ASSESSMENT OF SELECTED HEAVY METALS CONCENTRATIONS IN FRESH FRUITS AND HEALTH IMPLICATIONS TO CONSUMERS IN ELDORET TOWN, KENYA.

BY

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DECLARATION

Declaration by the candidate

This thesis is my original work and has not been submitted for a degree award to any other University or Institution of higher learning. No part of this thesis should be reproduced without prior permission of the author and/or University of Eldoret. All other sources of information cited herein have been duly acknowledged.

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DEDICATION

This thesis is dedicated to my parents Mr. and Mrs. Omutiti, for their inspiration and financial support in my life and during this study. This is an honour to you.

ABSTRACT

This study assessed levels of selected heavy metals (Lead, Chromium and Cadmium) in oranges and mangoes sold in Eldoret town and their health implications to consumers. A total of one hundred and eighty (180) samples were collected for analysis from randomly selected market sites within Eldoret town. Samples were wet digested using a mixture of 1:3 (65% HCl: HNO_3) and analyzed using Atomic Absorption Spectrophotometer version 200. One Way Analysis of Variance (ANOVA) was used to test the significance of selected heavy metal levels in consideration of market sites at 5% significance level. There was insignificant variance in mean chromium levels in mango fruits among market sites (f=2.1, f=3, p=0.10) with the highest mean level occurring at 2.43±0.24 mg/kg. Lead levels in orange fruits were significant (f=13.3, df=3, p=0.00) with the highest mean level occurring at 0.65±0.03 mg/kg. Cadmium levels were significant in mango fruits among market sites (f=6.5, df=3, p=0.00) with the highest level at 0.09±0.05 mg/kg. Risk Assessment in terms of values of Daily Intake of Metal (D.I.M) had chromium levels in mango fruits with the highest at 0.05mg/day, lead in orange fruits was at 0.02mg/day with the least D.I.M occurring in cadmium levels in mango fruits at 0.002mg/day. Mango and orange fruits sold in Eldoret town posed no health risks to consumers based on their D.I.M levels, as the values were within Provisional Daily Tolerable Intake standards of World Health Organization (WHO). The elevated chromium D.I.M levels in mango fruits in this study meant that environment in which mango fruits are grown were high in chromium content. There is need to initiate and sustain continued monitoring of heavy metals in fruits and food sold to consumers due to their different sources where contamination of heavy metals varies to ascertain food safety.

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LIST OF ACRONYMS

ANOVA	Analysis of Variance
CDC	Center for Disease Control
DIM	Daily Intake of heavy Metals
EU	European Union
FAO	Food and Agriculture Organization
GLOBOCAN	Global Statistics on Cancer
GOK	Government of Kenya
GPA	Global Program for Action
HQ	Hazard Quotient
IARC	International Agency for Research on Cancer
IPCS	International Program on Chemical Safety
KNBS	Kenya National Bureau of Statistics
mg/kg	Milligrams per kilogram
PTD1	Provisional Tolerable Daily Intake
PTWI	Provisional Tolerable Weekly Intake
pH	Potential of Hydrogen
g/cm^3	Grams per cubic centimeter
UNEP	United Nations Environmental Program
WCRF	World Cancer Research Fund
WHO	World Health Organization
µg/g	Microgram per Gram

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CHAPTER ONE

INTRODUCTION

1.1 General Background

Consumption of fruits on a regular basis is critical in providing health promoting nutrients to the human body. Protective antioxidants and phytonutrients in fresh fruits including: flavonols, anthocyanins and phenyl propanoids are critical to best functioning of human immune system, protecting against communicable and non-communicable diseases such as cancer and other degenerative diseases (Dauchet *et al*., 2010). Additionally, other vital components in fresh fruits such as vitamin C, carotenoids, minerals and dietary fibre are vital requisites to body's optimum immunity functions. These protective functions derived from fresh fruits necessitates that every human meal serving be accompanied with fresh fruit intake in providing a balanced diet and boosting of the body's immune system (Maggini *et al*., 2010). Okwi and Emenike (2008) attribute eating fresh fruits like sweet oranges (*Citrus sinensis*) to containing vital natural antioxidants and phytonutrients which are significant antioxidants in cardio-protective function of the human immunity system.

In the same perspective, the antioxidative content, vitamin C found in fresh fruits accounts for 65–100 % of the total antioxidant potential of beverages derived from citrus fruits. Stephen *et al*., (2012) upon reviewing cohort studies with the aim of seeking correlation between incidence rates of cancer to intake of fruits and vegetables, determined that there was a statistically significant protective effect ($p<0.001$) emanating from consumption of adequate levels of fresh fruits.

The public therefore is encouraged to consume more fruits containing higher antioxidant capacities. This will enhance increased protection against degenerative diseases that have become a rising health concern in this era of industrialization (Jarosz *et al*., 2011). Sweet citrus fruit, (*Citrus sinensis*) has been identified as a critical antioxidant fruit (Carol *et al*., 2011; Monica *et al*., 2010). Apart from providing antioxidative functions, fresh fruits are also critical in checking against human aging process (Reagan *et al*., 2010). The etiology of neuronal loss with aging is not fully understood, but it is hypothesized that enhanced vulnerability to oxidative stress is an important contributing factor to aging (Nikolay *et al*., 2011). Fresh fruits have nutritive properties to check against oxidants in the human body thus vital requirements in checking against oxidative stress that is a factor responsible in aging.

The importance of consuming fresh fruits still remains emphasized bearing in mind the different fruit consumption patterns between several geographical regions globally. There is a great discrepancy between developed and developing countries in respect to daily consumption of fresh fruits per person per capita with the objective of maintaining a healthy diet (Burlingare and Demini, 2011). Though being more health conscious pertaining the benefits of consuming fruits, only three countries in European continent have their population conforming to WHO (2012) minimum recommended levels of fresh fruit intake at 400 g per person per day. Representing 1.5 % of the European continent population, countries conforming to the standards of daily fruit consumption comprise of: Israel, Italy and Spain. This finding implies that a significant proportion of the European population does not adhere to healthy living as provided for in consumption of fresh fruits with its attributed antioxidative and vitamin qualities.

Developing countries like India, Mali and Pakistan have their citizens consuming a daily intake of fresh fruits at an average of 100 g per person per day resulting in an annual average of 36.5 kg per year per person (WHO, 2012). This is in stark comparison to fresh fruit consumption in United States where an average of 300 g of fresh fruit is consumed per person per day resulting in 109 kg per year per person (Jean *et al*., 2010). This fruit consumption discrepancy trend points to a strong inference that citizens in developing nations could be more vulnerable to degenerative diseases and conditions brought by lack of enough antioxidants and vitamins attributed to critical components of fresh fruits than their counterparts in the developed world. In this respect, low fruit intake is thought to be a major contributor to micronutrient deficiencies in the developing world, especially in populations with low intake of nutrient dense animal source foods such as meat and dairy products. Inadequate intake of fruits is also increasingly becoming recognized as one of the key risk factors for cardiovascular diseases and some form of cancer, the two leading causes of death in the world today (WHO, 2012).

Dauchet *et al*., (2010) provide statistics indicating a negative, non-significant relationship between incidences of cancer occurrence (as a degenerative disease) relative to fruit consumption among the Europeans ($p=-0.06$). Contrary to this, fruit consumption in adequate levels has been known to have greater protective effect from contracting cancer in both smokers and non-smokers (FAO/WHO, 2012). The important nutritive and antioxidative properties found in fresh fruits have neutralizing effects to quench radicals present in the human body system brought about by exposure to probable carcinogens thus effectively protecting against degenerative diseases.

No longer limited to developed countries, chronic degenerative diseases are on high incidences within the developing world at unprecedented rates, especially in countries undergoing rapid economic and related changes in diets and lifestyles (Ahmedin *et al.*, 2011). Fresh fruits do offer affordable sources of vitamins and antioxidants to citizens in the developing world. Compared to vegetables and their nutrient contribution to the human body, fresh fruits are usually taken in large quantities whereas vegetables are usually consumed in relatively small amounts as side dishes or relished with staple foods (Stewart *et al*., 2011). Fruits and vegetables rich in antioxidant compounds are widely consumed along with some underutilized fruits especially in rural communities in the global poor populations. Although this information points to the general population in third world countries being receptive to consuming fresh fruits for a healthy lifestyle, this population most of the times does not have clear information on the important fruit types to be consumed for robust health among individuals (Ercisli *et al*., 2011).

Despite extensive documentation on the importance of consumption of fresh fruits, fresh fruit consumption can be associated with some health risks arising from elevated concentrations of heavy metals emanating from various environmental sources impacting to these fresh fruits (Sobukola *et al*., 2010). These environmental sources include: use of synthetic fertilizers in fruit farming, use of pesticides and waste water in food crop farming and contaminated transport modes of transporting fresh fruits. Concentration levels of trace elements in fresh fruits are only beneficial to human immune system at low levels but become toxic when they exceed safe exposure limits (Sudhakar *et al*., 2012). Elevated uptake of mercury and lead as heavy metals in human food chain is associated with development of abnormalities in children (teratogenesis and mutagenesis) with long term intake.

1.2 Fruit plants exposure to heavy metal uptake in the environment

Inorganic fertilizers, pesticides and herbicides could contain different levels of heavy metals, these products when used in fruit farming for the purposes of providing plants with nutrients for growth and control of pests and diseases could result in deposition of heavy metals to the soil environment. Use of foliar sprays (pesticides, herbicides and fertilizers) that deposit fertilizer directly on fruits could be a concern in fruit safety with emphasis on contents of heavy metals in these substances (Heshmat *et al*., 2012). These heavy metals are absorbed by roots and deposited to fruits which when consumed could have health risks (Thomas *et al*., 2012; FAO/WHO, 2012). There has been a hundred fold increase in the use of inorganic fertilizers in fruit farming on a global perspective (FAO/WHO, 2012). Toxicity of pesticides is critical when considering environmental water systems and soil systems, two mediums that are easily contaminated (Fernando *et al*., 2012).

Low costs of pesticides have been long time preference for farmers in the fruit farming, a choice meant to cut on costs of production without emphasis being anchored on food safety (Samir *et al*., 2012). The use of unregulated pesticides in agricultural production could be linked to some manufactures who lower costs of pesticides in order to remain relevant in business (Ortelli *et al*., 2006). Farming in urban environment could be subjects of great sinks to heavy metal deposition from areas which in the past had been used as waste dumping sites and contamination of ground water from excessive use of chemical pesticides and fertilizers in agriculture

(Nabulo *et al*., 2006). Increasing knowledge about the potentially deleterious effects of heavy metals on environmental and human health has prompted closer examination of the presence and behaviour of such elements in agriculture ecosystems.

Current issues concerning heavy metal and nutrient management include natural cadmium enrichment in phosphorous fertilizer, anthropogenic heavy metal contamination of zinc fertilizer and copper contamination of soil resulting from historical pesticide application (ISHS, 2001). Cadmium as a heavy metal of concern in formulation of pesticides. Cadmium for instance can accumulate in plants and will not be toxic to them, yet are toxic to animals and humans eating the plants. Elevated level of cadmium in humans can cause kidney damage. Plants growing in a polluted environment can accumulate toxic metals at high concentration causing serious risk to human health when consumed (Yi-Chun *et al*., 2010).

Farmers, especially limited resource farmers, are continually opting for alternatives to synthetic fertilizers to cushion against the escalating production costs associated with the increasing costs of energy and fertilizers and the problems of soil deterioration and erosion associated with intensive farming systems. Organic matter content of composted municipal sewage sludge is high and its addition to agricultural soils often improves soil physical and chemical properties and enhances biological activities. On the other hand, accumulation of heavy metals by plants grown in municipal sewage sludge amended soil can be a serious problem that requires a continuous monitoring (Antonius and Synder, 2007). There is a concern that heavy metals in the composted product may transfer from soil and accumulate in edible plants. Municipal sewage sludge used for land farming typically contains heavy metals that might impact crop quality and human health (George *et al*., 2011). Soils in municipal waste dump sites commonly serve as fertile ground for the cultivation of a variety of fruits and leafy vegetables and the soils are also used as compost by farmers without regard for the probable health hazards the heavy metal contents of such soils may pose.

Soils in municipal waste dump sites have been known to have high levels of heavy metals including: Zn, Pb, Cd and Cu (Amusan *et al*., 2005). Crops growing in dump sites bio-accumulate considerably higher metal contents than those in normal agricultural soils. Studies have shown that heavy metals from municipal wastes can accumulate and persist in soils at environmentally hazardous levels (Antonius, 2009). In the present societies, intensive agricultural practices in most peri-urban areas globally take place with the use of waste water from industries or domestic fronts. This is meant to ensure food security in times when availability of fresh water for agricultural practices is limited (Monu *et al*., 2008). Wastewater contents have significant amounts of toxic heavy metals due to numerous applications of chemicals in both domestic and industrial uses (Chen *et al.,* 2005; Singh *et al*., 2004). Substantial deposition of heavy metals in farming land through use of waste water results in soil contamination and subsequently quality and safety of food grown using waste water, fruits included (Muchuweti *et al*., 2006).

Continued use of waste water for irrigation could continuously lead to contamination of food crops. It is advised that regions practicing irrigation farming with waste water, regular monitoring of levels of heavy metals from waste water and in food materials be made mandatory to check against excessive build-up of heavy metals in the food chain. Dietary intake of food results in long-term low level body accumulation of heavy metals and the detrimental impact becomes apparent only after several years of exposure (Monu *et al*., 2008). Dikinya and Areola (2010) reported that wastewater irrigated soils in the Glen Valley in Botswana had higher cadmium, nickel and copper levels (0.01, 0.20 and 0.20mg/kg), respectively. Levels of mercury, lead and zinc in wastewater irrigated soils were lower than maximum threshold values recommended for crop production.

Elevated levels of cadmium and mercury levels could imply that use of treated wastewater could cause a buildup of soil cadmium and mercury levels on the cultivated plots. Cadmium as a heavy metal has a relatively higher adsorption capacity to soils of clay type (Sánchez-Martin *et al*., 2007). The current economic development of societies towards large-scale urbanization and industrialization is leading to production of huge quantities of wastewaters (Singh and Agrawal, 2008). The effects of microbial pathogens found in wastewater and absorbed by plants are usually short term and vary in severity depending on the potential for human, animal or environmental contact (Toze, 2006), while heavy metals have longer term impacts that could be a source of contamination and be toxic to the soil and plant (Sharma *et al*., 2007).

Differences in climatic, vegetation, socio-economic conditions and also in quality of soil and wastewater between different regions and within different time periods in one region impacts differently on heavy metal uptake from the soil (Kalavrouziotis and Arslan, 2008). High concentration of heavy metals in wastewater leads to increased levels in soils (Mapanda, *et al*., 2005). The effects of wastewater irrigation on accumulation of soil heavy metals depend on various factors such as concentration of wastewater heavy metals, the period of wastewater irrigation, and soil properties (pH, texture, organic matter) (Rattan *et al*., 2005).

1.3 Description of Fruits under study

1.3.1 Sweet Oranges

Citrus fruits are the world's most popular fruits by consumption. Citrus plants originated in South East Asia and domesticated gradually to other countries globally. The two most important orange growing and processing regions on a global scale are Brazil and US (Florida). These two regions account for nearly 90% of global orange juice production. The fruit does play a major role in human nutrition, being excellent source of antioxidants like: ascorbic acid, carotenoids, tocopherols and phenolic compounds. These fruits contain a variety of sugars, citric acids, vitamins C and B. Citrus fruits and juices contain biologically active compounds which possess antioxidant activities that help to check against degenerative and non-communicable diseases that are presently on the rise in the society (Australian Government, 2008).

