyday routine of community and what they "*took for granted*", the rationale behind their practices and behaviours. Being on site allowed familiarization with the environment, people and provided the opportunity to see how things are organized so as to be able to carry out situation analysiss (Kawulich, 2005; Bryman, 2008).

Unstructured interview was conducted in Kiswahili to get an in-depth understanding of people's perceptions on pesticide exposure pathway associated with vegetable growing, availability and accessibility of consumed vegetables. The researcher asked participants' permission to observe field activities including pesticide mixing and spraying procedure. The observations started between 10am and 2pm and ended between 5pm and 6pm, because during those time most of the field activities like pesticide application were performed. Non-participatory observations alternated with participatory observations depending on the context and the observer wish. Photographs as well as written notes were taken. Visual supports as well as notes were useful in order to analyze, reflect and describe in details on what was being observed (Bryman, 2008).

The mini-markets located in each village center were visited. This was convenient place to witness customers buying vegetable items for their households. Several visits at different time were made where by photographs as well as written notes were taken. The purpose of the market observations was to know the source of vegetables, how vegetables were displayed and sold in terms of quantity and quality together with vegetables buying process. Transcription of both fields and market observations data were done on the same day to control memory loss bias. A systematic analysis of transcribed data was later performed that included data coding and classification of themes and subthemes (Granehei and Lundman, 2004).

3.6.2 In-depth interview

An interview checklist was developed which had key questions adopted from other previous studies (Worsfold and Griffith, 1997; FSA Report, 2000; NFI, 2003) (Appendix 1). A total of 12 respondents were interviewed during in-depth interview. The respondents were the ward executive officer (WEO), ward education coordinator (WEC), two village executive officer (VEOs), two secondary school teachers, one hamlet chairperson and one member of ward irrigation committee. Also other interviewees were the ward Maternal and Child Health care nurse (MCH), Livestock/agriculture field extension officer (LFEO) and two village health committee members.

The in-depth interview constituted 9 males and 3 female whose age ranged from 30 to 58 years old. The in-depth interview conversation was hand recorded and tape recorded and conducted in Kiswahili the national language known by majority of Tanzanians. Where necessary, a local assistant researcher translated the interview to Iraqw, the local language, after which translation was made to Kiswahili. The respondents opinions were raised in the following aspects: types of vegetables grown in the area and means of pests control; types of pesticide used and training or awareness meeting conducted to users and consumers on pesticide persistence in vegetables and their health hazards; pre-harvest interval practice, the use of personal protective equipments and knowledge on pesticide exposure pathway together with efforts of the government to safeguard community against pesticide health hazards and suggestion or comments on what should be done (Plate 1).

A) In-depth interview with VEO from Mang'ola Barazani village

B) In-depth interview with one of the village committee member

Plate 1: Picture (A & B) In-depth interview with key informants

3.6.3 Focus group discussion

In preparation for the FGDs, a theme guide containing questions (under relevant themes) was developed. This had the themes around which the discussions would focus. The checklist had key questions adopted from a review of literature (Worsfold and Griffith, 1997; FSA Report, 2000; NFI, 2003) (Appendix 2).

A total of 50 respondents (24 males and 26 females) participated in FGD and the respondents were divided into three age-sex categories. The FGD representatives were old males and females with the age ranged between 45 and 69, youth males and females with age range between 20 and 44 and teenager males and females with age range between 15 and 19. Two focus group discussions each with 6 to 12 participants were conducted in each of the three age-sex categories (Table 2).

Table 2: **FGD respondents' age-sex category (n=50)**

Group	Age (years)	Sex		Total number of participants
		Female	Male	
Teenagers	15-19	7	7	14
Youth	20-44	12	10	22
Elders	45-69	8	6	14
Total		27	23	50

The different group categories allowed free conversation and more contributed to ascertain different views between the participant groups. The information collected aimed to determine community awareness towards pesticide application practices and feeding habits associated with exposure pathways of pesticides and pesticide residual contaminants on human. Also to find out the preventive measures applied by the vegetable growers, pesticide applicators and vegetable consumers against the health hazard risks from pesticide and pesticide residue contaminants (Plate 2).

A) Conducting FGD with male elders above 45 years of age

B) Conducting FGD with youth males 20 – 44 years of age

C) Conducting FGD with female elders above 45 years of age

D) Conducting FGD with teenage 15-19 years of age

Plate 2: Pictures (A-D) shows FGD with different Age-sex categories

3.6.4 Conducting focus group discussions

A moderator and notes taker, who were trained to conduct focus groups in a standardized way, coordinated the discussions. Before the discussion started the moderator explained the need, purpose and the importance of the study together with the rules of conducting the discussion. He also introduced the theme and moderated the discussion while the notes taker hand-recorded and tape recorded the conversation. The discussions were conducted in Kiswahili the national language. Where it was difficult a local assistant translated the question into iraqw the local language of the respondents thereafter translated back to Kiswahili.

In order to harmonize the discussion, every focus group participants was asked to explain his/her daily routine activities. The participants gave their opinions on the following aspects: types of vegetables grown in their community and methods used to control pests, pesticide used and application practices, knowledge on pesticide persistence and pre-harvest interval; body discomfort and health problems encountered during field spray and other activities, the use of personal protective equipments and how to identify pesticide contaminated vegetables. Also their knowledge about pesticide exposure pathway and efforts required to safeguard the community from pesticide health risks. The Livestock field extension officer who acted as the agricultural education and extension officer also gave his opinions on community awareness regarding pesticide exposure pathways and comments on measures required to protect people against the impact of pesticide health hazards.

3.6.5 Questionnaires' surveys

A total of 132 respondents were interviewed using structured questionnaires in the three villages of Mang'ola ward in February 2013. The number of respondents interviewed were distributed according to village population (n=82 from Mang'ola barazani, n=28 from Maleckchand and n=13 from Laqreri) (Table 1). The equal number of 41 respondents among vegetable farmers, pesticide applicators and vegetable consumers and 9 agrovet dealers were involved in the study. Demographic variables collected including respondents' sex, age, level of education, occupation, marital status and household size.

The study involved face to face question administration at convenient place agreed by the respondent (field, home or shop) (Appendix 1). The questionnaire was designed to determine vegetable farmers, pesticide applicators, Agrovet dealers and vegetable consumers' knowledge and perceptions pertaining the pesticide exposure pathway, including farming and pesticide application practices as well as consumers awareness on pesticide residue contaminants in consumed vegetables. The questionnaires were pretested at Mang'ola barazani village in Mang'ola ward before the actual work of administration to respondents.

3.6.5.1 Vegetable farmers

The developed structured questionnaires with questions customized from previous study (Khan, 2005) were administered to explore details regarding type of vegetables grown, experiences on pests and pesticides; application practices, methods, frequency and the time of pesticide application. Respondent perceptions on pesticide health effects, exposures pathway and possible health problems were explored. On the other hand the information on storage of containers with and without pesticides, equipments as well as the disposal of empty pesticide containers, the place for bath and wash equipments used after pesticide application were explored. Respondents were also asked about interactions with pesticide dealers, extension officers or other experts for decision making regarding the use of pesticide. In addition, they were asked if they had attended any training on the safe and effective use of pesticide, awareness on residual persistence of pesticide and source of recommendations regarding time, pre harvest interval and whether they use personal protective equipments while handling and spraying the field. Moreover the information on signs and symptoms of pain or discomfort during pesticides application was collected

3.6.5.2 Pesticide applicators

The structured questionnaires for pesticide applicators were adopted and developed from previous studies (Alavanja *et al.,* 1996; Bonner and Alavanja, 2005). The questionnaires covered various questions pertaining pesticide handling, formulation and mixing. The questions covered aspects related to pesticide used and its frequency, tasks (mixing/applying pesticides; cleanliness of sprayer equipment), personal protective equipment (PPE) and application methods. Body discomfort and diagnosed diseases, medical consultations and treatment of related adverse health events occurring during field exposure were also included. On the other hand the exposure determinants like PPE (waterproof clothing, gas mask, gloves, face shields or goggles, hat or helmet and other protective clothing like boots, apron, and waterproof pants) were assessed. The information on the experience of mixing/applying pesticides and application time was also explored.

3.6.5.3 Agrovet dealers

The developed structured questionnaires adopted from previous study (Khan, 2005) were administered to explore details about business experience. The level of education of the agrovet dealer, training on handling agrochemicals, source of training, types of pesticide sold and advice on the pesticides health risks to users were among the information gathered from administered questions. Respondents were also asked if were seeking to know how knowledgeable their customers are on the use of PPE and observation of Pre-harvest interval (PHI) to safeguard the consumers. Furthermore, they were questioned on how expired products were handled and whether received comments and complaints from vegetable growers regarding pesticide effectiveness and efficacy and measures taken to rectify the problems.

3.6.5.4 Vegetable consumers

The developed structured questionnaire adopted from Acheampong *et al.* (2012) was administered and aimed to determine consumers' self-assurance on pesticide and pesticide residues exposure pathway. Attention was paid to the use of chemical pesticides in vegetable production and the presence of chemical residues on vegetables bought at the market or from fields and street vendors. The level of awareness from risks associated with consumption of vegetables with pesticide residues was determined by asking the respondents about type and source of the consumed vegetables, storage facilities, preservation and preparation method of raw or cooked eaten vegetables. Other information gathered included awareness on pesticide persistence in vegetables and the possibility of getting health problems due to consumption of pesticide residues in contaminated vegetables as well as preference attribute such as, freshness, color, appearance and aroma.

3.7 Studies on Community Eating Habits

The structured questionnaire was designed to investigate the eating habits of grown vegetables in the study area. This study involved 60 respondents (28 male; 32 female) selected from the study village members. The data was collected through face-to-face administration of structured questionnaires. Demographic variables together with a combined consumption frequency of vegetables and food choice questionnaire were used to assess household eating habits. The questionnaire was developed based on the previous work by Chen (2010) and Keller (2012). The general vegetable eating habit aspects assessed included, inclusion of vegetable diet in daily meals, how often the household members made effort to buy, grow and eat vegetables as well as how they felt when vegetable was not included in a meal. Also respondents were asked about the importance of vegetable diet and the number of meals per week as well as frequency of vegetable consumption. Vegetable choice factors together with likert scale questions proposed by Rensis (1932) were included to determine influencing factors for vegetable consumption (Appendix 3).

3.8 Household Daily Vegetable Record

Daily dietary record analysis form was designed to collect data on type and amount of vegetables consumed and leftovers discarded at household level on daily basis. The form was developed based on the previous study (Craig, *et al*., 2000; Reeves *et al*., 2001; Wilson and Lewis, 2004). Detailed description of the types and amount of vegetables was taken for two months from 9 households (Appendix 4).

Information on day, date, vegetable type, quantity (gm), number of meals, time consumed, place, quantity consumed (gm), and quantity discarded (leftovers) (gm) were recorded by trained respondent among the household members. In addition, the household members' demography was included in the study. The trained respondent was asked to record the daily bought portions (bundles) of vegetables before cooking and amount of leftovers into provided designed forms. On the other hand the portions (bundles) of different size of all available types of vegetables sold at the village mini-market or by street vegetable vendors were measured to obtain the actual average weight (gm) of each portion (Table 3). The average weight obtained from each type of vegetables was used to compute the final actual amount consumed on daily basis from each study household.

Table 3: Mean weight of different vegetables bought from village mini-markets or vegetable street vendors (n = 4)

Type of vegetable	Mean weight ± SD (gm/kg)
Amaranthus	310.8 ± 69.2
Cabbages	1142.5 ± 148.8
Chinese	298 ± 57.6
Carrot	199.3 ± 91.6
Green pepper	43 ± 12.2
Okra	128 ± 22.02
Salad	236.8 ± 26.8
Spinach	238.3 ± 12.1
Night shade	149 ± 8.8
Pumpkin leaves	188.3 ± 38.8
Legume leaves	857± 141.3
Kale	151.5 ± 33.4
African egg plants	30.7 ± 7.8
Potato leaves	343.3 ± 31.7
Onions	85.8 ± 35.2
Tomatoes	81.3 ± 8.3

3.9 Risk Characterization

Risk characterization was performed based on vegetable consumption data obtained from the study area. Nine household having eighteen (18) healthy adults were involved in the study. Data collected included the daily consumed type of vegetables over the past 2 months and the quantity consumed on each serving. Alongside amaranthus, tomatoes, onions, kale and spinach were selected for pesticide risk assessment due to their availability during sample collection and some of these products were consumed daily. Also these vegetables were mostly cultivated within the study area where pesticides application was very necessary to control pests. The aim of conducting risk characterization was to determine pesticide risk of exposure whereby estimates daily intake (EDI) was compared with reference health standards (acceptable daily intake (ADI) and Hazard Index (HI) to assess the likelihood of these standards being exceeded. The secondary unpublished data of analyzed vegetable samples were obtained from Monitoring and risk assessment of contaminants in Southern Africa: Arusha in Tanzania as a model (MORATANZ) project. The level of pesticide residues found in the analyzed samples is outlined in (Table 19). The analyzed pesticide residues concentrations were compared with recommended MRLs established by European Union (EU, 2005) and Codex Alimentarious Commission (CAC) (FAO/WHO, 2004).

The risk assessment of vegetable consumers' exposure was based on Estimated Daily Intake (EDI) which was compared to Acceptable Daily Intake (ADI). The calculation of EDI, expressed in mg/kg body weight/day, was based on the following equation: EDI = R (mean concentration of the residue in the food commodity in mg/kg) *C (daily consumption kg/person/day)*EP (edible portion, 0 to 1 values) *PF (Processing factor for the specific food commodity, 0 to 1 values) / BW (body weight, kg).

All calculations for determination of EDI were according to international guidelines (Iñigo-Nuñez *et al.,* 2010). Pesticide residue concentration levels used were those detected from the analyzed samples for each vegetable. The average daily vegetable intake for adult was considered to be 0.345 kg/person/day (Wang *et al*., 2005). The value of EP for all food commodities was 1 in order to represent the local practice in food consumption. As well the effects of processing factors were not taken into account in any case, therefore (PF=1) (Ioannis *et al*., 2011). Vegetable consumption was expressed as daily consumption divided by body weight, which was set at 50 kg for an adult person (Tejada *et al.*, 1995 and Botwe *et al.*, 2011). The ADI values for pesticides were taken from official CAC Pesticides Database.

