

ASSESSMENT OF MICROBIAL AND CHEMICAL SAFETY OF SELECTED  
URBAN-GROWN VEGETABLES (A CASE OF THIKA MUNICIPALITY-  
KENYA)

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H60/7463/2002

A thesis submitted in partial fulfillment for the requirements to the award of the degree in Master of Science in Hospitality and Tourism Management in the School of Hospitality and Tourism of Kenyatta University.

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**DECLARATION**

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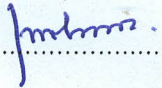
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## DEDICATION

I dedicate this thesis to God, the Creator of Thought, Emotion and Time. Affectionately too, to my lovely children: Mutuma, the pride of my girlhood; Mwenda, the comfort of my heart and Kinya, the joy of my love. Of all the titles they have used to address me, the one I cherish most, is simply “Mum”. Being a mother to them has been the highlight of my life. They have brought such special joy and strength to my life. God bless you mightily.

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## TABLE OF CONTENTS

<b>DECLARATION .....</b>	<b>ii</b>
<b>DEDICATION .....</b>	<b>iii</b>
<b>ACKNOWLEDGEMENTS .....</b>	<b>iv</b>
<b>TABLE OF CONTENTS .....</b>	<b>v</b>
<b>LIST OF TABLES .....</b>	<b>ix</b>
<b>ABBREVIATIONS AND ACRONYMS .....</b>	<b>x</b>
<b>ABSTRACT .....</b>	<b>xi</b>
<b>CHAPTER ONE .....</b>	<b>1</b>
1.0 INTRODUCTION .....	1
1.1 Background information .....	1
1.2 Problem Statement and Justification .....	3
1.3 Research questions .....	5
1.4 Hypothesis .....	5
1.5 General Objective .....	5
1.6 Specific objectives .....	5
1.7 Operational terms .....	6
1.8 Conceptual Framework .....	7
<b>CHAPTER TWO .....</b>	<b>8</b>
2.0 LITERATURE REVIEW .....	8
2.1 Urban farming .....	8
2.1.1 Production of Tomatoes .....	10
2.1.2 Food security .....	11

2.1.3 Food safety .....	12
2.1.4 Microbiological contaminants .....	13
2.1.5 Chemical contaminants .....	13
2.1.6 Food borne diseases.....	14
2.1.7 Organizational of urban agriculture .....	15
2.1.8 Policy and institutional innovation of urban farming.....	17
2.1.9 Supporting innovation processes in urban agriculture .....	18
2.2 Focus on livelihoods.....	19
2.2.1 Focus on enhancing innovative capacity and experiential learning .....	19
2.2.2 Technical innovation for strengthening urban farmer organizations .....	20
2.2.3 Link technical-organizational innovation with institutional innovation .....	20
2.2.4 Focus on urban enterprise development.....	20
2.2.5 Recognize the diversity in urban farming systems.....	21
2.2.6 Production environment of leafy vegetables and Tomatoes.....	21
2.2.7 Microbial hazard inputs from other sources.....	22
2.2.8 Microbial hazards .....	22
2.2.9 Epidemiology .....	23
2.3.0 Microorganisms and fresh leafy vegetables relevant to food safety .....	25
2.3.1 Microbial hazards from livestock and wildlife.....	27
<b>CHAPTER THREE .....</b>	<b>33</b>
3. 0 METHODOLOGY .....	33
3.1 Study site .....	33
3.2 Sampling and sample size .....	33

3.3 Determination of indicator pathogenic bacteria in vegetables, water and soil.....	34
3.4 Determination of heavy metals in vegetables, water and soil .....	35
3.5 Sample preparation and analysis .....	35
3.5.1 Spinach and tomatoes.....	35
3.5.2 Water sample.....	35
3.5.3 Analysis.....	36
3.5.4 Procedure for Soil sample digestion.....	36
3.6 Establishment of farmers' perceptions about food safety and quality .....	36
3.7 Ethical considerations.....	37
3.8 Data analyzes.....	37
<b>CHAPTER FOUR.....</b>	<b>38</b>
4.0 RESULTS AND DISCUSSIONS .....	38
4.1 Microbial pathogen load in tomatoes and spinach .....	38
4.2 Heavy metal loads in spinach and tomatoes in Thika Municipality.....	40
4.3 Demographic information of the respondents on food safety and training .....	41
4.4 Source of Seeds/Seedlings for the farmers.....	43
4.5 Farmers knowledge on pest control.....	44
4.6 Microbial pathogen load in soil and different water sources .....	45
<b>CHAPTER FIVE.....</b>	<b>49</b>
5.0 CONCLUSIONS AND RECOMMENDATIONS.....	49
5.1 Conclusions .....	49
5.2 Recommendations .....	51

<b>REFERENCES .....</b>	<b>52</b>
<b>APPENDICES .....</b>	<b>59</b>
Appendix 1: Letter of introduction.....	59
Appendix 2 : Questionnaire.....	60
Appendix 3: Forms for analysis of vegetables for microbial and chemical counts .....	63
Appendix 4: Analysis of water for microbial and chemical counts .....	64
Appendix 5: Analysis of soil for microbial and chemical counts .....	65
Appendix 6: ANOVA result for the variations in the three locations .....	66
Appendix 7: POST-ANOVA result for the variations in the three water sources .....	67

**ABBREVIATIONS AND ACRONYMS**

<b>CDCP</b>	Center for Disease Control and Prevention
<b>FAO</b>	Food Agricultural Organization
<b>FBD</b>	Food Borne Disease
<b>GAP</b>	Good Agricultural Practices
<b>GHP</b>	Good Hygienic Practices
<b>GOK</b>	Government of Kenya
<b>GSI</b>	Geographical Information Systems
<b>HACCP</b>	Hazard Analysis Critical Control Point
<b>NRI</b>	Natural research institute
<b>TCB</b>	Thermo tolerant Coli form bacteria
<b>UA/F</b>	Urban Agriculture/Farming
<b>WHO</b>	World Health Organization
<b>WTO</b>	World Trade Organization

**LIST OF TABLES**

Table 1:	The microbial pathogen load in vegetables	34
Table 2:	Levels of heavy metals (mg/kg) in vegetables	35
Table 3:	The microbial pathogen load in Water	39
Table 4:	Average presumptive results for presence of Coliforms in water	40
Table 5	Microbial pathogen load in soil and Water	42
Table 6:	Levels of heavy metals (mg/kg) in soils	43
Table 7:	Levels of heavy metals (mg/kg) in water	45

## ABSTRACT

Agricultural farming in many urban cities provides food security, income, employment and contributes to poverty reduction. An estimated 800 million people living in cities worldwide are engaged in urban agriculture worldwide. Rapid urbanization in developing countries and cities has resulted in the generation of huge volumes of municipal and industrial wastewater. Consumption of food contaminated with heavy metals and micro-pathogens is a major source of health problems for man and animals. Vegetable cropping along major highways with heavy vehicular movement is a major concern food safety. This study was conducted to assess the microbial and chemical safety of selected urban grown vegetables (tomatoes and spinach) in Thika municipality. Samples were randomly collected while demographic information of the urban famers was gathered using semi-structured questionnaires, oral interviews and focus group discussions. The samples were analyzed using standardized protocol for isolating the micro-pathogens and analyzing the heavy metal ions. Numerous indistinguishable pathogens were recovered from the vegetables, soil and water sources and these are believed to be responsible for the frequent disease outbreaks. The pattern of heavy metals deposition showed a decrease in concentration with increase in distance from the road and major factories and industries. Heavy metal concentrations in cultivated soils characterized by heavy traffic were significantly higher ( $P \leq 0.05$ ) than those cultivated on soils far from industries and factories. The high microbial contamination rates that are associated with these vegetable samples indicate that overall agricultural, hygiene, harvesting, production and sale practices are poor. Demographic results showed the need to give training to urban famers to improve their hygienic standards. The data presented show that the analyzed samples had high microbial load which is hazardous for public health. The outcome of this study provides a policy guideline on contamination for urban vegetable growers.

## CHAPTER ONE

### 1.0 INTRODUCTION

#### 1.1 Background information

The economy of Kenya is based primarily on agriculture and vegetables are an essential component of the livelihood of the subsistence farmers. In the national economy, vegetables contribute significantly as an important source of foreign exchange earnings through export. The availability of safe vegetables also improves public health and productivity. Fresh vegetables are important foods both from an economic and nutritional point of view (Kinton *et al*; 1999). They play a big role in our diets. Some literature highlights on the role of vegetables in providing anti-oxidants and other compounds that may lower the risk of cancer and other chronic diseases such as heart disease (FAO, 2002). Vegetables are rich in mineral salts and vitamins particularly vitamin C and Carotene which are good for health (Kinton *et al*; 1999). Despite the fact that these vegetables are useful, the presence of microbial and chemical contaminants affects their quality and safety.

The fifty-third World Health Assembly, in resolution WHA53.15, recognized food safety as a basic human right and an essential public health function (WHO, 2002). Globalization and increased consumer concerns lead to an increased focus on food safety standards. These standards need to be considered as an immediate requirement if access to world markets is an objective. For developing countries, food exports can contribute to economic growth and poverty alleviation. Urban agriculture and uncontrolled industrial development have contributed to an increased food contamination in both the industrialized world and in most developing countries.

This is the situation in Kenya where urban farming is on the increase because of rapid urban population growth (urbanization), placing enormous strain on urban food security (WHO, 2002).

One of the major public health consequences of food contamination is the ever-increasing incidence of food borne diseases (FBDs) caused by microbiological and chemical hazards.

Thousands of people fall ill and many die as a result of eating contaminated foods. In developing countries, significant increases have been reported in the incidence of diseases caused by

microorganisms transmitted mainly by foods such as *Salmonella* ssp(WHO,2002), *Escherichia coli* and *Campylobacter* ssp. Chemical contaminants in food include natural toxicants such as

mycotoxins and environmental toxic metals such as lead (Pb), mercury (Hg) and cadmium(Cd) (Awofolu et al.,2005).Apart from the health implications, the bioaccumulation of chemical

hazards have given rise to environmental and eco-toxicological effects (Awofolu *et al.*,2005).