Two predominant orange varieties available in Kenyan markets are: *Citrus sinensis* and *Citrus valencia. Citrus sinensis* is majorly grown in Kenya in parts of Rift-Valley, Eastern and Coast provinces. *Citrus valencia* being an import is mainly sourced from Egypt, Israel, Tanzania and South Africa. These two orange varieties formed the basis of this study because of their availability in markets and being preferred over other orange varieties by consumers in Eldoret town (Mounde *et al*., 2012). *Citrus sinensis* grows well within an altitude of below 2000 metres, characterized by variance in mean annual temperatures ranging from 5 to 40 ºC. Optimum soil conditions for the fruit plant growth includes well fertilized loam soils that are not water logged. The nutrient requirements for citrus fruit production are mainly: nitrogen and potassium which should be available throughout the year of plant growth.

These nutrients are provided in the application of organic and inorganic fertilizers during the plant growth but most significantly during fruiting seasons to increase fruit yields. Other micronutrients and pesticides are applied through foliar spray that encourages easy absorption and uptake by the fruit plant. This could be a critical pathway in which heavy metal content in organic fertilizers, pesticides and herbicides are absorbed by the orange fruit plants and deposited to the fruit parts of the plant. When orange fruits are consumed the heavy metal content therein impacts to the human food chain. Consuming oranges laden with environmental pollutants, consumers might be at a health risk of heavy metal toxicity (Fernando *et al*., 2012).

1.3.2 Mangoes

Mango fruit is a member of the family *Anacardiaceae.* The genus *Mangifera* includes 25 species with edible fruits such as *Mangifera caesia, Mangifera foetida, Mangifera odorata* and *Mangifera pajang*. *Mangifera indica* is the only mango fruit species that is grown commercially on a large scale, worldwide. On a global perspective mango farming covers an approximate 2.9 million hectares and earns nearly US$ 500 million in export revenues (FAOSTAT, 2012). Mango fruit under this study belongs to the species *Mangifera indica*. It is native to India, Bangladesh, Myanmar and Malaysia, but can also be found growing in more than 60 other countries throughout the world (Salim *et al*., 2002). Mean annual production of mango in Kenya stands at 140,000 tones with 2.3% being exported and the rest consumed locally (GOK, 2012). Mango production is best adapted to warm tropical monsoon climate with a pronounced dry season of about three months followed by rains, but also thrives under varied climatic conditions. Mango production does well in sandy soils at the coastline as well as on loam, black cotton and even murram soils at other elevations.

The essential prerequisites for development of mango trees are: deep soils (at least 3 m), appropriate annual rainfall (500-1000 mm), good drainage, suitable altitude (0-1200 m) and a pH value of between 5.5 and 7.5. Optimum growth and productivity of mango occurs in a range of 20-26°C temperature. Correct fertilizer requirements is critical and it is recommended that fertilizer be applied just after harvesting and during the rainy seasons (GOK, 2012).

In general, a mango tree at full bearing age (7 years and older) needs about 1.5 to 2.5 kg of Calcium Ammonium Nitrate (CAN) (26%), 2.25 kg Super Phosphate and 0.75-1.5 kg Potassium Chloride per year, or the equivalent inputs from manure or compost for small-scale farmers. To control pests and diseases periodic application of chemicals to achieve appropriate production levels should be maintained (Mounde *et al*., 2012). Mango fruit is a superior fruit in terms of vitamins when compared to oranges and Bananas (Table 1.1).

Table 1: Comparative nutritive values of selected fruits

Source: Mervyn 2000.

Component	Orange	Mango	Banana
Calories	53	63	116
Protein (g)	0.8	0.5	1
Calcium (mg)	22	10	7
Iron (mg)	0.5	0.5	0.5
Vitamin A (IU)		600	100
Vitamin C (mg)	40	30	10
Thiamine (mg)	0.05	0.03	0.05

Mangoes do exhibit an array of both nutritive and antioxidative properties with high content of ascorbic acid at 132 mg/100 g, β carotene at 35.59 mg/100 g and total phenolics at 19.30 mg/100 g of mango juice.

Ascorbic acid is an important and essential diet component for human health and functions as an antioxidant providing some protection against oxidative stress-related diseases such as cardiovascular disease and respiratory infection. β-carotene in mangoes does provide the highest vitamin A activity which contributes to protection against free radicals related to degenerative diseases. β-carotene is a very potent antioxidant in inhibiting the progression of atherosclerosis and cancer (Fenglei *et al*., 2012).

In Kenya, mangoes are grown in Eastern, Coast and Parts of Rift valley provinces. The climatic conditions of these areas favourable to growth of mangoes include: short spells of high rainfall and long durations of low rainfall (USAID, 2011). This fruit plant also requires nutrients especially potassium that is needed in plenty during flowering season to boost fruit yields. Diseases and pests are also critical to the final yield of mango fruits to farmers, consequently application of fertilizers and pesticides is done to the fruit in protecting economic value of the fruit. Mango fruits when ripe are harvested manually by hand, collected and packed openly or in sacks ready to be transported to markets for consumption. These can be sources of heavy metal contamination in form of environmental contamination and consequently health risks to consumers (Ammar *et al*., 2012).

1.4 Problem Statement

Lack of adequate intake of fruits and vegetables is a major contributory factor in enhancing risks related to lifestyle conditions and diseases such as cardiovascular ailments and forms of degenerative diseases that are significant in the present human mortality rates in the world (WHO, 2012). Fresh fruits inclusive of oranges (*Citrus sinensis*) and mangoes (*Mangifera Indica*) are consumed in Kenya among other countries on a daily basis forming critical part of human diet. The beneficial health effects of fruits depend on the type of fruit and the content of biologically active compounds in the fruit (Sobukola *et al*., 2010). Developed countries have fruit consumption pattern much better compared to developing countries although both fall short of meeting international recommended levels. Consumers being aware of health benefits derived from fresh fruits, consumption will strive to access the most affordable and easily available fruits in markets to keep healthy.

Current production capacity for oranges grown in Kenya does not sufficiently meet the country’s demand and thus imports are sought to meet this shortfall. These fruits (mangoes and oranges) are grown under different environmental conditions subjecting the fresh fruits to different environment pollution sources inclusive of uptake from soil environments. Kavita *et al*., (2010) attribute this to the fact that heavy metals accumulate in fruits of different plants at different concentrations. Heavy metal concentrations in fresh fruits mainly originate from the use of pesticides and commercial fertilizers used in fruit orchards. Other sources of anthropogenic contamination of fresh fruits with heavy metals include: addition of manures, sewage sludge, fertilizers and pesticides to soils (Raymond and Felix, 2011).

Regional and global standards on food quality over time have been made lower in values of the recommended concentration levels of heavy metals available to human uptake due to increased enhancement of the health implications these heavy metals pose to human health (Fernando *et al*., 2012). Considering modes of heavy metal contamination of fresh fruits from the use of waste water for irrigation purposes, use of pesticides and fertilizers for crop farming to transportation and handling, there could be different levels of heavy metal contamination to these fruits.

Unlike in developing countries, developed countries have installed robust bio-monitoring programs with the sole intent of ascertaining the safety of both imported and locally produced food produce with these products analyzed on the basis of levels of: pesticides and heavy metals among other variables under concern (Fernando *et al*., 2012). Such a program should be enhanced in Kenya as it will not only promote public health safety but also guarantee confidence among citizens on consumption of fresh food products with diverse areas of origin in productions.

1.5 Justification

Food safety is a major public concern worldwide. During the last couple of decade, increasing demand for food safety has stimulated research regarding risks associated with consumption of foodstuffs contaminated by pesticides, heavy metals and toxins (WHO, 2012). The increasing trends in food contamination in urban areas are largely attributed to polluted environment in urban agriculture, contaminated food handling, poor market sanitary and use of contaminated waste water for irrigation (Fernando *et al*., 2012). Special concern in this study was the different environmental settings that fresh fruits sold within Eldoret town are sourced. Regions in which some of the fruits are sourced are thought to be having varied levels of heavy metals in their soils and from environment. These heavy metals when absorbed by plants and deposited in fruits and subsequently consumed through human food chain can bring about health risks. Heavy metal contamination of fresh fruits cannot be underestimated as these foodstuffs are important components of human daily diet on a global scale (FAO/WHO, 2012).

Intake of heavy metal-contaminated fruits may pose a risk to the human health when the levels of toxic metals exceed recommended levels of intake. Heavy metal contamination of food items is one of the most important aspects of food quality assurance (FAO/WHO, 2012). Prolonged consumption of unsafe concentrations of heavy metals through fresh fruits contaminated with heavy metals may lead to chronic accumulation of heavy metals in the kidney and liver of humans causing disruption of numerous biochemical processes, leading to cardiovascular, nervous, kidney and bone diseases (Orish *et al*., 2012).

International and national regulations on food quality have lowered the maximum permissible levels of toxic metals in food items due to an increased awareness of the risk these metals pose to food chain contamination (Orish *et al.,* 2012). This has even made the society to be more conscious on safety of fresh fruits on heavy metal contamination. Presently research on fresh fruit contamination by heavy metals has been extensively reported on temperate fruits such as: strawberries, raspberries, blackcurrant and food crops namely asparagus, peanuts and tomatoes (Orish *et al*., 2012). It is in this perspective that it is also critical to have an analytical view of heavy metal contamination of tropical fruits such as mangoes and oranges. These fruits are consumed by large proportion of the population and therefore it's a prerequisite that their health safety has to be guaranteed.

In the past, research on levels of heavy metal concentrations in fruits and vegetables from the market sites has been carried out in some developed and developing countries. Nevertheless, limited published data are available on heavy metals concentrations in fresh fruits from the market sites of Kenya as a developing country and more specifically in Eldoret municipality. The processes involved in transporting, farming and handling of fresh fruits in the tropics are thought to be contributory factors to heavy metal contamination of fruits (Saeid, 2012). Limited knowledge is present about heavy metal contamination of tropical fruits such as mangoes and oranges which are among the favourite fruits consumed widely in the tropics. This study sought an assessment of the safety of consumption of fresh fruits (oranges and mangoes) based on the levels of heavy metal concentrations and to compare with standards established on international basis of food contamination as provided for by FAO/WHO (2012) standards.

Keeping in mind the potential toxicity and persistent nature of heavy metals and the frequent consumption of vegetables and fruits, it is necessary to analyze these fruit items to ensure the levels of these contaminants meet the accepted international requirements (FAO/WHO, 2012). Knowledge of heavy metal contents in fresh fruits is important for the identification of adequate, sub-adequate and marginal intake levels for humans so that diseases related to trace element deficiency as well as toxicity due to excessive intake can be minimized. Monitoring programs for residues and contaminants contribute to improving food safety, warn of actual and potential food health risks and facilitate evaluation of possible health hazards by providing continuous information on levels of environmental pollution in the country (Fenglei, 2012).

The beneficiaries of this study are all members of the society but most critical are the vulnerable members of the society in terms of health capacity. Fruit intake helps in checking free radicals occurring in the human body due to excessive heavy metals occurrence (Fernando *et al*., 2012). In contrast to the main functions of providing antioxidants and nutrients to the human bodies; fresh fruits contaminated with heavy metals can be sources of health risks. Results of this study will provide an insight of the risks of these fruits posed to consumers in advocating the need for an elaborate food safety program being instituted by the government in ensuring safety of food products. Safety in consumption of fresh fruits due to their trace elements has to be guaranteed as fruits are significant sources of critical vitamins to human health and are relatively affordable to large proportion of the population which is consumed in large amounts (FAOSTAT, 2012).

1.6 Scope and limitation of the Study

This study focused on levels of selected heavy metals in mango and orange fruits sold in Eldoret town. The heavy metals analyzed in this study included: Cd, Pb and Cr. The study focused on heavy metal content in the fruits on the basis that the levels of these metals in the fruits were as a result of uptake from the environment in which the fruits were grown. The study was limited in analyzing the heavy metal content in the fruit juicy parts and therefore analysis of outer surfaces of fruits was not conducted. This was done so as to ensure that data from the study indicates uptake of heavy metals from the soil environment of the growing region and not atmospheric deposition of heavy metal pollutants that are mainly adhered to fruit surfaces.

The study was selective on heavy metals: Cd, Pb and Cr because these metals have high background concentrations and additional concentrations from use of pesticides, fertilizers, use of wastewater in farming and herbicides in regions where fruits are grown (Ashraf *et al*., 2011). Further, these heavy metals are of great interest in toxicological research as their elevated uptake in the human food chain are thought to be precursors to non-contagious diseases of which are of concern in the modern day research (Orish *et al*., 2012).

1.7 Objectives of the Study

1.7.1 General objective

The main objective of this study was to assess levels of selected heavy metals in fresh fruits and how heavy metal contamination in these fresh fruits might have impact on food safety standards to local consumers in Eldoret municipality, Kenya.

1.7.2 Specific objectives

The specific objectives for this study were;

1. To determine the concentrations of lead, cadmium and chromium in mangoes and oranges sold in Eldoret Municipality.
2. To estimate health risks posed by heavy metals in fresh fruits sold to consumers in Eldoret Municipality.

1.8 Hypotheses, Null

H_{01}: Levels of selected heavy metals in fresh fruits sold in Eldoret Town are within International recommended health standards.

H_{02}: Consumption of fresh fruits sold in Eldoret Town possesses insignificant health risk to consumers due to uptake of heavy metals

CHAPTER TWO

LITERATURE REVIEW

2.1 Uptake of heavy metals from: Soil, Pesticides and Fertilizers

In many agricultural areas, pesticides are used intensely in fruit farming to protect against pests and diseases thus conserving economic value of these vital commodities (Vinoth *et al*., 2010). Use of pesticides and herbicides laden with heavy metals can pose health risks as plants do uptake these elements and deposit them in edible plant parts including fruits which are eventually consumed. There is a need to review the use of pesticides and herbicides that are considered unsafe to the environment in production of cocoa with an emphasis to levels of heavy metal contents (FAO/WHO, 2012). As a quality assurance tool to food safety, use of environmental friendly pesticides and herbicides are recommended for use in cocoa production to avoid further terrestrial toxicity.

Another intense fruit farming activity involving the use of pesticides and herbicides is the banana farming in Costa-rica. A range of diverse toxic residues including: heavy metals have all been detected in soil, water, sediments and fish in outlying areas of banana plantations or in areas in close proximity to banana plantations in the area. Substances defined as carrying the greatest risk of acute toxicity to human health from consumption of banana fruits were cadusaphus and chlorpiriphous and those with major risks of chronic environmental toxicity were: nematocides, cadusaphus and ethoprophus (Angela and Lee, 2012).

These pesticides are absorbed and deposited in banana fruits with heavy metals in their formulation; as such consumers of bananas are at a health risk arising from use of pesticides and heavy metals. Contribution of pesticides and fertilizers in human food chain contamination is still emphasized in the perspective of fruit orchard farming (Angela and Lee, 2012). Fruit orchard farming is an intensive farming where use of fertilizers, herbicides and insecticides applications is extensively employed by farmers. Application of chemicals may result in undesirable heavy metal contamination of soil, plants and fruits (Diane *et al.,* 2010). Fresh fruits produced locally in Malaysia are either grown on good agricultural land while in some cases they are grown on ex-mining land. Fruits grown on ex-mining land have shown unacceptable elevated levels of heavy metals like zinc, cadmium and copper. Fruit and vegetable grown in soils contaminated with heavy metals have a greater accumulation tendency of the metals than those grown in uncontaminated soils (Ashraf *et al*., 2011).

Agricultural application of phosphate fertilizers presents a direct input of cadmium to arable lands. Cadmium content of phosphate fertilizers varies widely and depends on the origin of the rock phosphate used in preparation of phosphate fertilizers. It has been estimated that fertilizers of West African origin contain about 160-225 g of cadmium per ton of phosphorus pentoxide while those derived from southern USA contains about 35 g per ton, cadmium in Africa having a concentration of 5.5 times more than that from USA. Cadmium in fertilizers is readily available for uptake by plants and becomes a heavy metal of concern because of its easiness in transfer from soils to edible portions of agricultural food crops being significantly greater than other heavy metals (Sabiha *et al*., 2009).