3.10 Hazard Risk Index

From a potential health perspective, it is certainly important to compare exposure estimates to established toxicological criteria such as EDI. EDI is a realistic estimation of pesticides residues exposure that was calculated in the international guidelines

(FAO/WHO, 1997; FAO, 2002). EDI of pesticide residues for each combination of pesticide and commodity was calculated by multiplying the residual pesticide concentration (mg/kg) by the food consumption rate (kg/day) and dividing by the body weight of 50 kg for an adult person.

3.11 Inclusion and Exclusion Criteria

Inclusion and exclusion criteria for the pesticide exposure pathway study included:

(a) Inclusion criteria

- Age between 15 and 70 years
- Able to understand the information given by data collector about the study prior to the beginning of the interview
- Study area residents (vegetable grower, applicator or consumer and pesticide dealer)
- Respondent willingness of participation

(b) Exclusion criteria

- Inability to understand or comprehend the information given by data collector
- Inability to communicate through verbal expression for consent
- Non study area residents (vegetable grower, applicator or consumer and pesticide dealer)
- Respondent unwillingness of participation
- Severe/terminal illness that hinders effective participation
- Age below 15 years or above 70 years

3.12 Ethical Considerations

Written research permissions were obtained from the Tanzania National Institute for Medical Research of Ministry of Health and Social Welfare number NIMR/HQ/R.8a/Vol. ix/1354 (Appendix 5). Sokoine University of Agriculture gave the research clearance letter (Appendix 6) and Karatu District Executive Director (DED) gave a letter of permission to carry out the study in the district. Participation in the study was based on voluntary bases. Before questionnaire administration, the interviewer explained the purpose and objective of the study, importance and the possible outcomes, thereafter asked permission to administer the questionnaire. High confidentiality and anonymity was observed during filling of questionnaires. The respondent name was not included in the questionnaire but a code known only to the interviewer for identification if needed. All respondents involved in the study were asked for a verbal consent to fill up the questionnaire and assured from the risk of harm.

3.13 Data Analysis

3.13.1 Questionnaires survey

Data gathered from baseline study was analyzed by using the Statistical Package Social Sciences, Version 12.0. Descriptive statistics (means, percentages, standard deviations and frequencies) were computed at 95% confidence interval (CI) to analyze knowledge, practice and perceptions on pesticide exposure pathways among the farmers, applicators, agrovet dealers and consumers at community level.

3.13.2 In-depth interview and Focus group discussion

The recorded in-depth interview and focus group discussions data were transcribed using Microsoft word office processing program by the moderators using the notes taken by the notes taker and the tape recordings. The Kiswahili language scripts were translated verbatim into English by the researcher. These scripts were in turn compiled into individual reports by organizing raw data into codes the method suggested by Ritchie and Spencer (1994) and Srivastava and Thomson (2009) based on the themes. To ensure the validity and reliability of data interpretation, five focus group discussion and 12 in-depth interview transcripts were independently coded and analyzed. The procedure was repeated and result was compared to find out if they arrived at similar interpretive data. The cut-off point of a theme idea was arbitrary set to be ≥ 90% for in-depth interview and ≥ 60% for FGD.

A note-based analysis of responses was done across all focus group discussion sessions and in-depth interviews results. Clusters were identified and assigned a code for each question. A cluster consisted of a group of similar ideas. Themes were then identified from the discussion responses. A theme was the strongest idea (or cluster of ideas) identified under each question in the discussion. In this study a theme was identified in response to the frequency of an idea or cluster raised by the majority of respondents during the focus group discussion sessions or in-depth interviews. The responses obtained from the similar questions asked in both the FGD, in-depth interviews and baseline survey questionnaire were used to cross-check the consistency of the information (data triangulation).

A different reference number was assigned to the response originated from the in-depth interviews (IDI) or focus group discussion (FGD) followed by a serial number. The age-sex of the respondents were specified for both citation originating from in-depth interviews and focus group discussions (i.e. “IDI01, F35 years or FGD01, F35 years”).

3.13.3 Eating habit study

Statistical analyses were performed using the Statistical Package for Social Sciences (version 12.0, SPSS, Inc) software. The computed results were expressed as means ± SD (standard deviations). Differences were considered statistically significant at P value < 0.05.

3.13.4 Daily Dietary record analyses

Data was entered, stored and computed by using Microsoft Office Excel 2007. Descriptive statistics (mean, and standard deviation) and analysis of variance (ANOVA) was used to determine the amount of vegetable consumed and to compare the result between the household at critical probability of $P<0.05$.

3.13.5 Risk Characterization

Risk characterization was determined by calculated concentration of pesticide residue x vegetable consumed / body weight formula compared to ADI and MRLs. Hazard Index (HI) was used for risk assessment of the mixtures of the detected pesticides belonging to the same chemical group (organophosphates, organochloride, pyrethroids, T. triadimefon and triazole). HI was calculated according to the following equation:

$$HI = EDI_1 / ADI_1 + EDI_2 / ADI_2 + \ldots + EDI_n / ADI_n = \sum_{i=1}^{n} \frac{EDI_i}{ADIi} \quad \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Where EDI is estimated daily intake, ADI is acceptable daily intake.

EDI_i is the EDI of each active ingredient of each chemical group and ADI_i is the corresponding acceptable daily intake (Amvrazi and Albanis, 2009). If the hazard index exceeds 1, the mixture has exceeded the maximum acceptable level (e.g. ADI) and there might thus be a risk and considered as not safe for human health (Darko and Akoto, 2008). The fractions (EDI_1/ ADI_1 etc.) are sometimes called the hazard quotients (HQ).

CHAPTER FOUR

4.0 RESULTS

4.1 Studies of Communities' Knowledge, Perceptions and Practices Related to Pesticide Exposure Pathways in Mang'ola Ward

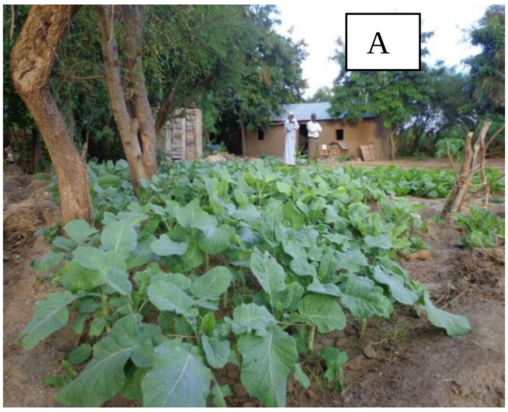
4.1.1 Field observation

Direct observation study conducted in Mang'ola ward provided key baseline information on local farmers and applicators practices and their possible exposure pathway in the community. The community of Mang'ola ward practiced mixed farming system with well established irrigation system. Crop cultivation contribution to the livelihood became more significant but with a wide range of combinations mainly from the availability of land and climatic conditions. The main crops grown were maize, rice and wide range of vegetables, (onions, tomatoes, kale, night shade, Chinese, okra and amaranthus). Farm equipment was comparatively limited to manual tools, an-ox plough as only few farmers owned tractors and trucks.

The farming system practiced labour-intensive whereby farmers cultivate three crops per year on the same plot. Crop farming was the main source of food and income. Food crops were cultivated in rotation with cash crops. Onions was the main cash crop cultivated under intensive irrigation system and pesticide application. The main cropping season for onions for the majority of farmers was from July to October while the rich farmers and investors grow onions annually. Some of the rich farmers practiced rotational system of cropping whereby from November to June they planted maize and rice for food and income. Although some of the farmers practiced crop rotation, lack of uniformity in cropping system was likely the main cause of the increased incidence of pests and diseases.

This study observed that reoccurrence of pests and vegetable diseases caused an indiscriminate use of agrochemicals. Therefore, utilization of agrochemicals was only the solution adopted by farmers to maintain the yield levels. Unfortunately, the practices also accompanied with inadequate pesticide application techniques include improper use of pesticides in terms of types, dose, application time and frequency associated with risks to health consequences to surroundings.

In general onions production was labour-intensive. Operations like transplanting, weeding, irrigating, spraying, harvesting, sorting, packaging, transportation and storage require an average of 100 days' work per acre with 90% of hired labour. In this case, rich farmers and investors employed many young men and women including children not only from Mang'ola ward villages but from Karatu bordered districts and regions. Most of them were temporarily employed for the onion season and returned to their homes after the harvest. They got a share of the harvest as payment, either in form of bags of onion or sometimes cash. The amount of salary depended on the harvest: the better the harvest the higher the payment. Onions production proved very lucrative when the market price was high. The input for the production was quite costly. The fluctuating market price was one of the main risks which threaten the gains. It was appropriate to employ one worker for one acre. But many farm owners had few workers compared to work load and the number of acres they owned to avoid the expenses; for example one field of 14 acres cultivated by 9 workers). Normally the workers' houses were located within the fields or close to the fields (Plate 3).



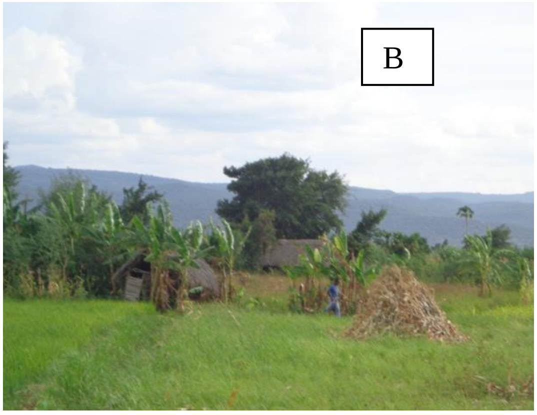


Plate 3: (A) and (B) Residential houses located close to pesticide treated fields

Canal irrigation farming was common throughout the year with very high intensity of cropping and use of pesticides. The common observed groups of pesticides used included insecticides, fungicides and herbicides. The pesticides were within easy reach since most of them were readily available at Agrovet dealers' shops around the town centers of all villages.

During this study it was observed that the majority of vegetable farmers and pesticide applicators had little knowledge regarding pesticide exposure pathway and health hazard risks associated with pesticides and pesticide residues. Farming practices was directly or indirectly associated with the pesticide exposure pathways. Among the farming practices that exhibit pesticide exposure pathway include misconduct on pesticide application mixing and spraying of pesticides without PPE were commonly practiced by farmers and pesticide applicators (Plate 4).

Plate 4: (A, B, C and D) Pesticide applicator mixing and spraying pesticides without PPE.

The majority of the farmers and pesticide applicators had little knowledge on pesticide formulations, therefore mixing of more than two formulation of the same active ingredient with different trade names was observed. For example selecron® 720EC and profecron® 720EC are insecticide with profenofos as active ingredient but were being mixed as different pesticides aimed to potentiate their effects against pests. Overdosing of applied pesticide was common regardless of prescribed recommended dose for the given pesticide. Majority of pesticide applicators performed pesticide applications without PPE and delaying on taking bath or change of cloths after spraying was common.

The indiscriminate disposals of empty pesticide containers in the fields and along the water canals were commonly practiced. During the rainfall season the scattered empty pesticide containers were removed into water sources and some of the empty pesticide containers were also re-used for domestic purposes such as storage of cooking oil, kerosene and drinking water. Incidents of pesticide poisoning among the farm labourers and pesticide applicators were not commonly reported because were regarded as a normal thing to feel sick when handling pesticides. Contaminated water from irrigation canals were used for domestic activities including washing home utensils, cloth, bathing, cooking and animal drinking. Domestic animals like cattle, goat, sheep and donkey also fed on crop and vegetable remains (maize, rice husks and onions leaves) and grazed in the same fields applied with pesticides after harvest. In addition, bed net pesticides (Ngao) were also used on vegetable fields to control pests (Plate 5).

(A) Fetching contaminated water for domestic use

(B) Livestock grazing in contaminated crop remains

Plate 5:Domestic use of contaminated water and crop remains

4.1.2 Sociological study

4.1.2.1 Farming practice in relation to pesticide exposure pathway

(a) Demographic characteristics

A total of 41 vegetable farmers were interviewed to explore the association between vegetable growing practice and pesticide exposure pathway in humans. The demographic characteristics of the respondents are summarized in the (Table 4).

Table 4: Demographic characteristics of vegetable growers respondents (n = 41)

Variable type	Variable category	Number of respondents (%)
Sex	Male	31 (75.6)
Age	Female	9 (22)
	18-30	14 (34.1)
	31-40	10 (24)
	41-50	9 (22)
	51-60	7 (17.1)
	>60	1 (2.4)
Education level	Informal	3 (7.3)
	Primary	37 (90.2)
	Secondary	1 (1) 2.4
Occupation	Farmer	41 (100)
Marital status	Single	12 (29.3)
	Married	28 (68.3)
	Separated	1 (2.4)
Family size	0	11 (26.8)
	1-3	10 (24.4)
	4-6	14 (34.1)
	>7	6 (14.6)

(b) Economic activities

Crop production was the main source of food and means of income generation as it comprised a significantly ($P<0.05$) high proportion (80.5%) of the respondents interviewed. The main crops produced were rice, maize and vegetables (onions, tomatoes, amaranthus, nightshade, kale, egg plant, peppers, green peppers, okra, spinach, sweet potato leaves, pumpkin leaves, legume green leaves and carrots). Other crops grown were beans and sunflower. Up to 51% of respondents had 1-5 years experience in vegetable production and all of them mentioned pests as the major limiting factors for optimal crop production and pesticide application was only the control measures practiced.