These challenges have so far not been met with an appropriate response either from research

planners' policy makers or farmers themselves. This is largely because the data and information available is insufficient to enable appropriate actions to be taken. To date very little is known

about extent and impacts of microbiological and chemical hazards on safety of vegetables grown

in urban areas. There are also information gaps regarding the exact composition of these contaminants as well as the societal responses to food safety standards. The present study

therefore intends to shed further light on the extent and composition of microbiological and chemical contaminants among urban vegetables growers Thika municipality.

## 1.2 Problem Statement and Justification

Despite a global emphasis on food safety, trends in overall outbreaks of food borne diseases (FBDs) in recent years have revealed that FBDs account for most morbidity in children, pregnant women and people already affected by other diseases (WHO, 2002). FBDs not only significantly affect public health and well-being but the economic losses attributed to them are also enormous (WHO, 2002). These diseases impose a substantial burden on health-care systems and markedly reduce economic productivity perpetuating the cycle of poverty especially in developing countries. Micro-organisms and chemical hazards are the main causes. This is the situation in Kenya where despite the government's commitment to achieving better health for all by 2015. Food safety standards are poor, putting the country's population at an ever-increasing risk of contracting food borne diseases.

In the last decade, however, changes in the pattern of food production including urban agriculture combined with uncontrolled industrial development may have led to greater food contaminant impacts in and around urban towns. Although the social, economic and environmental impacts of these effects could be very significant, the importance of this issue and its implications for both food borne diseases control and food safety policy has not been well investigated in Kenya and is the centerpiece of this study.

In order to ensure consumer safety and economic growth lack of food contaminant information and appropriate data was identified as a major constraint to the control of food borne diseases and contributed to 22% of the reasons developing countries do not undertake appropriate food safety management practices(WHO, 2002). Appropriate data and information on food hazards is therefore of great importance for urban agricultural development and public health, particularly in Kenya. Urban agriculture is wide spread in Kenya, yet most of the smallholder farmers use contaminated domestic and industrial waste water which is often untreated and could contain a lot of microbial pathogens and heavy metals. It is therefore important to characterize and determine the exact levels of these contaminants in vegetables grown in urban areas in order to improve public health through increased food safety.

### **1.3 Research questions**

- i. Are urban grown vegetables safe for consumption?
- ii. What are the health risks associated with consumption of urban grown vegetables?
- iii. Are vegetable farmers aware of food safety while growing these vegetables?

### **1.4 Hypothesis**

Urban grown vegetables are contaminated with microbial hazards and chemical hazards that put consumers at risk of contracting food borne diseases and chemical poisoning

### **1.5 General Objective**

The general objective is to improve the health of Kenyans by increasing the safety of urban grown vegetables

### **1.6 Specific objectives**

- i. Determine the microbial pathogen load in tomatoes and spinach
- ii. Determine the heavy metal load in tomatoes and spinach
- iii. To determine microbial pathogen load in soil and water
- iv. Establish the knowledge on food safety measures and practices of urban farmers

## 1.7 Operational terms

**Safety:** Being free from any dangerous material or condition and assurance not to cause harm to the consumer when it is eaten according to its intended use.

**Urban agriculture:** Type of agriculture/farming practiced within and around cities and urban areas.

**Vegetables:** Parts of various types of plants (leaves, tubers and roots) eaten as food.

**Heavy metals:** Metals or trace elements with specific gravity greater than five.

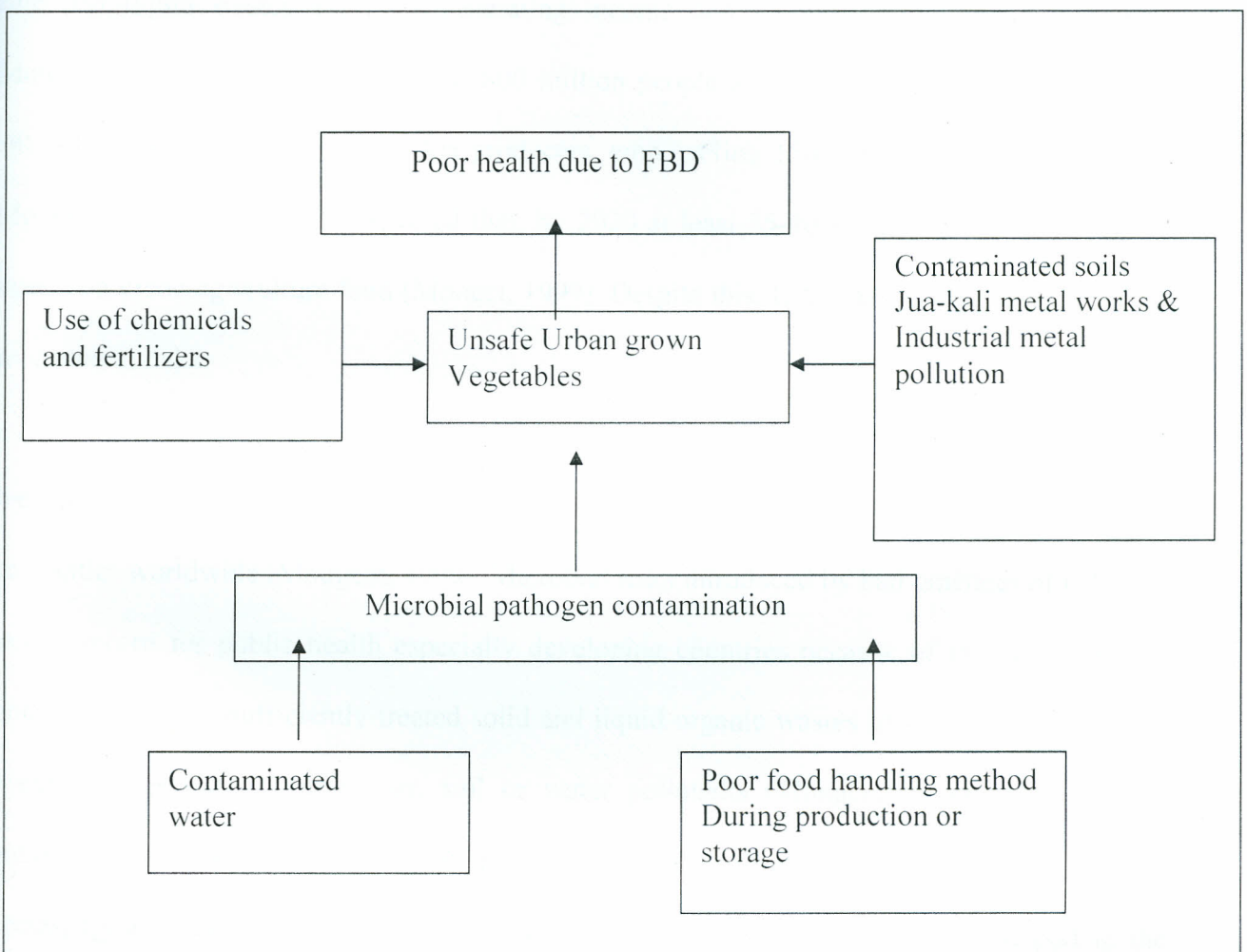
**Trace elements:** Metals whose occurrence in plants or animals is relatively low.

**Hygiene:** All conditions and measures to ensure safety and suitability of food.

**Contaminant:** Any biological or chemical agent or foreign matter or other substances not intentionally added to food, which may compromise food and suitability

## 1.8 Conceptual Framework

The conceptual framework shown in Figure 1 explains the various ways in which urban vegetables are likely to be contaminated.



**Figure 1:** Conceptual framework on various ways in which urban vegetables are likely to be contaminated

## CHAPTER TWO

### 2.0 LITERATURE REVIEW

#### 2.1 Urban farming

Urban Agriculture (UA) is one of the food security options for households in urban areas. It is an appropriate tool that uses productive urban open space through treating and/or recovering urban solid and liquid wastes and thus generating income and employment to urban population (Moterjemi *et al.* 1995). An estimated 800 million people are engaged in UA worldwide; and 200 million of these would be market producers, empowering 150 million in full time farming (Mougeot, 1999). Thus, it is expected that, by 2020 at least 35-40 million urban residents will depend on urban agriculture food (Mougeot, 1999). Despite this, UA is associated with health and environment risks.

Over the last decade, reported incidence of disease due to food-borne hazards has increased in urban cities worldwide (Mougeot, 1999). Microbial risks introduced by bad practices of UA are a major concern for public health especially developing countries because of the application of contaminated and insufficiently treated solid and liquid organic wastes to specific crops as well as exposure to either ambient air, soil or water pollutants (Mougeot, 1999). Heavy metal contamination is also of concern. Uptake of heavy metals by plants does vary across plant species, (grains versus vegetables) and varieties (cabbages versus beets) from one part to the other (roots versus foliage) as well from one heavy metal to another (calcium versus lead) (Mougeot, 1999). Contamination sources may be air, soil, water, excreta and other solid and liquid waste and may reach handlers and consumers via the plants (Mougeot, 1999).

Municipal sewage combines water and nutrients and is used widely by urban farmers mostly in its untreated form (FAO/WHO, 2002). Other studies indicated most municipalities in the South still do not treat their effluents and more often than not, trials have failed because systems are big, expensive and mismanaged, and many cities use the untreated water (Mougeot, 1999). Vegetables contaminated with unacceptable levels of pathogens and chemical contaminants impose substantial health risks to consumers and severe economic burdens on individual communities and nations (Moterjemi *et al.* 1995). Unfortunately many developing countries do not have a comprehensive safety food program integrated into their public health strategy (WHO, 2002).

In developing countries where an overwhelming majority of acute pesticide poisoning occurs, the published information indicates that there is significant exposure of the general populations to pesticide residues in food (FAO/WHO, 2002). In addition, mycotoxins and other natural occurring toxins are known to present acute and chronic health hazards in developing countries and the rest of the world. Most urban farmers are low-income men and women who grow food largely for self-consumption, on small plots, which they do not own, with little if any support or protection (Mougeot, 1999). Kenya is not an exception to urban agriculture health hazards. This is as reported from the health facilities of causes of diseases. A study on the levels of lead in Nairobi showed high levels of lead in vegetables grown within the city in comparison to WHO standards (FAO/WHO, 2002). This is because most crops are grown in the swamps and river valleys where most of the water used is from sewage. The industries emit effluents to rivers and areas where these crops are grown. Thika is an urban center and the second most industrialized town in Kenya.

