ASSESSMENT OF HEAVY METAL CONCENTRATION IN THE ENVIRONMENT AND PERCEIVED HEALTH RISKS BY THE COMMUNITY AROUND KADHODEKI DUMPSITE, NAIROBI COUNTY

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university or any other award

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DEDICATION

I dedicate this work to my husband Mathew Piero Ngugi, to my parents Njagi I Karugu and Margaret M Karugu. My parent's in-Law Mr & Mrs Njuki Maringa. My brothers and brothers' in-Law and sister and sister's in-Law.

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ABBREVIATIONS AND ACRONYMS

ATSDR: Agency for Toxic Substances and Disease Registry

DIMETAL: Daily metal intake

DNA: Deoxyribonucleic Acid

DWAF: Department of Water Affairs and Forestry

EDXRF: Energy Dispersive X-Ray Fluorescence

EGVM: Expert Group on Vitamins and Minerals

EMCA: Environment Management and Coordination Act

EU: European Union

FAO: Food and Agricultural Organization

FGD: Focused group discussion

FNB: Food and nutrition Board

IOSHIC: International Occupational Safety and Health Information Centre

KDHS: Kenya Demographic Health Survey

KNBS: Kenya National Bureau of Statistics

MAL: Maximum Allowable Limits

NEMA: National Environment Management Authority

RDI: Recommended Daily Intake

RNA: Ribonucleic Acid

SCF: Scientific Committee on Food

TF: Transfer Factor

TXRF: Total Reflection X-Ray Fluorescence

UL: Upper Limit

UNDP: United Nations Developmental Program

UNEP: United Nations Environmental Program

UN-HABITAT: United Nations Human Settlement Programme

USEPA: United States Environmental Protection Agency

WHO: World Health Organization

ABSTRACT

Solid wastes constitute a disaster for human health and environmental degradation. Dumpsites in Kenyan urban settlements are used as sources of nutrient rich soils for cultivating crops without regard to the risks of perceived toxic heavy metal pollution from the wastes. Water sources near the dumpsites are used as domestic water source for the people living near such sites. This water is often contaminated by toxic heavy metals leaching from the dumpsite. Heavy metals are known to accumulate in the plants then passed to the humans through the food chain. Prolonged consumption of unsafe concentrations of heavy metals through foodstuffs may lead to the accumulation of heavy metals in the humans causing disruption of numerous biochemical processes. The aim of this study was to determine the level of heavy metals in the vegetables, soil and water samples collected around Kadhodeki dumpsite. The study also sought to assess the knowledge, attitude and perceptions of the health risks posed by the site to the residents of the village. Heavy metal determination samples collected was carried out using X- ray fluorescence (XRF) analytical method. A descriptive cross sectional survey was carried out to assess the knowledge, attitudes and perceptions of people living around the study area. The analytical data was subjected to statistical tests of significance using ANOVA and post hoc analysis by Tukeys test ($P<0.05$) to determine whether there was any significant difference between the study sites. Chi square was used to determine if there were associations between the study variables in the survey. The research found that the vegetables under study had low levels of essential metals Fe, Mn, Zn and Cu while they had higher levels of Ni, Co, V, and more than maximum allowable levels (MAL) of Hg and Pb. V, Mn, Cu, Ni, Hg concentrations in the soil were higher than MAL for agricultural soils while Fe, Zn were within the limits. The water was contaminated by high than allowed levels of Mn (366-856 µg/l) and Fe (5132-12402 µg/l) in drinking water while Zn (40-336 µg/l) was below the WHO limits. The people living in Kadhodeki village had inadequate knowledge about the health risks which was significantly associated with the level of education ($\chi^2 = 20.86$ df=1 $P<0.01$). A significant association between level of education and perception was also revealed ($\chi^2=13.57$, df=1, $p<0.01$). Insignificant associations between age and the number of years the participants had lived in the village were found for the variables of knowledge, attitude and perception. Health education to the people living in Kadhodeki village on the dangers posed by the vegetables grown around the dumpsite should be done to prevent further consumption of contaminated crops. Farmers growing edible crops around the site should be advised to stop doing so and instead encouraged to grow other crops which can provide some earning and at the same time reclaim the land.

CHAPTER ONE: INTRODUCTION

1.1 Background Information

Rapid and relatively unorganized urban expansion, industrial developments coupled with inadequate waste management causes significant alterations in the physical environment and increases accumulation of municipal waste. Indeed, one of the most pressing concerns of urbanization in the developing world, especially in Africa, has been the problem of solid, liquid and toxic waste management. Some cities lack proper solid waste regulations and proper disposal facilities, for harmful waste. Such waste may be toxic or radioactive (Onibokun and Kumuyi, 1996; Wong *et al*., 2003; UNDP, 2006; Kimani, 2007).

These cities reveal aspects of waste-management problem such as heaps of uncontrolled garbage, roadsides littered with refuse; streams blocked with rubbish and inappropriately disposed toxic waste and disposal sites that constitute a health hazard to residential areas, (Kibwage, 2002; Rotich *et al*., 2006; Ebong *et al*., 2008). Occurrence of uncontrolled urban sewage farming is a common site in African cities which exposes consumers of such produce to poisoning from heavy metals (Ebong *et al*., 2008).

Abandoned waste dumpsites have been used extensively as fertile grounds for cultivating vegetables though research has indicated that the vegetables are capable of accumulating high levels of heavy metals from contaminated and

polluted soils (Garcia *et al*., 1981; Xiong , 1998; Cobb *et al*., 2000; Benson and Ebong, 2005).

Heavy metal pollution of the environment, even at low levels, and their resulting long-term cumulative health effects are among the leading health concerns all over the world (Oluyemi *et al*., 2008). Open dumps are a source of various environmental and health hazards. The decomposition of organic materials produces methane, which may cause explosions and produce leachates, which pollute surface and ground water. It ruins the aesthetic quality of the land (Cointreau – Levine, 1997; Oyelola *et al*., 2009).

Additionally dumpsites constitute health hazard even to a passers-by and those living near the dumps. This is due to the obnoxious smell oozing from the activities of micro-organisms on the organic waste. Uncontrolled burning of solid waste constitutes serious environmental pollution, adversely affecting solid waste workers and pickers. Toxic and hazardous wastes when burnt with other solid waste like asbestos fibre may introduce potential carcinogenic fibre to the smoke plume (Woodward, 1997; Oyelola *et al*., 2009).

Dumpsite managers in some cities have also been known to deliberately set periodic fires at the dumps in order to reduce the volume of the wastes, creating room for more wastes and thus extend the life of the dumps. Human scavengers may also cause intentional fires since metals are easier to spot and recover among ashes after the fires than among piles of mixed waste

(Woodward, 1997; USEPA, 2002; Pruss *et al*., 2000; UNDP, 2006). These are issues of great interest and concern to the public, the local authorities and private sector (Ebong *et al*., 2008).

Heavy metals from waste dumpsites can accumulate and persist in soils at an environmentally hazardous level (Alloway, 1996; Amusan *et al*., 2005). This constitutes serious health and environmental concerns because of phytotoxicity of these metals to the plants and the potentially health implications to humans and animals consuming such vegetables (Micieta and Murin, 1998; Ellias and Salt, 2003; Pillay *et al*., 2003). Studies have shown municipal refuse may increase heavy metal concentration in soil and underground water (Albores *et al*., 2000; Okoronkwo *et al*., 2005b; Okoronkwo *et al*., 2006). This may have effects on the host soils, crops and human health (Smith *et al*., 1996; Nyle and Ray, 1999). Thus, the environmental impacts of municipal refuse are greatly influenced by their heavy metal contents.

The three last decades have seen an increase in global concern over the public health impacts attributed to environmental pollution, in particular, the global burden of disease (UNDP, 2006). Most of these environment-related diseases are however not easily detected and may be acquired during childhood and manifested later in adulthood (Kimani, 2007).

In Kenya, solid wastes consist of wastes from household preparation, cooking and serving of food; market waste, storage and sales of produce and meals.

These wastes attract birds, rats, flies and other animals to the dump. Animals feeding at the dump may transmit diseases to human living in the vicinity (Etekpo, 1999; Eddy *et al*., 2006; Oyelola *et al*., 2009). Solid waste also consists non-biodegradable materials such as paper, plastics, clothes, rubber, leather, bottles, glass, ceramics and metal cans, ashes, street sweepings, abandoned vehicles, non-hazardous industrial waste, construction and demolition waste (Achankeng, 2003; Kimani, 2007).

Nairobi city faces solid waste management challenges. Many of the city estates are littered with garbage which when eventually collected finds its way into open dumps. The use of open dumps for municipal solid waste in Kenya makes environmental pollution highly probable. Both surface water and groundwater remain vulnerable to solid waste pollution because disposal dumps were chosen for convenience rather than based on environmental safety considerations. The extent of groundwater pollution in and around the dumpsites is still unknown because adequate pollution assessment studies have not been conducted on the groundwater (Rotich *et al*., 2006; Afullo and Odhiambo, 2009).

Dumping of waste at Kadhodeki dumpsite located in Waithaka Sublocation started in 1986 as a way of filling in the large gaping man holes that had been left open after quarrying activities in the construction of Nairobi/ Waiyaki highway. The dumping of the waste was a way of the land owners making some money. Since no one was particularly in charge, it was not possible to

control the type of solid wastes deposited there. As a result of several years of illegal waste solid disposal, the dumpsite was closed in 2007 by the Ministry of Environment and Natural Resources. This was done by putting up a poster warning that dumping activities were no longer carried out in the area.

Dumping still continues on the dumpsite despite the warning, although those that throw the wastes do it discreetly by using wheelbarrows instead of refuse trucks and depositing the waste at night instead of daytime. Since then the Ministry concerned and other relevant authorities have done little to rehabilitate the site as outlined in Environmental Management and Co-ordination Act (EMCA) 1999. The land owners have not been advised on methods that can reclaim the land so that it can be used for profitable agricultural activities. As a result due to essential hardships of the land owners, they use the dumpsite and soils around for farming while water from the nearby Nairobi River is either used for irrigation or domestic purposes without regard to the risk of toxic metal pollution by the wastes.