(c) Uses of pesticide in crops

The most frequently used pesticide group was insecticide which had 95.1 % of the respondents. The common used type of insecticide included thionex® (endosulfan) (39%) followed by selecron® (Profenofos) 36% and Marshal® (carbamate) 12%. Other pesticide group like fungicide commonly used was blue copper® (copper sulphate) (36.6%) and farmer zeb® (Mancozeb) 19.5%. In case of herbicides 29.3% of the respondents were not used while others 48% used galigan® (Oxyfluorfen). Majority of respondents use pesticide based on label instructions (34.1%), while 29.3% applied through their own experience, 14 .6% seek advice from agrovet dealers and only 7.3% seek advice from agricultural extension officer. Most of respondents (61%) applied pesticides once pests appeared in the field. While 87.8% of respondents had their own decision on type and time for pesticide application, only 4.9% consulted the agriculture extension officer. On the other hand 63.4 % of respondents were mixing more than two different pesticides at a go during spraying and (51.2%) of them practiced this behaviuor on their own decision and experience. Majority of small-scale farmers (65%) sprayed pesticide themselves while 34.1% employed pesticide applicators (Table 5).

Table 5: Data collected from vegetables growers (n = 41)

Variable	Variable category	No. of Respondents (%)
Use of PPE in pesticide spraying	Yes	9 (22)
	No	32 (78)
Discomfort when spraying pesticide	Yes	35 (85.4)
	No	6 (14.6)
Health problems effects on farmers	Yes	35 (85.4)
	No	6 (14.6)
Health treatment	Medical facility	14 (34.1)
	Own treated	27 (65.9)
Major route of pesticide exposure	Ingestion	3 (7.3)
	Inhalation	7 (17.1)
	Dermal	27 (65.9)
Where to take bath, wash cloth and equipment	River	2 (4.2)
	Canal	16 (39)
	Home	23 (56.1)
Where do you put pesticide empty containers?	Burry/burn	19 (65.5)
	Open disposal	12 (29.3)
	Re use	2 (4.9)
Where do you get pesticide spraying equipment	Own	9 (46.3)
	Lending	18 (43.9)
	Hiring	4 (9.8)
Storage of unused pesticides and sprayers	separate store	25 (61)
	In the house	15 (36.9)
Training, seminar and meeting on pesticide safety	Yes	3 (9.3)
	No	38 (92.7)
Knowledge about Pre-Harvest Interval	Yes	33 (80.5)
	No	8 (19.5)
Knowledge on pesticide persistence	Yes	38 (92.7)
Where do you dispose/store expired and remains	Burry/burn	21 (51.2)
	Open disposal	19 (46.3)
Do you use irrigation water system	Yes	38 (92.7)
Where was the source of water	River	23 (56.1)
	Canal	15 (36.6)
	Deep/shallow well	3 (7.3)

4.1.2.2 Pesticide applicators practice in relation to pesticide exposure pathway

(a) Demographical characteristics

The respondents largely composed of males. Only 2.4% were female and 41.5% respondents were at the age of 18-30 years. Most of them had primary school education level (82.9%) and 92.7% of respondents engaged in both farming and pesticide application activities. The married respondents were 61% and single 39% while 31.7% of family size had 4-6 children. This group depended on pesticide application activity as main source of income (Table 6).

Table 6: **Pesticide applicators demographic characteristics (n = 41)**

Variable	Variable category	Number of respondents (%)
Sex	Male	40 (97.6)
	Female	1 (2.4)
Age	18-30	17 (41.5)
	31-40	11 (26.8)
	41-50	7 (17.1)
	51-60	1 (2.4)
	>61	5 (12.2)
Education level	Informal	3 (7.3)
	Primary	34 (82.9)
	Secondary	4 (9.8)
Occupation	Farmer	38 (92.7)
	Employees	2 (4.9)
	Laborers	1 (2.4)
Marital status	Single	16 (39)
	Married	25 (61)
Family size	0	17 (41)
	1-3	7 (17.1)
	4-6	13 (31.7)
	7-10	3 (7.3)
	>10	1 (2.4)

(b) Characteristics of pesticide applicators

The results show that 87.8.9% of pesticide applicators had experience of more than one year. Up to 95% of the respondents were involved in preparation of pesticides (mixing activity) on the field. The majority had a tendency of mixing more than two pesticides at ago (75.6%). On the other hand 92.7% had not attended any training pertaining pesticide application skills (Table 7).

(c) Pesticide applicators methods and personal protection

Knapsack spray was used by all of the respondents. Only 2.4% followed instructions for mixing and applying pesticide as shown on the labels or as prescribed by Agricultural extension officers. The PPE were used by only 26.8% of the respondents. Over 58.5% of pesticide applicators agreed that pesticide was trickled in their bodies during spraying. Forty one percent adhered to pesticide label instructions for correct application and health risk precautions. The most exposed and experienced group was the youth (18-30 years) who were working without PPE (Table 6).

(d) Health status of pesticide applicator

There was high prevalence of pesticide health problems associated with pesticide application during the study. The most frequently reported signs included body weakness, dizziness, blindness, and skin and eye irritation (34.1%). Chest pain and body discomfort reported to be (19.5%). While skin irritation, stomachache, nausea and vomiting (4.9%), On the other hand symptoms like excessive fatigue, tiredness, headache and nervousness or depression were reported to be common to all pesticide applicators. Minority (14.6%) of pesticide applicators were reported to seek medical consultation, but the majority believed that drinking milk was the main treatment method against pesticide exposure (Table 7).

(e) Pesticide applicator exposure routes

The major routes of exposure encountered during the study included dermal contact (65.9%), inhalation (26.8%) and ingestion (4.9%). It was noted that pesticide applicators took bath and washed their contaminated clothes and equipments in water sources after spraying activities. The water sources included rivers irrigation canals (53.7%), home shower (41.9%) and (4.9%). Other dangerous practices were in-house storage of unused pesticide (46.3%) and open disposal of empty pesticide containers (41.5%). Most of these contaminated water sources were used for domestic purpose. In addition, the proximity of living houses to vegetables fields increased the risk of pesticide exposure pathway (Table 7).

Table 7: Pesticides application method practiced by pesticide applicators (n = 41)

Variable	Variable category	No. of respondent (%)
Experience	1-6 months	3 (7.3)
	7-12 months	2 (4.9)
	1-5 years	18 (43.9)
	> 6 years	18 (43.9)
Place for mixing pesticide	Home	2 (4.9)
	Field	39 (95.1)
Mixing more than two pesticides at a ago	Yes	31 (75.6)
	No	10 (24.4)
Attended any seminar or training on pesticide uses	Yes	3 (7.3)
	No	38 (92.7)
Body parts spilled with pesticide during application	Yes	41 (100)
Correctness on application of pesticide through	Label instructions	17 (41.5)
	Extension officer	2 (4.9)
	Neighbor experience	5 (12)
	Dealer	8 (19.5)
	Own assumption	18 (43.9)
Do you use PPE when spraying pesticide?	Yes	11 (26.8)
	No	30 (73.2)
Do you face health problems when applying pesticide?	Yes	39 (95.1)
In case you face health problem what do you do	Own treatment	35 (85.4)
	Medical treatment	6 (14.6)
	No	2 (4.9)
Body discomfort conditions mentioned include	Chest discomfort	8 (19.5)
	Stomachache, nausea & vomiting	2 (4.9)
	Weakness, blindness & irritation	14 (34.1)
Major routes of exposure	Ingestion	2 (4.9)
	Dermal contact	27 (65.9)
	Inhalation	11 (26.8)
Bath & equipment washing after pesticide spraying	River	2 (4.9)
	Irrigation canal	22 (53.7)
	Home	17 (41.5)
Where do you dispose empty pesticide container?	Burry/burn	23 (56.1)
	Open disposal	17 (41.5)
	Re-use	1 (2.4)
Storage of pesticide container & spraying equipment	Separate store	20 (48.8)
	Animal ban	2 (4.9)
	In the house	19 (46.3)

4.1.2.3 Agrovet dealer in relation to pesticide exposure pathway

The Agrovet dealers varied considerably both in size of operation and number of years in business within the study area. Their status varied from fulltime to casual dealers that engaged in business during the peak period of demand. Although majority of Agrovet dealers attended pesticide trading training, very few attended long course training and certified by the Tanzania Foods, Drugs and Cosmetics Authority (TFDA) and Tanzania

Pesticide Research Institute (TPRI). Most of them had more than one year experience in the business (Table 8).

Table 8: Demography characteristics of Agrovet dealers (n = 9)

Variable	Variable category	Number of respondents (%)
Sex	Male	1 (11.1)
	Female	8 (88.9)
Age	18-30	7 (77.8)
	31-40	1 (11.1)
	41-50	1 (11.1)
Education level	Primary	1 (11.1)
	Secondary	5 (55.6)
	College	3 (33.3)
Occupation	Farmer	3 (33.3)
	Business	6 (66.7)
Marital status	Single	6 (66.7)
	Married	3 (33.3)
Family size	0	6 (66.7)
	4-6	3 (33.3)
Attended short or long term training	Yes	8 (88.9)
	No	1 (11.1)
Training duration	0-3 months	5 (55.6)
	>four months	3 (33.3)
	Untrained	1 (11.1)
Business experience	1-6 months	1 (11.1)
	7-12 months	1 (11.1)
	More than a year	7 (77.8)

(a) Agrovet dealer service provision

Apart from selling pesticides, advisory services were also provided by the pesticide dealers that included how to prepare and use pesticides, assisting customers to read and interpret pesticide precautions and label instruction. They were also positively responding to customer's complaint and comments whenever forwarded to them. Some Agrovet dealers had their own vegetable farms which were being used as demonstration plot (Table 9).

(b) Pesticide demand period and Disposal of expired products

During observation study, it was noted that Agrovet dealers mostly involved on selling insecticide, fungicides and herbicides. The most demanded pesticide was insecticide (66.7%). The peak period of pesticide demand was during the dry season (88.9%).

Most of the pesticides were used on onions fields (80%). Burying or burning is the main methods used as a final disposal point of expired pesticides (55.6%), although few of them (22.2%) were returned to Manufacturer Company (Table 9).

Table 9: **Agrovet service provision (n = 9)**

Variable	Variable category	Number of respondents (%)
Complaint from vegetable grower/applicator	Yes	9 (100)
What are the complaints	High cost	1 (11.1)
	Fake pesticide	4 (44.4)
	Irregular supply	2 (22.2)
	Damaged crops	2 (22.2)
What are the comments	Use Kiswahili in label	1 (11.1)
	Seek alternative of pesticide	1 (11.1)
	Some had good efficacy	5 (55.6)
Vegetable grower/applicator seek advice	Yes	7 (77.8)
	No	2 (22.2)
Pesticide dealer assistance to customers	Yes	9 (100)
Peak period for pesticide demand	dry season	8 (88.9)
Which pesticide is in high demand?	Insecticide	6 (66.7)
Insecticide mostly sold	Marshal	3 (33.3)
	Thionex	3 (33.3)
	Profecron	2 (22.2)
	Dazburn	1 (11.1)
Herbicides mostly sold	Boxfan	5 (55.6)
	Galigan	4 (44.4)
Fungicide mostly sold	Victory	3 (33.3)
	Ebony	2 (22.2)
	Farmer zeb	1 (11.1)
	Linkoln	1 (11.1)
	Blue copper	2 (22.2)
Disposal of expired products	Burry or burn	5 (55.6)
	Return to company	2 (22.2)

4.1.2.3 Vegetable consumers practices in relation to pesticide exposure pathway

(a) Vegetable consumers' demographic status

Out of 41 vegetable consumers interviewed 51.2% were females. They included different age categories and 43.9.0% was youths ranged between 18-30 years of age (Table 10).

Table 10: **Vegetable consumers' demographic characteristics (n = 41)**

Variable	Variable category	Number of respondents (%)
Sex	Male	20 (48.8)
	Female	21 (51.2)
Age	18-30	18 (43.9)
	31-40	10 (24.4)
	41-50	5 (12.2)
	51-60	5 (12.2)
	>61	3 (7.3)
Education level	Informal	2 (4.9)
	Primary	30 (73.2)
	Secondary	9 (22)
Occupation	Farmer	34 (82.9)
	Business	7 (17.1)
Marital status	Single	26 (63.4)
	Married	15 (36.6)
Family size	None	15 (36.6)
	1-3	9 (22)
	4-6	11 (26.8)
	7-10	6 (14.6)

(b) Consumption prototype of vegetables and frequency

The knowledge among the vegetable consumers on pesticide exposure pathway was achieved through respondents' response. The vegetable consumers consumed almost all varieties which were available in the study area. Most of them knew that vegetables are good diet for the health. However, they had doubt on safety of vegetables produced. Majority of vegetable consumers (70.7%) purchased vegetables from various places but mostly at the market. Vegetable freshness was an important attribute before purchase of the product. The preparation method prior to raw eating or cooking included sorting, washing and slicing and the main sources of water for washing were tap water (63.4%) and from irrigation canal (29.3%). It was noted that 82.9% of respondents had knowledge on pesticide persistence in vegetable and admitted that most of the vegetables grown and consumed in their area had potential hazards. Ingestion of contaminated vegetables was the main exposure route of pesticide to vegetable consumers (53.7%). The vegetable consumer took precautions against the dangers of consuming contaminated vegetables through observing pesticide stains on vegetable leaves and smell while fresh or cooked (Table 11).

Table 11: Consumption prototype of vegetables; frequency of consumption (n = 41)

Variable	Variable category	No. of respondents (%)
Where do you obtain vegetable	Market	29 (70.7)
	Field	2 (4.9)
	Street vendors	4 (9.8)
	Own garden	6 (14.6)
Vegetable washing before cooking or eating	Yes	41 (100)
Source of water for vegetable washing?	Tap water	26 (63.4)
	River	2 (4.9)
	Irrigation canal	12 (29.3)
	Deep/shallow wells	1 (2.4)
Do you eat raw vegetables?	Yes	23 (56.1)
	No	18 (43.9)
Vegetable preparation method before cooking	Wash, slice and cook	26 (63.4)
	Sort, wash, slice and cook	9 (22.0)
	Slice and cook	6 (14.6)
Health problem from consumed vegetables	Stomachache, diarrhea and vomiting	19 (46.3)
	Dizziness and nausea	21 (51.2)
	None	1 (2.4)
Awareness on pesticide residues in vegetables	Yes	34 (82.9)
	No	7 (17.1)
Precautions against contaminated vegetables	Form formation and colour change	6 (9.8)
	Asking sellers	22 (53.7)
	Smelling	1 (2.4)
	Discard suspected contaminated vegetable	4 (9.8)
Knowledge on exposure routes of pesticide	Ingestion	22 (53.7)
	Dermal contact	6 (14.6)
	Inhalation	3 (7.3)
	I don’t know	10 (24.4)

During assessment of consumption prototype it was noted that, the most frequently consumed vegetables on daily basis were onions and tomato (97.6%). The other types of vegetables are detailed in Table 12.