### 2.1.1 Production of Tomatoes

Numerous outbreaks have been linked to tomatoes, but to date they have only been reported in the USA, where three deaths and 1840 illnesses have been linked to contaminated tomatoes. As these outbreaks have been linked to tomatoes from particular geographic regions in the USA, it is not clear whether this is a unique problem for this country or could be more widespread. Also, lack of clarity as to the source of the contamination (which may be birds, wildlife (e.g. lizards), or contaminated irrigation water) means that until more information is available it is difficult as yet to identify the global extent of this problem. Tomatoes are a widely grown commodity, with production figures in 2005 reaching approximately 35 million tonnes in developed countries and 90 million tonnes in developing countries. Production is, however, for both the fresh market as well as processing, and production systems may differ depending on the final use of the tomato.

There is also great diversity of production systems among the tomatoes grown for the fresh market, with field and greenhouse production. There is an increase in the variety of tomatoes grown for the fresh market. The tomato variety often determines the post-harvest measures that can be taken. The length of the distribution chain also varies. The potential for amplification of the hazard may be dependent on the way in which the product is marketed. An increase in the marketing of pre-cut tomatoes, for example in North America, which, depending on variety and state of ripeness, can provide an environment more amenable to pathogen amplification, particularly salmonellae, which can adapt to low pH environments, may lead to increased problems.

The limited information on the primary source of contamination means that our understanding of appropriate control is still inadequate. However, as with most commodities, the quality of the water used in irrigation and processing are important factors. Tomatoes are a widely traded product internationally. Different varieties of tomatoes are often sourced from different parts of the world. They are a major contributor to the economy of some countries and the global export value of fresh tomatoes in 2005 was approximately US\$ 5000 million. Thus, they are an important commodity from an economic perspective.

### **2.1.2 Food security**

Urban agriculture is one of the ways of enhancing food security in urban areas. This is especially when the people have low purchasing power and the only alternative is to turn to kitchen gardens. Surveys have shown that urban agriculture provides for 30% of vegetable consumption in Kathmandu, 45% in Hong Kong, 50% in Karachi, 60-85% in Shanghai, 70% in Dakar, 90% in Dar es Salaam (Wade, 1982 cited in Nugert, 1997). Urban agriculture also involves employing people thus some people get income to purchase food. The food produced in the urban areas adds to the food basket that the households buy. Before urban agriculture was fully incorporated in urban cities, nearly half of the largest urban areas in developing countries were spending 50-80% of their income in food. This improves the economic status of the household as some money is saved for other uses (FAO, 1997). The growing of these vegetables require little space and input.

### 2.1.3 Food safety

Food safety is a basic human right (WHO, 2002). It contributes to the economic growth and poverty alleviation, and is the first in reducing food borne illness. FAO and WHO experts committee on food safety in Geneva (1983) recommended that efforts be made to educate the personnel involved in the food trade and improve environmental conditions in which the trade is practiced. The education of food handlers and consumers helps to keep food safe.

They recommend that food handlers need to understand the mechanism of food infection so as to prevent infections at all points of the food chain. Good practices of handling, preparation, refrigeration and other treatment of food maintain quality and disseminate pathogenic micro organisms. The consumers alike should have knowledge of food handling in order to protect themselves from food borne diseases. In 2002, WHO drew up a global food strategy including surveillance and capacity building (WHO, 2002). From the strategy, the joint FAO and WHO Codex Alimentarius Commission (Codex) has elaborated many international standards on food safety and concluded in its report that <sup>4</sup>The role of Food safety in health and Development<sup>1</sup> caused by threats to human health, are an important cause of reduced economic productivity. WTO has put a lot of emphasis on the importance of Codex standards to protect public health and ensure fair practices in the food trade.

### 2.1.4 Microbiological contaminants

Micro-biological hazards can cause food borne illness (WHO, 2002). These illnesses are a growing public problem. These diseases are caused by pathogens such as *Salmonella*, *enterhemorjiagic Escherichia coli* and *campylobacter jejuni* (WHO, 2002). These infections are transmitted to food from fecal contamination of water and may cause Hepatitis A. Unwashed vegetables can also contain *Toxoplasma gondii* that transmits *Toxoplasmosis*. Bacteria constitute the highest percentage for causing of food borne diseases and are due to either food borne infection or food borne intoxication. Common diseases caused by bacteria include diarrhea, abdominal pain, botulism and abdominal cramps. Bacteria of concern include *Salmonella*, *Straphylococcus aureus*, *Escherechia coli*, *Bacillus cereus*, *Clostridium perfrigen*, *Clostridium Botulinum*, *Compylobacterjum* and *Lysteria monocytogenes* (WHO, 2002). Vegetables especially those eaten raw are among foods reported to have high bacterial contamination (Mougeot, 1999). Presence of *Salmonella* in vegetables and water is considered significant regardless of the levels of contamination but *Aeromanas* spp. isolated from vegetables has been shown to present a potential risk to public health.

### 2.1.5 Chemical contaminants

In terms of chemical contaminants, farmers need to improve good agricultural practices (GAPs) for improvement of safety standards (Kenny, 2002). The National press in Viet Nam reported that 63 people died from food poisoning (Kenny, 2002). Other scientific literature show that food hazards originate from a range of sources that include: the environment (land) agricultural practices and water sources (Kenny, 2002).

### 2.1.6 Food borne diseases

A lot of the vegetables consumed in cities and towns are often eaten raw or with minimal processing and if contaminated with pathogenic microbes, may represent a health hazard to the consumers. Scientific data show that there has been an increase in the number of outbreaks of food borne diseases with consumption of fresh vegetables (Beuchat, 1995; De Roever, 1999). Vegetables are one of the major exposures to pathogenic agents, both chemical and biological (virus, parasites and bacteria), from which no one in either developing or a developed country is spared (WHO, 2002). Food borne parasitic diseases are a major public health problem. For example, trematodes affect 40 million people. More than 10% of the world's population is at risk of infection (WHO, 2002). In former (West Germany) for instance, the reported incidence of infections with *Bacillus enteritis* rose to 193 per 100,000 in 1990 from 11 per 100,000 in 1965.

In USA, the estimated incidence for Salmonella alone is 20 cases per 100,000 with an estimated 7,000 deaths per year (FAO/WHO, 2002). There has been highlighted interest in outbreaks of human *gastroenteritis* that may be associated with urban vegetables. There are a number of reports indicating that raw vegetables may harbor potential food borne pathogens. *Listeria monocytogens* and *Salmonella* have been isolated from raw vegetables (Mougeot, 1999). The economic and social impact of food contaminants may be of serious consequences (Motarjemi *et al.*, 1995). The FBD can be very costly in terms of loss of income, manpower and medical care costs (Motarjemi *et al.*, 1995).

### 2.1.7 Organizational of urban agriculture

For the reasons mentioned above, urban producers are often poorly organized. More research is needed to identify existing informal networks and groupings of different types of urban producers; to analyze their problems and needs; and to identify effective ways to support urban farmer organizations and their involvement in urban planning and development processes. It is important to bear in mind that producer organizations in urban areas may take more diverse and unusual forms than those in rural settings. In the *Urban Agriculture Magazine* 16 on “Strengthening Farmer Organizations” Santandreu and Castro (2006) distinguish between *economically oriented organizations* (more like the rural agricultural cooperatives, with a main emphasis on improving production, cheaper inputs, savings and credit supply, and marketing), *socially oriented organizations* (community groups / gardens organized with the support of churches, community centres and NGOs to help vulnerable households enhance their food security/nutrition and self-help capacities) and *politically oriented urban producer organizations* (focusing on advocacy and lobbying activities to improve their legal status, enhance access to land, and increase their participation in urban planning).

Each of these types has its own dynamics and forms of innovation and will require different intervention strategies to strengthen that innovation. To deal with the low social capital in urban areas described earlier, a lot of attention needs to be given to capacity building in areas such as building group cohesion, conflict resolution, leadership development and participatory planning. Preferably, such organizational capacity building will be closely linked with processes of technical innovation and enhancing technical analysis and problem solving capacities (Arce *et al.* 2007, Prain 2006). In urban farming, more than in rural farming, innovation takes place in the form of *micro-enterprise development*. Due to their closer proximity to consumers, urban producers tend to engage more in direct marketing of their produce, in the form of fresh products (farm sales, local outlets and mobile shops, farmers' markets, direct sales to shops, restaurants and supermarkets), processed foods (preparation and vending of foods in local food stands and small restaurants, packaging, etc.) or as inputs (e.g. compost, earthworms). Innovation in urban agriculture can be greatly enhanced when research and support organizations link up with the micro and small enterprises engaged in agricultural processing and marketing activities to support their local initiatives and strengthen their entrepreneurial skills and business development capacity (Holmer 2001).

A good example of a successfully implemented micro-enterprise approach to innovation in urban agriculture is the PROVE programme in Brazil (Homen de Carvalho 2001), which combined capacity building and organizational strengthening, adaptation to municipal sanitary requirements, creation of a trademark serving as a quality seal, creation of "producers' kiosks" in supermarkets, and enhancing access to capital for investment in small agro-industrial processing facilities.

A “cluster development” approach might also be highly relevant in the urban context. In this approach groups of similar agricultural micro enterprises (e.g. small-scale mushroom producers) and closely associated (actual or potential) support services analyze how they might cooperate in order to overcome scale disadvantages, make more efficient use of scarce resources and facilitate innovation in their enterprises. This can be done through a small intervention leveraged across the cluster (Holmer 2001).

### **2.1.8 Policy and institutional innovation of urban farming**

In the urban setting, innovations in agriculture are strongly influenced by local institutions, policies and regulations, which are more pervasive and invasive in urban areas than in the rural areas. Innovation in many cities is constrained by the informal legal status of urban agriculture, lack of land use security, and lack of support from technical and financial institutions. Innovation processes in urban agriculture have a better chance of success if they are part of an integrated approach to urban development and are embedded in an enabling institutional and policy environment. Cuba serves as a useful example of how an enabling policy environment can impact the development of urban agriculture. Through effective policies and institutional support, urban agriculture developed between 1989 and 2000 from a marginal activity to a major component in the urban food system in Havana and other cities, a major employer of urban labour and an important source of micro-nutrients for the urban population. At the same time, it greatly reduced the accumulation of organic wastes (Novo 2003). No policy or institutional change related to urban agriculture can be achieved before the value and potential benefits of urban agriculture are recognized, the associated risks are made clear and the actual constraints to and opportunities for its development are known.