The extent to which this has been the case for the people around Kadhodeki dumpsite is not known. It is in this understanding therefore, that this study was undertaken. The study attempts to address part of this problem by assessing the levels of heavy metals in plant crops grown on and around the dumpsite, determining the concentration of these heavy metals in soil and water source found around the site. The study also attempted to find out the knowledge, attitude and perceptions of the community surrounding the site on whether the

dumpsite poses any health risks. Information generated is of great benefit to community around the dumpsite, public health and environmental health policy makers**.**

1.4 Problem Statement

Urban waste management is a growing concern, as the consequences of inadequate collection and disposal impact on the ecosystems of cities, contribute to the degradation of the urban environment and pose a health hazard to urban populations at large. Most affected are those living adjacent the dumpsites due to the potential of the waste to pollute water, food sources, land, air and vegetation (UN-HABITAT, 2008).

Nairobi is a city, with rapid urbanization in the midst of deteriorating economic, environmental and health conditions (Afullo and Odhiambo, 2009). In 2009 approximately 32.3 % of Kenya's population live in urban areas (KNBS, 2009). The great influx of population into the city without matched urban planning has continued to result in a wide variety of environmental problems (EMCA, 1999). Some of the problems include the current inability of urban authorities to adequately manage large quantities of the generated solid waste (UNDP, 2006). This has resulted to uncontrolled and unmonitored disposal of waste in open dumps with the consequence of contamination and subsequent pollution of the environment by heavy metals. This has become a global concern due to their widespread distribution and multiple effects on the ecosystem (Nriagu, 1990; Uwah *et al*., 2011).

Though large amounts of the waste comprise organic material, there are considerable proportions of plastic, paper, metal rubbish and batteries which are known to be real sources of heavy metal (Lisk, 1988; Zhang *et al*., 2002; Pasquini and Alexander, 2004). Indeed, the nutrient content of wastes makes them attractive as fertilizers, but when untreated wastes are used in crop production, consumers risk to contract the diseases like cholera and hepatitis, or to undergo heavy metal contamination (Drechsel *et al*., 1999). Furthermore, heavy metals are non-biodegradable and can accumulate in soils to toxic concentrations that affect plant and animal life (Karatas *et al*., 2006 ; Adjia *et al*., 2008).

Trace metals may enter the human body via consumption of contaminated drinking water or ingestion of soil or crops grown on contaminated land (Dudka and Miller, 1999; Cambra *et al*., 1999). Metals such as lead, mercury, cadmium and copper are cumulative poisons, cause environmental hazards and are reported to be exceptionally toxic (Yargholi and Azimi, 2008). These metals are a major source of oxidative stress in the cell and play an important role in the aetiology of diverse human pathologies such as carcinogenesis (Frenkel, 1992; Wang *et al*., 2004; Leonard *et al*., 2004; Hei and Filipic, 2004).

Exposure to heavy metal toxicity leads to brain damage, mental retardation, cerebral palsy, lung cancer, gastrointestinal abnormalities, and dermatitis, and death of the unborn foetus (USEPA, 2002; Rotich *et al*., 2006; UNDP, 2006). Many metals have been shown to directly modify and/or damage DNA by

forming DNA adducts that induce chromosomal breaks (Chakrabarti *et al*., 2001).

The unrestricted access to the dumpsite means that each day, scavengers search for raw materials, much of which eventually finds its way back to neighbourhoods as animal feed and even human food. Stray chicken, pigs, goats, dogs and cats roam the dumpsite eating the toxic matter and becoming vectors of pests and parasites that are eventually transferred to the surrounding home and hence causing diseases to both animals and human beings. Studies about vegetables grown around dumpsites have been conducted mainly outside Kenya.

1.3 Research Questions

i). What is the concentration of selected heavy metals in the soils found upstream, midstream and downstream around Kadhodeki dumpsite?

ii). What is the concentration of selected heavy metals in the vegetables planted upstream, midstream and downstream around Kadhodeki dumpsite?

iii). What is the concentration of selected heavy metals in the river water found upstream, midstream and downstream in Nairobi river near Kadhodeki dumpsite?

iv). What is the knowledge, attitudes and perceptions of people living around the study area on whether the dumpsite poses any health risk to them.

1.4 General Objective

To determine the concentration level of heavy metals in the soil, vegetables and water found upstream, midstream and downstream; and perceived health risks by the community around Kadhodeki dumpsite, Nairobi County

1.4.1 Specific Objectives

i). To determine the concentration of selected heavy metals in the soils found upstream, midstream and downstream around Kadhodeki dumpsite.

ii). To determine the concentration of selected heavy metals in the vegetables planted upstream, midstream and downstream around Kadhodeki dumpsite

iii) To determine the concentration of selected heavy metals in the Nairobi River water found upstream, midstream and downstream near Kadhodeki dumpsite.

iv). To assess the knowledge, attitudes and perceptions of people living around the study area on whether the dumpsite poses any health risk to them.

1.5 Research Hypothesis

The mean levels of heavy metal concentration in the soil, vegetables and Nairobi River water upstream and downstream are not significantly different from those next to Kadhodeki dumpsite.

1.6 Justification

World Health Organization (WHO) estimates that about a quarter of the diseases facing mankind today occur due to prolonged exposure to environmental pollution (Prüss-Üstün and Corvalán, 2006; Kimani, 2007). The

general belief that wastes are sometimes hazardous to health cannot be overemphasized. Dump sites are a common site in Nairobi and other cities in Africa. The sites are not only a site for sore eyes but a health hazard. The soil around the dump is usually rich in toxic heavy metals as a result of the dumped waste. This soil is used by the people living around the dump for planting vegetables and fruits. These plants bio- accumulates heavy metals from the soil and when they are eaten by human beings and animals, the heavy metal accumulate in the body with serious health effects (USEPA, 2002; UNDP, 2006; Rotich *et al*., 2006).

The water sources around the dumpsite also get contaminated with the heavy metals as a result of leaching and from rain water which drains into them having passed through the dump. This water is then used for irrigating crops around and domestic use including drinking and may directly cause heavy metal poisoning to the consumer. When used for bathing and laundry the water may cause skin infections and allergies. The dump site also acts as a breeding ground for disease vectors causing serious health problems in the neighbourhood (Etekpo, 1999; Eddy *et al*., 2006).

Hazardous waste can cause and has caused pollution, damage to health and even death. Exposure to multiple chemical combinations in populations living near waste dump sites has led to a series of human health disorders (Zupancic, 1997; Palmer *et al*., 2005; Alimba *et al*., 2006).

CHAPTER TWO: LITERATURE REVIEW

2.1 Approaches and Challenges to Municipal Solid Waste Management

Waste handling facilities are lacking in many highly populated areas in most developing and underdeveloped countries due to cost and lack of enforcement of relevant enactment. Poor regional and urban planning, lack of enforcement of relevant laws and edicts on waste disposal, lack of organised landfill sites contribute to the presence of dumpsites within living areas in developing nations. This results in the discharge of household sewage and refuse into the environment untreated. The surface run-off and leachates from dumpsites are sources of fresh water contamination (Abdus-Salam *et al*., 2011).

The recent population and industrial growth has led to increasing production of domestic, municipal and industrial wastes, which are indiscriminately dumped in landfill and water bodies without treatment (Ogunyemi *et al*., 2003). Municipal solid waste management constitutes one of the most crucial health and environmental problems facing governments of African cities. This is because even though these cities are using 20-50 percent of their budget in solid waste management, only 20-80 percent of the waste is collected. The uncollected or illegally dumped wastes constitute a disaster for human health and the environmental degradation (Achankeng, 2003).

Thousands of old landfills and dumpsites exist throughout the developing countries representing a threat for human health for the next decades, unless appropriate measures are taken. Most developing countries follow the practice

of open dumping of solid wastes causing environmental and health risks (Kurian *et al*., 2003). Industrialization, population growth and unplanned urbanisation have partially or totally turned our environment to dumping sites for waste materials (Ikem *et al*., 2002).

2.2 Effects of Municipal Solid Waste on the Environment

Poor waste management poses a great challenge to the well-being of city residents, particularly those living adjacent to dumpsites due to the potential of the waste to pollute water, food sources, land, air and vegetation. The poor disposal and handling of waste thus leads to environmental degradation, destruction of the ecosystem and may cause great risks to public health. The resultant accumulation of waste poses a health hazard to urban inhabitants, and also threatens the surrounding environment (UNEP, 2005; UNDP, 2006).

The environmental problems posed by solid waste ranges from health hazards, soil and water pollution, repulsive sight and offensive odour. The resultant of these is the degradation of our environmental quality (Abdus-Salam *et al*., 2011). Most dumpsites are located within the vicinity of living communities and wetlands. The dumpsites are often not lined nor basement prepared for selective adsorption of toxic substances. Therefore it is prone to release pollutants to nearby water and to the air through leachates and dumpsite gases respectively (Alimba *et al*., 2006). Many water resources have been rendered wholesome and hazardous to man and other living systems as a result of indiscriminate dumping of refuse (Bakare *et al*., 2005).

Most uncontrolled dumps are many years old, having grown over time from small dumps to large, unmanaged waste sites. Uncontrolled dumps have significant environmental impacts. Solid waste pose the greatest threat to life since, it has the potential of polluting the terrestrial, aquatic and aerial environments (Odukoya *et al*., 2000; Bishop, 2000). Soil samples represent an excellent media to monitor heavy metal pollution resulting from anthropogenic activities. Heavy metal contaminated soil affects the ecosystem due to leaching into ground water or when they are taken up by plants and animals which results in great risks due to bioaccumulation (Aluko *et al*., 2003; Rotich *et al*., 2006; Ebong *et al*., 2008; Bhagure and Mirgane, 2010).

Heavy metals and persistent organic pollution are of concern due to their potential harmful effects to humans and the environment. Wong *et al*. (2002) showed that heavy metals are potentially toxic to crops, animals, and humans when contaminated soils are used for crop production. Pollution of the biosphere with heavy metals, induced by industrial, agricultural, and domestic activities, poses serious problems for safe use of agricultural lands (Fytianos *et al*., 2001). Most studies of metal leaching in soil columns or field investigations conclude that trace metals are strongly bound to topsoil (Sukkariyah *et al*., 2005).

In some dumpsites, wastes are burnt in the open and ashes abandoned at the sites, with no regard to environmental implications. This poses a direct safety threat because of the danger of explosion. The burning of wastes gets rid of the

organic materials and oxidizes the metals, leaving the ash richer in metal contents. After the processes of oxidation and corrosion, these metals get dissolved in rain water and are then leached into soil from where they are picked up by growing plants thereby entering the food chain (Harrison and Chirgawi, 1989; Benson and Ebong, 2005).