Table 12: Frequency of consumption of different types of vegetables (n = 41)

Type	Variable category	Number of respondents (%)
Carrot	Daily	13 (31.7)
	Once a week	15 (36.6)
	Twice per week	6 (14.9)
	More than twice per week	2 (4.6)
Amaranthus	Daily	4 (9.8)
	Once a week	13 (31.7)
	Twice per week	8 (19.5)
	More than twice per week	5 (12.2)
Tomato	Daily	40 (97.6)
	More than twice per week	1 (2.4)
Onions	Daily	40 (97.6)
	More than twice per week	1 (2.4)
Kale	Daily	21 (51.2)
	Once a week	8 (19.5)
	Twice per week	4 (9.8)
	More than twice per week	5 (12.2)
Nightshade	Daily	6 (14.6)
	Once a week	10 (24.4)
	Twice per week	8 (19.5)
	More than twice per week	4 (9.8)
Okra	Daily	6 (14.6)
	Once a week	13 (31.7)
	Twice per week	5 (12.2)
	More than twice per week	6 (14.6)
Green pepper	Daily	9 (22.0)
	Once a week	6 (14.6)
	Twice per week	6 (14.6)
	More than twice per week	3 (7.3)
Eggplant	Daily	3 (7.3)
	Once a week	3 (7.3)
Chainese	Daily	9 (22.0)
	Once a week	16 (39.0)
	Twice per week	7 (17.1)
	More than twice per week	3 (7.3)
Salad	Daily	1 (2.4)
	Once a week	9 (22.0)
	Twice per week	2 (4.9)

4.2 In-depth Interview and Focus Group Discussion

4.2.1 Demographic characteristics of the respondents who participated in sociological study

Out of the 62 respondents involved in the in-depth interviews and focus group discussions, 32 were male. The age of the respondents ranged from 15 to 69 years, with a median age of 33.5 years and range of 54. The respondents had different level of education, 40% had secondary school education, 39% attended primary school education, 19% had college level of education after attending training courses with certificate or diploma awards and 2% did not have any formal education.

4.2.2 The importance of pesticide application on vegetable growing

The community in Mang'ola area and their neighbors' depends on cereal crops and vegetable growing (maize, rice, onions, tomato, Chinese, kale, nightshade, and beans) as a source of income. The most profitable activity was onions growing. This was observed as many adult individuals including children spent most of their time on the fields. They were involved in onions seedling transplanting, weeding, field irrigation, harvesting and packaging. These activities highly exposed workers to the pesticides. For example some respondents said:

> *"I wake up early in the morning after breakfast I spend my time on field activity, animal keeping and during the night I go back to the field for irrigation (FGD 01, male 27 years)".*
>
> *"Early in the morning I start to clean my house then from 9.00am I am fully engaged on farm activities, and I sleep at about 23.00pm (IDI 02, female 50 years)".*

Pests were the major destructive enemy for the vegetables growers and only pesticide was the solution for the problem despite of local method used by the farmers to prevent and control pests. The study participants said that pesticides were the most frequently applied in vegetables by the farmers otherwise they could not harvest. Sometimes the farmer harvested vegetables two to three days after pesticide application before the pre-harvest interval period (PHI is the recommended withdrawal period before harvest after pesticide application). The main reason for using pesticide was to protect vegetables from pest damage and sometimes the farmers were much concerned with money rather than consumers health. Some respondents commented that:

> *"In the vegetables we grow pesticide are used to control pests because you cannot get anything without spraying (IDI 09, M 36 years)".*
>
> *"During rain season pests are few we spray the minimal dose of pesticide to control but during the dry season there are a lot of pests so we normally overdose and sometimes we spray pesticide twice per week. (FGD 01, male, 40 years)"*
>
> *"Vegetables in our area are harvested 3 to 4 days after pesticide application due to vendors and consumers demand at the same time the vegetable growers' needs money. Therefore it is difficult for growers to observe PHI (FGD01, male, 40 years)".*

4.2.3 Respondents' perceptions about pesticide exposure pathway on human and health problems they cause

There were various thoughts about the persistence of pesticide in vegetable and exposure pathway on human with respect to health problems they face. A theme that appeared from these opinions was lack of pesticide exposure knowledge as illustrated by the following respondents' quotes:

“Majority of us don’t know about pesticide persistence or exposure due to lack of knowledge, but just through hear say. In case of onions is very difficult to know if there are pesticide remains dangerous for health without being educated. (IDI04, M52 years)”

“When you cook vegetables which has pesticide residue they give out foam and when eaten they cause stomach roar, heartburn and also you feel gas bloating. I do not advice people to buy or consume vegetable with sign of pesticides. (FGD06, female, 47 years)”.

“Meanwhile we do not experience side effects but I believe in the future many people will experience problems and even die unknowingly; pesticide applicators health is not fit, their body smells pesticide and many of them are found affected after medical checkup. (FGD05, Male, 40 years)”.

Despite of many health problems the respondents mentioned during discussions and in-depth interview that, most of the consumers cannot take precautions to protect themselves from the pesticide health risks. When the participants were asked about what could be done to prevent people from exposure to pesticide health risks there were numerous views and from these the concept of exposure pathway emerged as a theme idea. Views of the respondents were as follows:

“Government had conducted seminars and training to some people, I am one of trainee. The main subject was how pesticide entered in the human body. The trainer told us to use PPE and observe PHI if we want to get rid of pesticide exposure and its hazards. (FGD07, male, 33 years)”.

> *"Although we are responsible for dangerous practice like open disposal of the empty pesticide containers and bottles that contaminate water we use and our environment, the government has not played its role to help people. People need to be educated because only few have the little knowledge on pesticide exposure routes. (FGD02, male, 32 years)".*

Two major themes emerged during In-depth interviews and FGD concerning respondents' knowledge and perceptions on pesticide exposure pathway.

4.2.3.1 Theme 1: Concept of pesticide exposure pathway

Respondents had difficult to explain the meaning of the term exposure. However all had an idea on the practices that could make a person exposed to pesticide or pesticide residues. Due to intense application of pesticides and field activities, there were different pathways of getting exposed to pesticides directly or indirectly between farmers and applicators. Farmers were exposed to pesticides through working in sprayed fields where there was a direct contact with plants having pesticides, inhaled pesticide contaminated air; eating while in the field without proper hand washing; touching contaminated plant during weeding, harvesting as well as bathing in contaminated water from irrigation canals or rivers. In case of applicators, the nature of their activities led to direct touch or contact with pesticide during pesticide preparation and when spraying without using PPE, therefore they were considered to be at high risk of exposure compared to farmers and vegetable consumers. On the other hand the consumers were exposed to pesticides residues through consumption of contaminated vegetables unknowingly or knowingly. Due to inadequate income, consumers were forced to eat vegetables of whatever quality. Furthermore for those laborers living in the fields or close to environment where the vegetable fields were located were also considered to be at risk of exposure. Respondents had the following statements:

"Onions is our cash crop, through our experience we spray one week before harvest and at the same week we irrigate and the third day we uproot. The problem arises when people take home for use. That is the real situation we have experienced for along time now, so in case of being exposed already we are the victims. (FGD06, male, 45 years)".

"Open and random disposal of empty containers and bottles of used pesticide in and around river banks and irrigation canals end up on water contamination and in turn water is used for domestic purpose and livestock drinking. I believe we finally consume meat with pesticide residues. (IDI08, F38 years)".

"Applicators always apply pesticides without wearing PPE hence experience direct skin contact. Consumers, get exposed when consume vegetables harvested prior to PHI. Others i.e. field laborers' and workers are also exposed through different activities done on pesticide treated fields (IDI05, male, 43 years)".

4.2.3.2 Theme 2: The source and route of pesticides and pesticide residues

The respondents agreed that intense infestation highly damage vegetables and other crops in fields caused the farmers apply pesticides haphazardly. Not only that but also farmers harvest vegetables few days after pesticide application before PHI to avoid loss of vegetable for better price. The indiscriminate disposal of empty pesticide containers and bottles of used pesticide on the other hand contribute much on the increased sources of exposure due to the fact that this practice results in environmental and water contamination. Moreover the majority is not concerned about short-term or long-term pesticide exposure due to lack of education and awareness on health risks associated with pesticide exposure pathways.

"During rain season the insects are few compared to dry season where we usually mix two or even more than three pesticides and if insects are killed others will do the same. (FGD09, male, 36 years)".

"I think vegetable growers and pesticide applicators have inadequate knowledge on pesticide health risks because they apply pesticide without PPE and thereafter the empty bottles/containers are thrown randomly; eventually enter the water channels where they contaminate water and become dangerous to users and our livestock. On the other hand vegetable growers cannot observe PHI mean that consumers eat contaminated vegetable. (IDI 06, F29 years)"

4.3 The Scenario of Multiple Pesticide Exposure Pathways (Site Conceptual Model)

The Fig. 2 below summarizes the context of pesticide exposure pathways depicted at the study area. It shows the source of contamination, contaminated media and how they transport contaminants from the source to exposure points; also displays where the exposure points are and what are the potentially exposed populations. Developed site conceptual model helped to prioritize pathway for assessment. For example, consider a sprayed vegetable field with different activities carried out by people within or close to the field to the end point (final consumer) from this study.

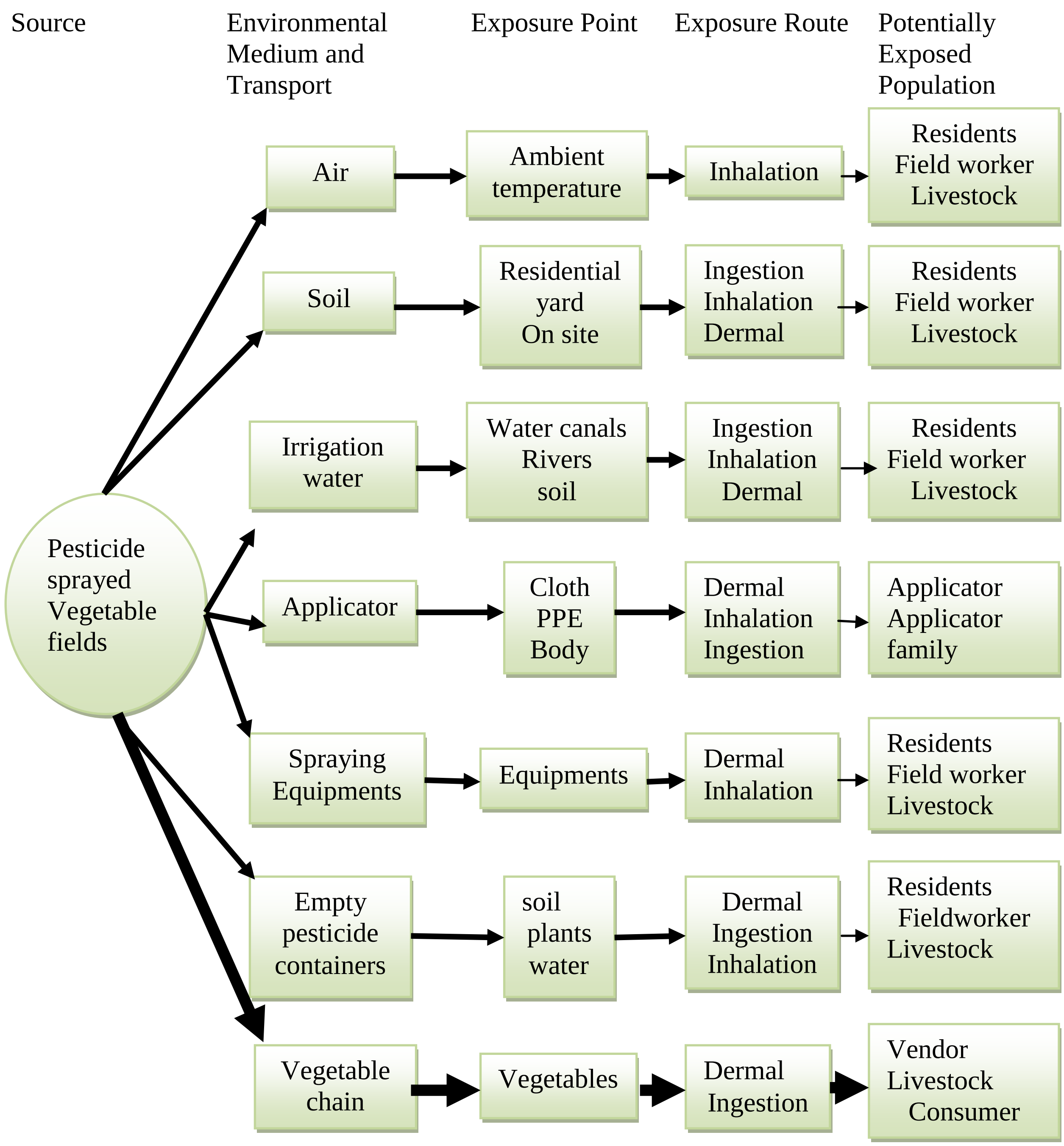


Figure 2: **Summary of site conceptual scenario for the sprayed vegetable fields that display the multiple pesticide exposure pathways.**

Note: Much bolded lines show pesticide exposure pathway to contaminated vegetables.

4.4 Eating Habit Study

In this study (60) questionnaires were administered to respondents with the age ranged between 20 to 70 years. Demographic information is summarized on Table 13.