Heavy presence of cadmium in fertilizers and pesticides used in fruit farming implies that they are available in large doses to human being exposure, consequently posing a great health risk because of its toxicity potential. Cadmium contamination of food crops differs from one area to another as application of fertilizers and environmental activities differ at each site. Phosphate fertilizers are the main source of soil heavy metal pollution (Sabiha *et al*., 2009). Cadmium is an impurity in phosphate rocks used in manufacture of inorganic fertilizers. Massive application of phosphate fertilizers to soils results in heavy contamination of soils by cadmium metal and its subsequent uptake by plants thereby posing a health risk to human food chain. Toxicity of cadmium is enhanced in human body through the inability of the excretion system to completely eliminate it. Doses of higher magnitude of cadmium upon exposure leads to severe respiratory irritation and is cited as a risk factor for chronic lung diseases and testicular degeneration leading to prostate cancer (Wang *et al*., 2012).

Data from animal experiments have indicated that under certain exposure conditions cadmium induces hypertension in animals. Doses of higher magnitude of cadmium in the human body are a major concern to kidney toxicity. Cadmium is responsible for structural deformation of proximal tubules of nephrons, a critical functional unit to kidney functioning. This is manifested at onset of leakage of low molecular weight proteins and ions like calcium as analyzed through their concentrations in urine (Fernando *et al*., 2012). This situation degenerates to a severe condition of total kidney failure that is irreversible known as frank kidney failure (Satarug *et al.,* 2010). Studies in Japan during World War II linked frank kidney failure condition to exposure of cadmium through consumption of rice grown on contaminated land with cadmium heavy metal.

This condition leads to condition of increased risk of bone fractures in women as well as decreased bone density and height loss a condition hypothesized from demineralization and compression of vertebrae (Satarug *et al*., 2010). Erum *et al*.,

(2009) did conduct a market basket survey of selected metals in fruits from Karachi city in Pakistan in which they reported that fruits in Pakistan city contained heavy metal content within safe limits of WHO standards. In this work, there was a clear association between cadmium concentration in soils and cadmium that is readily available for uptake by plants. Although this study reported that fruits sold in Karachi were safe for human health standards the authors did not specify the origin of the fruits. This aspect of environmental origin of food crops is critical to heavy metal accumulation as different environmental conditions impact differently to heavy metal accumulation (FAO/WHO, 2012).

2.2 Fruit contamination by heavy metals due to waste water used in irrigation

The use of waste water for food production has been necessitated due to the fact that availability of fresh clean water is continuously being limited on a global front. This calls for utilization of waste water to irrigate food crops especially in most urban farming systems. Waste water contains substantial amounts of toxic heavy metals which when used in crop farming can pose health risks to consumers. Excessive accumulation of heavy metals in agricultural soils through waste water irrigation may not only result in soil contamination but also affect food quality and safety (Aweng *et al*., 2010). Heavy metals are very harmful because of their non-biodegradability nature, with long biological half-life and their potential to accumulate in different body parts. Most of the heavy metals are extremely toxic because of their easiness in their solubility in body fluids. Even at low concentrations of heavy metals, they have damaging effects to human systems because there is no good mechanism for the elimination from the body (Igbinosa *et al*., 2012).

Often waste water from domestic and industrial process when drained to agricultural lands is used for growing crops including fruits and vegetables. These sewage effluents are considered not only a rich source of organic matter and other nutrients but also contain elevated levels of heavy metals like iron, manganese, copper, zinc, lead, chromium, nickel, cadmium and cobalt in receiving soils (Kumar and Nagar, 2012). As a result it leads to contamination of human food chain and consequently accumulates heavy metals in human vital organs, posing health risks. This situation causes varying degrees of illness based on acute and chronic exposure. Health risks due to heavy metal contamination of soil have been widely reported (Satarug *et al*., 2010).

Crops and vegetables grown in soils contaminated with heavy metals have greater accumulation of heavy metals than those grown in uncontaminated soils (Syed *et al*., 2012). Intake of fruits is an important path of heavy metal toxicity to human beings. Higher concentration of zinc can cause impairment of growth and reproduction. Monu *et al*., (2008) reported a substantial buildup of heavy metals causing a health risk concern in vegetables irrigated with water from different sources in Rajasthan, India. Plants in this study exhibited high levels of heavy metals content as follows: iron (116-378 mg/kg), manganese (12-69 mg/kg), copper (5.2-16.5) and zinc (22-46 mg/kg) respectively. The highest significant levels of iron and manganese were detected in mint and spinach ($P<0.001$). The levels of copper and zinc were highest in carrot ($P<0.001$). This study highlighted that both adults and children consuming vegetables grown in wastewater irrigated soils do ingest significant amounts of metals and are at health risk of heavy metal contamination. The authors did recommend that regular monitoring of levels of metals from effluents and sewage in vegetables and in other food materials is essential to prevent excessive buildup of these metals in the human food chain (Satarug *et al*., 2010).

Wastewater used in irrigation containing high levels of trace elements and heavy metals is likely to be toxic to plants, and also poses risk to human health. The issue of trace elements and heavy metals in wastewater for most developing countries is mainly related to the mixing of domestic and industrial wastewater in the same sewage system (WHO, 2012). This problem is further exacerbated by dumping of untreated industrial wastewater into water bodies, enabled by lax pollution control mechanisms.

Examples of potentially toxic trace elements found in waste water used in irrigation purposes include: mercury, lead, arsenic, copper, cadmium, manganese among others (Kumar and Nagar, 2012). Urban farmers do use wastewater containing industrial contaminants for irrigation, mainly due to lack of plenty clean water for farming. Trace elements and heavy metals in wastewater are likely to be toxic to plants at levels below that at which they pose significant risk to human health risk (Aweng *et al*., 2010).

Aweng *et al*., (2010) noted that heavy metal uptake varies according to plant species and at different parts of the plant. Leafy vegetables tend to accumulate more heavy metals, while in other instances monocot plants such as rice accumulate higher concentration of heavy metals in their roots. Studies conducted in China, Japan and Taiwan, show that rice accumulates high concentrations of cadmium and other heavy metals when it was grown in soils contaminated with irrigation water containing substantial industrial discharges. These examples indicate that certain food crops have a higher possibility of transferring heavy metals to humans (Sabiha *et al*., 2009). Heavy metals and trace elements therefore remain of great concern especially in instances where industrial effluent is an important factor.

In addition, health risks of heavy metals can be looked at from an occupational hazard point of view where chemical pollutants in wastewater can cause harm to farmers as a result of direct contact with water during farming (Afolami *et al.,* 2010). Chromium metal is of concern in waste water irrigation. Ingestion of food and drinks accounts for the main source of exposure of chromium to man.

About 0.4% to 1.2% of total chromium content in human body is absorbed through small intestines to blood stream which is then distributed to all parts of the body, passing through the kidney and eliminated in urine (Ashraf *et al*., 2011). Chromium in its trivalent form has been known to exhibit very low toxicity and not known to cause cancer. Hexavalent form of chromium is known to be toxic and can cause cancer if it is inhaled. The consequences of ingesting hexavalent chromium are damages to nose lining and irritation of lungs and gastrointestinal tract. When swallowed, chromium inflicts damages to stomach, liver and kidneys. Environmental Protection Agency in United States classifies hexavalent chromium as a human carcinogen (Ashraf *et al*., 2011).

Sobukola *et al*., (2010) analyzed content of heavy metal levels in sixteen different fruits and leafy vegetables from selected markets in Lagos, Nigeria. The levels of lead, cadmium, copper, zinc, cobalt and nickel were at a mean of 0.072, 0.003, 0.002, 0.039, 0.014 and 0.070 mg/kg, respectively for the sampled fruits. These values were within tolerable limits of heavy metal exposure. The high levels of Pb in some of these fruits were attributed to pollutants in irrigation water, farm soil or due to pollution from the highways traffic. It was concluded that fruits and vegetables sold in this market were safe for human consumption. This study agrees with a previous study by Syed *et al.*, (2012) in terms of abundance of heavy metals in the collected fresh fruit samples as follows: Fe>Cr>Mn>Pb>Ni>Co>Zn>Cu>Cd.

CHAPTER THREE

STUDY AREA AND RESEARCH METHODOLOGY

3.1 The Study Area

3.1.1 Location

Field sampling for this study was carried out in selected markets within Eldoret town in Uasin-Gishu County, Kenya. Fresh fruit samples were collected in both open air market vendors and in enclosed markets fruit vendors. Uasin-Gishu county extends between longitude $34^{o}50'$ and $35^{o}37'$ East and latitude $0^{o}03'$ and $0^{o}55'$ North with its headquarters located in Eldoret town, situated at Longitude 35^{o}N 12^{o}E and Latitude 0^{o} 35^{o}N (Figure 1). Eldoret town is located 300km North-West of Nairobi city, the capital city of Kenya. The area elevation above sea level ranges from 2100 to 2700 metres. Uasin-Gishu County covers an area of 3,327.8 km^2, bordering Nandi, Kericho, Baringo, Elgeyo Marakwet, Trans Nzoia and Kakamega counties. Uasin-Gishu county has three administrative districts namely; Eldoret East, Eldoret West and Wareng (GOK, 2008). Eldoret town serves as a regional commercial centre for North Rift of Kenya, with one of the commercial activities being trading in fresh fruit produces where fresh fruits are sold to consumers in the markets.

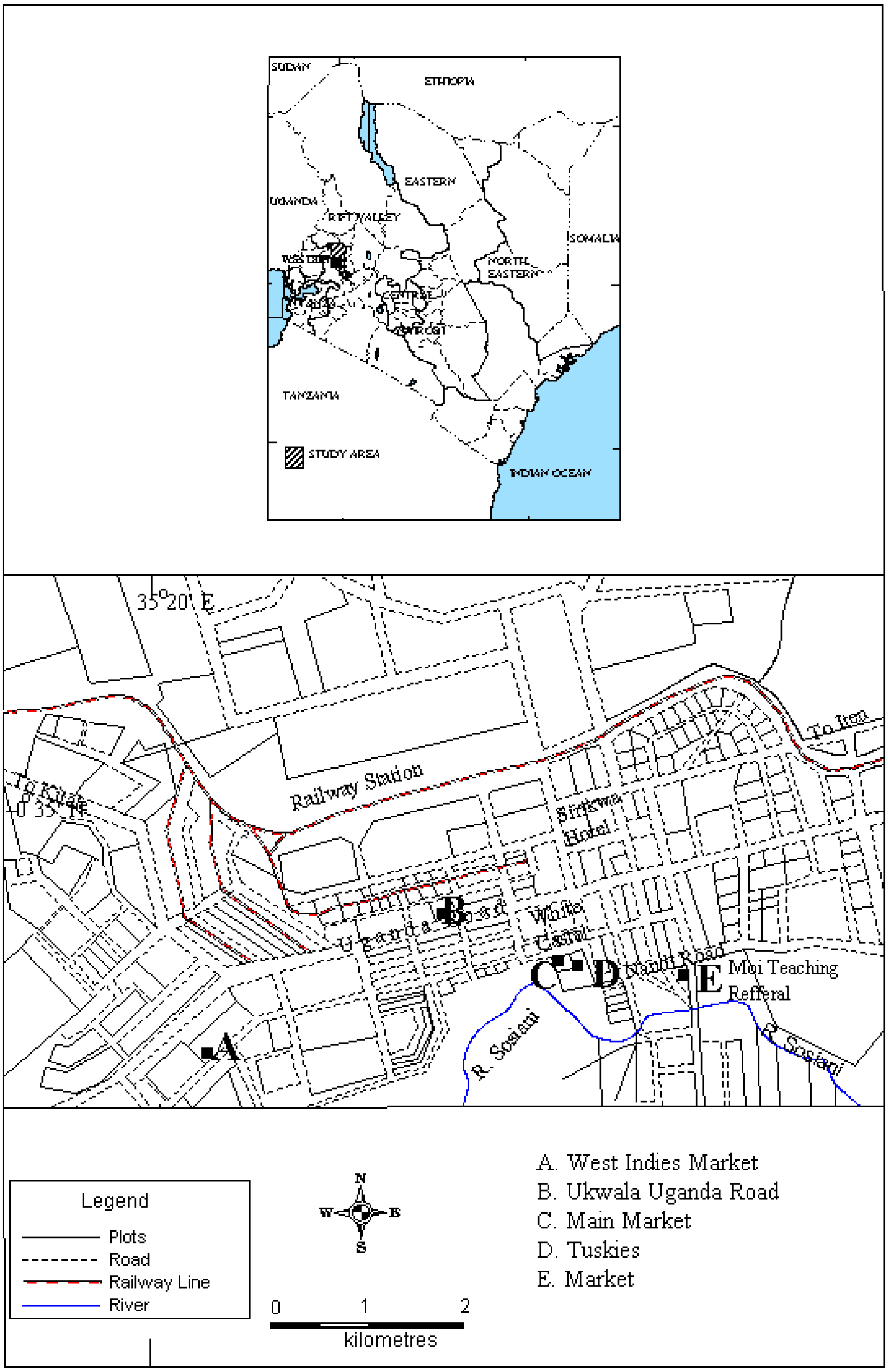

Figure 1. Map showing study area

3.1.2 Geological and Agricultural activities

An estimated 90 % of the entire land area in Uasin Gishu county is arable and can be classified as high potential. There are four major soil types in the area, all of which are suited for agricultural production. These soil types include: red loam, red clay, brown clay and brown loam. A total of 29,801.92 hectares in Uasin-Gishu County falls under gazetted forest. Out of this, 13,183.54 hectares (44%) is under agricultural plantation, while 16,618.38 hectares (56%) is under indigenous forest cover. Eldoret municipality lies over tertiary volcanic rocks derived from basalt and phonolyte with no known commercial available minerals. The geology of this area is made up of metamorphosized basement system. Over time and under pressure basement rocks have weathered to brown sandy soils that are lighter in texture and less fertile. Soil types in Uasin-Gishu County are mainly: Acrisols and Ultisols characterized by red and yellow coloration. Soils have a low nutrient exchange capacity and are known to be deficient in phosphorous. Most common rocks are of metamorphic origin like schist, gneiss, slate, granite and basalt (GOK, 2008).

Most residents within Uasin-Gishu county do undertake agricultural activities as means in supplementing their livelihoods. The total arable land in the county covers an area of 766.2 km^2. The average farm size for small scale farming is 3 acres while large scale farming has an average farm size of 8 acres. The major agricultural activities in the county are maize and wheat farming as the county produces more than two thirds of the country's production in these crops. Other agricultural endeavours within the county include pyrethrum production, sunflower production, fish production, animal husbandry, sheep and goat rearing, poultry and bee keeping (KNBS, 2009).

Fresh fruits sold in Uasin-Gishu County more specifically in Eldoret municipality markets originate from several places within Kenya and imports. Mangoes are sourced from Coast and Eastern provinces and parts of Rift Valley province including the Marakwet and Pokot regions. Oranges supplied to the Eldoret Municipality markets comes from both Kenyan and also from imported sources. Areas in Kenya that oranges are grown include: North Rift areas, Eastern and Coastal provinces whereas imported sources include: Tanzania, Egypt and South Africa countries (United States of America Development Agency, 2011).

These sources of fresh fruits have different environmental exposure to heavy metals. Starting with different concentration of heavy metals in the soil systems of the areas that grow fruits, use of pesticides and fertilizers laden with different levels of these metals and possible use of waste water in fruit farming being possible sources of heavy metal contamination (Fernando *et al*., 2012). Another avenue of heavy metal contamination of fresh fruits is the mode of transportation, handling and storage. In Kenya fruit when sourced from farms are packed in gunny bags and loaded to trucks to markets. Gunny bags are exposed to environmental deposition of heavy metals from exhaust fumes of machinery and also dust laden with heavy metals as encountered during the fruit display to consumers in open vendors (Sobukola *et al*., 2010).