Heavy metals concentration in the soil are associated with biological and geochemical cycles and are influenced by anthropogenic activities such as agricultural practices, industrial activities and waste disposal methods (Ndiokwere and Ezehe, 1990; Usman *et al*., 2002; Eja *et al*., 2003; Zauyah *et al*., 2004; Zukowska and Biziuk, 2008).

Waste dumpsites can transfer significant levels of toxic and persistent metals into the soil environment (Alloway, 1996; Olajire and Ayodele, 1996; Cobb *et al*., 2000; Udosen *et al*., 2006). These metals are taken up by plants and transferred into the food chain (Benson and Ebong, 2005). Cultivated plants take up these metals either as mobile ions in the soil solution through their roots (Udosen *et al*., 2006) or through their leaves thereby making them unfit for human consumption (Onianwa and Egunyomi, 1983; Chapel, 1986; Zupancic, 1997; Yusuf *et al*., 2003).

Consequently, higher soil heavy metal concentration can result in higher levels of uptake by plants (John *et al*., 1972). The rate of metal uptake by a plant could be influenced by factors such as metal species, plants species, plant age

and plant part (Juste and Mench, 1992; Moreno *et al*., 2005; Amusan *et al*., 2005; Singh et al., 2010).

2.3 Heavy Metals and Human Health

Strictly speaking, heavy metals are defined as those with higher density than 5 mg mL^{-1} (Jarup, 2003) but the collective term now includes arsenic, cadmium, chromium, copper, lead, nickel, molybdenum, vanadium and zinc. Some interest also exists in aluminium, cobalt, strontium and other rare metals (Khanna and Khanna, 2011).

A heavy metal is not toxic per se and it is only toxic when its concentration in the plant and animal exceeds a certain threshold ("it is the dose that makes the effect"). Some elements, called trace elements or micronutrients, have essential functions in plant and animal cells. This has been shown for Co, Cu, Fe, Mn, Mo, Ni and Zn. Only when the internal concentration exceeds a certain threshold do they demonstrate toxic effects, and then they are commonly termed "heavy metals" (IOCC, 1996; Klaus-J, 2010).

Studies done on soils at dumpsites show that the soils contain different kinds and concentration of heavy metals, depending on the age, contents and location (Udosen *et al*., 1990; Haluschak *et al*., 1998; Odukoya *et al*., 2000). Field investigations as well as soil column studies have reported rapid leaching of significant concentrations of zinc, copper, chromium and cadmium (Sukkariyah *et al*., 2005). Municipal waste contains such heavy metals as As,

Cd, Co, Cu, Fe, Hg, Mn, Pb, Ni, and Zn which end up in the soil and are leached out from the dump sites (Fatoki, 2000).

Studies of heavy metal in water, sediments and plants carried out in Sosiani River, Uasin Gishu County, Kenya reveal that the plants found in the study area showed a preferential zinc metal uptake and may lead to accumulation in exposed plants posing Zn exposure risks along the food chain. The same study showed that the site near the Moi Teaching and Referral Hospital (MTRH) had the highest total heavy metals concentration in water at: Cu (0.18 ppm); Pb (0.46 ppm) and Zn (0.70 ppm) and sediments: Cu (1.62 ppm); Pb (1.27 ppm) and Zn (6.73 ppm) respectively. Fractionation of heavy metals in sediments showed low percentage solubility (Cu 9.3%; Pb 8.5%; Zn 4.2%). Concentration of zinc in studied plants was highest (3.60 ppm), with a bioconcentration factor of 15.1 based on soluble zinc fraction (Jepkoech *et al*., 2013)

Other studies carried out to monitor exposure to heavy metals among children in Lake Victoria reported significant correlations between Pb, Cd and Cu in hair, nails and heavy metals from fish consumed. The study suggested fish consumption as a possible pathway of heavy metals in humans and possible health risks from heavy metals toxicity. This was due to consumption of higher quantities of fish from the geological basins. Concentration of Pb and Cu in water reflected anthropogenic pathways, while Cd and Cr reflected accumulation from the catchment basin. Higher concentration of heavy metals in the nails samples than the hair samples suggested longer term exposure. The

estimated intake of Cd and Cr from fish in one site associated with high concentration of the metals from geological sources was appreciably above the respective recommended daily allowance, signifying possible health risks to humans (Oyoo-Okoth, *et al.,* 2010).

A study on assessment of heavy metals concentrations in urban grown vegetables in Thika town Kenya revealed that the mean concentrations of lead, zinc and cadmium in all the vegetables studied had more than the maximum permitted concentrations. Lead concentration in the vegetables was reported to be above the maximum limit of 0.3 mg/kg accepted for human health by World Health Organization (WHO) standards (Inoti, *et al*., 2012).

Muiruri *et al*. (2013) reported that there was evidence of bioaccumulation of heavy metals in the fish. The study also showed that the concentrations of heavy metal found in the water from the Athi River tributaries and gills of the tilapia fish examined was higher than the WHO limits, therefore posing potential risk for inhabitants that depended on the river (Muiruri *et al*., 2013).

2.3.1 Routes of heavy metal exposure

Heavy metals enter the human body mainly through two routes which are inhalation and ingestion. Ingestion is the main route of exposure to these elements in human population (Türkdogan *et al*., 2003; Damek-Poprawa and Sawicka-Kapusta, 2003; Ejaz ul *et al*., 2007). Absorption through the skin is another route of exposure when the metals come in contact with humans in agriculture and in manufacturing, pharmaceutical, industrial, or residential

settings. Industrial exposure accounts for a common route of exposure for adults (Roberts, 1999; Ngan, 2006).

Ingestion is the most common route of exposure in children. Children may acquire toxic levels from the normal hand-to-mouth activity with contaminated soil or by actually eating objects that are not food (Dupler, 2001). Less common routes of exposure are during a radiological procedure, from inappropriate dosing or monitoring during intravenous nutrition and from broken thermometers (Smith *et al*., 1997).

2.3.2 Classifications of heavy metal exposure

Exposure to toxic heavy metals is generally classified as acute, 14 days or less; intermediate, 15-354 days; and chronic, more than 365 days. Heavy metals are not easily biodegradable and so they can accumulate in vital human organs. This situation causes varying degrees of illnesses based on acute and chronic exposures (Demirezen and Aksoy, 2006). Chronic low level intakes of heavy metals have adverse effects on human beings and other animals due to the fact that there is no effective mechanism for their elimination from the body (Bahemuka and Mubofu, 1999). Metals such as lead, mercury, cadmium and copper are cumulative poisons. These metals cause environmental hazards and are reported to be exceptionally toxic (Ellen *et al*., 1990). Additionally, acute toxicity is usually from a sudden or unexpected exposure to a high level of the heavy metal.

Chronic toxicity results from repeated or continuous exposure, leading to an accumulation of the toxic substance in the body. Chronic exposure may result from contaminated food, air, water, or dust; living near a hazardous waste site; spending time in areas with deteriorating lead paint; maternal transfer in the womb; or from participating in hobbies that use lead paint or solder. Chronic exposure may occur in either at home or workplace. Symptoms of chronic toxicity are often similar to many common conditions and may not be readily recognized (WHO, 1998; Roberts, 1999; IOSHIC, 1999; Ferner, 2001; Dupler, 2001; Sharma *et al*., 2008b).

Chronic accumulation of heavy metals in the kidney and liver of humans causes disruption of numerous biochemical processes, leading to cardiovascular, nervous, kidney and bone diseases. Furthermore, the consumption of heavy metal-contaminated food can seriously deplete some essential nutrients in the body causing a decrease in immunological defences, intrauterine growth retardation, impaired psycho- social behaviour, disabilities associated with malnutrition and a high prevalence of upper gastrointestinal cancer (Jarup, 2003; Arora *et al*., 2008).

2.3.3 Hazardous effects of heavy metals on human health

Metals can contaminate the general environment through many routes. Because of their stability, they may penetrate environmental compartments, in some cases, many years after the initial deposition pollution of the soil and water systems may also arise from the weathering of disposed product (Nordberg *et*

al., 2005). Heavy metal accumulations in plant and soil from natural and artificial sources and subsequent consequences represent important environmental pollution problems. Food safety issues and potential adverse health risks make this one of the most serious environmental concerns (Cui *et al*., 2004; Singh *et al*., 2011).

Some heavy metals such as copper, zinc, manganese, cobalt and molybdenum act as micronutrients for the growth of animals and human beings when present in trace quantities, whereas others such as cadmium, arsenic and chromium acts as carcinogens (Freig *et al*., 1994; Trichopoulos *et al*., 1997). Mercury and lead are associated with the development of abnormalities in children (Gibb and Chen, 1989; Pitot and Dragan, 1996; Saplakoglu and Iscan, 1997; Hartwig, 1998) have reported that long term intake of cadmium causes renal, prostate and ovarian cancers.

Generally, at the biochemical levels, the toxic effects caused by excess concentrations of heavy metals include competition for sites with essential metabolites, replacement of essential ions, reactions with –SH groups, damage to cell membranes and reactions with the phosphates groups (Alloway and Ayres, 1997; Nikolic and Sokolovic, 2004 ; Okoronkwo *et al*., 2005a).

2.4 Heavy metals in vegetables

Vegetables are an important part of a human beings diet because they are a source of nutrients. Vegetables constitute important functional food

components by contributing protein, vitamins, iron, calcium and other nutrients which have marked health effects (Thompson and Kelly, 1990; Arai, 2002). There is an inherent tendency of plants to take up toxic substances including heavy metals that are subsequently transferred along the food chain (Singh *et al*., 2010). And as such, heavy metal contamination in vegetables cannot be underestimated as food stuffs are important components of human diet. Heavy metal contamination of the food items is one of the most important aspects of food quality assurance (Marshall, 2004; Wang *et al*., 2005; Radwan and Salama, 2006; Khan *et al*., 2008).