Table 13: **Eating habit demography (n=60)**

Variable	Variable category	Number of respondents (%)
Sex	Male	32 (53.3)
	Female	28 (46.7)
Age	18-30	5 (8.3)
	31-40	10 (16.7)
	41-50	20 (33.3)
	51-60	20 (33.3)
	>61	5 (8.3)
Education level	Informal	5 (8.3)
	Primary	40 (66.7)
	Secondary	15 (25)
Occupation	Farmer	34 (56.7)
	Livestock keeping	14 (23.3)
	Business	9 (15)
	Employee	3 (5)
Marital status	Single	22 (36.7)
	Married	36 (60)
	divorced	2 (3.3)
Family size	None	3 (5)
	1-3	27 (45)
	4-6	22 (36.7)
	7-10	8 (13.3)

4.4.1 Vegetable choice, preferences and motivations

The important factors for vegetable preferences and motivations that had the highest score were “Richness in natural ingredients” (75%). Other driving factors for preferences to vegetables were “Is nutritious” (70%); “It makes me feel good” (68.3%); “Is readily available” (65%); “Is familiar” (63.3%) and “It has a nice smell” (61.7%). Factors with the lowest score were “It keeps me awake/alert” (6.7%) and “Easy to prepare” (5%). Other factors were moderately considered important to respondents (Table 14).

Table 14: **Vegetable choice questionnaire descriptive statistics (n=60)**

Factor	No	Item	No. of respondents (%)
Health	1	Contains vitamins/minerals	6 (10)
	2	Keeps me healthy	5 (8.3)
	3	Is nutritious	42 (70)
Mood	1	It keeps me awake/alert	4 (6.7)
	2	It makes me feel good	41(68.3)
	3	No reason	15 (25)
Convenience	1	Easy to prepare	3 (5)
	3	It is easily accessible	5 (8.3)
	4	Is readily available	39 (65)
Sensory appeal	1	It has a nice smell	37 (61.7)
	2	It taste good	13 (21.6)
	3	No reason	10 (16.7)
Natural content	1	Is rich in natural ingredients	45 (75)
	2	Require no additives	8 (13.3)
	3	No reason	7 (11.7)
Price	1	It is cheap	36 (60)
	2	It is expensive	18 (30)
	3	No reason	6 (10)
Familiarity	1	Is what I usually eat	12 (20)
	2	Is familiar	38 (63.3)
	3	No reason	10 (16.7)

4.4.2 Vegetable dietary eating habit

Vegetable diet was part and parcel of daily meal of respondents interviewed in this study. With regard to frequency of daily meals, all respondents had two meals a day (lunch and dinner) and 96.7 % had breakfast daily. About 42% were willing to eat vegetables and 63.3% regarded vegetable as important part of health diet. Up to 91% had 1-2 vegetable servings per day and 68.3% recommended 1-2 vegetable servings per person per day for good health. Other included study variables about vegetables eating habit are in (Table 15).

Table 15: Vegetable dietary habits (n=60)

Item	Variable category	No. of respondents (%)
Use of vegetables as part of daily meal at HH level	Yes	60 (100)
Efforts of HH to eat vegetables as health a diet	Often	52 (86.7)
	Sometimes	6 (10)
	Seldom	2 (3.3)
Willingness of HH members to eat vegetables	Extremely willing	16 (26.7)
	Very willing	25 (41.7)
	somewhat	16 (26.7)
	Slightly	1 (1.7)
Number of breakfast per week	0-1	2 (3.4)
	6-7	58 (96.7)
Number of lunch per week	6-7	60 (100)
Number of dinner per week	6-7	60 (100)
Importance of vegetable to provide health diet	Very important	13 (21.7)
	important	38 (63.3)
	Slightly	4 (6.7)
	Not important	1 (1.7)
	Extremely not important	4 (6.7)
HH members do not like to eat vegetables	Strongly agree	4 (6.7)
	Agree	15 (25)
	Disagree	31 (51.7)
	Strongly disagree	10 (16.7)
HH members get vegetables from the far	Strongly agree	21 (35)
	Agree	5 (8.5)
	Disagree	15 (25)
	Strongly disagree	19 (31.7)
HH members most like to eat vegetables	Strongly agree	19 (31.7)
	Agree	27 (45)
	Disagree	11 (18.3)
	Strongly disagree	3 (5.0)
Number of vegetable servings eaten/day	0	1 (1.7)
	1-2	54 (91.7)
	3-4	4 (6.7)
	5-6	1 (1.7)
HH recommended servings/ person for good health	1-4	41 (71.6)
	5-6	1 (1.7)
	>6	1 (1.7)
	No answer	14 (23.3)

4.5 Daily Dietary Record Analysis

The analyzed vegetables daily dietary records were as follows. Amaranthus had the highest p-value (5.4306) followed by potato leaves (4.2605), onion (3.0337), tomato (1.9912), carrot (1.2536), salad (1.0810) and the lowest p-value observed were 0.000671 (green pepper) and 0.003517 (kale). While for computed mean as observed per household, the highest was the mean for amaranthus (326.69±0.72) per HH03 followed by tomato (313.02±0.29) per HH05, carrot (245.04±0.26) per HH09 and onion

(244.01±0.22) per HH03. The lowest mean was zero due the fact that not all type of vegetables consumed by the house hold where the data collected (Table 16, 17 and 18).

Table 16: **Result of one way ANOVA (P< 0.05) of Vegetables consumed at 9 HH (n = 9)**

Vegetable type	Calculated P-value
Amaranthus	5.4306
Cabbage	0.5372
Carrot	1.2536
Chinese	0.0079
Green pepper	0.0007
Nightshade	0.2600
Okra	0.4783
Onion	3.0337
Potato leaves	4.2605
Pumpkin leaves	0.1696
Kale	0.0035
Spinach	0.0752
Salad	1.0810
Tomato	1.9912

Table 17: The highest mean of consumed vegetables and the leading household (HH) (n = 9)

Vegetable type	Mean SD	Household code
Amaranthus	326.7±715.9	HH3
Cabbage	18.7±146.3	HH1and HH3
Carrot	245.0±263.4	HH9
Chinese	122.1±378.4	HH1
Green pepper	79.7±303.0	HH3
Nightshade	46.4±177.4	HH4
Okra	83.9±655.6	HH8
Onion	244.0±225.6	HH3
Potato leaves	185.7±522.7	HH4
Pumpkin leaves	37.0±164.2	HH5
Kale	195.3±492.7	HH5
Spinach	50.8±226.5	HH1
Salad	155.3±381.5	HH4
Tomato	313.2±29.2	HH5

HH = stands for a household code

Table 18: **Total means consumption of 5 vegetables collected from 9 HH at Mang'ola ward for 8 weeks (n = 9)**

Vegetable type	Total Mean (gm/kg)	Daily mean consumption (gm/kg)	Daily mean consumption (gm/kg) / person
Amaranthus	1737.3	29.0	0.7
Onion	1205.6	20.1	0.4
Kale	905.3	15.1	0.3
Spinach	152.3	02.0	$6.9x10^{-03}$
Tomato	1955.5	33.0	0.6

4.6 Pesticide Residue Concentrations in Vegetables

Secondary data (Mette, 2013 unpublished data) on levels of various pesticides in vegetables were used in risk characterization study. In that study Mette randomly collected 10 types of vegetables in Mang'ola for pesticide residue analysis. Out of 10 samples analyzed 8 had detectable levels of pesticides. The results are presented in Table 19.

Table 19: **Levels (mg/kg) of various pesticides in vegetables in Mang'ola ward, Karatu District, Tanzania, June, 2011 (n = 16)**

Vegetable	Sample	Pesticide	Concentration* (mg/kg)	MRLs** (mg/kg)
Amaranthus	1	Lambdacyhalotrin	0.21	0.5
		Dimethoate	0.012	0.02
		Profenofos	0.10*	0.01
		Tebukonazol	0.42*	0.01
		Triadimefonog-menol	0.13*	0.01
Amaranthus	2	Chlorpyrifos	0.74*	0.02
		Cypermetrin	0.22*	0.02
		Profenofos	1.1*	0.01
Amaranthus	3	negative	----	
Tomato	1	Lambdacyhalotrin	0.079	0.1
		Tebukonazol	0.075	1
		Triadimefonog-menol	0.11	1
Tomato	2	Chlorpyrifos	0.16	0.2
		Chlorothalonil	0.045*	0.02
		Dimethoate	0.017	0.02
		Profenofos	0.031	10
Tomato	3	Negative	----	
Kale		Profenofos	18.1*	0.05
Onion	1	Chlorpyrifos	0.022	0.02
		Profenofos	0.46*	0.05
Onion	2	Profenofos	0.59*	0.05
Spinach	1	Dimethoate	0.30*	0.02
		Tebukonazol	1.6*	0.05
		Endosulfan	0.14*	0.05
		Lambdacyhalotrin	0.67*	0.5

Concentration* = Exceeds the recommended concentration
MRLs** = According to EU and CAC

4.7 Risk Characterization

Pesticides cumulative hazard risk index (HRI) estimated for the adults (50 kg) showed that, organophosphate pesticide had HRI = 5.92288, that exceeded the value of 1 hence it is a risk to consumers. Pyrethroids did not exceed the value of 1 (HRI= 0.965572) but had high value enough to constitute a risk. While Organochloride, triazole and Triadimefonog-menol pesticides had HRI = 0.04102, HRI = 0.22366 and HRI = 0.06204 respectively which were very low compared to the HRI index value of 1. Therefore the main health risks were mainly due to organophosphate and Pyrethroids (Table 20 and 21).

Table 20: Estimated Daily Intake of vegetable consumptions (n = 9)

Vegetable	Pesticide	Mean concentration (mg/kg)	Daily mean Consumption (mg/kg) /person	Body weight (kg)	EDI (mg/kg/bw/day)
Amaranthus	Dimethoate	0.012	0.66	50	$1.584x10^{-04}$
Tomato	Dimethoate	0.017	0.63	50	$2.142x10^{-04}$
Spinach	Dimethoate	0.30	$6.9x10^{-03}$	50	$4.14x10^{-05}$
Amaranthus	Chlorpyrifos	0.74	0.66	50	$9.768x10^{-03}$
Tomato	Chlorpyrifos	0.16	0.63	50	$2.016x10^{-03}$
Onion	Chlorpyrifos	0.022	0.39	50	$1.716x10^{-04}$
Amaranthus	Profenofos	0.10	0.66	50	$1.32x10^{-03}$
Amaranthus	Profenofos	1.1	0.66	50	0.01452
Tomato	Profenofos	0.031	0.63	50	$3.906x10^{-04}$
Onion	Profenofos	0.46	0.39	50	$3.588x10^{-03}$
Onion	Profenofos	0.59	0.39	50	$4.602x10^{-03}$
Kale	Profenofos	18.1	0.29	50	0.10498
Spinach	Endosulfan	0.14	$6.9x10^{-03}$	50	$1.932x10^{-05}$
Tomato	Chlorothalonil	0.045	0.63	50	$5.67x10^{-04}$
Amaranthus	Cypermethrin	0.22	0.66	50	$2.904x10^{-03}$
Amaranthus	Lambdacyhalotrin	0.21	0.66	50	$2.772x10^{-03}$
Tomato	Lambdacyhalotrin	0.079	0.63	50	$9.954x10^{-04}$
Spinach	Lambdacyhalotrin	0.67	$6.9x10^{-03}$	50	$9.246x10^{-05}$
Amaranthus	Tebukunozol	0.42	0.66	50	$5.544x10^{-03}$
Tomato	Tebukunozol	0.075	0.63	50	$9.45x10^{-04}$
Spinach	Tebukunozol	1.6	$6.9x10^{-03}$	50	$2.208x10^{-04}$
Amaranthus	Triadimefonog-menol	0.13	0.66	50	$1.716x10^{-03}$
Tomato	Triadimefonog-menol	0.11	0.63	50	$1.386x10^{-03}$

EDI = R (mean concentration of the residue in the food commodity in mg/kg) *C (daily consumption kg/person/day)*EP (edible portion = 1) *PF(Processing factor for the specific food commodity = 1)/BW(body weight = 50 (kg).

Table 21: **Cumulative intake of pesticide groups detected in all samples based on HRI method. (n = 16)**

Chemical group	Pesticide	EDI in mg/kg/bw/day	ADI in mg/kg/bw/day	EDI/ADI	Vegetable
Organophosphates	Dimethoate	$1.584x10^{-04}$	0.001	0.1584	Amaranthus
	Dimethoate	$2.142x10^{-04}$	0.001	0.2142	Tomato
	Dimethoate	$4.14x10^{-05}$	0.001	0.0414	Spinach
	Chlorpyrifos	$9.768x10^{-03}$	0.01	0.9768	Amaranthus
	Chlorpyrifos	$2.016x10^{-03}$	0.01	0.2016	Tomato
	Chlorpyrifos	$1.716x10^{-04}$	0.01	0.01716	Onion
	Profenofos	$1.32x10^{-03}$	0.03	0.044	Amaranthus
	Profenofos	0.01452	0.03	0.484	Amaranthus
	Profenofos	$3.906x10^{-04}$	0.03	0.01302	Tomato
	Profenofos	$3.588x10^{-03}$	0.03	0.1196	Onion
	Profenofos	$4.602x10^{-03}$	0.03	0.1534	Onion
	Profenofos	0.10498	0.03	3.4993	Kale
	∑EDI/ADI = HI			5.92288	
Organochloride	Endosulfan	$1.932x10^{-05}$	0.006	$3.22x10^{-03}$	Spinach
	Chlorothalonil	$5.67x10^{-04}$	0.015	0.0378	Tomato
	∑EDI/ADI = HI			0.04102	
Pyrethroids	Cypermethrin	$2.904x10^{-03}$	0.015	0.1936	Amaranthus
	Lambdacyhalotrin	$2.772x10^{-03}$	0.005	0.5544	Amaranthus
	Lambdacyhalotrin	$9.954x10^{-04}$	0.005	0.19908	Tomato
	Lambdacyhalotrin	$9.246x10^{-05}$	0.005	0.018492	Spinach
	∑EDI/ADI = HI			0.965572	
Triazole	Tebukunozol	$5.544x10^{-03}$	0.03	0.1848	Amaranthus
	Tebukunozol	$9.45x10^{-04}$	0.03	0.0315	Tomato
	Tebukunozol	$2.208x10^{-04}$	0.03	$7.36x10^{-03}$	Spinach
	∑EDI/ADI = HI			0.22366	
Limefon	Triadimefonog-menol	$1.716x10^{-03}$	0.05	0.03432	Amaranthus
	Triadimefonog-menol	$1.386x10^{-03}$	0.05	0.02772	Tomato
	∑EDI/ADI = HI			0.06204	

CHAPTER FIVE

5.0 DISCUSSION

This study conducted to assess pesticide exposure pathways in order to determine if the vegetable consumers and farm workers were predisposed to the risk of pesticide residues that may be present in various sources. It specifically intended to establish baseline data on pesticide exposure pathways scenario, assess the vegetable eating habits and characterize the risks for identified hazards based on FAO/WHO guidelines. It was generally found that there was indiscriminate use of pesticides with minimal consultation to Agricultural Extension Officers. The community was exposed to pesticides mainly through ingestion of contaminated vegetables. Concentration of pesticide residues in vegetables ranged from <0.01 to 18.10 mg/kg with estimated cumulative pesticide Hazard risk index (HRI) of 5.9 for organophosphates which posed risks to the consumers. Therefore, deliberate measures ought to be taken including health education on pesticide safety and increased community awareness on pesticide residues exposure pathways so as to safeguard them from likely effects caused by short and long term exposure to pesticides.