Therefore it is necessary to raise awareness among politicians and institutional managers and to provide them with adequate information that will allow them to involve other local stakeholders. Various communication and lobbying strategies are used to better inform decision makers (Dubbeling 2005). The most effective strategy is to stimulate institutional engagement in urban agriculture, that is, to engage all relevant institutional “stakeholders”, including policymakers, right *from the beginning* in the situation analysis and design of research and action projects, in the monitoring and evaluation of results and in determining consequences for actual policies and programmes of the local government, national organizations and other stakeholders. The RUAF “Cities Farming for the Future (CFF) programme” brings together local authorities, NGOs, universities, farmer groups and other “stakeholders” in a joint learning and planning process on urban agriculture by assisting in the establishment of a Multi-Stakeholder Forum on Urban Agriculture, the formulation of a City Strategic Action Plan, and the revision of existing policies and regulations on urban agriculture. The CGIAR Urban Harvest programme similarly emphasises engagement with policymakers and relevant local institutions to facilitate the development of safe and sustainable agriculture. This programme has implemented Stakeholder and Policy Analysis and Dialogue (SPAD) in Lima and Hanoi (Tinh, 2004), among other areas.

### **2.1.9 Supporting innovation processes in urban agriculture**

The experiences gained to date with promoting innovation in urban agriculture in the RUAF-CFF and CIPUrban Harvest programmes have resulted in a number of “lessons learned” regarding the best ways to support urban producers in innovation processes.

## **2.2 Focus on livelihoods**

For urban agriculture to be viable and sustainable, innovation needs to take into account that in the urban context agriculture usually complements other income-earning activities undertaken by the household and contributes to and draws on the diverse set of household assets. In order to come to a correct understanding of the actual role of farming in the livelihoods of the urban poor and the opportunities/constraints for its development, a situation analysis should be based on the livelihoods concept.

### **2.2.1 Focus on enhancing innovative capacity and experiential learning**

Given the dynamic and challenging urban conditions, innovation support to urban producers should focus strongly on building their problem-solving capacities (problem analysis, identification and testing of alternative solutions) as well as their capacity to identify and utilize new opportunities (e.g. analysis of specific requirements of various market segments, adaptation of crop choice and production practices, certification and trademarks, strategic alliances, etc.). The most effective approaches seem to be those that help urban producers identify gaps in their actual knowledge and skills and provide practical learning and experimentation opportunities to fill these gaps (Prain, 2001).

### **2.2.2 Technical innovation for strengthening urban farmer organizations**

Considering the high socio-cultural diversity among urban producers their lack of producer organizations and the multiple livelihood strategies of the urban poor, continuous efforts are needed to enhance group cohesion, build up trust and cooperation, enhance motivation and self confidence and strengthen organizational skills when engaging in processes of agricultural innovation with urban producers of the poorer sections of the population. An emphasis on group building would facilitate the technical innovation process at hand as well as the organization of urban producers and their claim-making capacity.

### **2.2.3 Link technical-organizational innovation with institutional innovation**

The need for institutional innovation (both public and private) is even stronger in the urban context than in the rural areas due to the tradition of institutional neglect of the urban agricultural sector.

### **2.2.4 Focus on urban enterprise development**

In the urban setting a focus on micro-enterprise development and enhancement of entrepreneurial skills, such as the capacity to analyze markets and react to new opportunities, will greatly enhance the innovation process (in production as well as in processing and marketing). The importance of enhancing the food security and nutrition of the urban poor should not be forgotten, but the need for cash income is high in the urban context; and in order to arrive at sustainable urban production systems, intensification (in a safe and ecological way) and a greater market orientation will be needed.

### **2.2.5 Recognize the diversity in urban farming systems**

Urban farming systems vary widely from purely subsistence to fully commercial and from micro-units to large enterprises. The development needs and opportunities of the various urban farming systems thus also differ widely. The most promising approaches therefore appear to be those that recognize this diversity and tune support and interventions to the needs and opportunities of each specific type of producer (for example: jasmine growers, community gardeners, intra-urban zero grazing dairy units, peri-urban intensive horticulture).

### **2.2.6 Production environment of leafy vegetables and Tomatoes**

Leafy vegetables and herbs, regardless of the production system used, are grown in environments that have a wide range of accidental or intentional inputs that are potential sources of microbial food borne hazards and may lead to contaminated produce (Beuchat, 2006; Brackett, 1999). The major potential inputs identified are wildlife, livestock, human activity and wastes, water, soil and soil amendments, seeds and plant stocks. Other inputs identified that may affect the risk of contamination were climate and flooding, topographical features of growing fields, and prior use of the growing field land. This section discusses the impact of these inputs on the contamination risk of leafy vegetables and herbs, and discusses approaches to risk mitigation.

### **2.2.7 Microbial hazard inputs from other sources**

In addition to direct contamination of growing sites by animals, fields for growing leafy vegetables and product can be contaminated by indirect means, such as contaminated water, aerosols and dust from livestock production and feeding facilities and other human activities such as landfills and wastewater treatment sites. Wildlife may play a role in dispersal of pathogens from these sources to fields used for vegetable production. For example, landfills and wastewater treatment attract wildlife, the wildlife pick up pathogens from farms and landfills, and water near these facilities can become contaminated with microorganisms (Nesse et al., 2005). Finally, it should be noted that farm workers and contaminated equipment may also be vehicles by which pathogens are transferred from contaminated locations to the growing field.

### **2.2.8 Microbial hazards**

Fresh produce at harvest has a natural epiphytic micro flora much of which is non-pathogenic. During any of the steps in the farm-to-consumer continuum (growth, harvest, processing, packaging, transportation, handling, retail) further microbial contamination can occur from a variety of sources, e.g. environmental, animal or human. There is a risk that this may include pathogenic microorganisms. A review of major microbial pathogens contaminating fresh vegetables has been undertaken previously (WHO, 1998) and the report of the 2007 FAO/WHO meeting also provides an overview of the pathogens most commonly associated with fresh fruit and vegetables. Fresh vegetables and herbs, including those of the leafy variety, have been implicated as vehicles for the transmission of microbial food borne disease worldwide (Beuchat, 2006)

### 2.2.9 Epidemiology

Data on the number of incidents of food borne illness attributed to leafy vegetables and herbs is limited by several characteristics of this product group, and they are not directly comparable between countries (EU, 2002). Identifying the role of leafy vegetables and herbs in an outbreak can be difficult, especially when they are a component of a salad made up with a dressing and other foods that are equally suitable for transmission of the pathogen. Epidemiological reports often categorize the attributed food as a “salad”, “green salad” or “coleslaw”, so that is not possible to identify specifically the leafy vegetables and/or herbs and other ingredients. Specific attribution of these foods can be further complicated by the multiple and intermittent culinary use over a period of a single purchase of these products. A food vehicle is more often implicated in an outbreak involving two or more persons than in sporadic cases.

For this reason, available information has to be considered an underestimate, as most reports on the incidence of food borne disease associated with leafy vegetables and herbs are based on outbreaks and do not include sporadic cases. Other factors that contribute to underestimation of food borne illness for this group are the lack of traceability of leafy vegetables and herbs in the past, and the incompleteness or lack of disease surveillance in some countries. Reported outbreaks associated with leafy vegetables and herbs have been notable for the wide geographical distribution of the contaminated products and the high numbers of consumers exposed, and thus the large number of cases. The proportion of total outbreaks of food borne disease attributed to leafy vegetables and herbs varies between.

Outbreaks attributed to leafy vegetables and herbs are often implicated among fresh produce outbreaks, 70% of the total fresh produce outbreaks in the USA (data from CSPI for the period 1998–2005) and 75% of the total fresh produce outbreaks in Brazil were attributed to leafy vegetables and herbs. There are reports of increasing incidents of food borne illness attributed to leafy vegetables and herbs. For example, in the USA between 1998 and 2002, vegetables were associated with 2.9% (192/6647) of the total food borne outbreaks recorded (Lynch *et al.*, 2006). More recently, food borne vegetable outbreaks specifically associated with leafy vegetables were analyzed in the USA by Herman, Ayers and Lynch (2008). Between 1973 and 2006, 502 (4.8%) outbreaks, 18,242 (6.5%) illnesses and 15 (4.0%) deaths were associated with “leafy greens”, described as lettuce, cabbage, mescaline mix, spinach or a salad item containing one or more of these leafy vegetables. Within this period both the consumption of leafy vegetables (based on per capita availability of leafy vegetables) and the proportion of outbreaks attributed to leafy vegetables increased.

The authors conclude that the increase cannot be explained simply by increased consumption, implying other production factors are involved. The epidemiology will be influenced by the exposure of consumers to leafy vegetables and herbs. The consumption of leafy vegetables and herbs is not specific to any consumer group, although the very young may be less likely to be exposed to raw products. Similarly, their consumption is not specific to any geographical region. Although some varieties may be more common to a specific region, increasing international trade has made a wide variety of produce available all year round, particularly in developed countries.

### 2.3.0 Microorganisms and fresh leafy vegetables relevant to food safety

Leafy vegetables and herbs have a natural epiphytic flora and may be contaminated by various intentional or accidental inputs to the growing field environment (e.g. water, soil amendments, animals and birds), farm equipment and farm workers. Factors influencing the survival and growth of microbial hazards include the characteristics of the organism, the physiological state of the plant and its inherent resistance to microbial metabolic processes, the intrinsic factors of the plant environment (e.g. pH, water activity, atmospheric composition) and the effect of processing, if employed (de Roever, 1998). The availability of information in the scientific and peer-reviewed literature is limited, and does not provide a global picture. There are significant differences between studies in the sizes of the samples examined, the locations of the sampling, and the methodology used. Comparisons cannot therefore be made. Much of the microbial flora associated with fresh plants is of no known public health significance, although pathogens may be present.