3.1.3 Climate

Located on a plateau, Uasin-Gishu county has a cool and temperate climate regimes spread over the year. Rain in the area is evenly distributed throughout the county. Main rainy season occurs between the months of March to September, peaking up in May and August; during this period lowest mean temperatures are at 8˚C experienced in the coldest month of July. The region experiences a dry spell between the months of September to February, a period characterized by daily average temperatures of 27 ˚C. Annual average rainfall ranges between 1000 to 1200 millimetres, a characteristic attributed to highland climate (GOK, 2008).

3.1.4 Socio -Economic Activities

As per the 2009 Kenya National Bureau of Statistics census, Uasin-Gishu County had a human population of 894,179 with 202,291 households and a population density of 269 people per km^2. Eldoret municipality had a population of 289,380 persons representing 33% of the total Uasin-Gishu county population. The age distribution bracket for persons in the age bracket (0-14) years comprised 41.5% of the total population, those within the age bracket of 15-64 years comprised 55.7% of the total population with those aged above 65 years representing 2.9% of the total population. Poverty level in the county stands at 49%. (KNBS, 2009). Major causes of poverty are: unemployment, poor markets for the farm produces, high cost of inputs and poor food storage facilities. A high rate of population growth has contributed to increasing poverty since social facilities such as health, education, and transport have been overburdened.

Water is accessible to all residents of Eldoret municipality but variation is noted on how clean the water is (KNBS, 2009). Only 0.3% of residents have access to piped water, 2.5% have access to portable water that is provided by Eldoret Water Treatment and Sanitation Company which sources water from Chebara dam. Eldoret municipality is served by one permanent river, Sosiani. Most of the urban residents are connected to electricity (15.6%). The use of alternative power sources such as solar power is very minimal in the county as most residents use kerosene, firewood and charcoal for cooking and lighting up their households. These choices of fuel pose a challenge to conservation of the county's forest cover (GOK, 2008).

In provision of health facilities, Uasin-Gishu County already has a number of Government hospitals, Private hospitals, Rural health centers and dispensaries. The most common diseases in this county are: clinical malaria 25.3%, upper respiratory tract infection 21.9%, skin disease 8.5%, confirmed malaria 4.9%, pneumonia 3.1%, accidents 2.5%, urinary tract infections 1.8%, typhoid fever 1.8% and eye infection at 1.6%. The area residents rely mostly on Moi Teaching and Referral Hospital for in-patient services and specialized treatment (GOK, 2008).

3.2 Research Methodology

3.2.1 Field Sampling

A total of 180 samples for two fresh fruit samples consisting of two types of fruits (mangoes and oranges) were purchased from four market sampling sites located in Eldoret town. The four market sites were indentified randomly. Orange and mango fruits in this study were sampled randomly from each market site twice a month for a period of three months (January-March, 2011) in triplicates. Selection of fresh fruits for this study was based on their availability and consumption. Fruits upon collection from sites were packaged in clean, dry, high density clear plastic bags immediately after purchase and then stored in refrigerator at $4^{o}C$ for further heavy metal analysis.

3.2.2 Apparatus preparation for laboratory analysis

All glass and non-glassware apparatus used in this analysis were washed with deionized distilled water and immersed in 2% nitric acid (HNO_3) for 24 hours to prevent heavy metal contamination. The glass ware used in analysis had no metal liners that could contaminate the samples. Fruits were cleaned with distilled water and peeled with stainless steel knife and sliced to get the edible parts while an electric blender with stainless steel rotor knives were used for homogenizing the edible parts of the fruits to get the fruit juice for analysis (Cui *et al*., 2010).

3.2.3 Fresh Fruit Juice Analysis

Edible parts of fruits were sliced using a stainless steel knife. These parts were homogenized into a 100 ml juicy paste using an electric blender for each fruit sample. Samples were extracted using acid digestion method according to Cui *et al.*, (2010). Reference materials for analysis were of standard type, MERCK sourced from Darmstadt, Germany. Three aliquots of 30 ml each representing three replicates for each fruit were accurately measured and placed in a 200 ml flask beaker to which 30 ml of 10 % concentrated HNO_3 was added and left to stand for 15 minutes. Wet acid digestion followed in 10 ml consisting of 1:3 mixture of concentrated 65 % HCl: HNO_3 (Merck) using a hotplate, till clear solution was obtained. Digested samples were allowed to cool off at room temperature and then acidified with 10 ml of 1:1 mixture of HCl: H_2O and filtered through 0.45 micron filter paper and the volume made up to 50 ml with distilled water. The filtrate was transferred to clean dry plastic bottles awaiting heavy metal concentration analysis using Atomic Absorption Spectrophotometer Version 200.

3.3 Quality Control

Appropriate quality assurance procedures and precautions were observed to ensure the reliability of results. Samples were carefully handled to avoid contamination. Glass ware was properly cleaned and reagents were of analytical grade. De-ionised water was used throughout the sample preparation and analysis (Cui *et al*., 2010). Reagent blank determinations were used to correct the readings. All samples were analyzed in duplicate and three quality control samples consisting of: reagent blank, sample duplicate and spiked sample were run for every batch of five samples. Mean fractional recoveries were satisfactory being in excess of 90% for the analyzed selected metals (Lead, Cadmium and Chromium).

3.4 Data Analysis

Analysis using One Way analysis of variance (ANOVA) test was carried out to examine the statistical significance of differences in mean concentrations of heavy metals in the fruits (oranges and mangoes) vis a vis market sites using SPSS version 16. A probability level of $P<0.05$ was considered significant.

3.5 Exposure and Risk Assessment

Exposure of consumers to potential related health risks arising from uptake of heavy metals in fresh fruits is usually expressed as Provisional Tolerable Daily Intake (PTDI), a reference value established by joint FAO/WHO. The FAO/WHO has set limits for heavy metal intake based on body weight for an average adult (70 kg body weight for males and 60 kg body weight for females). PTDI for Pb, Cd and Cr are 180 µg, 60 µg and 200 µg, respectively (FAO/WHO, 2012).

Based on the average concentration and the average consumption of fresh fruits consumed by an adult in a day, estimates of amount of each heavy metal consumed was calculated. An assessment of health risk posed to human beings through consumption of contaminated fresh fruits was done by comparing concentrations of the heavy metals in the sampled fresh fruits with FAO/WHO 2012 limits. The daily intake of heavy metals through the consumption of the fresh fruits was calculated (Cui *et al*., 2010).

3.6 Hazard Quotient

Potential health risk posed by selected elevated heavy metal concentrations in fresh fruits are characterized by hazard quotient values (HQ). This is a ratio of heavy metal dose present in food in conformity to reference dose (R_fD). Consumers of fresh fruits will be at no health risk if this ratio is less than 1 and they will be vulnerable to health risks when the ratio is equal to or greater than 1 (Wang *et al*., 2010 and Cui *et al*., 2010). The expression used to calculate hazard quotient is expressed as:

$$HQ = \frac{DIM}{R_fD}$$

Where: HQ = Hazard Quotient
DIM = Daily Intake of Metals (mg/kg)
R_fD = Reference Dose (mg/kg)

3.7 Daily intake of metals (DIM)

There was need to quantify daily intake of heavy metals from fresh fruits consumed by residents of Eldoret town in comparison to those given by WHO (2012). Daily intake of metals (DIM) was calculated using the following equation (Sajjad *et al*., 2009).

$$DIM = \frac{(P)X(Q)X(R)}{B}$$

Where: DIM = Daily intake of Metals (mg/kg)
P = Heavy metal concentrations in fruits (mg/kg)
Q = Conversion factor= 0.085. The ratio is used to convert fresh fruit wet weight to dry fruit
R = Daily Intake of fruit in kg
B = weight of a person in kg (Male adult=70kg, female adult =60kg.

3.8 Response dose (R_fD)

Maximum allowable daily intake of heavy metals through food is provided by provisional Daily Intake (PTDI) for heavy metal intake based on body weight of average human being as provided in table 3 below (FAO/WHO, 2012).

Table 2: PTDI of selected heavy metals
Source: FAO/WHO, 2012

Heavy metal	Amount in mg/day
Lead	0.18
Cadmium	0.06
Chromium	0.2

CHAPTER FOUR

RESULTS

4.1 Lead levels in Oranges and Mangoes

4.1.1 Lead levels in Oranges

Lead levels in oranges sold in Eldoret town had significant variance in mean levels among sampling sites (f=13.33, df=3, p=0.00), (Appendix 1). Mean Pb levels were significant in oranges sampled between sites A and C (q=4.142, p=0.000); sites B and C (q=6.18, p=0.000) and sites C and D (q=2.990, p=0.017). Oranges sampled from site B had the highest mean level of Pb at 0.651±0.032 mg/kg, followed by those from site A at 0.581±0.017 mg/kg. Pb levels in oranges from site D had the third highest level of Pb at a mean of 0.542±0.022 mg/kg, with those from site C with the least mean level at 0.439±0.024 mg/kg respectively (Table 3, Figure 2). Oranges from site B had the highest range value of Pb levels at 0.629 mg/kg followed by sites D, C and A at 0.542 mg/kg, 0.477 mg/kg, 0.326 mg/kg, respectively.

Table 3: Lead levels in Orange fruits

Sampling Site	Mean level (mg/kg)	Std. Error (mg/kg)	Minimum level (mg/kg)	Maximum level (mg/kg)	Range level (mg/kg)
A	0.581	0.017	0.409	0.735	0.326
B	0.651	0.032	0.355	0.984	0.629
C	0.439	0.024	0.222	0.699	0.477
D	0.542	0.022	0.282	0.824	0.542

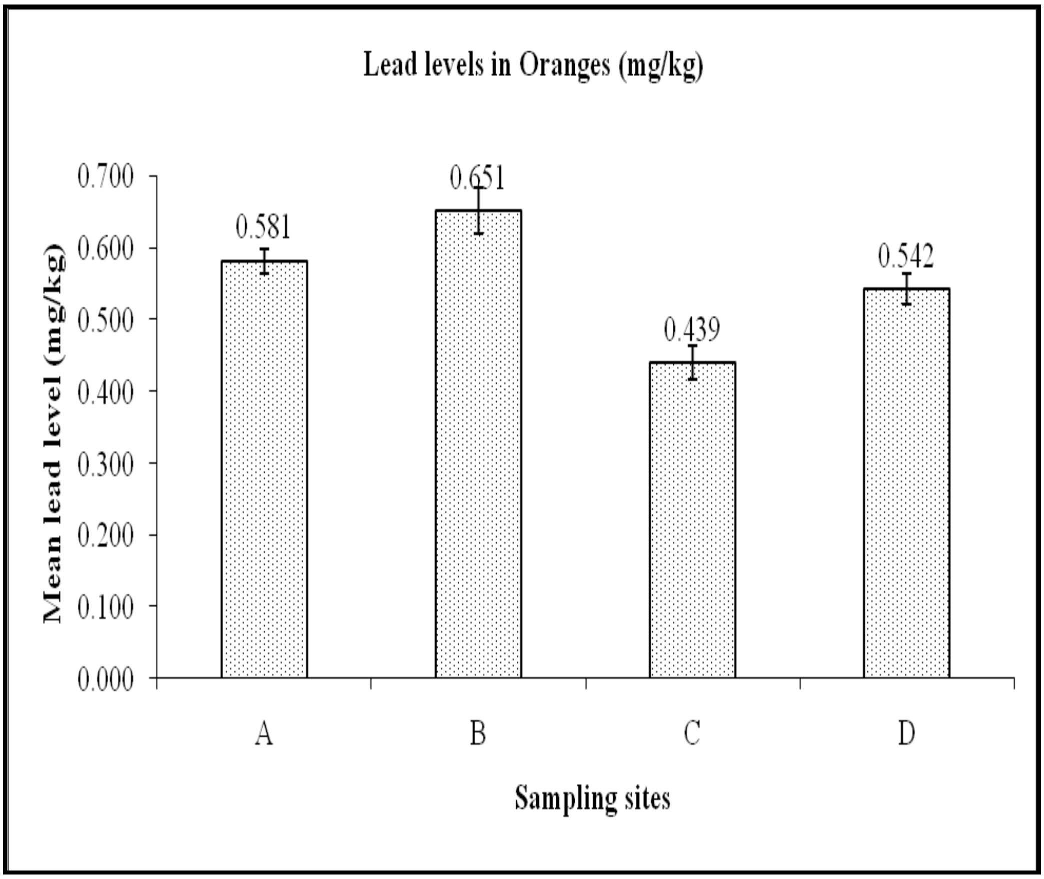

Figure 2: Lead levels in Orange fruits

4.1.2 Lead levels in Mangoes

Lead levels in mangoes had significant variance in mean concentrations among sampled sites in Eldoret town (f=21.87, df=3, p=0.000) (Appendix 2). Mean lead levels were significant in mangoes sampled between sites A and B (q=5.251, p=0.000); site A and C (q=7.844, p=0.000) and site A and D (q=5.437, p=0.017). Mangoes sampled from market site A had highest mean level of lead at 0.606±0.039 mg/kg, followed by site B at 0.409±0.023 mg/kg, site D had a mean level of 0.403±0.019 mg/kg, with site C at 0.313±0.020 mg/kg, respectively (Table 4, Figure 3). Mangoes from site A had the highest range of lead levels at 1.007 mg/kg followed by 0.659 mg/kg, 0.603 mg/kg and 0.479 mg/kg respectively in sites B, D and C.

Table 4: Lead levels in Mango fruits

Sampling Site	Mean level (mg/kg)	Std. Error (mg/kg)	Minimum level (mg/kg)	Maximum level (mg/kg)	Range level (mg/kg)
A	0.606	0.039	0.155	1.162	1.007
B	0.409	0.023	0.159	0.818	0.659
C	0.313	0.020	0.037	0.640	0.603
D	0.403	0.019	0.147	0.626	0.479

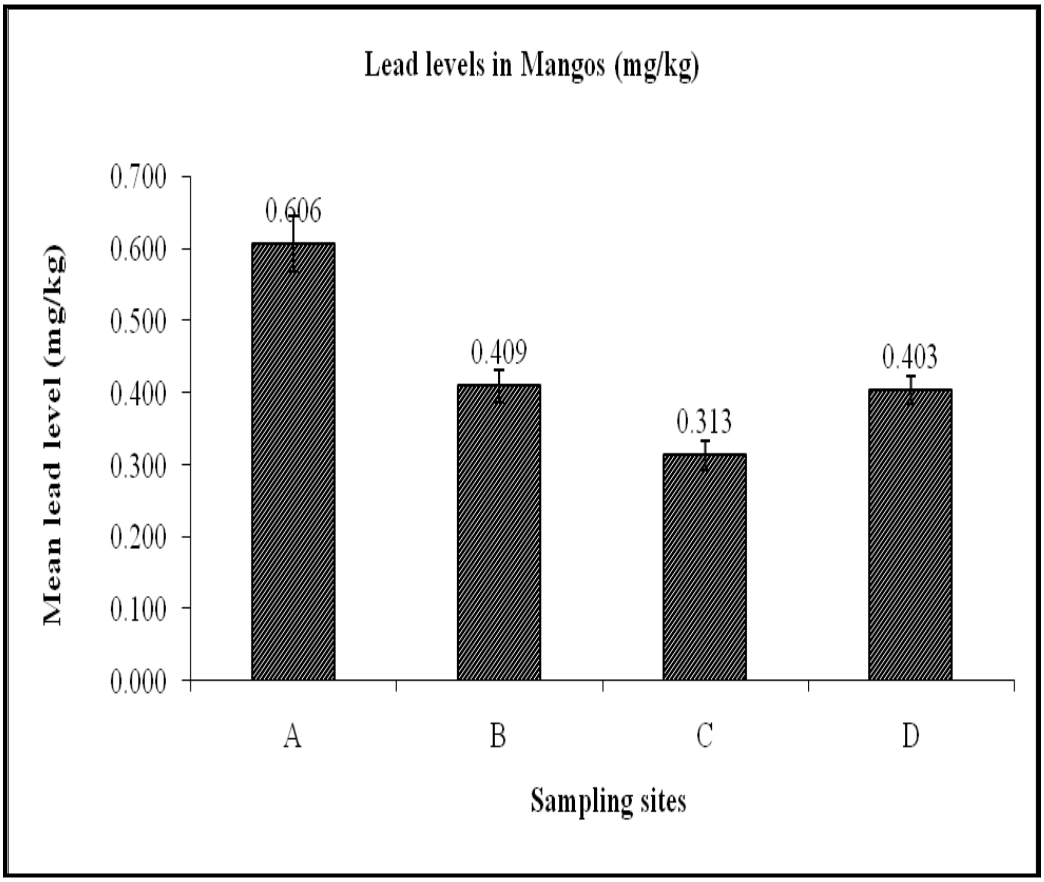

Figure 3: Lead levels in Mango fruits

4.2 Cadmium levels in Oranges and Mangoes

4.2.1 Cadmium levels in Oranges

Cadmium levels in oranges had no significant variance in mean concentrations among sampling sites in Eldoret town (f=1.848, df=3, p=0.141) (Appendix 3). Oranges sampled from site B had the highest mean cadmium level at 0.057±0.004 mg/kg, oranges from site C, A and D had mean cadmium levels at: 0.052±0.004 mg/kg, 0.048±0.003 mg/kg, 0.046±0.003 mg/kg, respectively (Table 5, Figure 4). Oranges from site B showed the highest range values of cadmium levels at 0.11 mg/kg followed by 0.084 mg/kg, 0.076 mg/kg and 0.064 mg/kg in oranges sampled from sites: C, A and D, respectively.