5.1 Communities' Knowledge, Perceptions and Practices Related to Pesticide Exposure Pathways

The sociological and baseline studies demonstrated that pesticide use is a common practice to control pests and diseases in vegetable farms. The reported pest problems caused higher uses of pesticides in particular insecticides (95%). The study further found that pests control resulted to indiscriminate use of pesticides. This was due to limited knowledge on effects of pesticide on human health and the general environment. Easy access to the agrochemicals in the local market with unrealized agrochemical expenses propelled the rampant use of pesticides in the study areas. Shortage of Agricultural extension staff that could advice the farmers on Good Agricultural Practice (GAP), Good Hygienic Practice (GHP) or other alternative methods for pest control and associated public health risks may also be among the factors. Similar results have been reported in other studies in Tanzania (Ngowi *et al*., 2007; Nonga *et al*., 2011). This findings indicates that the majority of respondents excised routine application of high dose of pesticides sometimes twice per week particularly on vegetables. Although it is undeniable that vegetable crops need high dose of pesticides for control of pests and diseases, it remains doubtful if the frequency of application were justifiable (Nonga *et al.*, 2011). On the other hand, the use of pesticides in agriculture for crop protection and pest control has been reported to be associated with problems of environmental contamination and human health worldwide (Celina *et al.*, 2006). Community misconduct on pesticide application in the study area indicates that education background could partly contribute because most of the farmers (90%) and pesticide applicators (82.9%) had primary school level of education hence might face difficulties of reading and/or understanding instructions for pesticide applications written in English. Beyond that the integrated pest management (IPM) and organic agricultural strategies could be the alternatives to excess use of pesticides (Wilson and Tisdell, 2001).

The study further showed that there is potential for environmental pollution when vegetable farmers and pesticide applicators bathed, washed pesticide sprayers in rivers and discarded pesticides remains and empty containers randomly. Several pesticide containers were sometimes seen lying alongside farms, rivers and irrigation channels. Indiscriminate disposal of empty pesticide containers and pesticide remains in farms present a potential pollution problem to the environment and public health at large as previously reported by Ngowi (2010).

The findings of the present study identified bad practices on vegetable farming such as mixing of different pesticide mixing “cocktail”, loading, transport and misuse of agrochemicals. On the other hand, among the vegetable farm workers and pesticide applicators were frequently exposed to health risks by working in immediate pesticide sprayed vegetable fields. This further signifies lack of knowledge and awareness on pesticide exposure pathways. The majority of vegetable field workers (85%) and pesticide applicators (95%) experienced body discomfort symptoms and signs like body weakness, dizziness and nausea, headache, skin and eyes irritation. This is comparable to Fenske and Day (2005) who reported that pesticide applicators that mix, load, transport and apply formulated pesticides and workers in immediate sprayed vegetable fields are considered to be in the greatest risk of exposure and possible acute intoxications. Similarly Smallwood (2005) said that misuse of pesticide concentrations in crop spraying areas are the source of the wide range of health problems.

5.2 Pesticide Exposure Pathways and Routes in Humans

5.2.1 Work-to-home exposure or a “take-home pathway

This study identified multiple pesticide exposure pathways and unacceptable levels of pesticide residues concentrations in consumed vegetables that predispose farm workers and vegetable consumers to the health risks. The findings indicate that pesticides may pass through several pathways before entry into a person’s body. Pesticides may reach a human body through different media and means of transport like water, air, soil, dust, equipment, clothing, and contaminated crops and vegetables. The nature of activities performed in vegetables fields implies existence of pesticide take-home exposure pathway within Mang’ola area. This finding is in agreement with the report by Pamela, (2008) who observed that vegetable farmers, pesticide applicators and field workers hands and other parts of the body were directly contacted pesticide on treated fields or during pesticide application.

In agricultural settings, work-to-home exposure, or a “take-home pathway,” has been identified as a key source of pesticide residues to humans primarily for organophosphates (Coronado *et al*., 2006). Workers who are exposed on the job on a daily basis, whether as applicators or re-entry workers are likely to carry home pesticides on their shoes, clothes, skin, and pesticide spraying equipments (Curl *et al.*, 2002). It was observed during this study that most workers were not washing or changing facilities used in the farm like shoes and clothes to remove residues before leaving the worksite. This behaviuor contributed to the risk of take-home pesticide exposure pathways. Failure of farm workers to take basic precautions (e.g., removing work shoes outside the house, or showering before picking up any home article and in-house storage of pesticide and pesticide application equipment) transferred residues directly to other household members at home.

5.2.2 Pesticide contaminated wind spray drift exposure pathway

The significant pesticide residues might also reach homes which are nearby treated farms through wind spray drift. It was observed that some of vegetable farms which were being sprayed with pesticides were very close (about 5 to 10m) to/or surrounded residential houses. This signifies that the pesticides droplets may easily be taken to houses through wind spray drift and the community can easily get exposed to pesticides. This finding is similar to studies that showed a significant relationship between proximity of the households to the treated field and the levels of pesticide in house dust (Simcox *et al.*, 1995 and Lu, Fenske and Simcox, 2000). There was a Statistical correlation between homes located within 50 feet (about 15 m) from the orchard and the dust levels of OPs among agricultural homes within 200 feet was twice as high as those in agricultural families living more distantly. While the study by Fenske *et al.* (2002) found levels in closer homes nearly three times higher than in distant houses.

Having farms applied with pesticides nearby houses and little knowledge on pesticide formulations were regarded as major factors that accelerated the risk of exposure pathways. This is supported by the fact that only 4.8% of pesticide applicators consulted Agricultural Extension officers or Agrovet dealers for instructions on pesticide uses and formulations. Fenske and Day (2005) reported that, formulation form of pesticide products may affect the extent of exposure pathways. Pesticides in liquid forms are prone to splashing and occasionally spillage, resulting in direct or indirect skin contact through cloth contamination. Solids may generate dust while being loaded into the application equipment, resulting in exposure to the face, eyes and respiratory duct. Wind increases considerably spray drift and resultant exposure to the applicator. A study by Gil *et al*. (2008) also found that the amount of pesticide that is lost from the target area and the distance the pesticide moves increased as wind velocity increases, so greater wind speed generally will cause more drift

The conclusion by Gomes *et al*. (1999) said that workers and pesticide applicators who avoid mixing and spraying during windy conditions can reduce the exposure to pesticides when this is coupled with proper use and maintenance of protective clothing. Therefore, it is important to consider the climatic conditions before mixing and applications of pesticides to crops so as to take care of wind drift exposure pathway.

5.2.3 Pesticide contaminated vegetables consumption exposure pathways.

This study further showed that eating vegetables contaminated with pesticide residues was the common pesticide exposure pathway for the population in Mang'ola area.

Nevertheless, 51% of respondents denied the possibility of consumers having health problems from consumption of pesticide contaminated vegetables. NRC (1993) and ILSI (1999) reported that food and drinking water were considered the primary exposure pathway for most pesticides. Vegetable consumption behaviuor showed that most of the population consumed vegetables daily and the mostly consumed vegetables onions, tomatoes and kale. It was noted during the FGD that most of these vegetables were harvested before the pesticide withdrawal period (Pre-harvest interval) and some of the vegetables were consumed raw (i.e. uncooked). This supports the argument of increased exposure to Oral pesticides exposure pathways. Other studies also disclosed that non-occupational exposure originating from consumption of pesticide residues in food and drinking water generally involved low doses and normally chronic or semi-chronic in nature (Davis *et al*., 1992; Jaga and Dharmani, 2003). The actual acute consumption exposure pathway, however, may be higher than that anticipated due to certain food preferences, residue variability between individual food items and the greater than average consumption of a particular food item only at one sitting.

5.2.4 Exposure through working in pesticide sprayed vegetable fields

This study observed certain behaviours and practices of the farm workers that directly exposed to pesticide while working in the vegetable fields. They were regularly exposed to pesticides in various ways, from loading, mixing or applying pesticides to planting, weeding, harvesting and prolonged direct contact with spray equipments and recently sprayed foliage. Other incorrect work practices noted among farm workers were also re-entering recently sprayed area, wiping sweat off the face, spraying against the wind and pesticide spills at the back and hands. Re-entry intervals exist was not known for many farm workers to prevent foliar contact while the pesticide on foliage is still toxic. In addition, farm workers often live in or near treated fields, and harmful pesticides vapours can drift into their homes. Despite the high risk and frequency of exposure, farm workers did not wear proper personal protection equipments while working on pesticides sprayed fields. Normal cloth was the only protective equipment worn by majority of the farmers. Cloths face masks which do not offer adequate protection to exposed pesticide contaminants and improvise forms of PPE such as handkerchiefs, long sleeves and plastic pants were used to protect their body. Re-entering a recently sprayed area has been the cause of a poisoning outbreak in Poland in 2002 after applicators re-entered a contaminated area before the required safety period has lapsed. In the same country, 22 poisoning cases were seen as a result of spraying without adequate protective gear as reported by Przybylska (2004) and Jink (2007).

5.2.5 Pesticides exposure pathway routes

The findings identified that vegetable growers, pesticide applicators and vegetable consumers in Mang'ola experience multiple routes of exposure to pesticide and pesticide residues. Dermal exposure is the main route of pesticide exposure and is highly relevant in the agricultural environment, followed by the inhalation route in workers handling pesticides in vegetable fields. Similar observations were also reported by Kromhout and Heederik (2005). As observed in this study, pesticide applicators were not appropriately protected at the time of pesticide application. The daily work-load (amount of pesticide sprayed/ha/day) coupled with ordinary application technology (use of knapsack) and exposure durations increased the frequencies for pesticide exposures through dermal and inhalation routes. This was supported by the association between non-proper use of PPE and the symptoms of headache, dizziness and skin irritation.

The group of the pesticide applicators that experienced long term pesticide exposure health risk was the youth (18-30 years of age). This group was found to have more than five years of working experience without PPE, appropriate and suitable safety equipments for this job. The study conducted by Fenske and Day (2005) reported that, the frequency and duration of pesticide handling both on a seasonal and lifetime basis increased the risk to pesticide exposure. In particular, the exposure of an individual farmer that applies a pesticide once a year is lower than that of a commercial applicator who is normally applies pesticides for many consecutive days or weeks in a season.

5.3 Vegetable Consumers Eating Habit

Other important finding in this study was the eating habit of the respondents. It was found that consumption of vegetables was on daily basis since were easily accessible at an affordable price. Many of the respondents incorporates tomatoes and/ or onions in every meal prepared. Therefore, vegetables were part and parcel of the daily diets of most people in the study area. If such vegetables had pesticide contaminants, the exposure risks increased. These findings are similar to other studies conducted by Smith and Eyzaguirre (2007) and Acheampong *et al*. (2012) in Kumasi and Cape coast, Ghana.

Worse still, during FGD the majority of the participants agreed that, consumers judgments towards the safety of vegetables was based on appearances. Vegetables were considered to be safe if were fresh, clean and attractive through visual assessment, a finding that was similar to what was reported by Oboubie *et al*. (2006) in Ghana. As well, Penau *et al*. (2006) and Sakagami *et al*. (2006) pointed out that freshness was an important preference in purchasing vegetables and fruits in many countries. Appearance had a positive and significant impact on the willingness for vegetable consumers when making purchasing decision. As one of the FGD participants during discussion said that:

"When I buy vegetables I consider freshness and attractive colour, usually vendors will tell you that they contain no pesticide. So I try to smell, if has no pesticide smell I take it home. (FGD08, female, 49 years)".

Indeed, this is not a reliable test for detecting pesticide contaminated food products like vegetables. Therefore, further research and education programmes to the farmers, vegetable consumers and the general public is needed on better methods of testing pesticide contaminated vegetables and other crops before consumption.

In addition, with respect to preferences on vegetable choice, most of the respondents have rated "richness in natural ingredients", "nutritious" and "it makes me feel good" as an important factors on vegetable selection. Therefore this result concludes that healthy, mood, natural content, and sensory appeal are the basic determinants of vegetable choices, while familiarity, price and convenience are the least important determinants. Moreover the mean frequency of vegetable consumption show that female have a higher mean of consuming vegetables compared to males. This result is contrary to the study conducted by Wardle *et al*. (2004) who reported that women had preference to vegetables so as to control body weight while the respondents in this study said that poverty was the main reason for many families to depend on vegetable diet.