The factors that influence the presence or level of pathogens at any point in time is multifactorial, and in addition to the inputs mentioned above, other factors such as the plant type, weather, floods or the prior use of the land can influence the microbial communities present (Brackett, 1999). Populations of mesophilic aerobic bacteria of up to  $8 \log_{10}$  cfu/g were commonly reported on produce at various points in the food chain from farm-to-retail. Coliforms are common members of these populations and reports of counts up to  $8 \log_{10}$  MPN/g were recorded; however, these counts varied between studies, plant varieties and point of sampling.

Because fresh produce may have high levels of natural flora, genera of which are included in the coliform group and yet not considered food borne pathogens, these indicators have little significance when considering food safety. *E. coli* is a more specific indicator of faecal contamination. Mukherjee et al. (2004) found *E. coli* in 10.7% (9/84) of field samples of leafy vegetables, with 22.4% (12/49) lettuce, 10.2% (4/39) cabbages and 13.3% (2/15) bok choy contaminated.

Exposure to risk factors for faecal contamination was linked to higher rates of *E. coli* contamination. For example, leafy crops fertilized with inadequately composted manure and those fertilized with animal manure were found to have a higher risk of *E. coli* contamination (Mukherjee et al., 2004; Mukherjee and Diez-Gonzalez, 2007). A similar situation was noted for watercress irrigated with contaminated water (Edmonds and Hawke, 2004). Bacterial food safety hazards, if present in foods that are not implicated in an outbreak, are usually present in low numbers amongst large numbers of background microbial flora. There are certain limitations associated with the testing of foodstuffs for these hazards, as amplification or enrichment of the bacterial hazard is required. Thus test results are reported as either presence or absence of the bacterium, usually in a 25 g sample. Analyzes for parasites and viruses are more complex, and in the case of viruses such as rotavirus and hepatitis A, may rely on the use of DNA-based or immunological assays to confirm the viral presence, while parasite detection methods for cysts may not establish the viability of the cysts detected.

In 1998, Beuchat in reviewing studies of leafy vegetables and decontamination (WHO, 1998) reported that: (i) *Salmonella* was detected in less than 8% of samples (there were 2 exceptions, i.e. it was detected in 17% of cabbages and 68% of lettuces), (ii) *Campylobacter* was detected in 3.1% of lettuces (n=67), (iii) *E. coli* O157 was detected in 25% of cabbages, 19.5% of cilantro, and 20% of coriander samples, and (iv) *Listeria monocytogenes*, an environmental bacterium, was detected in cabbages (up to 7%), leafy vegetables (22.7%) and lettuce (20%). Lower detection rates were reported by Sagoo, Little and Mitchell (2003) in a study undertaken in the United Kingdom on open, ready-to-eat (RTE), prepared salad vegetables from catering or retail premises. *E. coli* O157, *Campylobacter* spp. and salmonellas were not detected in any of the samples examined (n=2950). One sample (<1%) was of unacceptable microbiological quality because of the presence of *Listeria monocytogenes* at 840 cfu/g.

### **2.3.1 Microbial hazards from livestock and wildlife**

A large number of infectious agents, including those most important to the microbiological safety of leafy vegetables and herbs, have been identified in domestic animals and wildlife. Food borne pathogens may be present in the faeces of domestic and wild animals without causing outward signs of illness or disease, making it difficult, if not impossible, to determine by visual inspection if an animal is carrying a specific pathogen. To briefly describe infection dynamics, an infected animal population can be classed as either a maintenance or spillover host, depending on the dynamics of the infection. In a maintenance host, infection can persist by intraspecies transmission alone, and may also be the source of infection for other species. In a spillover host, infection will not persist indefinitely unless there is re-infection from another species or the environment.

Transmission from a spillover wild host to domestic livestock or other wild host may also occur, and vice versa, and therefore, maintenance and spillover hosts may both act as disease vectors (Morris, Pfeiffer and Jackson, 1994). Risks posed by livestock and wild animals are dependent upon the prevalence, incidence, and magnitude of pathogen carriage in the animal hosts (Morris, Pfeiffer and Jackson, 1994), the degree of interaction between the animals and the growing environment (Jay *et al.*, 2007), animal behaviour and ecology (Carter *et al.*, 2007). With respect to wildlife, the most abundant species in a particular region are of the greatest concern as the risk of faecal contamination by these animals is the highest. Most mammalian pests range fairly close to crops, whereas birds are particularly problematic because they have the ability to transmit pathogens over substantial distances and are difficult to control. Control of birds would require a regional plan or completely protected enclosures for a specific growing area. *E. coli* O157 has become an important cause of illness attributed to leafy vegetables and herbs. Ruminant animals are among the most common reservoir species for this pathogen, with cattle being considered the primary maintenance reservoir host (Hancock *et al.*, 2001).

The prevalence of *E. coli* O157 in cattle may vary from 0 to over 50%, depending on location and season (Renter and Sargeant, 2002) and the number of cells excreted in faeces averages around 3.3 log<sub>10</sub> cfu/g (Berg *et al.*, 2004). In addition, *E. coli* O157 and other Shiga-toxigenic *Escherichia coli* (STEC) are present in a large variety of other ungulates (deer, sheep, goats) and numerous other domestic and wild animals, including horses, pigs, chickens, turkeys and dogs (Doane *et al.*, 2007).

In studies of free-ranging deer, the faecal prevalence of *E. coli* O157:H7 was estimated to range from zero to less than 3% (Sargeant et al., 1999; Fisher et al., 2001; Branham et al., 2005). Among samples from feral pigs, 23% of faecal samples were positive for *E. coli* O157 in California, USA (Jay et al., 2007). STEC have been isolated from other wildlife, including rodents, birds (gulls, geese, starlings and passerines), insects and molluscs, e.g. houseflies, beetles and slugs (Nielsen et al., 2004). These may be incidental hosts due to their proximity to ruminant hosts, or independent hosts.

Near an English sheep farm, 0.2% of slugs were found to be carriers of STEC (Sproston et al., 2006) and 1.4 to 2.9% houseflies associated with cattle in Kansas, USA, were carrying the bacterium (Alam and Surek, 2004). Results from studies on rodents vary. Hancock, Besser and Rice (1998) did not detect *E. coli* O157:H7 in 300 samples of rodents on cattle farms in the USA Pacific Northwest, whereas Nielsen et al. (2004) found 2 out of 10 rat samples carried other pathogenic forms of *E. coli* on farms in Denmark. Wild birds close to farm animals may play a possible role in STEC transmission. Nielsen et al. (2004) found 1.6% of these birds positive for STEC, and other studies have supported this. For example, *E. coli* O157 was detected in 2.9% of gulls from English natural areas and in 0.9% of gulls associated with landfills (Wallace, Cheasty and Jones, 1997). Furthermore, 1% of passerines and woodpeckers studied in Wisconsin, USA (Brittingham, Temple and Duncan, 1988), 1.6% of wild birds living close to cattle and pig farms in Denmark (Nielsen et al., 2004) and 0.5% wild birds on cattle ranches in the USA Pacific Northwest (Hancock, Besser and Rice, 1998) carried *E. coli* O157 or other pathogenic *E. coli*. The prevalence of transmission between ruminant hosts and associated incidental insects and pests is not certain.

Experimental studies have been used to demonstrate that flies are capable of transmitting in excess of  $3 \log_{10}$  cfu at each landing (DeJusús et al., 2004). This suggests that if flies acquire the bacterium from a source such as cattle faeces, they would be capable of transmitting many bacteria to the next surface (e.g. vegetables leaves). It is estimated that herd or flock prevalence of *Salmonella* in domestic animals varies between 0% and 90%, depending on the animal species and region (Forshell and Wierup, 2006).

Among wild animals, an apparently low prevalence of *Salmonella* faecal shedding occurs (Renter et al., 2001), although *Salmonella* were detected in 8% of rumen samples from whitetailed deer (Renter et al., 2006). Prevalence of microbial pathogens such as *Salmonella*, associated with foodborne illness, is usually low among wild birds. Gulls have been found to carry *Salmonella*; Palmgren et al., (2006) found 4% positive and Fenlon (1981) reported 12.9% positive where they may have been associated with human waste. *Listeria monocytogenes* is a saprophytic organism that is commonly present in the environment, especially soils enriched with plant matter (Weis and Seeliger, 1975). Domestic livestock, especially cattle and other small ruminants play an important role in the amplification and environmental dissemination of *L. monocytogenes*. Thirty percent of animals on individual farms may be shedding *L. monocytogenes* in their faeces (Nightingale et al., 2004).

Furthermore, this pathogen has been isolated from the faeces of poultry, wild birds and a number of wildlife species, including deer, moose, otters and raccoons (Hellström *et al.*, 2008; Lapen *et al.*, 2007). It is important to note that the list of prevalence studies of food borne pathogens is not exhaustive, and studies have not been conducted in every species and every geographical region. Therefore the prevalence of pathogens in a particular region may differ significantly (lower or higher) from the values in the examples provided. Although they have not been reported as causes of foodborne disease outbreaks in leafy vegetables, a number of other organisms that may cause food poisoning, such as, *Yersinia pseudotuberculosis*, *Cryptosporidium*, *Giardia* and hepatitis E virus are occasionally present in the manure of domestic and wild animals.

Moreover, it is possible that (i) pathogens may be present in animal species that have not been extensively studied, (ii) novel zoonotic pathogens may emerge as important causes of zoonoses (Bengis *et al.*, 2004), or (iii) pathogens may emerge in species not previously infected with a specific organism. Although not evaluated, re-emergence of diseases is usually associated with areas where people are associated with animals and agriculture (e.g. this may be of concern in preharvest areas where animal excreta may reach crops). Since the Norovirus genus comprises viruses that infect humans, pigs, cattle and mice, the possibility for zoonotic transmission of infection exists.