Table 5: Cadmium levels in Orange fruits

Sampling Site	Mean level (mg/kg)	Std. Error (mg/kg)	Minimum level (mg/kg)	Maximum level (mg/kg)	Range level (mg/kg)
A	0.048	0.003	0.012	0.096	0.084
B	0.057	0.004	0.027	0.137	0.11
C	0.052	0.004	0.018	0.094	0.076
D	0.046	0.003	0.015	0.079	0.064

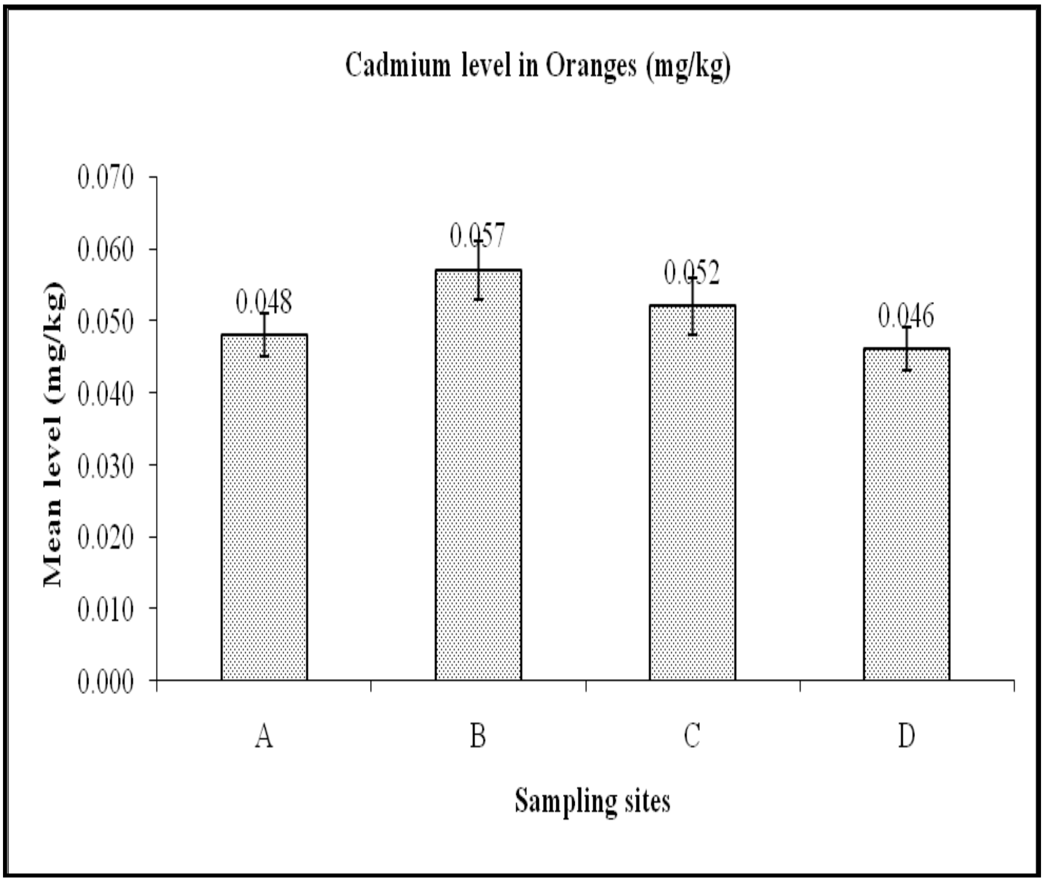

Figure 4: Cadmium levels in Orange fruits

4.2.2 Cadmium Levels in Mangoes

Cadmium levels in Mangoes had significant variance in mean levels among sampling sites in Eldoret town (f=6.5, df=3, p=0.00), (Appendix 4). Mean cadmium levels were significant in mangoes sampled between site A and C (q=4.092, p=0.00); sites A and D (q=2.700, p=0.000) and sites B and C (q=3.051, p=0.015). Mangoes sampled from site C had highest mean level of cadmium at 0.089±0.051 mg/kg, followed by those sampled from sites: D, B and A at 0.081±0.004 mg/kg, 0.072±0.002 mg/kg, and 0.066±0.005 mg/kg, respectively (Table 6, Figure 5). Mangoes sampled from site A exhibited the highest range in levels of cadmium at 0.091 mg/kg with those sampled from sites A, B and C having range values of 0.083 mg/kg, 0.053 mg/kg and 0.036 mg/kg, respectively.

Table 6: Cadmium levels in Mango fruits

Sampling Site	Mean level (mg/kg)	Std. Error (mg/kg)	Minimum level (mg/kg)	Maximum level (mg/kg)	Range level (mg/kg)
A	0.066	0.005	0.005	0.096	0.091
B	0.072	0.002	0.054	0.137	0.083
C	0.089	0.005	0.041	0.094	0.053
D	0.081	0.004	0.043	0.079	0.036

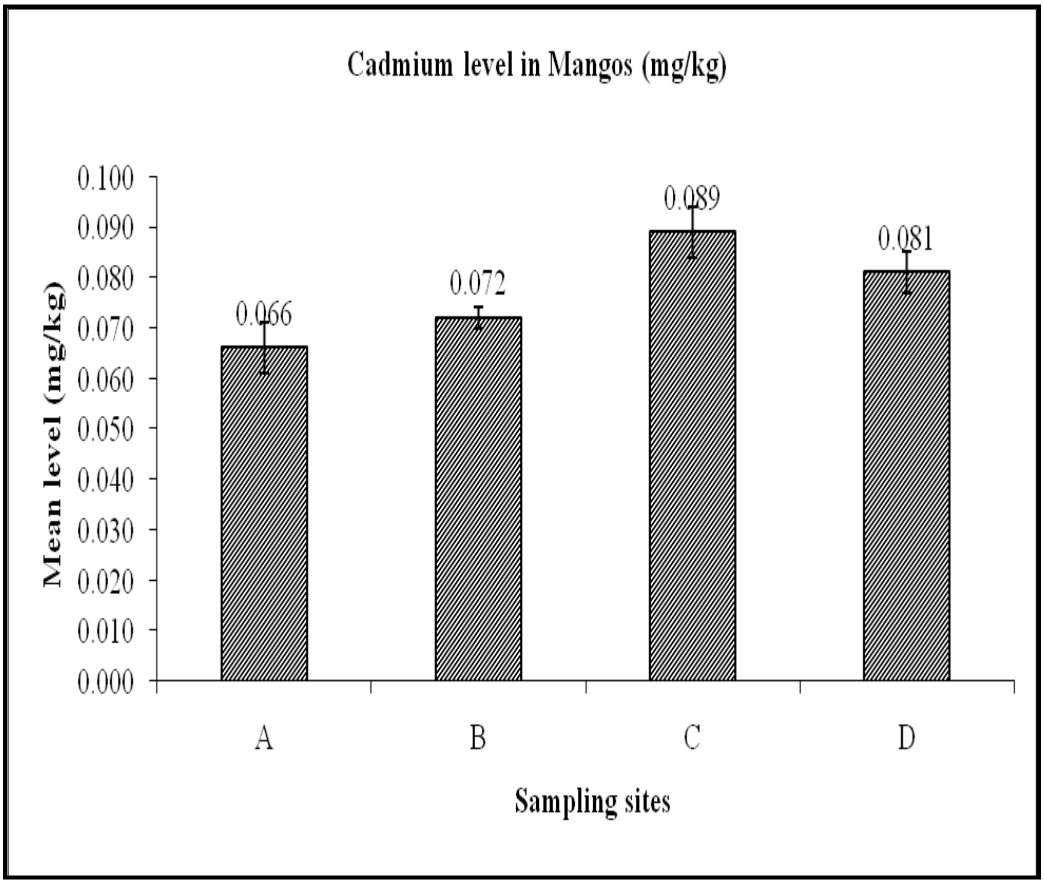

Figure 5: Cadmium level in Mango fruits

4.3 Levels of Chromium in Oranges and Mangoes

4.3.1 Chromium levels in Oranges

Chromium levels in sampled orange fruits had significant variance in mean concentrations among sites in Eldoret town (f=3.5, df=3, p=0.018), (Appendix 5). Mean Chromium levels were significant in oranges sampled between sites A and B (q= 2.62, p=0.048); sites A and D (q=2.69, p= 0.040). Oranges sampled from site A had the highest mean chromium level at 1.741±0.060 mg/kg, followed by levels in oranges from sites: C, B and D at 1.620±0.086 mg/kg, 1.402±0.097 mg/kg and 1.393±0.115 mg/kg, respectively (Table 7, Figure 6). Orange fruits sampled from site D had the highest chromium level range at 3.261 mg/kg with those from sites C, B and A having 2.253 mg/kg, 2.246 mg/kg and 1.537 mg/kg, respectively.

Table 7: Chromium level in Orange fruits

Sampling Site	Mean level (mg/kg)	Std. Error (mg/kg)	Minimum level (mg/kg)	Maximum level (mg/kg)	Range level (mg/kg)
A	1.741	0.060	0.947	2.484	1.537
B	1.401	0.097	0.319	2.565	2.246
C	1.619	0.086	0.421	2.674	2.253
D	1.393	0.115	0.353	3.614	3.261

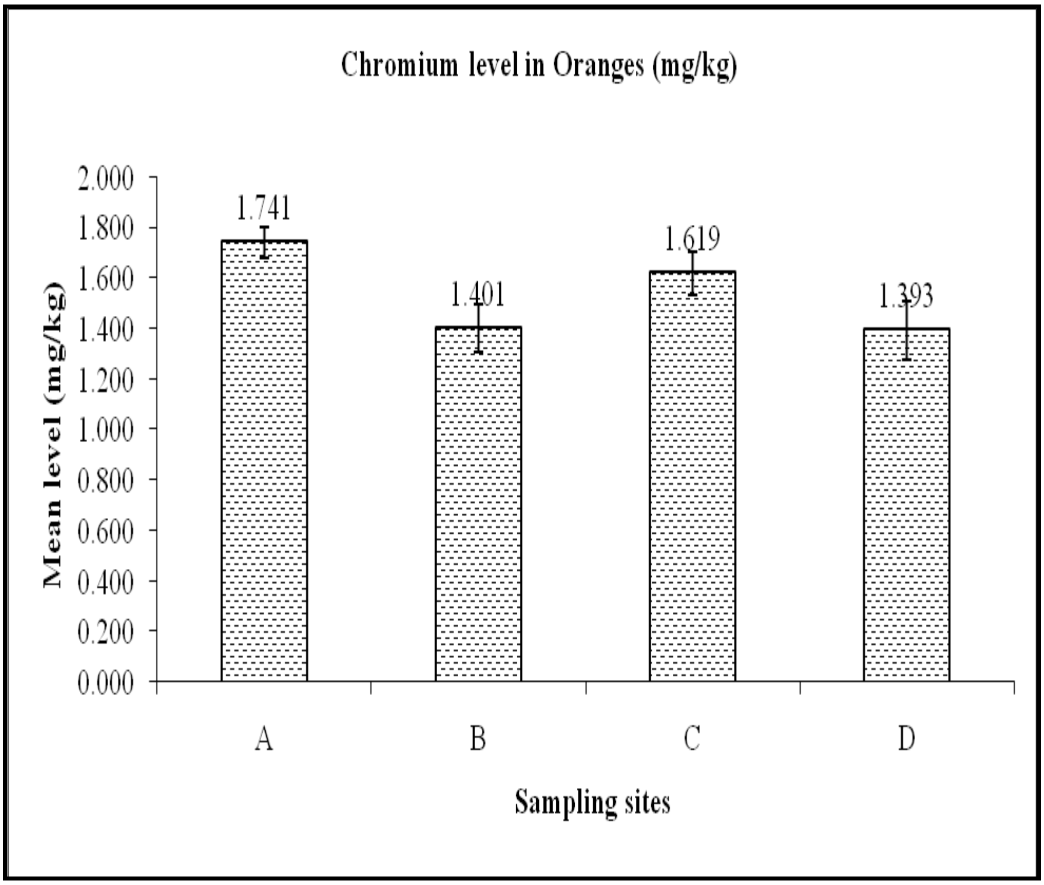

Figure 6: Chromium levels in Orange fruits

4.3.2 Chromium levels in Mangoes

Chromium levels in mangoes had no significant variance in mean concentrations among sampling sites in Eldoret town (f=2.14, df=3, p=0.10), (Appendix 6). Mangoes sampled from site D had highest mean level of chromium at 2.429±0.243 mg/kg, followed by levels in mangoes from site C, B and A at 2.283±0.149 mg/kg, 2.014±0.145 mg/kg and 1.915±0.054 mg/kg, respectively (Table 8, Figure 7). Mango fruits sampled from site D exhibited the highest range value of 6.163 mg/kg with those from sites C, D and A having range values of 3.616 mg/kg, 3.192 mg/kg and 1.55 mg/kg in sites, respectively.