5.4 Risk Characterization

The use of daily dietary record analysis result helps to estimate the probability of occurrence of pesticide health risk in a human population based on the exposure information, consumed vegetable diet and pesticide concentration level in relation to maximum residual levels (MRLs) and acceptable daily intake (ADI). Since vegetables are one of the most important food sources in Mang'ola, intake of especially toxic pesticides from vegetables is of great concern to human health. This study provides insight into the magnitude of potential exposures from vegetable contamination. The secondary retrieved data of pesticide residues concentration ranged from <0.01 to 18.10 mg/kg and the detectable ones were in groups of organophosphates, organochlorines, pyrethroids, triazole and triadimefonog-menol. The highest health indices (HI) were found for pyrethroids (0.96 ≈1) and organophosphate (5.9). Therefore the main health hazards may be posed by organophosphate since their Hazard Risk Index (HRI) level exceeded 1, while pyrethroids level was likely to cause risk to exposed consumers and the remaining pesticide groups (organochlorines, triazole and triadimefonog-menol) present no risks. It is noteworthy that dietery pesticide intakes estimated in this study considered only exposures from vegetables and excluded other food products consumed within the study area (i.e. fruits, grains, dairy, fish, and meat). Therefore, estimates are not considered as total dietary exposure to the pesticides, nor consider drinking water, residential or occupational exposures.

This indicates that exposure to organophosphate pesticides was likely to result in adverse health effects. There may be several causes for the occurrence of pesticide residues in vegetables. The vegetable farming practices in Mang'ola were burdened with abuse, misuse and overuse of pesticides. Pests and diseases pose big problems in vegetable production leading to farmers use chemical pesticides, without training in the choice of chemicals or application technique (Chowdhury *et al*., 2012). The findings regarding pesticide residues also indicate that several pesticides are used within a crop-growing season. Similar to what described by Danso *et al*. (2002) and Ntow *et al.* (2006) that vegetable farmers mix cocktails of various pesticides to increase the potency of the compounds.

Although some of the detected pesticide residue concentration levels in analyzed vegetables exceed the recommended MRLs. It is not a health-based exposure limit and thus exposure to residue in excess of MRL does not necessarily imply a risk to health (Boobis *et al*., 2008). However, the persistent nature of the pesticides is of great concern due to their bio-accumulative behaviour and toxic biological health effects on human (Shakhaoat, *et al*., 2013).

It is noteworthy that dietary pesticide intakes estimated in this study considered only exposures from vegetables and did not include other food products including fruits, grains, dairy, fish and meat. Therefore, estimates are not considered as total dietary exposure to the pesticides, nor consider drinking water, residential or occupational exposures. So, it is an underestimation of the total exposure of pesticides studied. Moreover, not all registered pesticides used and all vegetable usually consumed were measured in this study. At the same time, processing and edible portion factors were ignored, whereas some vegetables are often peeled, cooked or boiled before consumption, resulting in an overestimation of the actual exposure to pesticide residues. Furthermore, the effect of pesticides on more vulnerable groups such as children and pregnant women could all affect these calculations (Chen *et al*., 2011). Children's likewise pregnant women exposures to pesticides may be more extensive than those of adults because children consume more food and liquids in proportion to their body weight than do adults. They may also experience toxic effects at a lower exposure dose than adults due to differences in target organ sensitivity (USEPA, 2000).

At the same time, in some of the analyzed samples there were no detectable level of pesticide residues, this observation however does not necessarily mean that the content is truly zero. The content may just be too low for detection with the currently available methods and technology (Chen *et al*., 2011).

The important limitations in this study included source of uncertainty arising from the vegetable consumption data. Data on vegetable consumption were collected from a limited number of household, which may not be representative of vegetable dietary patterns of population at large. Better characterization of consumption pattern of vegetables across a wider sample size and occupational diversity may be needed to reduce the uncertainty associated with the consumption data. Other equally important uncertainties, which this study did not consider are the edible factors (EP) and processing factors (PF) that would probably affect the pesticide residues concentration level of ready consumed vegetables. In spite of the limitations associated with the analysis, the results point out the potential pesticide health risks in humans and represent an important step toward better characterization of such health risks.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

Based on the findings of the present study, the following conclusions are made:

There are malpractice of pesticide application on vegetable farming activities within Mang’ola area that poses health risks to the community, livestock and the environment at large. Majority of the respondents were unaware of the pesticide exposure risks during cropping, mixing, loading, and application.

The results of this study are consistent with the theory of take-home exposure pathway and proximity. Whereby, farm workers whether applicators or field re-entry workers are likely to carry home pesticides on their shoes, clothes, skin, and pesticide spraying equipments. On the other hand, residence located within or 15 meter from the pesticide treated were at high exposure risks due to wind spray drift.

Despite that health risks from pesticides are based on dietary and take-home exposure pathways. It is important to know that occupational exposure provides almost certainly the primary source of pesticide exposed communities.

The households in which members engaged in pesticide application agricultural activities, or live in proximity to pesticide-treated farms have higher risk of exposures than others living in the same community. These households thus have additional exposure pathways beyond diet, drinking water, and residential pesticide use.

In this study estimation of pesticide cumulative HRI give a good indication of pesticide health risks status for planning intervention strategies. As pesticide residues can bio-accumulate and bio-magnify several fold in a food chain over time, continuous and strict monitoring programs should be enforced to check and limit these residual levels in vegetable items.

Limited research on toxicology testing and effective dose of pesticide required to kill the target pests led to increased pest resistance and associated pesticide exposure pathways. Access to this information would allow the vegetable growers to select and apply the required potential pesticide for identified pests.

There was lack of established and enforcement of prevention and intervention programs regarding the safe use of pesticide and monitoring of health risks. The community preventive and control measures efforts against pests is not consistent to pesticide health risks.

Mixing of pesticides as a common practice increased the risk to pesticide exposure.

6.2 Recommendations

From the conclusions drawn, it is therefore recommended that:

i) Education about pesticide safety is an important measure for preventing pesticide health risks. Community at large should be offered additional education on appropriate methods that can be necessary to prevent or reduce take-home pesticide exposure pathways

ii) Frequent monitoring of amount of pesticide residues is needed to avoid excessive concentration by inculcating in the growers and applicators the necessity to strictly follow the recommended and correct ways of using pesticides.

iii) Research efforts should be directed toward determination of the health risks that exposure levels are at high rate and toward a better understanding of the importance of all exposure pathways in agricultural communities.

iv) Governmental support in restructuring the production system with respect to environmental health risks, conducting better training for public health workers, enforcing current legislation and, when necessary modifying laws to ensure effective oversight and monitoring.

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APPENDECES

Appendix 1: **A questionnaire to explore vegetable farmers, pesticide applicators, agrovet dealers and vegetable consumers' knowledge, perceptions and practices related to pesticide exposure pathways on humans in Mang'ola area.**

1. Date of interview …………………………………………………………………
2. Ward ……………………………………………………………………………...
3. Village ……………………………………………………………………………
4. Sub-village ……………………………………………………………………….

Part A: Personal Information

Respondent name ………………………………………………………………..

Sex	Age	Marital status	Education level	Family size	Important IGA		
Male	Fema le				1	2	3

Note: IGA= Income Generating Activity

Part B: General information

Information on pesticide exposure pathways on humans associated with nature of activity/or consumption of pesticide contaminated vegetables

Group A: Vegetable growers

1. What is your main income generating activity?
2. What type of vegetables do you grow and for what purpose?

S/N	CROP	PURPOSE		
		1 = Food	2 = Sell	3 = Food and Sell
1				
2				
3				
4				
5				

3. For how long have you been growing vegetables? (years / months)
4. Is there any pest problem in your farm? Yes / No
5. How do you confirm the type of the pest present on your farm? (by consulting e.g. neighbor, agriculture extension, your-self, others)
6. How do you control pests; (no action / consult e.g. dealer, agriculture extension, neighbor, agriculture research, others)
7. Do you apply pesticides on your farm? Yes / No
8. If yes, what type of pesticide do you apply?
9. Which pesticide(s) is/are often used by vegetable growers to control pests in vegetables?
10. Which insecticides are most preferred for insects attacking vegetable?
11. Which fungicides are most useful for controlling fungus attacking vegetables?
12. Which herbicides are most useful for controlling weeds in the field?
13. Do you consult any expert on how to apply pesticides? (consult e.g. Agrovet dealer, agriculture extension, neighbor, other)
14. When do you apply pesticides?
15. With regard to safe use of pesticide, who decides when and how to spray? (Own decision / agriculture extension/ neighbor / dealer)
16. Do you mix pesticides during application? Yes / No

17. If yes, who recommend? (You're self, agriculture extension, dealer, neighbor, or others)
18. Who sprays pesticide on your vegetable fields? (Your self / applicator)
19. If you're self, do you use Personal Protective Equipment (PPE)? Yes / No
20. If yes, mention it ……………………………………………………………….
21. If no, do you feel any discomfort? Yes / No
22. If yes, can you mention few of them?
23. Do you face health problems during and after pesticide application? Yes / No
24. If yes, what are those problems?
25. In case you face health problems what do you do? Consult e.g. Doctor, dealer, neighbor, agriculture extension, own treatment?
26. What is a major route(s) of exposure to pesticide residues on human do you know?
27. Where do you take bath, wash your clothes, and clean the equipments after pesticide application? (Home, river, in field stream)
28. What do you do with empty containers? (Bury them / sell / home use/ others)
29. Where do you get pesticide equipments? (own, lending, hiring, others)
30. Where do you store the equipments and pesticide contained? (Separate store, house, or animal barn)
31. Do you have any knowledge about expiry date of pesticide? Yes / No
32. Have you attended any seminars, workshop or training on safe and effective use of pesticide? Yes / No
33. Do you know about preharvest withdrawal period/interval (PHI)? Yes / No
34. Are you aware that pesticide applied on farm remains in vegetables as residues? Yes / No
35. For how long do you stay without harvesting following pesticide application?
    a. One day
    b. Three days

c. Seven days

d. Twenty one days

36. How do you dispose off /or store the remaining pesticides and the empty containers?

37. What are the sources of water for vegetable irrigation?

a. River

b. Shallow wells

c. Streams

d. Drainage system

e. Tap water

f. Others specify …………………………………………………………………

Group B: Pesticide Applicators

1. What is your main income generating activity?
2. For how long have you been engaged on pesticide application? (Years / months)
3. Where do you prepare and mix pesticide before applying?
4. When mixing and applying pesticides, which part of your body usually contact with the pesticide?
5. How do you know the correct pesticide application methods? (You're self through labeled instructions? / consult e.g. dealer, agriculture extension, neighbor, others)
6. How do you know pesticide formulation and the frequency of use?
7. Do you face health problems during and after pesticide application? Yes / No
8. If yes, what are those problems?
9. In case you face health problems what do you do? (Consult e.g. Doctor, dealer, neighbor, agriculture extension, agriculture researcher, own treatment?)
10. What is a major route(s) of exposure to pesticide on human do you know?
11. Where do you take bath, wash your clothes, and clean the equipments after pesticide application? (Home, river, in field stream)

12. What do you do with empty containers? (Bury them / open disposal/ sell / home use/ others)
13. Where do you store the equipments and pesticide contained? (Separate store, house, or animal barn)
14. Have you attended any seminars, workshop or training on safe and effective use of pesticide? Yes / No
15. Do you use Personal Protective Equipment (PPE) during pesticide application? Yes / No
16. If the answer is no from the question above, do you feel any discomfort? Yes / No
17. If yes, from the question above can you mention few of them?
18. What equipment do you use for spraying pesticides?
19. If you spill some of pesticide on your clothes, when do you change clothes?
20. After applying pesticides, when do you usually change into clean clothes?
21. After mixing and applying pesticides, where do you usually wash up or shower?
22. Do you wash pesticide equipment after use? Yes / No
23. If the answer is yes from the question above, explain how and where do you wash it?

Group C: Agrovet Dealers

1. What is your main income generating activity?
2. Any training attended as a pesticide dealer? Yes / No
3. If the answer is yes for the question above, for how long? ….. Institution………….
4. For how long have you been in this business?
5. What are you doing with expired pesticides? (Bury it / open disposal / return to company / use it/others)
6. What is the peak period of demand for pesticides?
7. Which pesticides are in high demand by vegetable growers?
    a. Insecticides
    b. Fungicides
    c. Herbicides
    d. All of the above
8. Among the insecticide, which one is highly demanded by vegetable growers?
9. Among the fungicides, which one is highly demanded by vegetable growers?
10. Among the herbicides, which one is highly demanded by vegetable growers?
11. Do vegetable growers bring comments on pesticide efficacy? Yes / No
12. If the answer is Yes for the above question, what are those comments?
13. If no, how do you know the required pesticide for their problems?
14. Do vegetable growers bring any complaints on pesticide efficacy? Yes / No
15. What complaints do you receive from the vegetable growers?
16. In case of vegetable growers seeking your help/advice, what do you do?
17. Do you advice the applicators on how to use pesticides? Yes / No
18. Do you tell the vegetable growers about pesticide residue persistence and withdrawing period? Yes / No
19. Do you tell the vegetable growers about pre-harvest withdrawing period / Interval? (PHI) Yes / No

20. ***Group D: Vegetable Consumers***

1. What is your main income generating activity?
2. Do you include vegetable in your daily meals? Yes / No
3. Circle all types of vegetables you consume
    a. Spinaches
    b. Cabbages
    c. Amaranths
    d. Carrots
    e. Tomatoes
    f. Onions
    g. Others specify ………………………………………………………………
4. Where do you obtain/ buy vegetables?
    a. At the market
    b. Directly from the farmer
    c. Street vendors
    d. Others specify ………………………………………………………………
5. Do you wash the vegetables before cooking? Yes / No
6. If the answer is yes for the question above, where do you get water? (Circle the correct answer(s)) From the
    a. River
    b. Shallow wells
    c. Streams
    d. Drainage system
    e. Tap water
    f. Others specify ………………………………………………………
7. Do you eat raw vegetables? Yes / No
8. If the answer is yes from the above question, mention those vegetables?
9. How do you prepare fresh vegetables for cooking?