Recent findings highlight a possible route for indirect zoonotic transmission of noroviruses through the food chain, which could also involve leafy vegetable contamination (Mattison et al., 2007; FAO/WHO, 2008). *Salmonella* Typhi and hepatitis A are obligate human pathogens and are not found in animal reservoirs. Besides humans, *Shigella dysenteriae* may colonize non-human primates, but not other domestic or wild animals (Nizeyi et al., 2001). Although indistinguishable pathogens have been recovered from animals and leafy produce implicated in disease outbreaks, it has not been possible to conclusively determine if the animals were indeed the source of the product contamination or a sentinel of broader environmental contamination that infected the animals and contaminated the crop simultaneously (Jay et al., 2007). Animals in crop production environments may be incidental, or animals may be attracted to leafy vegetable crop protection sites for various reasons.

## CHAPTER THREE

### 3.0 METHODOLOGY

#### 3.1 Study site

The study was carried out in Thika municipality. It is one of the industrial towns with several manufacturing firms and factories. Three locations were randomly selected. These are Makongeni (Location 1), Majengo (Location 2) and Komu (Location 3).

#### 3.2 Sampling and sample size

The method used was basket-sampling technique. Vegetables were collected during both wet and dry seasons from the selected farms in well-labeled polythene bags and transported in a cool box to the Jomo Kenyatta University and Kenyatta University laboratories for storage at 4° C before being analyzed. Soil and water samples were also taken randomly from the study farms and analyzed for microbial and chemical contaminants according to the methods described by Singh (1992) and Ochieng (2000). Since the prevalence here is unknown, the ICCIDD (1994) formula was used to give a sample size:

$$n = Z^2 \times P(1-P) / e^2$$

where n = sample size; p = prevalence (0.5); z = standard deviation (1.96) and e = prevalence estimates - true prevalence (0.1).

$$n = 1.96^2 \times 0.05 (0.05) / 0.1^2$$

$$n = 96$$

Based on the above formula, the study targeted 100 farmers who grow vegetables; in selected urban areas in Thika municipality. The study was carried out using questionnaires, observations checklist and laboratory experiments to determine the behavior and characteristics of respondents and hygiene practices among the urban farmers in Thika Municipality. The microbial load of vegetables, soil and water used by the farmers was also determined. The components investigated in this study included personal, food and environmental hygiene. At the end of this study, the level of hygiene practices among urban farmers in Thika Municipality and factors predisposing food to contamination had been established. The results and discussions are represented in different locations (Makongeni-Loc.1, Majengo-Loc. 2 and Komu-Loc. 3).

### **3.3 Determination of indicator pathogenic bacteria in vegetables, water and soil**

The samples were prepared and analyzed for the microbiological contamination of vegetables, soil and water as described by Johannessen *et al.*, (2002). Different techniques including multiple tube fermentation method, membrane filter method and rapid seven-hour fecal coliform test were used.

### **3.4 Determination of heavy metals in vegetables, water and soil**

The heavy metals were analyzed, identified and quantified to determine those that were essential for contamination of urban agriculture. These heavy metals analyzed included; Iron (Fe), Cadmium (Cd), Chromium (Cr), Lead (Pb), Arsenic (As) and Mercury (Hg). This was done using Atomic Absorption Spectroscopy (AAS) method (Arnold *et al.*, 1992; Ochieng, 2000; Awofolu *et al.*, 2005). All samples were analyzed in duplicate. Factors that influence bioremediation of heavy metals such as topography, meteorology, and land use patterns were also analyzed using GIS maps to help in data interpretation.

### **3.5 Sample preparation and analysis**

#### **3.5.1 Spinach and tomatoes**

2g were washed at 550°C for 5 hours and dissolved in 100ml of 1N HCL. A reagent blank was also prepared using the acid D indicator of 100/2.

#### **3.5.2 Water sample**

The water was digested as follows: 30ml of the sample was taken and diluted to 100ml. 10ml of the 6N HCL and 2ml of 7N HNO<sub>3</sub> were added and then the mixture heated on a hot plate until a volume of 30ml was left. This was then topped up to 100ml using distilled water. A reagent blank was prepared in a similar way.

### **3.5.3 Analysis**

The prepared sample solutions were then analyzed using Atomic Absorption/Flame Emission Spectrophotometer, Model-Shimadzu AA-6200 controlled by a computer. Arsenic was analyzed with the help of Hydride Vapour Generator attached to the ASS whereas mercury was analyzed with the help of the Mercury Vapour Unit (MVU). All the elements were quantified using standard reference.

### **3.5.4 Procedure for Soil sample digestion**

The soil was dried in the oven at 105°C for 1-3 hours and ground into powder, 1g weighed into each 100ml. 5ml was added to the mixture, shaken well and allowed to stand for 5mins. It was then digested on a hot plate starting at 70°C through to 120°C until volume reduces to about 1ml until white fumes of SO<sub>3</sub> was clearly observed. The mixture was allowed to cool to room temperature and 20ml of 5% HCL acid was added and then allowed to cool. The sample was filtered using Whatman into a 100ml volumetric flask and topped up with 5% HCL. All samples were analyzed using AAS except Arsenic. Arsenic was mixed with 2ml of 20% potassium iodide solution at least for 15mins before AAS analysis.

### **3.6 Establishment of farmers' perceptions about food safety and quality**

Self-administered questionnaires were used to collect data on hygienic practices from vegetable farmers. The research instruments were pre-tested among selected farmers in Thika Town in order to enhance validity and reliability of the instrument.

### **3.7 Ethical considerations**

In order to ensure confidentiality and anonymity, the researcher sought consent from the farmers. The researcher also explained the purpose and importance of the study to the farmers.

### **3.8 Data analyzes**

Data analysis was carried out using computer package; Statistical Package for Social Sciences (SPSS). Analysis of Variance (ANOVA) was used to answer questions on probability that the variation among a group of sample means occurred as a result of randomly selected samples from a common population. The quantitative data was summarized using descriptive statistics namely; mean, standard deviation, frequency distribution and percentages. T-test was used to separate the means. The qualitative data were coded and described and used for understanding the emerging themes. Data was presented using tables and graphs.

## CHAPTER FOUR

### 4.0 RESULTS AND DISCUSSIONS

#### 4.1 Microbial pathogen load in tomatoes and spinach

As illustrated in table 1(next page), the study noted that fresh produce mainly spinach at harvest had a natural epiphytic micro flora much of which is non-pathogenic. During any of the steps in the farm-to-consumer continuum (growth, harvest, processing, packaging, transportation, handling, retail) further microbial contamination can occur from a variety of sources, e.g. environmental, animal or human. There is a risk that this may include pathogenic microorganisms. This confirms earlier studies (WHO, 1998) that provided an overview of the pathogens most commonly associated with fresh fruit and vegetables. These have been previously confirmed as the main modes of transmission of food borne diseases (Beuchat, 2006).

Table 1: The microbial pathogen load in tomatoes and spinach grown in different locations in Thika municipality

Area	Sample	Dilution (cm <sup>3</sup> )	No. of colonies (cfu/g)	Comments
Location 1	Spinach	10x10 <sup>2</sup>	0	Absent
	Spinach	10x10 <sup>2</sup>	4.8x10 <sup>1</sup>	Medium
	Tomatoes	10x10 <sup>2</sup>	6	Low
	Tomatoes	10x10 <sup>2</sup>	4.8x10 <sup>1</sup>	Medium
Location 2	Spinach	10x10 <sup>2</sup>	1.09x10 <sup>2</sup>	High
	Spinach	10x10 <sup>3</sup>	3.5x10 <sup>1</sup>	Medium
	Tomatoes	10x10 <sup>2</sup>	1.09x10 <sup>2</sup>	High
	Tomatoes	10x10 <sup>3</sup>	3.5x10 <sup>1</sup>	Medium
Location 3	Spinach	10x10 <sup>2</sup>	5	Low
	Spinach	10x10 <sup>3</sup>	0	Absent
	Tomatoes	10x10 <sup>2</sup>	21	Low
	Tomatoes	10x10 <sup>2</sup>	1.17x10 <sup>2</sup>	High

## 4.2 Heavy metal loads in spinach and tomatoes in Thika Municipality

Table 2: Levels of heavy metals (mg/kg) in tomatoes and spinach grown in different sites in Thika municipality

Sample	Metal levels on the foodstuff (Mean $\pm$ SE)					
	Fe	Cd	Cr	Pb	As	Hg
<b><u>Spinach:</u></b>						
Loc. 1	843.05 $\pm$ 2.6	0.67 $\pm$ 0.1	63.77 $\pm$ 1.00	16.00 $\pm$ 1.04	15.0 $\pm$ 1.2	158.3 $\pm$ 1.7
	12.73 $\pm$ 4.1	0.52 $\pm$ 0.2	60.6 $\pm$ 1.00	24.33 $\pm$ 1.59	41.9 $\pm$ 3.4	2095.17 $\pm$ 2
Loc. 2	344.71 $\pm$ 2.9	0.7 0. $\pm$ 18	65.07 $\pm$ 3.21	29.50 $\pm$ 1.26	39.3 $\pm$ 1.9	0 $\pm$ 0.0
	678.5 $\pm$ 2.3	0.55 $\pm$ 0.1	70.0 $\pm$ 2.08	18.7 $\pm$ 1.17	0 $\pm$ 0	628.3 $\pm$ 70.7
Loc. 3	811.3 $\pm$ 2.9	0.41 $\pm$ 0.16	76.9 $\pm$ 0.8	13.3 $\pm$ 1.53	106.8 $\pm$ 3.0	783.3 $\pm$ 20.9
	423.69 $\pm$ 0.9	0.46 $\pm$ 0.2	75.32 $\pm$ 2.04	13.50 $\pm$ 0.5	30.3 $\pm$ 1.2	0 $\pm$ 0.0
<b><u>Tomatoes:</u></b>						
Loc. 1	123.24 $\pm$ 0.6	0.4 $\pm$ 0.15	80.94 $\pm$ 2.88	10.5 $\pm$ 0.76	115.3 $\pm$ 0.8	0 $\pm$ 0.0
	23.66 $\pm$ 1.2	0.7 $\pm$ 0.10	80.66 $\pm$ 2.55	11.2 $\pm$ 1.42	57.1 $\pm$ 1.4	1620 $\pm$ 108.2
Loc. 2	75.18 $\pm$ 0.9	0.59 $\pm$ 0.09	80.37 $\pm$ 2.53	10.17 $\pm$ 0.88	93.8 $\pm$ 2.2	0 $\pm$ 0.0
	88.4 $\pm$ 1.2	0.75 $\pm$ 0.17	81.09 $\pm$ 2.75	20.50 $\pm$ 0.76	103.6 $\pm$ 0.3	956.3 $\pm$ 8.2
Loc. 3	133.46 $\pm$ 0.57	0.8 $\pm$ 0.18	90.03 $\pm$ 1.50	17.33 $\pm$ 0.67	103.3 $\pm$ 0.0	870.2 $\pm$ 4.8
	48.03 $\pm$ 0.25	0.95 $\pm$ 0.21	92.05 $\pm$ 1.38	3.5 $\pm$ 0.58	0 $\pm$ 0.0	0 $\pm$ 0.0

In table 2 (pg 40), iron levels in tomatoes were significantly higher than the levels in spinach ( $P=0.01$ ). There was a significant relationship in the levels of Iron in spinach with those in tomatoes in all the site locations where the samples were collected. Cadmium levels in tomatoes were not statistically significant ( $P > 0.05$ ) while Chromium levels in tomatoes were significant compared to those of spinach ( $P < 0.05$ ). Arsenic levels in tomatoes were higher than those in spinach ( $P < 0.05$ ). Lead levels in tomatoes were lower than the levels in spinach ( $P < 0.05$ ). The mercury levels were found to be higher in spinach than in tomatoes, this could be due to the contamination through handling and soils.