Contamination of foods by heavy metals has become a challenge for producers and consumers. The main sources of heavy metals to vegetable crops are their growth media (soil, air, nutrient solutions) from which these heavy metals are taken up by the roots or foliage (Lokeshwari and Chandrappa, 2006). The toxic and detrimental impacts of heavy metals become apparent only when long-term consumption of contaminated vegetables occurs. Regular monitoring of heavy metals in vegetables and other food items should be performed in order to prevent excessive build up of these heavy metals in the human food chain (Khanna and Khanna, 2011).

Vegetables can take up and accumulate heavy metals in quantities high enough to cause clinical problems to humans (Alam *et al*., 2003). Daily metal intake estimate does not take into account the possible metabolic ejection of the metals but can easily tell the possible ingestion rate of a particular metal.

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 (Oluyemi *et al*., 2008; Orisakwe *et al*., 2012).

Leafy vegetables grown on heavy metal contaminated soils accumulate higher amounts of metals than those grown in uncontaminated soils because of the fact that they absorb these metals through their roots (Bahemuka and Mubofu, 1999; Al-Jassir *et al*., 2005; Sharma *et al*., 2006; Sharma *et al*., 2007; Marshall *et al*., 2007). Heavy metals are persistent in the environment and are subject to bioaccumulation in food-chains. They are easily accumulated in the edible parts of leafy vegetables, as compared to grain or fruit crops (Mapanda *et al*., 2005).

2.4.1 Sources of heavy metal pollution in vegetables

a) Water

Pollution of water bodies with heavy metals from variety of sources is becoming a matter of global concern (Dike *et al*., 2004). Though effects of chemical contamination of drinking water are not felt on short-term bases, their accumulation over a long period in the body has significant health effects (Musa *et al*., 2004).

Water contamination by heavy metals in some areas is practically inevitable due to natural process (weathering of rocks) and anthropogenic activities (industrial, agricultural and domestic effluents) (Sugiyama, 1994). Rivers passing along urban centres are used for irrigation of the vegetables grown on

their banks. Waters of such rivers have often been reported to be polluted by heavy metal and most of these lands are contaminated with heavy metals through industrial effluents, sewage and sludge, and vehicular emission. Vegetables grown in such lands, therefore, are likely to be contaminated with heavy metals and unsafe for consumption (Kashem and Singh, 1999; Mashauri and Mayo, 1990; Othman, 2001; Bilos *et al*., 2001; Ejaz ul *et al*., 2007).

Industrial or municipal wastewater is mostly used for irrigation of crops mainly in periurban ecosystem. This is because waste water is easily available coupled with disposal problems and scarcity of fresh water (Arora *et al*., 2008). The waste water from the industries of mining, electroplating, and paint or chemical laboratories often contains high concentrations of heavy metals, including cadmium, copper and lead. These elements, at concentrations exceeding the physiological demand of the plants, not only could administer toxic effect in them but also could enter food chains, get biomagnified and pose a potential threat to human health (Sugiyama, 1994; Sawidis *et al*., 2001; Mapanda *et al*., 2005).

Waste water is known to contribute significantly to the heavy metal contents of soils; hence disposal of sewage and industrial waste into agricultural lands leads to contamination of crops including vegetables grown on that land. This is because these effluents that are considered a rich source of organic matter and other nutrients also have high levels of heavy metals such as iron, manganese, copper, zinc, lead, cadmium, nickel and cobalt. Most of the heavy

metals are extremely toxic because of their solubility in water (Singh *et al*., 2004; Arora *et al*., 2008; Khanna and Khanna, 2011).

b) Air and other emissions into the environment

Vegetables can absorb metals from soil as well as from deposits on the parts of the vegetables exposed to the air from polluted environments (Haiyan and Stuanes, 2003). Emission of heavy metals from the industries and vehicles may be deposited on the vegetable surfaces during their production, transport and marketing. Al-Jassir *et al*. (2005) have reported elevated levels of heavy metals in vegetables sold in the market of Riyadh city in Saudi Arabia due to atmospheric deposition. Similarly, Sharma *et al*. (2008 a,b) reported that atmospheric deposition can significantly elevate the levels of heavy metals contamination in vegetables commonly sold in the markets of Varanasi, India.

c) Soil

When plants decay, heavy metals that had been taken into the plants are redistributed so the soil is then again enriched with the pollutants (Sawidis *et al*., 2001). It has been established that heavy metals in soil are associated with various chemical forms that relate to their solubility which directly bear on their mobility and biological availability. Heavy metals in soluble form have high relation to their uptake by plants (Miller and McFree, 1983; Xian, 1989; Arora *et al*., 2008).

Apart from the source of heavy metal, the physical and chemical properties of the soil also affect the concentration of heavy metals in soils (Qishlaqi and Moore, 2007). The uptake and bioaccumulation of heavy metals in vegetables is influenced by many factors such as climate, atmospheric depositions, the concentrations of heavy metals in soils, the nature of soil and the degree of maturity of the plants at the time of the harvest (Scott *et al*., 1996; Voutsa *et al*., 1996).

Results obtained from a study carried out by Ebong, *et al*. (2008) on heavy metal contents of municipal and rural dumpsite soils and rate of accumulation by C*arica papaya* and *Talinum triangular* revealed that plants grown on dumpsite soils bio-accumulated higher metal concentrations than their counterparts obtained from normal agricultural soils (Ebong *et al*., 2008).

2.5 Selected heavy metals

a) Zinc

Zinc is an essential nutrient in humans and animals and is necessary for the function of a large number of metalloenzymes. These enzymes include alcohol dehydrogenase, alkaline phosphatase, carbonic anhydrase, leucine aminopeptidase, superoxide dismutase, and deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) polymerase. An acute oral dose of zinc may cause symptoms such as tachycardia, vascular shock, dyspeptic nausea, vomiting, diarrhoea, pancreatitis and damage of hepatic parenchyma (Salgueiro *et al*., 2000; ATSDR, 2005b).

When high levels of zinc are ingested inhibition of copper absorption through interaction with metallothionein at the brush border of the intestinal lumen occurs. Both copper and zinc appear to bind to the same metallothionein protein; however, copper has a higher affinity for metallothionein than zinc and displaces zinc from metallothionein protein. Copper complexed with metallothionein is retained in the mucosal cell, relatively unavailable for transfer to plasma, and is excreted in the feces when the mucosal cells are sloughed off. Thus, an excess of zinc can result in a decreased availability of dietary copper, and the development of copper deficiency (Gyorffy and Chan, 1992; Barone *et al*., 1998).

On the other hand zinc deficiency has been associated with dermatitis, anorexia, growth retardation, poor wound healing, hypogonadism with impaired reproductive capacity, impaired immune function, and depressed mental function; increased incidence of congenital malformations in infants has also been associated with zinc deficiency in the mothers (Sandstead, 1981; Elinder, 1986; Cotran *et al*., 1989).

b) Copper

Copper is an essential nutrient that is incorporated into a number of metalloenzymes involved in haemoglobin formation, drug/xenobiotic metabolism, carbohydrate metabolism, catecholamine biosynthesis, the cross-linking of collagen, elastin, and hair keratin, and the antioxidant defense mechanism. Copper-dependent enzymes, such as cytochrome C oxidase,

superoxide dismutase, ferroxidases, monoamine oxidase, and dopamine β-monooxygenase, function to reduce activated oxygen species or molecular oxygen. Symptoms associated with copper deficiency in humans include normocytic, hypochromic anaemia, leukopenia, and osteoporosis (ATSDR, 2004a).

Although copper homeostasis plays an important role in the prevention of copper toxicity, exposure to excessive levels of copper can result in a number of adverse health effects including liver and kidney damage, anaemia, immunotoxicity, and developmental toxicity. Many of these effects are consistent with oxidative damage to membranes or macromolecules. Copper can bind to the sulfhydryl groups of several enzymes, such as glucose-6-phosphatase and glutathione reductase, thus interfering with their protection of cells from free radical damage (ATSDR, 2004a).

c) Manganese

Manganese is essential for normal development and body function across the life span of all mammals (Keen *et al.,* 2000). Manganese binds to and/or regulates many enzymes throughout the body. It is a required co-factor for arginase, which is responsible for urea production in the liver, superoxide dismutase, which is critical to prevent against cellular oxidative stress, and pyruvate carboxylase, an essential enzyme in gluconeogenesis. The brain is the major target organ for manganese toxicity as it retains manganese much longer than other tissues. Following chronic overexposure, manganese can produce a

progressive, permanent neurodegenerative disorder, with few options for treatment and no cure (Carl and Gallagher, 1994; Keen *et al*., 2000; Crossgrove and Zheng, 2004).

d) Iron

An elevated dietary iron intake enhances the incidence of carcinogen-induced mammary tumors in rats and estrogen-induced kidney tumors in Syrian hamsters. Estrogen administration increases iron accumulation in hamsters and facilitates iron uptake by cells in culture. In humans, increased body stores of iron have been shown to increase the risk of several estrogen-induced cancers (Liehr and Jones, 2001).

Iron acts as a catalytic center for a broad spectrum of metabolic functions. Iron is also a component of various tissue enzymes, such as the cytochromes, that are critical for energy production, and enzymes necessary for immune system functioning. The fact that serum copper has been found to be low in some cases of iron deficiency anemia suggests that iron status has an effect on copper metabolism (Michael *et al*., 2009).

Iron deficiency includes symptoms such as reduced resistance to infection, reduced work productivity, reduced physical fitness, weakness, fatigue, impaired cognitive function, and reduced learning ability, increased distractibility, impaired reactivity and coordination, itching, inability to regulate body temperature and eating pica (Beard, 2001)

e) Nickel

There is evidence of uptake and accumulation in certain plants. Nickel is an essential trace element in animals, although the functional importance of nickel has not been clearly demonstrated. It is considered essential based on reports of nickel deficiency in several animal species. Nickel deficiency is manifested primarily in the liver; effects include abnormal cellular morphology, oxidative metabolism, and increases and decreases in lipid levels. Decreases in growth and hemoglobin concentration and impaired glucose metabolism have also been observed. The essentiality of nickel in humans has not been established, and nickel dietary recommendations have not been established for humans (ATSDR, 2003b).