Table 8. Chromium levels in Mango fruits

Sampling Site	Mean level (mg/kg)	Std. Error (mg/kg)	Minimum level (mg/kg)	Maximum level (mg/kg)	Range level (mg/kg)
A	1.915	0.054	1.258	2.808	1.550
B	2.014	0.145	0.166	3.358	3.192
C	2.283	0.149	0.788	4.404	3.616
D	2.428	0.243	0.043	6.206	6.163

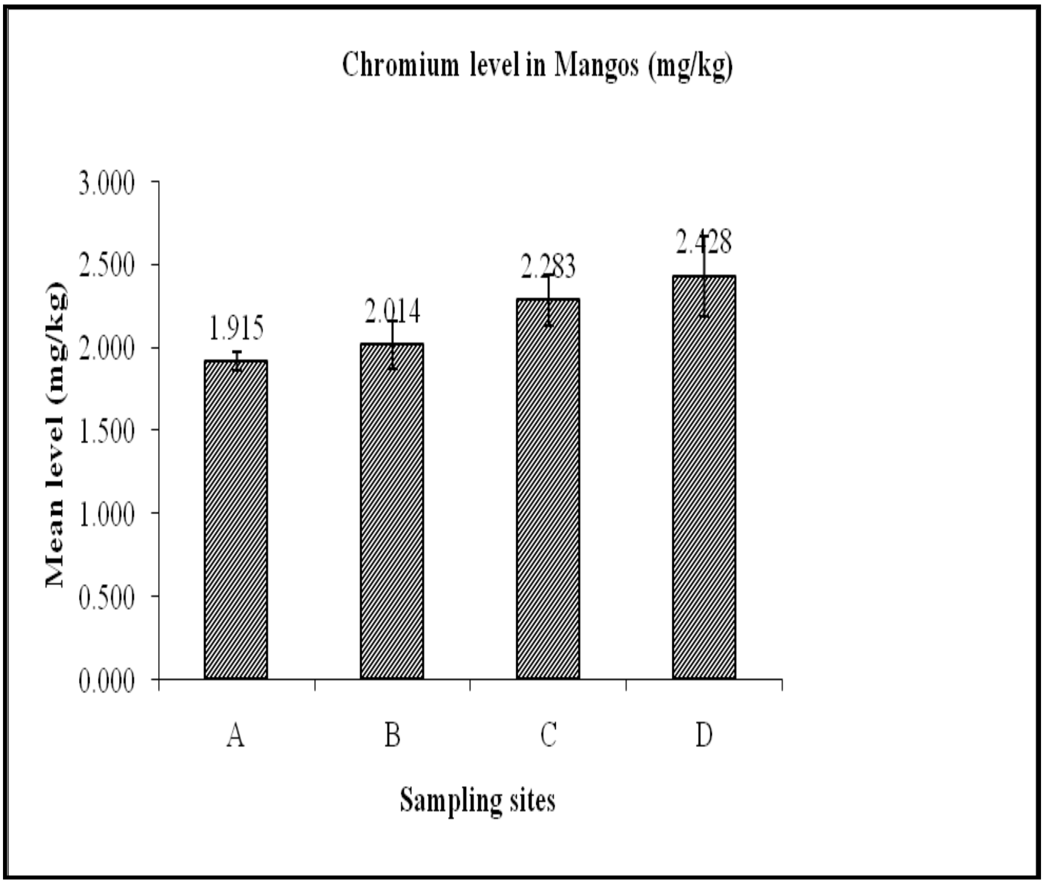

Figure 7: Chromium Levels in Mango fruits

4.4 Risk Assessment of heavy metal intake from fresh fruits

Risk assessments for uptake of selected heavy metals from the fruits by adults were calculated based on the Provisional Daily Tolerable Intake model **(**Cui *et al*., 2010).

$$\text{Daily intake of heavy metals (mg/day)} = \frac{A*B*C}{D}$$

Where: A= Daily fresh fruit consumption (kg)
B= Fresh fruit heavy metal concentration (mg/kg)
C= 0.085, Conversion factor of wet-weight to dry-weight.
D= Average weight of a person (kg).

Assumption used in this model was that an adult average weight is at 70kg and eats 250 grams wet-weight of either fruit per day on average. The computed values of Daily Intake of heavy metals (D.I.M) was compared to Provisional Tolerable Daily Intake (P.T.D.I) values provided for each metal according to FAO/WHO, 2012 standards to ascertain if there was health risk due to consumption of the fruits. There was a concern of a health risk if the D.I.M values surpassed the P.T.D.I levels and no concern of health risk when D.I.M values were within P.T.D.I levels.

4.4.1 Risk Assessment of Chromium in fresh fruits

In this study, Chromium as a selected heavy metal exhibited the highest DIM in mango fruits (0.05 mg/day) compared to orange fruits (0.04 mg/day), (Table 9, Figure 8). The highest D.I.M occurred in mangoes sampled from site C (0.05 mg/day) whereas the highest D.I.M in oranges was recorded in sampling site C (0.04 mg/day). The lowest D.I.M level in mango fruits occurred in samples from sites A and B with the lowest D.I.M in orange fruits occurring in sampling sites B and D at 0.03 mg/day.

Table 9: Chromium D.I.M values of fruits

	Daily Intake of Chromium Metal (mg/day) per fruit		Maximum Daily Intake, mg/day (WHO, 2012)
Sampling site	**Orange**	**Mango**	
A	0.04	0.04	0.2
B	0.03	0.04	0.2
C	0.04	0.05	0.2
D	0.03	0.05	0.2

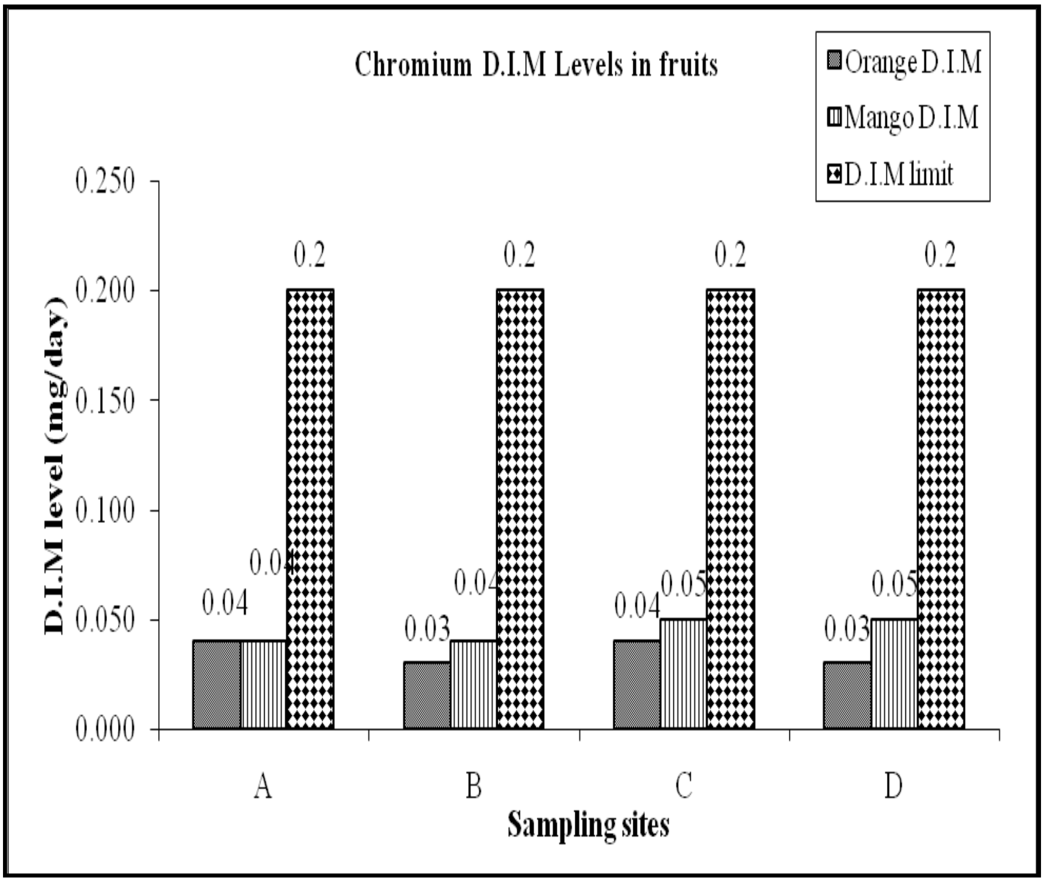

Figure 8: Chromium D.I.M levels in fruits

4.4.2 Risk Assessment of Lead in fresh fruits

Lead as a selected heavy metal exhibited the highest D.I.M in sampled orange fruits (0.02 mg/day) compared to sampled mango fruits (0.013 mg/day), (Table 10, Figure 9). The highest D.I.M level occurred in orange fruits from sampling site B (0.02 mg/day) whereas highest D.I.M levels in mango fruits was recorded in sampling site A (0.013 mg/day). The lowest D.I.M level in orange fruits occurred in samples from sites A, C and D (0.01 mg/day) with the lowest D.I.M levels in mango occurring in sampling sites B, C and D (0.008 mg/day).

Table 10: Lead D.I.M values of fruits

	Daily Intake of Metal (mg/day) per fruit		**Maximum Daily Intake, mg/day (WHO, 2012)**
Sampling site	**Orange**	**Mango**	
A	0.01	0.013	0.18
B	0.02	0.008	0.18
C	0.01	0.008	0.18
D	0.01	0.008	0.18

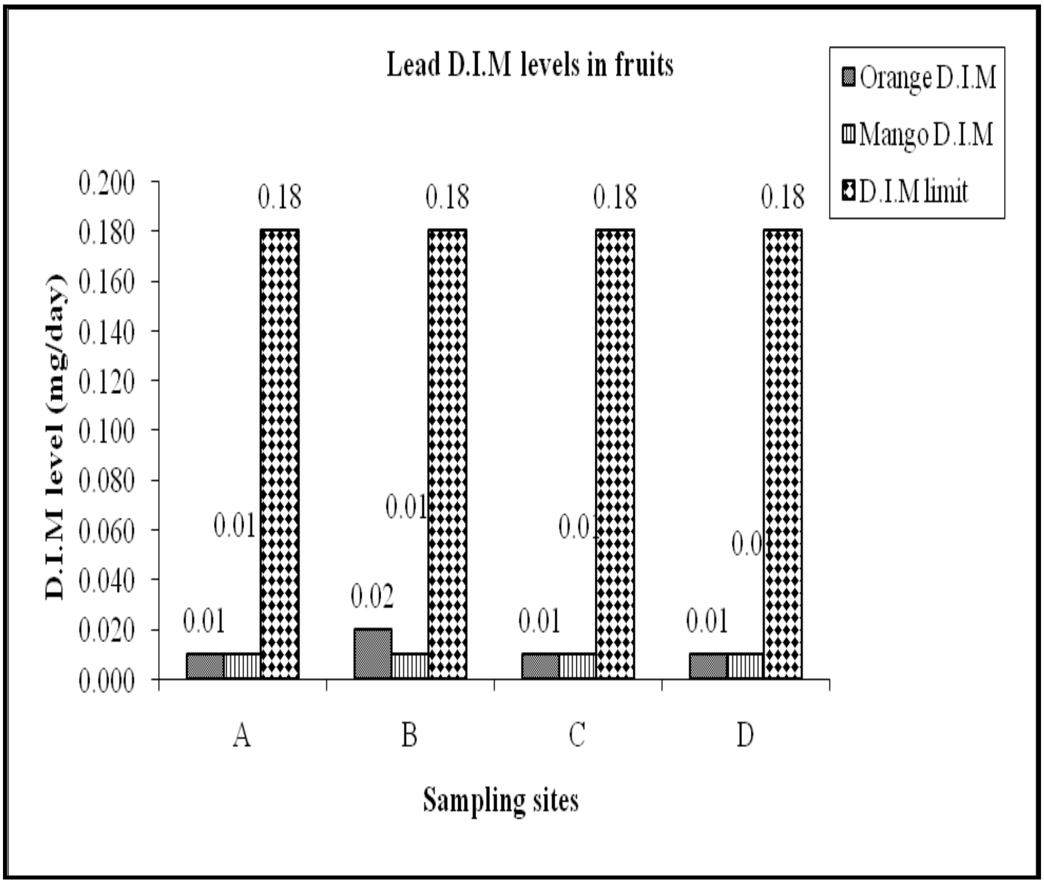

Figure 9: Lead D.I.M levels in fruits

4.4.3 Risk Assessment of Cadmium in fresh fruits

Cadmium exhibited the highest D.I.M levels in mango fruits (0.002 mg/day) compared to mango fruits (0.001 mg/day) (Table 11, Figure 10). D.I.M level of 0.002 mg/day was reported in all mango fruit samples in all sampling sites whereas a value of 0.001 mg/day was reported in orange fruits from all sampling sites.

Table 11: Cadmium D.I.M values of fruits

	Daily Intake of Metal (mg/day) per fruit		**Maximum Daily Intake, mg/day (WHO, 2012)**
Sampling site	**Orange**	**Mango**	
A	0.001	0.002	0.06
B	0.001	0.002	0.06
C	0.001	0.002	0.06
D	0.001	0.002	0.06

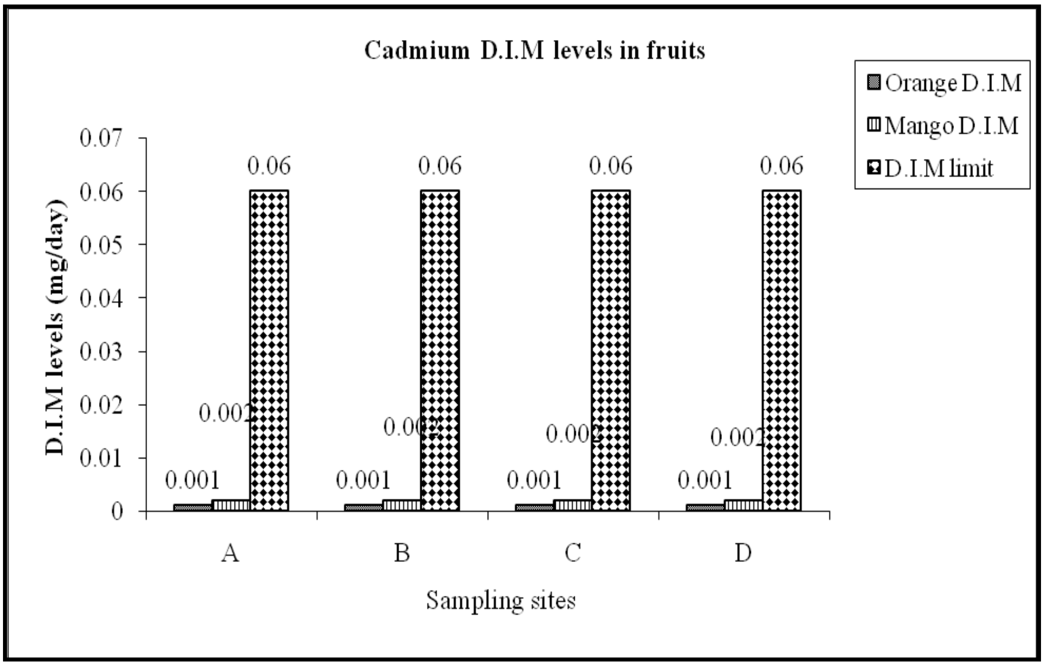

Figure 10: Cadmium D.I.M levels in fruits

CHAPTER FIVE

DISCUSSION

5.1 Chromium levels and health risk in Mangoes and Oranges

The highest daily intake of chromium metal based on average concentration level was 0.05 mg/day from mango fruits in this study. This level was within the recommended P.T.D.I standard of 0.2 mg/day (WHO, 2012). This D.I.M value indicated that consumers in Eldoret town were not at a health risk due to uptake of chromium levels in mangoes and oranges. Elevated chromium levels in mango fruits compared to lower levels in orange fruits sampled could be hypothesized to the fact that mangoes and oranges sold in Eldoret town could have originated from different ecological regions. Different environmental conditions under which these fruits are grown could have different impacts on the uptake of heavy metals from the soil to deposition levels in mango fruit plant.

In agreement with this study, Erum *et al*., (2009) in a study of market basket survey of selected metals in fruits from Karachi city in Pakistan found out that chromium metal exhibited high concentrations in mango fruits at an average value of 4.09 mg/kg whereas this present study had the highest chromium concentration in mangoes at 2.42 mg/kg. Studies by Erum *et al*., (2009) and Lou *et al*., (2009) single out mango fruit having the highest levels of chromium compared to other fruits under study. This difference in chromium level between mangoes and oranges could be attributed to specific levels of the metal in the specific environments in which these fruits are grown. Lou et *al*., (2009) reported that chromium was a heavy metal of concern in food crops as it is the most bio-available element in soil uptake and subsequent deposition to plant parts including fruits.