It has been reported that plant metal levels highly vary when related to soil metal levels (Renter et al., 2006). Similar studies have also confirmed uptake of heavy metal varies widely depending on the vegetable species grown and the uptake is controlled by such variable as soil pH, organic matter content and soil type (Fleming and Parle, 1977). Most of heavy metals are less available to plants under alkaline conditions, than under acid conditions as reported by Hess (1971). It's therefore important to encourage urban famers to use alkaline based fertilizers to reduce heavy metal contamination.

### **4.3 Demographic information of the respondents on food safety and training**

A total of 100 respondents were sampled. 33 of the people were from Makongeni, 32 from Majengo and 35 from Komu area. 69.4% of the respondents were male, while 30.6% were female. Most of the respondents 49.5% had secondary level of education. 24.2% had college/University education while 25.3% had only completed primary level. Besides farming, 52.6% had other forms of occupation.

These were mainly casual laborers 35.2% and business 31.5%. Other occupations noted were, civil service 18.5%, employment in private sector 11.1% and others 3.7%. Majority of the respondents 92.9% have not undertaken any training in farming.

Two men of the trained farmers had their training on Bio-intensive farming, one man on kitchen gardening and five people on other farming techniques including organic and general farming. In many cases, 94.9% of the farmers had no training on food safety measures. Three farmers from Komu and two from Makongeni had some training on food safety. All the farmers from Majengo had not received any training on food safety. The farmers with College/University level of education have not received any training on food safety. 8.0% and 6.3% of farmers with primary and secondary level of education, respectively, had received education on safety.

This study has shown that due to the high socio-cultural diversity among urban farmers in Thika, their lack of producer organizations and the multiple livelihood strategies of the urban poor, continuous efforts are needed to enhance group cohesion, build up trust and cooperation. It's also important to enhance motivation, self confidence and strengthen organizational skills when engaging in processes of agricultural innovation with urban producers of the poorer sections of the population. An emphasis on group building would facilitate the technical innovation process at hand as well as the organization of urban producers and their claim-making capacity.

#### 4.4 Source of Seeds/Seedlings for the farmers

The farmers from these three areas in Thika Municipality acquire their seeds/seedlings mainly from the local shops. However some farmers get their seeds from Agro-vet shops. When they are selecting seeds/seedlings, 69.7% of the farmers consider the seed quality, 19.2% seed costs and 11.1% of them consider the availability of the seeds/seedlings.

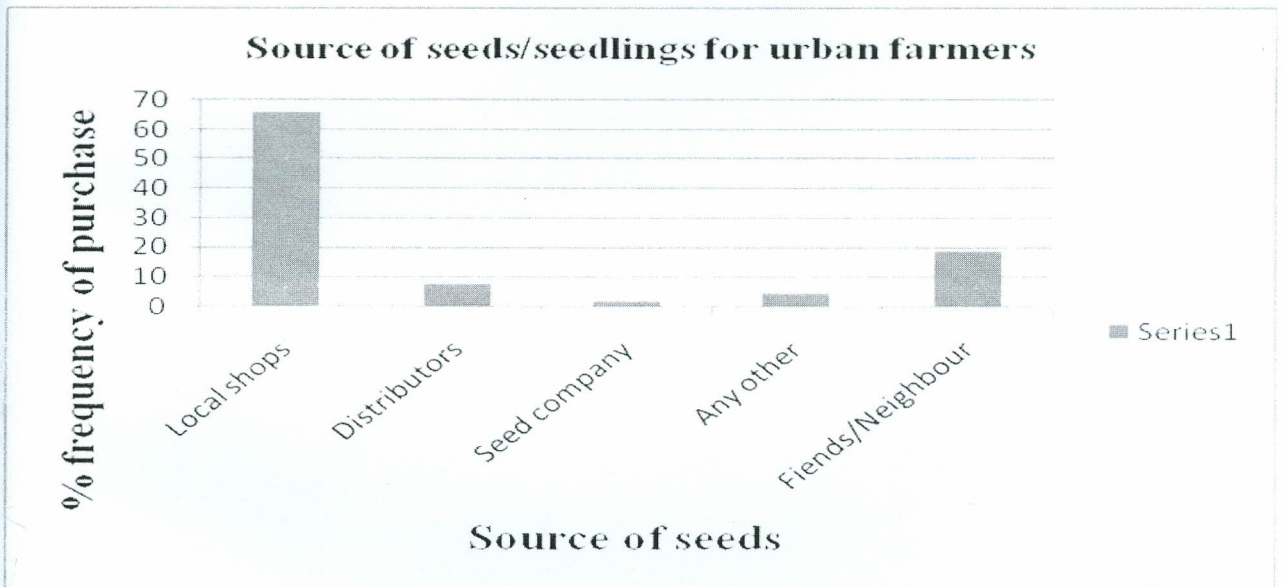


Figure 1: Different sources of seeds and seedlings for urban famers in Thika municipality

#### 4.5 Farmers knowledge on pest control

In order to control the vegetables against pest, the study revealed that 69.1% of the farmers use chemicals and 30.9% do not use any chemical. More of the chemical use is commercial, used by 87.5% of the farmers. Fewer farmers, 11.1% use domestic chemicals. Even though the farmers use the chemicals, they take safety precautions to ensure their vegetables are safe for consumption by using clean water to wash the vegetables after harvest. After visiting the toilets, it is a common practice by the farmers to always wash their hands. The study also established that, 70% of the farmers' rate farming practices as "very important" and 29% feel that it is an "important" factor to food safety.

#### 4.6 Microbial pathogen load in soil and different water sources

Table 3 Microbial pathogen load in soil and different sources of water in Thika municipality

Area	Sample	Dilution (cm <sup>3</sup> )	No. of colonies	Comments
<b>Loc. 1</b>	Soil	10x10 <sup>2</sup>	7	Low
	Soil	10x10 <sup>3</sup>	2	Low
	Household water	10x10 <sup>2</sup>	1.62x10 <sup>2</sup>	Medium
	Household water	10x10 <sup>3</sup>	7	Low
	Tap water	10x10 <sup>2</sup>	6	Low
	Tap water	10x10 <sup>3</sup>	3	Low
	River	10x10 <sup>2</sup>	3	Low
	River	10x10 <sup>3</sup>	0	Absent
<b>Loc. 2</b>	Soil	10x10 <sup>2</sup>	9.2x10 <sup>1</sup>	Medium
	Soil	10x10 <sup>3</sup>	7.3 x10 <sup>1</sup>	Medium
	Household water	10x10 <sup>2</sup>	3.0x10 <sup>2</sup>	High
	Household water	10x10 <sup>3</sup>	3.5x10 <sup>2</sup>	High
	Tap water	10x10 <sup>2</sup>	8	Low
	Tap water	10x10 <sup>2</sup>	2	Low
	River	10x10 <sup>2</sup>	4	Low
	River	10x10 <sup>3</sup>	1	Low
<b>Loc. 3</b>	Soil	10x10 <sup>2</sup>	8.3 x10 <sup>1</sup>	Medium
	Soil	10x10 <sup>3</sup>	6.7 x10 <sup>1</sup>	Medium
	Household water	10x10 <sup>2</sup>	1.46x10 <sup>2</sup>	Medium
	Household water	10x10 <sup>3</sup>	6	Low
	Tap water	10x10 <sup>2</sup>	7.2x x10 <sup>1</sup>	Medium
	Tap water	10x10 <sup>3</sup>	1	Low
	River water	10x10 <sup>2</sup>	3.1 x10 <sup>1</sup>	Low
	River water	10x10 <sup>3</sup>	1	Low

Table 4: Average presumptive results for presence of Coliforms in different sources of water in Thika

Water source		Innoculum's strength			
		10ml	1.0ml	0.1ml	Index
Loc. 1	House hold	3	3	3	>1100
	River water	3	3	3	>1100
	Tap water	3	3		240
Loc. 2	Household	3	3	3	>1100
	River water	2	1	0	15
	Tap water	3	1	0	43
Loc. 3	Household	3	3	0	>1100
	Tap water	0	0	0	
	River	3	3	3	>1100

In table 3 and 4 (pages 45 and 46 respectively), the results show that there was no significant difference in the colony counts in the three water sources ( $P > 0.05$ ). Analysis of the presumptive Coliform results from different water showed a significant difference in the colony counts ( $F_{24} = 7.372, P < 0.05$ ). One of the samples from tap water was noted to have no bacterial growth while those from household were higher than the ones from River water. Water from Household source had significantly higher coliform bacterial colony counts than tap water. River water had less bacterial colony counts than House hold water but more colony counts than tap water from all the locations.

The study shows that in addition to direct contamination of growing sites by animals, fields for growing leafy vegetables and product can be contaminated by indirect means, such as contaminated water, aerosols and dust from livestock production and feeding facilities and other human activities such as landfills and wastewater treatment sites. Wildlife may play a role in dispersal of pathogens from these sources to fields used for urban vegetable production. For example, landfills and wastewater treatment attract wildlife, the wildlife pick up pathogens from farms and landfills, and water near these facilities can become contaminated with microorganisms. Finally, it should be noted that farm workers and contaminated equipment may also be vehicles by which pathogens are transferred from contaminated locations to the growing field.