Nickel compounds are known carcinogens in both human and animal models (Harman, 1981; Feder *et al*., 1996). There is evidence that the genotoxic effects of nickel compounds may be indirect through the inhibition of DNA repair systems. As a result of this inhibition it has been suggested that accumulation of nickel in breast tissue may be closely related to malignant growth process (Rothenberg *et al*., 1994; Beyersmann, 2002; ATSDR, 2005a).

f) Vanadium

Vanadium has not been shown to be essential for humans and has no nutritional value. Therefore, nutritional requirements or intake recommendations have not been established. The Scientific Committee on Food (SCF) stated that evidence supporting the essentiality of vanadium has

yet to be established (SCF, 1993). A maximum intake level of 1.8 mg vanadium/day for adults is recommended by Food and Nutrition Board (FNB, 2001). The Expert Group on Vitamins and Minerals (EGVM) stated that there are insufficient data to establish a safe upper level for vanadium (EGVM, 2003).

Vanadium compounds have been shown to mimic the action of insulin in isolated cell systems, animal models and diabetic patients. Therefore, their use in the therapy of diabetes mellitus has been considered (Shechter, 1990; Shamberger, 1996). Vanadium has also been suggested as an aid in body building, but there is no evidence that it is effective (Fawcett *et al*., 1997). Studies show that vanadium is rather toxic to mammals and is accumulated and retained in the bones (Melchior *et al*., 1999).

g) Cobalt

As a component of cyanocobalmin (vitamin B12), cobalt is essential in the body; the cobalt has been identified in most tissues of the body, with the highest concentrations found in the liver (ATSDR, 2004b). Cobalt enters the air through burning of oil and cobalt compounds that are used as colorants in glass, ceramics, and paints, as catalysts, and as paint driers. Cobalt compounds are also used as trace element additives in agriculture and medicine (ATSDR, 2004b). After it enters the air cobalt is associated with particles which will settle to the ground within few days. Some of the compounds may then settle

in water, food and drinking water and these are the largest sources of exposure to the general population (Udeh, 2004).

h) Mercury

Mercury is a ubiquitous environmental toxin that produces a wide range of adverse health effects in humans (Ratcliffe *et al*., 1996; Sweet and Zelikoff, 2001; Campbell *et al*., 2003; Guzzi and La Porta, 2008). The most common natural forms of mercury found in the environment are metallic mercury, mercuric sulfide (cinnabar ore), mercuric chloride, and methylmercury (ATSDR, 1999b; Guzzi and La Porta, 2008). Each of them has its own profile of toxicity. Methylmercury is of particular concern because it can build up in certain edible freshwater and saltwater fish and marine mammals to levels that are many times greater than levels in the surrounding water (ATSDR, 1999b; Campbell *et al*., 2003; Guzzi and La Porta, 2008; Wiwanitkit, 2009).

Metallic and inorganic mercury enters the air from mining deposits of ores that contain mercury, from the emissions of coal-fired power plants, from burning municipal and medical waste, from the production of cement, and from uncontrolled releases in factories that use mercury. Metallic mercury is a liquid at room temperature, but some of the metal will evaporate into the air and can be carried long distances. In air, the mercury vapor can be changed into other forms of mercury, and can be further transported to water or soil in rain or snow.

Inorganic mercury may also enter water or soil from the weathering of rocks that contain mercury, from factories or water treatment facilities that release water contaminated with mercury, and from incineration of municipal garbage that contains mercury (for example, in thermometers, electrical switches, or batteries that have been thrown away (ATSDR, 1999b; Balshaw et al., 2007). Mercury can enter and accumulate in the food chain. The form of mercury that accumulates in the food chain is methylmercury (Sweet and Zelikoff, 2001; Balshaw *et al*., 2007; Wiwanitkit, 2009).

Symptoms of mercury poisoning include permanent damage to the brain and kidneys, personality changes (irritability, shyness, and nervousness), tremors, changes in vision, deafness, muscle incoordination, loss of sensation, and difficulties with memory (ATSDR, 1999b).

i) Lead

Lead is a toxic element that can be harmful to plants, although plants usually show ability to accumulate large amounts of lead without visible changes in their appearance or yield. Lead is a well-known neurotoxin. Impairment of neurodevelopment in children is the most critical effect. Exposure in uterus, during breastfeeding and in early childhood may all be responsible for the effects. Lead accumulates in the skeleton and its mobilization from bones during pregnancy and lactation causes exposure to fetuses and breastfed infants (ATSDR, 2007). In many plants, lead accumulation can exceed several hundred times the threshold of maximum level permissible for human

(Wierzbicka, 1995). It has been suggested that lead on a cellular and molecular level may permit or enhance carcinogenic events involved in DNA damage, DNA repair, and regulation of tumour suppressor and promoter genes (Silbergeld, 2003).

A study carried out by Finster *et al*., (2004) demonstrated that plants grown in lead-contaminated soils accumulate low levels of lead in the edible portions of the plant from adherence of dusts and translocation into the tissues. In this study, thirty-two different types of fruits or vegetables were grown in urban gardens with soils containing high lead levels (27–4,580 mg/kg). Samples were harvested and washed with either water or detergents and analyzed for lead content. Only one fruiting vegetable among 52 samples contained lead levels greater than the detection limit of 10 μg/g in the edible portion. However, 39% of the leafy vegetables and herbs had lead levels >10 μg/g in the edible shoot portion following washing of the vegetables with detergent and water (Finster *et al*., 2004).

2.6 Mechanism of action of heavy metals

The heavy metal ions form complexes with proteins, in which carboxylic acid (–COOH), amine ($–NH_2$), and thiol (–SH) groups are involved. These modified biological molecules lose their ability to function properly and result in the malfunction or death of the cells. When metals bind to these groups, they inactivate important enzyme systems, or affect protein structure, which is linked to the catalytic properties of enzymes. This type of toxin may also cause

the formation of radicals, dangerous chemicals that cause the oxidation of biological molecules (Dhar, 1973; Neal and Guilarte, 2012)

2.7 Laboratory Testing and diagnosis for the presence of heavy metals

Diagnosing heavy metal toxicity requires observation of presenting symptoms, obtaining a thorough history of potential exposure, and laboratory tests. Routine laboratory tests include blood tests, liver and renal function tests, urinalysis, fecal tests, x-rays, and hair and fingernail analysis. Many of these tests are not routinely performed in a doctor's office. However, physicians can take blood samples and send them to the appropriate testing laboratory. Chest x-rays are recommended for persons with respiratory symptoms, and abdominal x-rays can detect ingested metals (ATSDR, 1999b; ATSDR, 2003b; ATSDR, 2004a; ATSDR, 2004b; ATSDR, 2005b; ATSDR, 2007; ATSDR, 2009)

2.8 Management of Heavy Metal poisoning

Metal toxicity is unique in that the toxic agent may not be metabolised. Compounds containing metals may certainly be metabolised to hasten their excretion and the properties of metals may change, but the body cannot reduce a toxic metal to a non-toxic metal. One mechanism that may reduce the toxicity of metals is a metal carrier protein, metallothionein, which may complex with the metal, preventing it from exerting a toxic effect, and transport it to the kidney where it may be filtered and excreted (Dhar, 1973; Neal and Guilarte, 2012)

A common treatment for metal intoxication is the use of chelators. A chelator is a flexible molecule with two or more electronegative groups that can form stable complexes with cationic metal atoms. The complexes are then eliminated from the body. The most widely used chelator is ethylenediaminetetraacetic acid (EDTA). It has four binding positions (two nitrogen atoms and two oxygen atoms) that focus on the metal ion. It works very well on many metals, the most notable being calcium, magnesium, and lead (Howland, 2011c; Neal and Guilarte, 2012)

Chelating with drugs is indicated primarily for acute poisonings by some metals, especially lead, arsenic, mercury, and iron. Though the drugs may have dangerous side effects, the risks are considered worthwhile in the face of toxicity which may be fatal or cause serious, even permanent injury (Kosnett, 2010)

Approved chelating drugs include succimer, dimercaprol (BAL), edetate calcium disodium, deferoxamine, and penicillamine. They are given only for diagnosed metal toxicity because they may have serious side effects, even when their use is needed; and they are non-specific and can bind even essential “trace” metals in the body, for example copper and zinc. They can sometimes bind calcium, too. Chelation of these substances can cause symptoms related to their deficiency (Howland, 2011a; Howland, 2011b; Howland, 2011c; Howland, 2011d; Nelson, 2011)

CHAPTER THREE: MATERIALS AND METHODS

3.1 Study Location

Nairobi County hosts the capital city of Kenya. It lies at an altitude of 1,670 meters above sea level and occupies an area of 696 km^2. It is divided into eight administrative divisions namely; Embakasi, Makadara, Pumwani, Central, Kasarani, Westlands, Kibera and Dagoreti (figure 3.1 below).

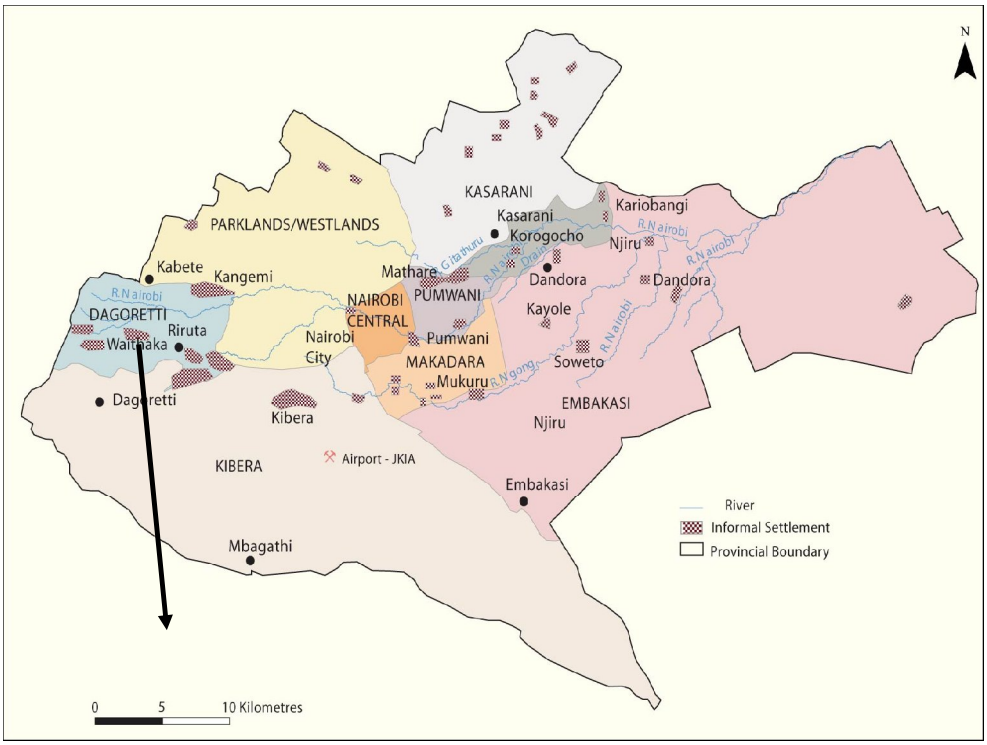

Figure 3.1: Map of Nairobi County. The arrow shows the study Location

This study was carried out in Kadhodeki Village in, Waithaka Sublocation, Dagoretti Division, Nairobi County, Kenya. The village is home to Kadhodeki Dumpsite, an open dumpsite declared illegal by the Nairobi City Council. The coordinates for the study area are 1016'31.58"S, 36043'52.95"E (the red patch shows the area occupied by the dumpsite; all units are in square metres).