10. Are there vegetable leftovers at your home? Yes / No

11. If the answer of the question above is yes, what do you do with the leftovers?

12. Have you experienced health problems due to consumption of vegetables at home

Yes / No

13. If the answer for the above question is yes, can you mention them?

14. Do you know that pesticides are use in vegetable growing? Yes / No

15. If the answer for the above question is yes, do you get any health problems from consuming vegetable with pesticides? Yes / No

16. If the answer for the above question is yes, mention them ……………………….

17. What precautions do you take against consumption of vegetables with pesticide?

18. Which ways can person be affected with pesticide?

19. What are the type of food do you eat?

a. Mixed diet
b. Vegetarian
c. Meat only
d. Fish only
e. Strictly vegetarian

21. How often are you consuming the following types of vegetables?

Type of vegetable	Never	Once a week	Twice a week	More than twice a week but not every day	Every day
Spinaches					
Cabbages					
Amaranths					
Carrots					
Tomatoes					
Onions					
Others					
(i)					
(ii)					
(iii)					

Thank you very much for your devoted time and good cooperation

Appendix 2: **A guide for the in-depth interviews and focus group discussions during a sociological study on pesticide exposure pathways on humans in Mang'ola area, Karatu District, Arusha Region**

Part A: In-Depth Interview

1. Your area is very popular for vegetable growing, what are the common types of vegetable grown in your area?
2. What do you address the community about pesticide application on vegetable growing?
3. From your experience;
    a. How the vegetable growers prevent pests?
    b. If they apply pesticides, what are the common types of pesticides used?
    c. Are they aware on the pesticide health hazard risks?
    d. Are they aware on pesticide persistence in vegetables?
    e. What advices are given to farmers, applicators and vegetable consumers on pesticide residues in vegetables?
    f. What effort is taken to safeguard applicators, vegetable growers and consumers against pesticide residues health hazards?
    g. What are the common health problems the community experiences from short term or / long term exposure to pesticides residues?
    h. Do vegetable growers observe pre harvest withdrawal interval (PHI)?
    i. Do applicators use PPE when they spray pesticide in the fields?
4. What are the major route(s) of pesticide residues on humans?
5. How the community protect themselves from the effects of vegetable pesticide residues?
6. Does the government safeguard community from the effects of pesticide health risks?

Part B: Focus Group Discussion

7. What are the main types of vegetables grown and consumed in your community?
8. What are the methods used to prevent pests attacking vegetables in field?
9. Which problems people can get from pesticide applied in vegetable fields?
10. Are there any health problems from consumption of vegetables applied with pesticides?
11. Are there any farming practices that can put people into pesticide health risks?
12. Vegetable growers from your community observe pre harvest interval (PHI)?
13. What ways the applied pesticide can be taken from one place to another?
14. What are the preventive measures the government takes to safeguard people from pesticide health risks?
15. What should be done to prevent problems caused by pesticide contaminants in vegetables?

Before I wind up, I would like to hear from you what do you think about the subjects we have discussed? Do you think that this group covered issues that are important on pesticide exposure pathways? Thank you all for your time and ideas. This has been extremely helpful. As I said in the beginning, the purpose of this discussion was to help me learn about pesticide exposure pathways on humans. Please remember that we agreed to keep this discussion confidential.

Thank you very much for your devoted time and good cooperation

Appendix 3: **A questionnaire to assess vegetable eating habit among the household individuals living in Mang'ola area**

1. Date of interview …………………………………………………………………
2. Ward ……………………………………………………………………………...
3. Village ……………………………………………………………………………
4. Sub-village ……………………………………………………………………….

Part A: Personal Information

Respondent name ………………………………………………………………..

Sex		Age	Marital status	Ed. level	Family size	Important IGA		
M	F					1	2	3

In this questionnaire vegetable means wide variety of vegetables grown with pesticides to control pests or weeds and consumed within the research area.

1. Does your household use vegetables in daily meal? Yes / No
2. How often does a member of your household;
   a. Attempt to eat vegetable as a healthy diet?
      i. Often
      ii. Sometimes
      iii. Seldom
      iv. Never
   b. Feel guilt or pester for not eating vegetables for health diet?
      i. Often
      ii. Sometimes
      iii. Seldom
      iv. Never
   c. Encourage growing and eating vegetables?
      i. Often

ii. Sometimes
iii. Seldom
iv. Never

d. Encourage buying and eating vegetables?

i. Often
ii. Sometimes
iii. Seldom
iv. never

3. In general, how willing are members of household to eat vegetables as part of health diet?

a. Very willing
b. Willing
c. Slightly willing
d. Not at willing

4. In a typical week, how often does your household eat the following meals?

a. Breakfast

i. 1 days/week
ii. 2 – 3 days/week
iii. 4 – 5 days/week
iv. 6 – 7 days/week

b. Lunch?

i. 1 days/week
ii. 2 – 3 days/week
iii. 4 – 5 days/week
iv. 6 – 7 days/week

c. Dinner?

i. 1 days/week
ii. 2 – 3 days/week
iii. 4 – 5 days/week
iv. 6 – 7 days/week

5. How important do you feel to include vegetable diet in providing health diet?
    a. Very important
    b. Important
    c. Not important
    d. Not very important
6. Vegetables dietary assessment:

   For each vegetable listed, circle a letter of correct response indicating how often on average the household used last month

Kind of vegetable	Never or less than once / month	1 – 3 / month	1 / week	2- 4 / week	5- 6 / week	1 / day	2- 3 /day	4 – 5 / day	6 + / day
Amaranthus									
Spinach									
Beans									
Onions									
Tomatoes									
Cabbages									
Lettuce									
Carrot									
cauliflower									
Okra									
Green beans									
Leeks									
Egg plant									
Greenpeper									
Others									

7. How much do you agree or disagree with the following statements?

	Statement	Strongly agree	Agree	Disagree	Strongly disagree
i.	The household get vegetables from the farm				
ii.	Members of household buy vegetables from the market				
iii.	Vegetables are expensive				
iv.	Members of household does not like to eat vegetables				
v.	Members of household have no time to prepare vegetables				

8. The next questions provide the simple to measure how many servings of vegetables normally the household eat.

a. How many servings of vegetables does your household eat each day)

   i. 1- 2
   ii. 3 – 4
   iii. 5 – 6
   iv. 7 or more

b. About how long does the household have been eating this number of daily servings of vegetables?

   i. Less than one month
   ii. 1 -3 months
   iii. 4 -6 months
   iv. Longer than 6 months.

c. Are the members of household seriously thinking about eating more servings of vegetables? Yes / No

d. How many servings of vegetables does the members of household think a person should eat / day for good health

   i. 1 – 2
   ii. 3 – 4
   iii. 5 – 6
   iv. 7 or more

9. Factors for vegetable choice (circle the correct responses)

a. Factor 1—Health

   i. Contains a lot of vitamins and minerals
   ii. Keeps me healthy
   iii. Is nutritious
   iv. Is high in fiber and roughage

b. Factor 2—Mood

   i. Helps me cope with stress
   ii. Helps me relax

iii. Keeps me awake/alert

iv. Makes me feel good

c. Factor 3—Convenience

i. Is easy to prepare
ii. very simple to cook
iii. Takes no time to prepare
iv. Is easily available in markets

d. Factor 4—Sensory Appeal

i. Smells nice
ii. Looks nice
iii. Has a pleasant texture
iv. Tastes good

e. Factor 5—Natural Content

i. Contains no additives

ii. Contains natural ingredients

iii. Contains no artificial ingredients

f. Factor 6—Price

i. Is expensive

ii. Is cheap

iii. good value for money

g. Factor 8—Familiarity

i. Is what I usually eat

ii. Is familiar

iii. Is a tradition

Appendix 4: **Household daily dietary analysis records**

Household code No. …………………

Name of the household head…………………………………………………

Sex ……………………………   Age …………..……….

Marital status (circle the correct response)

a) Single   b) Married   c) Divorced   d) Separated   e) widow

Total number of household children ……………………...……………………..

Males …………………………   Females……………….…………………..

List of the household members

PARENTHOOD		**NAME**	**SEX**	**AGE**	**WEIGHT**
Father					
Mother					
Others (specify)					
Children	1				
	2				
	3				
	4				
	5				
	6				
	7				
	8				

Daily vegetable consumption records

DAY	**DATE**	**FOOD (VEGETABLES)**			**SPECIFICS**			
		Type	Quantity (gm)	Number of Meals	Time consumed	Place consumed	How much consumed (gm)	Leftovers (gm)

THANKS!

Appendix 5: National Institute for Medical Research clearance certificate for conducting medical research in Tanzania

THE UNITED REPUBLIC OF
TANZANIA

National Institute for Medical Research
P.O. Box 9653
Dar es Salaam
Tel: 255 22 2121400/390
Fax: 255 22 2121380/2121360
E-mail: headquarters@nimr.or.tz

Ministry of Health and Social Welfare
P.O. Box 9083
Dar es Salaam
Tel: 255 22 2120262-7
Fax: 255 22 2110986

NIMR/HQ/R.8a/Vol. IX/1354

29th June 2012

Prof. Robinson Hammerthon Mdegela
Sokoine University of Agriculture
Faculty of Veterinary Medicine & Public Health
P O Box 3121, MOROGORO

CLEARANCE CERTIFICATE FOR CONDUCTING MEDICAL RESEARCH IN TANZANIA

This is to certify that the research entitled: Monitoring and risk assessment of contaminants in Southern Africa: Arusha Tanzania as a model, (Mdegela R H *et al),* has been granted ethics clearance to be conducted in Tanzania.

The Principal Investigator of the study must ensure that the following conditions are fulfilled:

1. Progress report is submitted to the Ministry of Health and the National Institute for Medical Research, Regional and District Medical Officers after every six months.
2. Permission to publish the results is obtained from National Institute for Medical Research.
3. Copies of final publications are made available to the Ministry of Health & Social Welfare and the National Institute for Medical Research.
4. Any researcher, who contravenes or fails to comply with these conditions, shall be guilty of an offence and shall be liable on conviction to a fine. NIMR Act No. 23 of 1979, PART III Section 10(2).
5. Approval is for one year: 29th June 2012 to 28th June 2013.

Name: Dr Mwelecele N Malecela

Signature

CHAIRPERSON
MEDICAL RESEARCH
COORDINATING COMMITTEE

Name: Dr Donan Mmbando

Signature

ACTING CHIEF MEDICAL OFFICER
MINISTRY OF HEALTH, SOCIAL
WELFARE

CC: RMO
DMO

Appendix 6: A research introductory letter of Sokoine University of Agriculture

KIBALI CHA KUFANYA UTAFITI NCHINI TANZANIA

CHUO KIKUU CHA SOKOINE CHA KILIMO
OFISI YA MAKAMU WA MKUU WA CHUO
S.L.P. 3000, MOROGORO, TANZANIA
Simu:023-2604523/2603511-4; Fax:023-2604651, MOROGORO

Kumb. Zetu : SUA/ADM/R.1/8 **Tarehe** 01/10/2012

Mkurugenzi Mtendaji,
Halmashauri ya Wilaya Karatu,
Mkoa wa Arusha.

UTAFITI WA WAALIMU NA WANAFUNZI WA CHUO KIKUU

Madhumuni ya barua hii ni kumtambulisha kwako **Mwanafunzi Mhauka Arthur Bernard** wa Shahada ya Uzamili ya Afya ya Jamii na Usalama wa Chakula (**MSc. Public health and Food Safety**) hapa Chuo Kikuu cha Sokoine cha Kilimo. Hivi sasa yuko katika shughuli za utafiti.

Chuo Kikuu cha Sokoine cha Kilimo (SUA) kilianzishwa na Sheria ("Universities Act No.5 of 2005") na Hati Ridhia ("SUA Charter, 2007") ambayo ilianza kutumika Januari 1, 2007. Hati Ridhia ilichukua nafasi ya Sheria Na.6 ya mwaka 1984. Moja ya majukumu ya SUA ni kufanya tafiti mbalimbali na kutumia matokeo ya tafiti hizo. Kwa sababu hiyo, waalimu, wanafunzi na watafiti wa Chuo hufanya tafiti mbalimbali katika nyakati zinazostahili.

Ili kufanikisha utekelezaji wa tafiti hizo Makamu wa Mkuu wa Chuo SUA amepewa mamlaka ya kutoa vibali vya kufanya utafiti nchini kwa waalimu, wanafunzi na watafiti wake kwa niaba ya Serikali na Tume ya Sayansi na Teknolojia.

Hivyo basi tunaomba umpatie Mtaalamu aliyetajwa hapo juu msaada atakaohitaji ili kufanikisha uchunguzi wake. Gharama za malazi na chakula chake pamoja na usafiri wake atalipia mwenyewe kutokana na fedha alizopewa na Chuo Kikuu. Msaada anaouhitaji zaidi ni kuruhusiwa kuonana na viongozi na wananchi ili aweze kuzungumza nao na kuwauliza maswali aliyo nayo.

Kiini cha Utafiti wa mwanafunzi aliyetajwa hapo juu ni: **"Tathmini ya njia zinazosababisha kuwepo kwa viatilifu mwilini mwa binadamu (ASSESSMENT OF PESTICIDE EXPOSURE PATHWAY ON HUMANS".**

Sehemu anazofanyia utafiti huo ni: **Mang'ola na Ngarenanyuki, mkoani Arusha.**
Ikiwa kuna baadhi ya sehemu ambazo zinazuiliwa, ni wajibu wako kuzuia zisitembelewe.
Muda wa Utafiti huo ni kuanzia tarehe **08/10/2012** hadi **30/01/2013.**
Ikiwa utahitaji maelezo zaidi tafadhali wasiliana nami.

Wasalaam,

Prof. Gerald C. Monela
MAKAMU WA MKUU WA CHUO

MAKAMU WA MKUU WA CHUO
CHUO KIKUU CHA SOKOINE CHA KILIMO
S. L. P. 3000
MOROGORO, TANZANIA

Nakala: **Mtafiti: Mhauka Arthur Bernard.**