The samples from the soil, household, tap and river water sources were tested using TCBS media. The results confirmed the presence of *Vibrio cholera* in samples obtained location from 3 (house hold and river water from location 2 and 1) while River water from location did test positive for the presence of any micro-pathogen. The results from TCBS and EAPW media for the presence of *Vibrio cholera* in the samples, revealed a relationship that  $r = 0.472$ ,  $P < 0.05$ . This showed that either of the media can effectively be used to indicate the presence of *Vibrio cholera* in the samples. The samples were further subjected to 24 hr. Oxidase test on Nutrient agar. This further indicated possible presence of *Vibrio cholera* in all the samples from location 3 when tested using EAPW. The farmer knowledge was based on the number of those who had participated in any formal training through seminars and workshops. It was however discovered that limited number of farmers had adequate information regarding hygienic food handling.

## CHAPTER FIVE

### 5.0 CONCLUSIONS AND RECOMMENDATIONS

#### 5.1 Conclusions

The study has revealed that there is a stronger institutional innovation (both public and private) in the urban context than in the rural areas due to the tradition of institutional neglect of the urban agricultural sector. The study also noted the importance of enhancing the food security and nutrition of the urban poor. However the need for cash income is high in the urban context; and in order to arrive at sustainable urban production systems, intensification and a greater market orientation will be needed. The study showed that the level of information available on the different commodities varies significantly. This, without doubt, has an impact on the safety of urban fresh produce, but could not be avoided. In many cases, the level of understanding of the hazards, the routes of contamination and the controls were found to be limited to a few farmers with formal training. The other problem identified was the lack of adequate scientific information available to prioritize the urban farming community.

It is important to reduce health and environmental risks by facilitating the adoption of practices based on Integrated Pest Management (IPM) or organic farming practices and enhancing farmers' capacity to apply safe management practices when using urban wastewater and organic wastes. The improvement of the fertility of the soils due to compaction, overuse, presence of trash and farming on marginal land, fertility in urban farming systems is often a problem and therefore should involve the incorporation of organic materials, e.g. composted urban organic wastes, or transfer to popular hydroponics and organoponics.

There should be enhanced access to low-cost seed and planting material, which is of major importance for the poor urban producers. This can be addressed through the promotion of local seed networks and the use of indigenous species that produce easily harvestable and storable seeds.

## 5.2 Recommendations

There is need for the urban farmers to undergo training on good hygiene practices (GHP) carried out on site based on seed selection, application fertilizers, personal hygiene, environmental hygiene and general farming practices. The training should also include managerial skills and entrepreneurial skills that will enable the urban farmers to manage their finances and sustain their ventures adequately.

- To minimize the high microbial count, the urban farmers should use good farming practices including the use of certified seeds and fertilizers. Health talks should be organized and addressed by the local leaders, public health officers, agricultural extension officers and Director of town inspectorate. The farmers should also be encouraged to participate in cleaning up of drainages, garbage collection and proper waste disposal.
- A special force within the municipal council *Askaris* should be set up to ensure that urban farming is carried out at designated sites to avoid cases where farmers plant their vegetables close and along sewer lines as this will reduce contamination.
- The relevant authorities including public health officers, administration and political leaders should ensure that laws and regulations regarding urban farming are enforced.
- Relevant agencies or organizations should be encouraged to sponsor training and technical support through training on good hygiene practices.
- Urban farmers should be encouraged to get training on urban farming to improve hygienic standards for their produce.

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## APPENDICES

### Appendix 1: Letter of introduction

Dear respondent,

I am JUDITH INOTI from Kenyatta University. I am undertaking a research on microbial and chemical safety of selected urban-grown vegetables in Thika municipality.

I would be glad if you would spare some time and provide me with the information required.

Any information given will be treated with utmost confidentiality and will only be used for the purpose of this study.

Thanks.

Please indicate your willingness to participate in the research and respond to the Questionnaire.

YES ( ) NO ( )

## Appendix 2 : Questionnaire

Questionnaire No \_\_\_\_\_ Date \_\_\_\_\_

Study area \_\_\_\_\_ Name of interviewer \_\_\_\_\_

Name of respondent \_\_\_\_\_ Sex of farmer \_\_\_\_\_ 1.M2.F

1. What is your education level (highest completed)?

1. Primary 2.Secondary 3.College/University 4. None 5.Any other (specify) \_\_\_\_\_

2. Do you have any other form of occupation apart from farming? \_\_\_\_\_ 1. Yes 2. No

3. If yes, which one? \_\_\_\_\_

1. Civil servant      2. Business      3. Private sector      4. Casual labourer

5. Any other (specify)

4. Have you received any training in farming? \_\_\_\_\_ 1. Yes      2. No

5. If yes, state the areas trained? \_\_\_\_

1. Bio-intensive farming      2. Kitchen gardening      3. Any other (specify)

6. Have you received any training on food safety measures? 1. Yes      2. No

7. What is the size of your farm? \_\_\_\_\_ Acres

8. State the ownership status of your land?

1. Rented 2. Owned 3. Kitchen garden 4. Public land 5.Any other (specify)

9. Which vegetables do you grow? \_\_\_\_\_

1. Tomatoes 2.Spinach 3. Dhania 4. Carrots 5. Kales 6. Cabbage 7.Onions

8. Amaranth 9. Pepper      10. Any other (specify) \_\_\_\_\_

	For Sale	For Domestic use
Tomatoes		
Spinach		
Dhania		
Carrots		
Kales		
Cabbage		
Onions		
Amaranth		
Pepper		

10. How do you market the vegetables?

1. Direct from farm 2. Store before sale 3. Any other (specify)

11. Who buys the vegetables from your farm? \_\_\_\_\_

1. Brokers 2. Retailers 3. Local/neighbors 4. Any other (specify)

12. Where do you get your seeds/seedlings from? \_\_\_\_\_

1. Local shops 2. Neighbors/friends 3. Seed company 4. Distributors  
5. Any other (specify) \_\_\_\_\_

13. Which factors do you consider when selecting seeds/seedlings?

1. Cost 2. Quality 3. Availability 4. Any other (specify) \_\_\_\_\_

14. Where do you get the water used for growing vegetables?

1. Municipal council tap water supply 2. River water 3. Used domestic water

4. Any other (specify) \_\_\_\_\_

15. Which of the following do you use to enrich soil?

1. Manure 2. Fertilizer 3. Both 4. None 5. Any other (specify)

16. What are the types of manure/fertilizer used (fill the table below)

	Types
Manure	1
	2
Fertilizer	1
	1

Manure: 1 Farmyard manure 2.Compost manure 3. Any other (specify)

Fertilizer 1. CAN 2. NPK 3. DAP 4. Any other (specify)

17. Do you use chemicals to control the vegetables against pests? \_\_\_\_\_ 1. Yes 2. No

18. If yes, which chemical do you use? \_\_\_\_\_

1. Homemade 2. Commercial 3. Any other (specify) \_\_\_\_\_

19. Which safety measures do you practice to ensure your vegetables are safe for?

Consumption?

L. Use of clean water to wash after harvest 2. Use of clean seeds 3. Personal hygiene

When handling vegetables 4. Any other (specify) \_\_\_\_\_

20. Do you wash hands after visiting the toilets? \_\_\_\_\_ 1. Yes 2. No

21. How would you rate fanning practices as a contributing factor to food safety? \_\_\_\_\_

1. Very important 2.Important, 3.Not important

**Appendix 3: Forms for analysis of vegetables for microbial and chemical counts**

Text Number \_\_\_\_\_ Date \_\_\_\_\_

Type of vegetables \_\_\_\_\_

Test for \_\_\_\_\_

Sample Sources	FARM No.	1 <sup>st</sup> Analysis	2 <sup>nd</sup> Analysis	3 <sup>rd</sup> Analysis	4 <sup>th</sup> Analysis
Makongeni	1				
	2				
	3				
	4				
	5				
Majengo	1				
	2				
	3				
	4				
	5				
Komu	1				
	2				
	3				
	4				
	5				

### Appendix 4: Analysis of water for microbial and chemical counts

Text Number \_\_\_\_\_ Date \_\_\_\_\_

Test for \_\_\_\_\_

Sample Source		Sample	1 <sup>st</sup> Analysis	2 <sup>nd</sup> Analysis	3 <sup>rd</sup> Analysis	Mean
Makongeni	Tap	1				
		2				
		3				
	River	1				
		2				
		3				
Majengo	Tap	1				
		2				
		3				
	River	1				
		2				
		3				
Komu	Tap	1				
		2				
		3				
	River	1				
		2				
		3				

**Appendix 5: Analysis of soil for microbial and chemical counts**

Text Number \_\_\_\_\_ Date \_\_\_\_\_

Test for \_\_\_\_\_

Sample Sources	Sample	1 <sup>st</sup> Analysis	2 <sup>nd</sup> Analysis	3 <sup>rd</sup> Analysis	Mean
Makongeni	1				
	2				
	3				
	4				
	5				
Majengo	1				
	2				
	3				
	4				
	5				
Kому	1				
	2				
	3				
	4				
	5				

**Appendix 6: ANOVA result for the variations in the three locations**

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3.852	2	1.926	1.169	.328
Within Groups	39.556	24	1.648		
Total	43.407	26			

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	16.519	2	8.259	7.372	.003
Within Groups	26.889	24	1.120		
Total	43.407	26			

**Appendix 7: POST-ANOVA result for the variations in the three water sources**

(I) water source	(J) water source	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Household. water	River water	.6667	.49897	.390	-.5794	1.9127
	Tap water	1.8889(*)	.49897	.003	.6428	3.1350
River water	Household water	-.6667	.49897	.390	-1.9127	.5794
	Tap water	1.2222	.49897	.055	-.0238	2.4683
Tap water	Household water	-1.8889(*)	.49897	.003	-3.1350	-.6428
	River water	-1.2222	.49897	.055	-2.4683	.0238

\* The mean difference is significant at the .05 level.