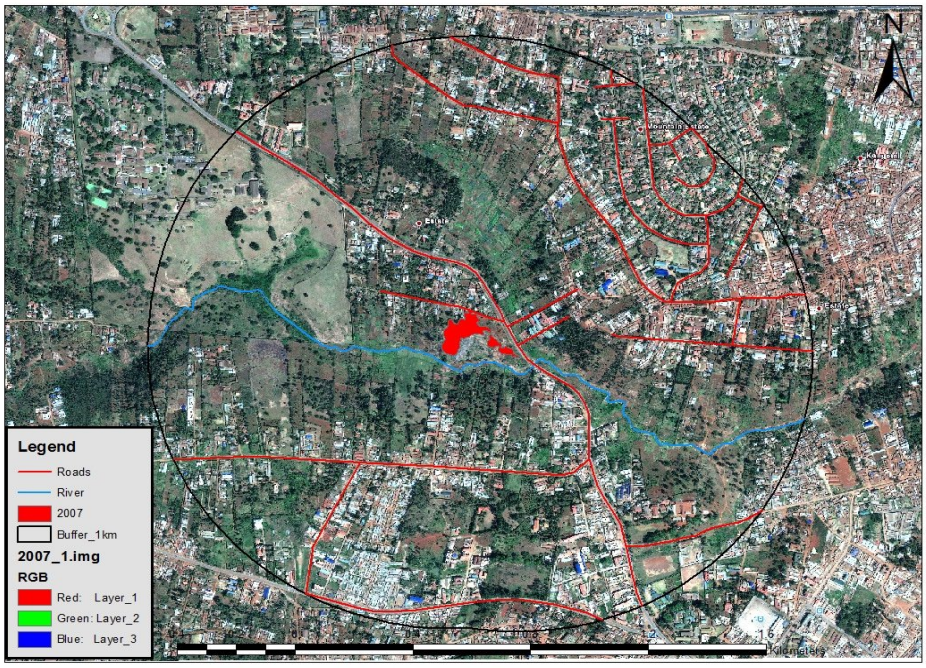

Figure 3.2: Map of the study site showing the dumpsite (red) patch and the Nairobi River (Blue line)

3.2 Study Design

The research was carried out in two phases; the first phase was the analytical phase involving the environmental media, sample collection, preparation and laboratory work. Because of the socioeconomic nature of the study and the risks to the human health involved the study involved a second phase which was cross sectional in nature. There was need to know whether the people that live around the dumpsite are aware of its risks in terms of knowledge, attitude and perception.

3.2.1 Analytical Methods

The analytical phase involved the analysis of mean heavy metal concentrations in soil samples, edible vegetables collected on and around the dumpsite,

downstream and upstream which was treated as the control site. Samples of water upstream, on the dumpsite and further downstream after the dumpsite were collected and analysed to measure the impact of the dumpsite on water and the dilution effect.

3.3 Analytical procedures

3.3.1 Sampling Techniques

3.3.2 Plant sample collection and preparation

The vegetable were collected along transect lines (Melville and Welsh, 2001). This was done for the vegetables planted upstream (this was the control site, it was 300 m up along the Nairobi river from where the dumpsite was located) around the dumpsite and downstream (this was 300 m down along the Nairobi river from where the dumpsite is located). The following vegetables were collected/ harvested at maturity (two months after planting seedlings).

Photos showing plates of the vegetables under study

Plate 3.a. A photo of *Spinacia oleracea*

Local name: Spinach

Plate 3.b. A photo of the *Brassica oleracea Acephala*

Local names: Sukuma wiki (Swahili)

Plate 3.c. A photo of *Amaranthus Spp*

Local names: Mchicha (Swahili), Terere (Kikuyu), Lidodo (Luhya), Ododo (Luo), Kelichot (Kipsigis), W'oa (Kamba), Emboga (Kisii), Kichanya (Taita)

Plate 3.d. A photo of *Solanum Villosum*

Local names: Mnavu (Swahili), Managu (Kikuyu), Namaska (Luhya), Osuga (Luo), Isoiyot (Kipsigis), Kitulu (Kamba), Ormomoi (Maa), Ndunda (Taita)

Four samples each of the leafy edible vegetables above growing along the transect lines in the three study sites were collected. They were then packed into clean polythene bags for laboratory preparation. The vegetables were placed under running tap water to wash off soil particles and other debris then rinsed with distilled water. The samples were then cut into small pieces and then air dried at room temperature in enclosed chambers for about two weeks and then pulverized to fine powder using a stainless grinder. Ground plant samples were then collected in labelled polythene bags and were placed in a desiccator awaiting laboratory analysis (Faithfull, 2002; Ebong *et al*., 2008).

3.3.3 Soil sample collection and preparation

The soil samples were collected along transect lines (Melville and Welsh, 2001). Transect lines were drawn in each sampling site. This was done for the soil samples collected upstream, midstream and downstream.

Four samples of the top soil were then taken along each of the transect line. Soil samples at each of the three sites were collected to a depth of 15 cm from the same locations where the vegetable plants were sampled. The 0-15 cm depth was considered to represent the plough layer and average root zone for nutrients uptake and heavy metals burden by plants (Nyangababo and Hamya, 1986; Eddy *et al*., 2006; Odai *et al*., 2008). The soil samples were then air dried, crushed, passed through a sieve, put in clean polythene bags and stored at room temperature for laboratory analysis.

3.3.4 Water sample collection and preparation

Samples of water were collected from different sites along the river course (300 m up along the Nairobi river from where the dumpsite was located, around the dumpsite and downstream which was 300 m down along the Nairobi river from where the dumpsite is located) using depth integrated water sampling method at 10 cm, 20 cm and 30 cm depths and 60 cm from the river bank. The samples were mixed together to produce a composite sample (Afullo, 2009). From this a 500 ml representative sample was then collected in white plastic bottles according to standard procedures (DWAF, 1992; DWAF, 1996).

3.4 Heavy metal concentration determination

3.4.1 Determination of heavy metal concentration in plant and soil samples using energy dispersive X- ray fluorescence spectroscopy (EDXRF) system

Ten grams of soil and 5 g of starch were mixed and pressed into 7 mm disc in thickness and 4.1 cm in diameter in a mould with a force of 200kN for 5 sec. This was repeated for the vegetable samples and in order to retain the original dry mass of the samples, the discs were stored in desiccators till EDXRF analyses were done. The above procedure was repeated four times for each vegetable and soil sample. The mineral element concentrations were determined from the soil and plant material by EDXRF analyses using ray EDX-720, EDXRF spectrometer. The following elements were quantified; V, Mn, Fe, Co, Ni, Cu, Zn, Hg and Pb. The results were expressed as milligrams per kilogram (mg/kg) of the dry matter.

3.4.2 Determination of heavy metal concentration in water samples using Total Reflection X-ray Fluorescence Spectroscopy (TXRF)

The micro reaction tube was filled with 1ml of the water sample to be tested. A 5 µl internal standard (IS) solution (Ga, 100 mg/L, end concentration 500 µg/L) was added and the sample was then homogenized. A sample of 10 µl homogenised solution was then pipetted on a siliconized sample carrier and dry heated at (60 °C) (Dike et al., 2004). All measurements were performed using the bench top TXRF spectrometer S2 PICOFOX (Stosnach, 2007). The following elements were quantified; V, Mn, Fe, Co, Ni, Cu, Zn, Hg and Pb. The results were expressed as micro grams per litre (µg/l).

3.5 Descriptive Cross Section methods

This was carried out in an attempt to provide answers for the second phase. In this study a pre-tested questionnaire and a face-to-face interview were used to capture data on the respondent's knowledge, attitude and perceptions on whether the dumpsite posed any health risk to them. Simple random sampling of the households was done from a list of the households of 2009.

3.5.1 Target and Study Population

This study targeted all the residents who live around dumpsites. The study population was all the residents living in Kadhodeki village.

3.5.2 Inclusion Criteria

The inclusion criteria involved head of household aged 18 years and above living in Kadhodeki village for more than six months at the time of the study, who consented to be involved in the study.

3.5.3 Exclusion Criteria

Exclusion criteria involved residents living in Kadhodeki village for less than six months and less than 18 years of age at the time of study and those who did not consent.

3.5.4 Sample Size determination

For the fourth objective the sample size was determined using the Fischer *et al*., (1998) formula

$$n=\frac{Z^2 pqD}{d^2}$$

where n= is the desired sample size (if target population is > 10000)

z- Is the standard normal deviation = 1.96 which corresponds to 95% confidence interval

p= proportion of the target population estimated to have the desired characteristics (0.3)

q=1-p (proportion without the characteristic)

d= the level of statistical significant set at 0.05 degrees of freedom)

D= the design effect = 1

A study carried by Kimani, (2007) on Dandora dumpsite shows that 30% of the children tested had size and staining abnormalities of their red blood cells, confirming high exposure to heavy metal poisoning. Hence a p value of 0.3 was employed in sample size determination

$$n=\frac{1.96^2 x0.3x0.7}{0.05^2}$$

= 323 respondents

3.5.5 Study variables

3.5.5.1 Independent variables

The independent variables used in the study included the participants' level of education and the number of years they had lived in the village.

3.5.5.2 Dependent variables

The dependent variables were knowledge, attitude and perception of the study participants on the health risks posed by the dumpsite.