Subsequently, the higher chromium levels in mango fruit sampled could be attributed to the specific high affinity of mango fruit to uptake of chromium in mango plant compared to orange fruits. In concurrence with this study, Malekil and Masoud (2008) reported elevated average levels of chromium in tarragon, an edible vegetable at a mean value of 7.90±1.05 mg/kg in a study conducted in Iran. The authors reported that consumers were at a health risk of consuming the vegetable since the daily intake of 1.72 mg/day of chromium surpassed the recommended level of 0.2 mg/day by a factor of 8.6 times. The source of chromium contamination in the study was singled out to be due to use of waste water for vegetable farming.

Use of cheap municipal sewage sludge as an alternative to synthetic fertilizers is a source of chromium metal to the environment to plant uptake and subsequent deposition to fruit plants. George *et al*., (2011) reported high levels of chromium in municipal sewage sludge than yard manure. As a result, chromium levels were greater in sweet potato plants grown in a mixture of both municipal sewage sludge and yard manure (though within recommended levels) compared to the levels in soils without sewage sludge and yard manure. This supports the present study in which the high levels of chromium in mango and orange fruits.

George *et al*., (2011) attribute potential bioaccumulation and mobility of heavy metals from municipal sewage sludge into growing plants could increase the potential transfer of heavy metals through crops to animals and humans. Ogunlade and Agbeniyi (2010) reported high levels of chromium content in areas where cocoa is grown in Nigeria. The levels of chromium in the soil varied between 0.88 to 1.3 mg/kg. The critical aspect in this study was that two critical sources of chromium to uptake by cocoa plants were noted to be use of pesticides and fertilizers in growth of the plants.

Safety of pesticides and fertilizers in relation to levels of heavy metals should be a concern as the products are critical in provision of food crops. Ingestion of food and drinks accounts for main source sof exposure of chromium to man. About 0.4% to 1.2% of total chromium content in human body is absorbed through small intestines to blood stream which is then distributed to all parts of the body, passing through the kidney and eliminated in urine. Chromium in its trivalent form has been known to exhibit very low toxicity and not known to cause cancer. Hexavalent form of chromium is known to be toxic and can cause cancer if it is inhaled. The consequences of ingesting hexavalent chromium are damages to nose lining and irritation of lungs and gastrointestinal tract. When swallowed, chromium inflicts damages to the stomach, liver and kidneys.

5.2 Lead levels and health risk in Mangoes and Oranges

The highest daily intake value of lead of 0.02 mg/day from oranges was within the recommended level of 0.18 mg/day (WHO, 2012). Consumers in Eldoret town are not at a health risk due to elevated levels of lead in terms of concentration levels in the fresh fruits under study. The elevated levels of lead in oranges as compared to mangoes could be as a result of growing the fruit crops in areas with high levels of lead in the soil and high specific affinity of lead uptake by orange fruits. In agreement to this study, Uboh *et al*., (2011) reported high lead contamination levels in fluted pumpkin leaves grown in close proximity to traffic highways in Lagos, Nigeria. Lead which was in the past a major constituent of exhaust fumes from machineries, it was expected that its deposition was magnified in food items sold or grown within the vicinity of areas that it is emitted with high traffic density. Due to improvement of current technology in which lead in fuel has been reduced significantly, high levels of this element in food crops can be majorly attributed to its uptake of lead contaminated soils.

Aweng *et al*., (2010) reported that the level of lead in fruits ranged from 0.63 to 8.71 mg/ kg in mango (*Mangifera indica*), seedless guava (*Psidium guajava*) and papaya (*Carica papaya*) which were grown on agricultural and ex-mining lands of Bidor, Malaysia. Lead content of guava collected from ex-mining land was shown to have about 17 fold greater than the permissible lead limit. The elevated concentration of lead in the fruits could have resulted from direct contacts with contaminated source of ex-mining land with an extreme acidic soil conditions with pH <3.0 facilitating abundance and uptake of lead in the fruit plants.

In agreement with Aweng *et al*., (2010), Wang *et al*., (2010) reported estimated daily intake of heavy metals in vegetables and rice grown on an ex-mining land in south China to having elevated values of lead above the recommended health standards. The inhabitants consuming food crops from this region were estimated to have a daily intake of lead of 0.516 mg/day above the recommended level of 0.18 mg/day. This was 2.9 times above the recommended limits, thus being more vulnerable to lead toxicity. The high uptake of lead in vegetables compared to rice was attributed to high affinity of vegetable plants to lead uptake than rice.

The same aspect can be inferred to this present study that reported high lead levels in oranges than mango fruits. Lead has been known to have several toxicological effects to the human system. Upon exposure to human body, lead is absorbed and distributed to target organs systematically. Within soft tissues lead is distributed rapidly as opposed to slow distribution within the skeletal system (WHO, 2012). Toxicity arising from lead depends critically on dose quantity reaching the system and organs of target; therefore mode of toxicity is clearly distinctive between groups of population as evident between children and adults.

Environmental Protection Agency (EPA) of United States classifies lead as a probable human carcinogen that targets a wide array of human organs and systems (ISHS, 2001). Young children and the unborn are the most vulnerable group to lead toxicity that is neurological in nature. Several studies do indicate even at low doses of exposure within a range of 5-25 μg/dL in blood among children less than five years, lead toxicity is associated with low Intelligence Quotient marks (WHO, 2012; Carlisle, 2009).

Studies have demonstrated that lead stored within a mother's bone skeletal system undergoes mobilization which is then transmitted to the young and unborn during pregnancy and lactation. Low calcium intake correlates with high lead intake and availability. During stages of lactation and pregnancy calcium is very vital in formation of bones of the young children. A situation whereby a mother has a low calcium content means that lead in large doses will be passed on to the young. The provisional tolerable intake of 3.57 μg/kg body weight per day is recommended for all age groups for the derivation of human health soil quality guidelines for lead (WHO, 2012).

5.3 Cadmium levels and health risk in Mangoes and Oranges

The highest level of cadmium occurred in mango fruits at 0.089±0.051 mg/kg compared to the highest level of 0.057±0.004 mg/kg reported in orange fruits. The highest daily intake of cadmium of 0.02 mg/day in mangoes was within the recommended standards of 0.06 mg/day (WHO, 2012). Therefore consumers were not at a health risk as a result of consuming oranges and mangoes at these levels of cadmium. Different levels of cadmium between the highest and lowest in mangoes in this study could be explained to be due to different affinity of specific fruit plants to specific heavy metal uptake (Wang *et al*., 2010). In agreement to this study, Wang *et al*., (2010) provided estimates of health risks of residents in South China who consumed rice and vegetables on an ex-mining land. They reported that the inhabitants were exposed to an elevated average D.I.M level of cadmium (0.4 mg/day) intake in comparison to the maximum allowed level (0.06 mg/day), which was six times above the recommended level. These residents were at health risk due to heavy metals that had been absorbed from the soils and into food crops, a study that showed importance of the level of heavy metals in the environment and how this affects subsequent uptake and deposition in food crops.

Rice crop in this study had been shown to have a high affinity to uptake of cadmium in the soil and subsequent deposition to the edible grain part as compared to leafy low affinity in uptake of cadmium in leafy vegetables (Antonius and Synder, 2007). Cadmium levels in mangoes and oranges sold in Eldoret town could be from multiple sources of environmental pollution of heavy metals in the environment in which these fruit plants are grown. In agreement to this, several studies have reported different values of cadmium in food crops due to uptake from the soil environment.

Further in support of the current study, Saeid *et al*., (2012) reported concentrations of 1.8 mg/kg of cadmium in oranges and 2.14 mg/kg in mangoes collected in India city market with high concentrations of 15.39 mg/kg of cadmium in oranges and 16.9 mg/kg in mangoes collected at Yeshwantur market. Fruits sourced from Yeshantupur market had high concentration of heavy metals due to a combination of several environmental factors including uptake from soil due to use of fertilizers, use of waste water and pesticides in fruit farming. In the same study and the current study, the two reports gave high levels of cadmium in mango fruits than in orange fruits, a further indication that specific fruit plants (mangoes and oranges) have specific affinity to uptake of cadmium and deposition in edible fruit parts. High levels of cadmium were attributed to factors like growing of food on contaminated soils, atmospheric pollution and use of synthetic fertilizers.

The International Agency for Research on Cancer (IARC) classifies cadmium as a human carcinogen group 1. Data from animal experiments have indicated that under certain exposure conditions cadmium induces hypertension in animals. Toxicity of cadmium is enhanced in human body through the inability of excretion system to completely eliminate it. Doses of higher magnitude upon exposure leads to severe respiratory irritation and is cited as a risk factor for chronic lung diseases and testicular degeneration leading to prostate cancer (Almasiova *et al*., 2012; WHO, 2012). Doses of lower magnitude are a major concern to kidney toxicity. Cadmium has been reported to be responsible for structural deformation of proximal tubules of nephrons, a critical functional unit to kidney functioning.

This is manifested at onset of leakage of low molecular weight proteins and ions like calcium as analyzed through their concentrations in urine. This situation degenerates to a severe condition of total kidney failure that is irreversible known as frank kidney failure (Satarug *et al*., 2000).

Studies in Japan during World War II linked frank kidney failure condition to exposure of cadmium through consumption of rice grown on contaminated land. This led to conditions of increased risk of bone fractures in women as well as decreased bone density and height loss a condition hypothesized from demineralization and compression of vertebrae (Satarug *et al*., 2000). Joint Codex Alimentarius Commission stipulates that recommended maximum levels of cadmium in both fruity and leafy vegetables at 2.3 mg/kg dry weight. Therefore cadmium levels in sampled fruits in Eldoret town differed in concentrations due to different environments that these specific fruits are grown and the specific uptake affinity by the fruit plants to cadmium from soil.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

This study showed that orange fruits had elevated exposure levels of lead compared to mango fruits exceeding the recommended level of 0.3 mg/kg as provided by FAO/WHO Standards. However, there was no health risk due to lead uptake as the highest Daily Intake of Metal in lead was reported of 0.02 mg/day compared to the maximum level at 0.18 mg/day. Mango fruits exhibited the highest levels of chromium compared to orange fruits with a mean level of 2.428 mg/kg. The order of heavy metal occurrence in both orange and mango fruit followed the order: chromium>lead>cadmium. Based on estimated Daily Intake of Metal values to ascertain if a health risk existed due to consumption of fruits, there was no potential health risk concern for all analyzed heavy metals. The D.I.M values in this study were within the recommended levels as provided for by FAO/WHO standards.

Chromium levels in sampled fruits was of concern among the heavy metals analyzed, though it did not exceed the safe exposure limits as provided for in the food standards. Based on critical literature review, elevated chromium levels in fruits are significantly contributed by uptake of chromium from soil to the plants during growth of the plants. Therefore the environments under which these fruit produces are grown seem to be rich in Chromium concentration.

6.2 Recommendations

1. There is need to conduct a correlation study between the levels of heavy metals in fruits to that present in soils in which these fruits are grown. This information is vital especially to specialists in crop production who will device best crop farming practices, and disseminate to relevant stakeholders so that safety of fresh fruits is catered for the final consumers.

2. The government should set up robust bio-monitoring programs similar to those in developed countries whose main mandate is to ensure the safety of food products consumed by the public irrespective of the area of origin. This body will continuously assess safety of food products in regard to toxicants like heavy metals and pesticides residues.

REFERENCES

Afolami. I., Anyakora. C., Ebuehi, O. and Bolawa, O. (2010). Lead levels in some edible vegetables in Lagos, Nigeria. *Scientific Research and Essays.* No.5, Vol.8: 813-818.

Ahmedin, J., Freddie, B., Melissa, M., Ferlay, M., Elizabeth, W. and David, F. (2011). Global Cancer Statistics. *Journal of Clinical Cancer.* Vol.61: 69–90.

Almášiová, V., Agneša L., Katarína, H., Viera, C. and František, N. (2012). Effect of Lifetime Low Dose Exposure to Cadmium on Lipid Metabolism of Wistar Rats. *Journal of Microbiology, Biotechnology and Food Sciences*. Vol 2. 293-303.

Ammar, Z., Ali, Y., Mac, J.M., Fatnul,S., Mohd, N., Abu, H. and Latifa, M. (2012). Improved Maturity and ripeness classification of *Mangifera indica* cultivar. Hurumanes mango through sensor fusion of an electronic acoustic sensor. *Journal of censors.* Vol.12: 6023-6048.

Amusan, A., Ige1, V. and Olawale, R. (2005). Characteristics of Soils and Crops Uptake of Metals in Municipal Waste Dump Sites in Nigeria. *Journal of Human Ecology.* No 17, Vol.3: 167-171.

Angela, S. and Lee, D. (2012). Effects of banana plantations pesticides on the immune response of lepidopteran larvae and their parasitoid nationa enemies. *Journal of Insects.* Vol.3: 616-628.

Antonious, G.F. (2009). Enzyme activities and heavy metal concentrations in soil amended with sewage sludge. *Journal of Environmental Science and Health.* Vol.44: 1019-1024.

Antonious, G. and Synder, J. (2007). Accumulation of heavy metals in plants and potential phytoremediation of lead by potato, *Solanum tuberosum L.* J*ournal of Environmental Science and Health.* Vol.42: 811-816.

Ashraf, M., Maah, M.. and Yuseff, I. (2011). Heavy metal accumulation in plants growing in ex-mining catchment. *International Journal on Environmental Public Health.* Vol.8: 401-416.

Australian Government (2008). Australia 2020 Summit: Long term health Strategy. Retrieved April 11th 2008. http://www. Australia2020.gov.au/topics/health.cfom

Aweng, R., Rarimah, M. and Suhamu, O. (2010). Heavy metal concentrations of irrigation water, soils and fruit vegetables in Kota Bharu area, Kalantan, Malaysia. *Journal of Applied Science in Environmental Sanitation.* Vol.6: 463-470.

Burlingare, B. and Demini, S. (2011). Sustainable diets: The Mediterranean diet as an Example. *Public Health Nutrition.* Vol 14: 2285-2287.

Carlisle, J.C., Dowling, K.C., Siegel, D.M. and Alexeeff, G.V. (2009). Blood Lead benchmark for assessing risks from childhood lead exposure. *Journal of Environmental Science Health*. Vol.15: 1200-1208

Carol, E.O., Theresa, A.N., Michael, Z. and Victor, L.F. (2011). Diet Quality is positively associated with 100% fruit juice consumption in children and adults in United States. *Nutritional Journal.* Vol.90: 10-17.

Chen, Y., Wang, C. and Wang, Z. (2005). Residues and source identification of persistent organic pollutants in farmland soils irrigated by effluents from biological treatment plants. *Journal of International Environment*. Vol 31: 778-783.

Cui, Y.J., Zhu, Y.G., Zhai, R.H., Chen, D.Y., Huang, Y.Z., Qiu, Y. and Liang, J.Z. (2010). Transfer of metals from soil to vegetables in an area near a smelter in Nanning,China. *International Journal of Environment*. Vol.30: pp 785–791.

Dauchet, L., Montaye, M., Ruidavets, J., Arveiler, D., Kee, F., Bingham, A. Ferriere, J., Haas, B., Evans, A., Ducimetiere, P., Amouyel, P. and Dallongeville, J. (2010). Association between the frequency of fruit and vegetable consumption and cardiovascular disease in male smokers and non-smokers. *European Journal of Clinical Nutrition.* Vol.64: 578-586.

Diane, S.L., Marlies, H., Julien, S.L. and Francis, B. (2010). Comparative Assessment of soil contamination by lead and heavy metals in Riparian and Agricultural areas (Southern Quebec, Canada). *International Journal of Environmental Public Health.* Vol.7: 3100-3114.

Dikinya,O. and Areola, O. (2010). Comparative analysis of heavy metal concentration in secondary treated wastewater irrigated soils cultivated by different crops. *International Journal of Environmental Science Technology.* Vol.2: 337-346.

Ercisli, S., Sengul, M., Yildiz, H., Sener,D., Duralija,B., Voca, S. and Purgar, D. (2011). *Journal of Applied Botany and Food Quality.* Vol.85: 86-90.

Erum, Z., Iftikhar, M. and Sheikh, M. (2009). Market basket survey of selected metals in fruits from Karachi city, *Pakistan Journal of Basic and Applied Sciences* Vol. 5:47-52.

Fenglei, L., Qiang, L.V., Yuqin, Z., Guibing, H., Guodi, H., Jiukai, Z., Chondde, S., Xian, L. and Kunsong, C. (2012). Quantification and Purification of Mangifera from Chinese Mango (*Mangifera Indica*) cultivars and its protective effect on Human umbilical vein endothelial cells under H_2O_2 Induced stress. *International Journal of Molecular Science.* No.11, Vol.13: 11260-11274.

Fernando, G., Anderson, T., Takashi, M., Nericlerus, M. and Solange, C. (2012). Heavy metals in Vegetables and potential risk for human health. *Journal of Agricultural Science.* Vol. 69: 54-60.

Food and Agriculture Organization Statistics (FAOSTAT), (2012). Database, Rome, Italy.

Food and Agriculture Organization and World Health Organization (FAO/WHO), (2012). Food additives and contaminants. Joint Codex Alimentarius Commission, FAO/WHO Food standards Programme. ALINORM 01/12A.

George, F., Antonious, S.O., Dennis, J.M. and John, C.S. (2011). Heavy metals uptake in plant part of sweet potato grown in soil fertilized with municipal sewage sludge.
International Journal of Geology. Vol. 5: 14-20.

Government of Kenya. (2012). Draft National Horticulture Policy, June 2012.

Government of Kenya. (2008). District Development Plan-Uasin Gishu District. Nairobi: Government Printers.

Heshmat, S., Aldesunguy, S., Abo, H., Mohamed, A. and Abeer, E. (2012). Role of glycne, betaine and salicyclic acid in improving growth vigor and physiological aspects of droughted wheat cultivars. *Journal of Stress Physiology and Biochemistry.* No.1, Vol. 8: 151-171.

Igbinosa, O., Uyi, O., Odadjare, E., Ajuzie, U., Orhue, O. and Adewole, M. (2012). Assessment of Physicochemical qualities, heavy metal concentrations and bacteria pathogens in Shanomi creek in Niger Delta, Nigeria. *African Journal of Environmental Science and Technology.* No.11, Vol.6: 419-424.

ISHS (2001). Acta Horticulture 564: IV International symposium on mineral nutrition of deciduous fruit crops. Heavy metal contamination in deciduous tree fruit Orchards: Implication for mineral nutrient management.

Jarosz, M., Wlodzimierz, S., Ewa, R. and Katarzyma, F. (2011). Impact of diet on long term decline in gastric cancer incidence in Poland. *Journal of Gastroenterology.* No.1, Vol.17: 87-79.

Jean, C., Buzby, W., Aylin, K., Biing, L., Gary, L. and Agnes, P. (2010). Canned fruit and vegetable consumption in the United States. An Updated Report for Congress, October 2010.

Kalavrouziotis, K. and Arslan, I. (2008). Reuse of urban wastewater and sewage sludge in the Mediterranean countries: case studies from Greece and Turkey. *Fresenius Environmental Bulletin.* Vol.6: 625-639.

Kavita, G., Basudeb, B., Slyum, B.L. and Arunabha, R. (2010). Effects of diesel exhaust, heavy metals and pesticides on various organ systems: Possible mechanisms and strategies for prevention and treatment. *Indian Journal of Experimental Biology.* Vol.3: 710-721.

Kenya National Bureau of Statistics (KNBS) (2009). Kenya Population Census report.

Kumar, V. and Nagar, N. (2012). Effect of Industrial Effluent on content nutrient and heavy metals in plants and soils. Paper presented to the International Conference on Chemical, Biochemical and Environmental Science: December 14-15, 2012. Singapore.

Lou, L., Ma, Y., Zhang, S., Wei, D. and Zhu, Y.G. (2009). Inventory of trace element inputs to agricultural soils in China. *Journal of Environmental Management.* Vol.90: 2524-2530.

Maggini, S., Wenzlaff, S. and Horing, D. (2010). Essential Role of Vitamin C and Zinc in Child Immunity and Health. *Journal of International Medical Research.* Vol. 38: 386-414.

Malekil, A. and Masoud, A. (2008). Heavy metals in selected edible vegetables and estimation of their daily intake in Sanandaj, Iran. 2008. *Southeast Asian Journal of Tropical Public Health.* No.2, Vol. 39: 335-340.

Mapanda, F, Mangwayana, N., Nyamangara, J. and Giller, E. (2005). The effect of long term irrigation using wastewater on heavy metal contents of soils under vegetables in Harare, Zimbabwe. *Journal of Agriculture Ecosystems and*

Environment. Vol.107: 151-165.

Monu, A., Bala, K., Shwela, R., Anchal, R., Barinder, K. and Neeraj, M. (2008). Heavy metal accumulation in vegetables irrigated with water from different sources. *Journal of Food Chemistry.* Vol. 3: 811-815.

Monica, H., Bente, H., Kari, H., Siv, B., Steinar, D., Laura, S., Carol, W., Yuko,U.,Chiho, S., Ingrid, B., Nega, B., Walter, C., Katherine, P., David, R.J. and Rune, B. (2010). The Total antioxidant component of more than 3100 foods beverages, spices, herbs and supplements used worldwide. *Journal of Nutrition.* Vol.9: 5-9.

Mounde, L.G., Ateka, E.M., Kihurani, A.W. and Wasilwa, L. (2012). Morphological Characterization and identification of *Phytophthora* species causing *Citrus gummosis* in Kenya. *African Journal of Food, Agriculture, Nutrition and Development.* No.7, Vol 12: 7072-7087.

Muchuweti, M., Birkett, W., Chinyanga, E., Zvauya, R., Scrimshaw, D. and Lester, J. (2006). Heavy metal content of vegetables irrigated with mixture of wastewater and sewage sludge in Zimbabwe: implications for human health. *Journal of Agriculture, Ecosystem and Environment.* Vol.112: 41–48.

Nabulo, G., Oryem, H. and Diamond, M. (2006). Assessment of lead, cadmium, and zinc contamination of roadside soils, surface films and vegetables in Kampala City, Uganda. *Environmental Research.* Vol.101: 42-52.

Nikolay, L., Xiaoxia, W. and Tatiana, V. (2011). Oxidation as “The Stress of Life”. *Journal of Aging.* No.9, Vol.3: 906-910.

Ogunlade, M.O. and Agbeniyi, S.O. (2011). Impact of pesticides use on heavy metals pollution in cocoa soils of Cross-River State, Nigeria. *African Journal of Agricultural Research.* Vol.6: 3725-3728

Okwi, E. and Emenike, N. (2008). Citrus fruits: A rich source of phytochemicals and their roles in human health. International Journal of Chemical Science No.2, Vol.6: 451-471

Orish, E.O., John, K.N., Cecilia, N.A., Daniel, O.D. and Onyinyechi, B. (2012). Heavy metals health risk assessment for population via consumption of food crops an fruits in Oweri, South Eastern Nigeria. *Journal of Central Chemistry.* Vol.6: 1-7.

Ortelli, D., Edder, P. and Corvi, C. (2006). Multiresidue analysis of 7 pesticides in fruits and vegetables by liquid chromatography-electrospray-tandem. *Journal of Anayiticia Chemica.* Vol.520: 33-45.

Rattan, K., Datta, P., Chhonkar, K., Suribabu, K. and Singh, K. (2005). Long-term impact of irrigation with sewage effluents on heavy metal content in soils, crops and groundwater. *Journal of Agriculture Ecosystems and Environment.* Vol.109: 310-322.

Raymond, N. and Felix, O. (2011). Heavy metals in contaminated soils: A review of sources, chemistry, rocks and best available strategies for remediation. *Journal of International Scholarly Research Network.* Vol. 4: 5-10.

Reagan, S., Egget, D., Mukhtar, H. and Ahmad, N. (2010). Antiproliferative effects of apple peel extract against cancer cells. *Nutrition and Cancer.* No.4, Vol.62. 517- 524.

Sabiha, J., Mohamed, T., Chaudry, M. and Tufail, M. (2009). Heavy metal pollution from phosphate rock used in production of fertilizer. *Journal of Environmental Health*. 2009. Vol.91: 94-99.

Saeid, N. (2012). Concentration of Heavy metal in edible vegetable widely consumed in shalroud, the North East of Iran. *Journal of Applied Environmental Biology.* No.8, Vol.2: 386-391.

Sajjad, K., Robina, F., Shagufta, S., Mohamad, A. and Mana, S. (2009). Health Risk Assessment of heavy metals for population via consumption of vegetables. *World Applied Sciences Journal.* No.12, Vol.6: 1602-1606.

Salim, S., Simons, J., Orwa, C., Chege, J., Owuor, B. and Mutua, A. (2002). Agroforestry database: a tree species reference and selection guide. Kenya: International Centre for Research in Agroforestry.

Samir, G., Zidan, H., Hassan, M., Sobhy, A. and Selim, T. (2012). Monitoring of Pesticide Residues in Strawberry and Soil from Different Farming Systems in Egypt. *American-Eurasian Journal of Agriculture and Environmental Science.* No.12. Vol 2: 177-187.

Sánchez-Martín, M. J., García-Delgado, M., Lorenzo, L. F., Rodríguez-Cruz, M. S. and Arienzo, M. (2007). Heavy metals in sewage sludge amended soils determined by sequential extractions as a function of incubation time of soils. *Journal of Geoderma*. Vol. 142: 262-273.

Satarug, S., Scoh, G., Mary, S. and Donald, A. (2010). Cadmium, Environmental exposure and Health Outcomes. No.2, Vol.118: 182-190.

Sharma, K., Agrawal, M. and Marshall, F. (2007). Heavy metal contamination of soil and vegetables in suburban areas of Varanasi, India. *Journal of Ecotoxicology and Environmental Safety*. Vol.2: 258-266.

Singh, P. and Agrawal, M. (2008). Potential benefits and risks of land application of sewage sludge. *Journal of Waste Management.* Vol.2: 347-358.

Singh, P., Mohan, D., Sinha, S. and Dalwani, R. (2004). Impact assessment of treated/ untreated wastewater toxicants discharged by sewage treatment plants on health, agricultural, and environmental quality in the wastewater disposal area. *Journal of Chemosphere*. Vol.55: 227–255.

Sobukola. P., Adeniran, M., Odedeno, A. and Kajihausa, E. (2010). Heavy metals of some fruits and leafy vegetables from selected markets in Lagos, Nigeria. *African Journal of Food Science*. No.2, Vol.4: 389-392.

Somnath, B., Badal, K.D. and Ajay, K.S. (2012). Determination of Mineral content and heavy metal of some traditional important aquatic plants of tripora, India using Atomic Absorbption Spectroscopy. *Journal of Agricultural Technology*. 2012. No.4, Vol.8: 1467-1476.

Stephen, J., Maxine, A., and Rabow, M. (2012). Cancer, Current Medical Diagnosis and Treatment. 51st Edition. McGraw-Hill. Publishing Press.

Stewart, H., Hyman, J., Buzby, C., Frazao, E. and Carbo, A. (2011). How much do fruits and vegetables cost? Washington DC: USDA: Economic Research Service.

Sudhakar, K., Verma, R., Kurba, B. and Kumar, L. (2012). Heavy metals in Environment, Living system and herbal preparations: An Overview.*International Research Journal of Pharmacy*. No.7, Vol.3: 128-130.

Syed, R., Dilara, K., Tanveer, A., Mohammed, I., Mohammed, A. and Mohammed, A. (2012). Assessment of heavy metals contamination of Agricultural soil around Dhaka Export Export Processing zone, Bangladesh: Implication of seasonal variation and Indicies. *Journal of Applied Sciences.* Vol.2: 584-601.

Thomas, Y., Omueti, A. and Ogundayomi, O. (2012). Effect of Phosphate Fertilizers on heavy metals in soils and *Amaranthus caudatus*. Agriculture and Biology *Journal of North America.* No.4, Vol.3: 145-149.

Toze, S. (2006). Reuse of effluent water-benefits and risks. *Journal of Agriculture Water Management*. Vol. 80: 147-159.

Uboh, E., Akpanabiatu, E. and Okon, E. (2011). Distribution of heavy metals in fluted pumpkin (*Telfeiria ocidentalis*) leaves planted at different Distances away from the traffic congested highways. *International Journal of Advanced Biotechnology*. Vol.2: 250-256.

United States of America Development Agency (2011). Kenya feed the future strategy. Report submitted to Government of Kenya on June 8th 2011.

Vinoth, K.M., Balaraman, R., Dezoder, P. and Tana, R. (2010). Hemidescus and Hibiscus rosa effects ischema injury in isolated rat heart. *Evidence based complementary and Alternative medicine*. Vol.11: 1-8.

Wang, X., Sato, T., Xing, B. and Tao, S. (2012). Health risk of Heavy metals to the general public in Tianjin, China via consumption of Vegetables and Fish. *Science of Total Environment*. Vol.350: 28–37.

Wang, Y., Chen, P., Cui, R., Si, W., Zhang, Y. and Ji, W. (2010). Heavy metals concentrations in water, sediment and tissues of two fish species (*tripohysa pappenherini, Gabro hwangherin*) from lanzhuo section of Yellow River, China. *Environmental Monitoring Assessment.* Vol.165: 97-102

World Health Organization (2012). Global Health Observatory (GHO) 2012. World health Organization, Geneva.

www.http://www.who.int/gho/mortality_burden_diseases/countries/ben/index.html.

Wu. X., Jin. T. and Wang. Z. (2001). Urinary calcium as a biomarker of renal dysfunction in a general population exposed to cadmium. *Journal of Occupational Environmental Medicine*. No.10, Vol.43: 898-904.

Yi-Chun, L., Cairre, D., Antonio, N., James, D., Taran, J. and Andrew, M. (2010). Childhood lead poisoning associated with Gold ore processing: a village level investigation-Zamfara state, Nigeria. *Environmental health Perspectives.* Vol.120: 1450-1455.

APPENDICES

Appendix I: One Way ANOVA for lead levels in Orange fruits sold in Eldoret town

ANOVA

	Sum of Squares	**df**	**Mean Square**	**f**	**p**
Between Groups	0.830	3	0.277	13.33	1.12E-07
Within Groups	2.824	136	0.021		
Total	3.654	139			

Appendix II: One Way ANOVA for lead levels in Mango fruits sold in Eldoret town

ANOVA

	Sum of Squares	**DF**	**Mean Square**	**F**	**Sig.**
Between Groups	1.601	3	0.534	21.873	1.27708E-11
Within Groups	3.318	136	0.024		
Total	4.920	139			

Appendix III: One Way ANOVA for Cadmium levels in Orange fruits sold in Eldoret town

ANOVA

	Sum of Squares	DF	Mean Square	F	Sig.
Between Groups	0.002	3	0.001	1.848	0.141
Within Groups	0.054	136	0.000		
Total	0.056	139			

Appendix IV: One Way ANOVA for Cadmium levels in Mango fruits sold in Eldoret town

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.011	3	0.004	6.49712	0.0004
Within Groups	0.077	136	0.001		
Total	0.088	139			

Appendix V. One Way ANOVa for Chromium levels in Orange fruits sold in Eldoret town

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3.061	3	1.020	3.47573	0.01787
Within Groups	39.920	136	0.294		
Total	42.980	139			

Appendix VI. One Way for Chromium levels in Mango fruits sold in Eldoret town

ANOVA

	Sum of Squares	DF	Mean Square	F	Sig.
Between Groups	5.904	3	1.968	2.135	0.099
Within Groups	125.341	136	0.922		
Total	131.245	139			