3.5.6 Reliability

The research questionnaire and questions to be used for the FGD were constructed according to study's specific objectives. The questionnaire was pretested in Asian Quarters a village near an open dumpsite in the Municipal Council of Nyeri (about 200 km from Kadhodeki) with similar characteristics with study area.

3.6 Ethical Considerations

Permission was sought from Kenyatta University Graduate School, Kenyatta University Ethics Research Committee and the National Council for Science and Technology (Appendix 8 and 9) respectively. Informed consent was sought from the individual participants after explaining to them the objective of the study (Appendix 5 and 7). Confidentiality was ensured throughout the study.

3.7 Data Management and Analysis

The heavy metal data was analysed using Microsoft excel to get the mean and standard error of the mean which was then subjected to statistical tests of significance using ANOVA ($p<0.05$). The results that were found to be statistically different were subjected to a Tukeys post hoc analysis test (XL Daniel's toolbox version 4.01 for post ANOVA). This was to determine whether there was any statistical difference between the mean concentrations of the heavy metals in the three sites for vegetables, soil and water samples.

Mean heavy metal results were extrapolated to calculate the estimate for calculated daily intake of metal (DIMetal). Transfer factors of heavy metals from the soil to the plant were also calculated.

Statistical analysis for the cross sectional survey was carried out using Predictive Analytic Software for windows (SPSS version 16). Inferential statistics were made using Chi square to test for associations between the different variables and knowledge, attitude or perception of the respondents.

Descriptive statistics such as frequencies and percentages were used to summarize the data in the questionnaires. Tables and graphs were used to present the results.

CHAPTER FOUR: RESULTS

4.1 Mean heavy metal concentrations in soils at the sampled sites

The determination of heavy metal in soil samples was done using energy dispersive X-ray fluorescence spectroscopy (EDXRF) system. Table 4.1 below shows that the concentrations of vanadium, manganese, iron, and nickel and mercury were low upstream. The levels increased to maximum in the soils collected next to the dumpsite. The heavy metal content slightly lowered as indicated by the concentrations of the metals in the soil samples collected downstream.

Copper concentrations in the soil increased from a mean of 143.02 ±29.69 mg/kg upstream, to a high mean of 2089.61±67.44 mg/kg at the dumpsite; a distance of only 300m. However, further downstream this concentration slightly declined to 1665.89 ±53.79 mg/kg implying that the dumpsite is heavily contaminated owing to the waste. The concentrations of zinc, cobalt and lead levels remained constant across the three study sites.

Table 4.1: Mean heavy metal concentrations in soils obtained at the sampled sites

Element	Upstream	Midstream	Downstream
	mg/kg		
Vanadium	337.05±77.30[a]	5077.95±208.97[b]	4402.15±45.89[b]
Manganese	5490.60±1371.77[a]	14419.10±254.73[b]	13835.41±253.51[b]
Iron	22.01±7.90[a]	525.50±33.59[b]	338.48±60.21[b]
Copper	143.02±29.69[a]	2089.61±67.44[b]	1665.89±53.79[c]
Zinc	128.11±21.54[a]	289.27±31.58[a]	217.32±30.34[a]
Cobalt	2767.91±766.22[a]	6003.90±121.05[a]	5974.57±236.17[a]
Nickel	5250.62±1439.42[a]	11968.76±255.87[ab]	10954.29±124.60[b]
Mercury	7.43±1.41[a]	436.70±67.88[b]	171.24±35.15[ab]
Lead	19.79±5.78[a]	60.22±15.58[a]	56.64±16.19[a]

Results are expressed as Means ± standard error of the mean (SEM) for four determinations. Within rows, means with different alphabets are statistically different at $p<0.05$ by ANOVA and Tukeys' test. The first site was the control site which was at a point of 300m upstream along the nearby Nairobi River from where the dumpsite was located, the second site was next to the dumpsite and the third collection point was 300m downstream from where the dumpsite was located.

4.2 Heavy metal concentration in the leaves of the vegetables grown at the three study sites

The determination of heavy metal concentration in vegetables was done using energy dispersive X- ray fluorescence spectroscopy (EDXRF) system.

4.2.1 Mean heavy metal concentrations in *Spinacia oleracea*

Table 4.2 below shows the mean metal concentrations of vanadium, manganese, iron, copper, zinc, cobalt, nickel, mercury and lead in the *Spinacia oleracea* at the three studied sites. According to the results, vanadium and cobalt metal concentration in *Spinacia oleracea* increased from the levels indicated upstream of 1.30±0.40 mg/kg and 19.10±0.40 mg/kg respectively to highest levels in vegetables that were grown next to the dumpsite 7.28±0.06

mg/kg and 23.15±0.43 mg/kg respectively. The heavy metal content however decreased to 1.64±0.47 mg/kg and 20.29±0.12 mg/kg in the vegetables grown downstream respectively, to a similar level as that displayed by the vegetables grown at the control site.

Manganese, nickel and mercury showed a different pattern whereby the content of these three metals in the *Spinacia oleracea* collected at the upstream was low. The levels increased to maximum in the vegetables grown next to the dumpsite. The heavy metal content remained at a constant as indicated by the concentrations of the metals in the *Spinacia oleracea* grown downstream.

Iron, copper, zinc and lead mean levels in the *Spinacia oleracea* did not statistically change from the levels shown for vegetables grown upstream to those grown next to the dumpsites and those grown downstream.

Table 4.2: Mean heavy metal concentrations in *Spinacia oleracea*

Elements	Upstream	Midstream	Down stream
	mg/kg		
Vanadium	1.30±0.40[a]	7.28±0.06[b]	1.64±0.47[a]
Manganese	1.41±0.27[a]	5.22±0.35[b]	3.62±0.12[b]
Iron	0.39±0.19[a]	1.66±0.08[a]	1.14±0.19[a]
Copper	0.75±0.22[a]	0.76±0.22[a]	1.13±0.19[a]
Zinc	1.13±0.19[a]	1.62±0.01[a]	1.96±0.16[a]
Cobalt	19.10±0.40[a]	23.15±0.43[b]	20.29±0.12[a]
Nickel	17.44±0.81[a]	35.23±1.04[b]	32.08±1.46[b]
Mercury	0.38±0.19[a]	1.81±0.15[b]	1.63±0.07[b]
Lead	0.75±0.22[a]	1.51±0.00[a]	1.13±0.19[a]

Results are expressed as Means ± standard error of the mean (SEM) for four determinations. Within rows, means with different alphabets are statistically different at $p<0.05$ by ANOVA and Tukeys' test. The first site was the control site which was at a point of 300m upstream along the nearby Nairobi River from where the dumpsite was located, the second site was next to the dumpsite and the third collection point was 300m downstream from where the dumpsite was located.

4.2.2 Mean Heavy metal concentrations in *Solanum villosum*

Table 4.3 below shows that the pattern of heavy metal concentration displayed by vanadium, manganese, iron, cobalt nickel and mercury for *Solanum villosum* at three sites is similar. The content of these metals in the *Solanum villosum* collected upstream was low. The levels increased to maximum in the vegetables grown next to the dumpsite, then remained at a constant as indicated by the concentrations of the metals in the vegetables grown downstream. Copper, zinc and lead heavy metal levels in the *Solanum villosum* did not change across the three sites.

Table 4.3: Mean Heavy metal concentrations in *Solanum villosum*

Elements	Upstream	Midstream	Down stream
	mg/kg		
Vanadium	1.15±0.19^{a}	4.89±0.38^{b}	3.42±0.34^{ba}
Manganese	4.10±0.55^{a}	8.66±0.57^{b}	5.84±0.27^{ba}
Iron	0.76±0.22^{a}	2.55±0.10^{b}	1.84±0.16^{ba}
Copper	0.75±0.22^{a}	1.72±0.11^{a}	0.75±0.22^{a}
Zinc	1.51±0.00^{a}	2.43±0.15^{a}	1.39±0.25^{a}
Cobalt	21.74±0.50^{a}	26.13±0.20^{b}	23.47±0.65^{ba}
Nickel	14.62±0.44^{a}	24.89±0.97^{b}	22.03±1.78^{ba}
Mercury	0.39±0.19^{a}	2.68±0.08^{b}	1.77±0.09^{b}
Lead	0.75±0.22^{a}	1.59±0.03^{a}	1.14±0.19^{a}

Results are expressed as Means ± standard error of the mean (SEM) for four determinations. Within rows, means with different alphabets are statistically different at $p<0.05$ by ANOVA and Tukeys' test. The first site was the control site which was at a point of 300m upstream along the nearby Nairobi River from where the dumpsite was located, the second site was next to the dumpsite and the third collection point was 300m downstream from where the dumpsite was located.

4.2.3 Mean heavy concentration levels in *Amaranthus spp*

According to the results, showed in the Table 4.4 below, manganese concentration in *Amaranthus spp* vegetables increased from 1.63±0.07 mg/kg

the levels indicated upstream to highest levels of 8.57±0.72 mg/kg in vegetables that were grown next to the dumpsite. The heavy metal content however decreased to 3.11±0.44 mg/kg in the vegetables grown downstream.

Vanadium, iron, cobalt, nickel, and mercury metals showed a different pattern whereby the content of these three metals in the *Amaranthus spp* vegetables collected upstream was low. The levels increased to maximum in the vegetables grown next to the dumpsite. The heavy metal content remained at a constant as indicated by the concentrations of the metals in the vegetables grown downstream. Copper, zinc and lead heavy metal levels in the *Amaranthus spp* did not change across the three sites.

Table 4.4: Mean heavy concentrations in *Amaranthus spp*

Elements	Upstream	Midstream	Down stream
	mg/kg		
Vanadium	0.46 ±0.23^{a}	14.26±2.50^{b}	4.01±1.00^{ba}
Manganese	1.63±0.07^{a}	8.57±0.72^{b}	3.11±0.44^{a}
Iron	0.38±0.19^{a}	2.74±0.12^{b}	1.77±0.32^{ba}
Copper	1.13±0.19^{a}	1.53±0.00^{a}	1.14±0.19^{a}
Zinc	1.83±0.17^{a}	1.56±0.02^{a}	1.33±0.23^{a}
Cobalt	19.66±0.28^{a}	24.38±0.05^{b}	22.86±0.15^{b}
Nickel	17.52±0.34^{a}	34.93±1.00^{b}	30.30±0.68^{b}
Mercury	0.40±0.20^{a}	2.06±0.10^{b}	1.80±0.10^{b}
Lead	0.75±0.22^{a}	1.51±0.00^{a}	1.13±0.19^{a}

Results are expressed as Means ± standard error of the mean (SEM) for four determinations. Within rows, means with different alphabets are statistically different at $p<0.05$ by ANOVA and Tukeys' test. The first site was the control site which was at a point of 300m upstream along the nearby Nairobi River from where the dumpsite was located, the second site was next to the dumpsite and the third collection point was 300m downstream from where the dumpsite was located.

4.2.4 Mean heavy metal concentrations in *Brassica oleracea Acephala*

The table below shows that the pattern of heavy metal concentration displayed by iron, cobalt, zinc, lead and mercury for *Brassica oleracea Acephala* at three sites is similar. The content of these metals in the vegetables collected upstream was low. The levels increased to maximum in the vegetables grown next to the dumpsite, then remained at a constant as indicated by the concentrations of the metals in the vegetables grown downstream. Vanadium, manganese, copper and nickel heavy metal concentrations in the *Brassica oleracea Acephala* did not change across the three sites.

Table 4.5: Mean heavy metal concentrations in *Brassica oleracea Acephala*

Elements	Upstream	Midstream	Down stream
	mg/kg		
Vanadium	0.48±0.24	2.87±0.45^{a}	0.50±0.25^{a}
Manganese	0.75±0.22^{a}	4.29±0.95^{a}	2.79±0.26^{a}
Iron	0.38±0.19^{a}	1.83±0.16^{b}	1.51±0.00^{ba}
Copper	1.14±0.19^{a}	1.52±0.01 ^{a}	0.38±0.19^{a}
Zinc	0.38±0.19^{a}	1.73±0.07^{b}	1.67±0.08^{b}
Cobalt	17.42±0.08^{a}	21.02±0.34^{b}	19.90±0.54^{ba}
Nickel	13.02±0.54^{a}	22.54±1.57^{a}	21.46±1.88^{a}
Mercury	0.38±0.19^{a}	2.60±0.21^{b}	1.56±0.03^{ba}
Lead	0.39±0.20^{a}	1.56±0.03^{b}	1.51±0.00^{b}

Results are expressed as Means ± standard error of the mean (SEM) for four determinations. Within rows, means with different alphabets are statistically different at $p<0.05$ by ANOVA and Tukeys' test. The first site was the control site which was at a point of 300m upstream along the nearby Nairobi River from where the dumpsite was located, the second site was next to the dumpsite and the third collection point was 300m downstream from where the dumpsite was located.

4.2.5 Extrapolation of Daily metals intakes estimate (DImetal)

This study sought to estimate the approximate daily metal intake for the participants living in Kadhodeki village. Experts have recommended a daily intake of at least 400g of vegetables (Sharma *et al*., 2008a). The daily metals intakes estimate of the metals (Fe, Mn, Zn, Cu, Ni, Co and V) from each vegetable in this study were calculated by multiplying the daily intake (400g) by the metals concentrations of the vegetables determined in this study. The DImetal were compared with the recommended daily intakes/or allowances and the upper tolerable daily intakes for the metals (UL) (USEPA, 1989; ATSDR, 1999a; FNB, 2001; Garcia-Rico *et al*., 2007).

Table 4.6 below shows that the DImetal values for zinc, copper and iron were below the recommended daily allowance of 11(8) mg/day, 0.9 mg/day and 8(18) mg/day, respectively. A biological role of vanadium in humans has not yet been identified. Therefore, neither an estimated average requirement, RDA, nor Adequate Intake was determined for vanadium, though an upper limit of 1.8 mg/day has been set (FNB, 2001). The vegetables grown in the three sites had DImetal vanadium values below the set upper limit of 1.8 mg/day apart from *Spinacia oleracea*, *Solanum villosum* and *Amaranthus spp* grown next to the dumpsite which recorded values higher than 1.8 mg/day.

DImetal values for manganese metal in the vegetables under study were within the RDA range 1.8-2.3 mg/day except in *Solanum villosum* and *Amaranthus spp* grown next to the dumpsite. However, the DImetals values for those two

vegetables grown next to the dumpsite below the upper limit of 11 mg/day for that mineral.

No studies to determine the biological role of nickel in higher animals or humans have been reported. Therefore, neither an estimated average requirement, RDI, nor Adequate Intake was established for nickel (FNB, 2001). ATSDR, (1999a) has set an acceptable range of nickel daily intake of 3-7 mg/day. The results shows only those vegetables grown upstream in the three study sites had DImetal values for nickel below the acceptable range of 3-7 mg/day. The other two study sites had values higher than the acceptable ranges for the four vegetables under study. The DIMetal values for cobalt in the three sites under study for all the vegetables was above the tolerable upper limits of 0.25 mg/day.

Indeed the self reported symptoms indicated by the participants could be as result of the above implications of DImetal with both deficiencies of essential metals in the body and toxicities of non essential metals.

Table 4.6: Daily metals intakes estimate (DImetal) of the participants

	V	Mn	Fe	Cu	Zn	Co	Ni
UL(mg/ day)	**1.8**	**11.00**	**45**	**10**	**40**	**0.250**	**3-7**
RDI(mg/ day)	**N/A**	**2.3(1.8)**	**8 (18)**	**0.90**	**11(8)**	**10-20µg**	**N/A**
***S. oleracea* [1]**	0.52	0.56	0.15	0.30	0.45	7.64	6.98
***S. oleracea* [2]**	2.91	2.09	0.66	0.30	0.65	9.26	14.09
***S. oleracea* [3]**	0.66	1.45	0.45	0.45	0.79	8.11	12.83
***S. villosum* [1]**	0.46	1.64	0.30	0.30	0.60	8.70	5.85
***S. villosum* [2]**	1.96	3.47	1.02	0.69	0.97	10.45	9.96
***S. villosum* [3]**	1.37	2.34	0.74	0.30	0.56	9.39	8.81
***Amaranthus spp*[1]**	0.18	0.65	0.15	0.45	0.73	7.86	7.01
***Amaranthus spp* [2]**	5.87	3.43	1.10	0.61	0.62	9.75	13.97
***Amaranthus spp* [3]**	1.61	1.25	0.71	0.45	0.53	9.14	12.12
***B. oleracea* Acephala [1]**	0.19	0.30	0.15	0.46	0.15	6.97	5.21
***B. oleracea* Acephala [2]**	1.15	1.72	0.73	0.61	0.69	8.41	9.02
***B. oleracea* Acephala [3]**	0.20	1.12	0.60	0.15	0.67	7.96	8.59

Figures in brackets () indicate the RDI for females
The number in the parentheses [1, 2, 3] indicate the site where the vegetable was collected
1-Vegetables grown at the control site (upstream)
2-Vegetables grown next to the dumpsite (midstream)
3-Vegetables grown downstream

4.2.6 Transfer factors (TF) of the heavy metals from soils to vegetables

Transfer factor (TF) is the ratio of the concentration of heavy metal in a plant to the concentration of heavy metal in soil. It signifies the amount of heavy metals in the soil that ended up in the vegetable crop site (Chamberlain, 1983; Harrison and Chirgawi, 1989; Smith *et al*., 1996). Transfer factor (TF) was calculated to understand the extent of risk and associated hazard due to ingestion consequent upon heavy metal accumulation in edible portion of vegetables. The transfer factors for each heavy metal were computed based on the method described by Harrison and Chirgawi, (1989). The heavy metal transfer from soil to the vegetables was calculated as follows:

Transfer factor = Metal content in plant (mg/kg)/ Metal content in soil (mg/kg)

From the results in Table 4.7 below, nickel, manganese and vanadium had virtually zero transfer ratios. The highest ratios were observed for mercury for all the vegetables grown at the control site at 0.05 followed by lead at 0.04 for *Spinacia oleracea*, *Solanum villosum* and *Amaranthus spp* grown at the control site. Lead had a transfer factor of 0.03 for all the vegetables grown next to the dumpsite.

Table 4.7: Transfer Factors (TF) of the heavy metals from soils to vegetables collected at the three study sites

	V	Mn	Fe	Cu	Zn	Co	Ni	Hg	Pb
Amaranthus spp [1]	0.00	0.00	0.02	0.01	0.01	0.01	0.00	0.05	0.04
Amaranthus spp [2]	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.03
Amaranthus spp [3]	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.01	0.02
Spanacia oleracea [1]	0.00	0.00	0.02	0.01	0.01	0.01	0.00	0.05	0.04
Spanacia oleracea [2]	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.03
Spanacia oleracea [3]	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.02
Brassica oleracea Acephala [1]	0.00	0.00	0.02	0.01	0.00	0.01	0.00	0.05	0.02
Brassica oleracea Acephala [2]	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.03
Brassica oleracea Acephala [3]	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.03
Solanum villosum [1]	0.00	0.00	0.03	0.01	0.01	0.01	0.00	0.05	0.02
Solanum villosum [2]	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.03
Solanum villosum [3]	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.01	0.02

The number in the parenthesis [1, 2, 3] indicate the site where the vegetable was collected

1- **vegetables grown at the control site (upstream)**
2- **vegetables grown next to the dumpsite (midstream)**
3- **vegetables grown downstream**

4.3 Heavy metal concentration of the water samples collected from the three study sites

Water samples from three sites along the Nairobi River which flows along the dumpsite were collected and analysed for heavy metals using Total Reflection X-ray Fluorescence Spectroscopy (TXRF) method. Table 4.8 shows the mean heavy metal concentrations of water samples collected from three different sites. The heavy metal levels were compared with those of WHO (2004, 1993) and EU (1998) drinking water standards. According to the results below vanadium, copper, lead and mercury levels in water samples analysed were below the detection limits.

The results show that there was an increase in mean heavy metal concentrations of manganese (366±33 µg/l), iron (5132±59 µg/l), cobalt (56±3 µg/l) and zinc (40±7 µg/l) in the water samples collected from upstream to 856±93 µg/l, 12402±1789 µg/l, 125±11 µg/l and 262±8 µg/l respectively in the samples collected midstream. The concentrations then decreased as the river flowed downstream away from the dumpsite.

Table 4.8: Mean Heavy metal concentrations in water and recommended drinking water standards

Metal	Upstream	Midstream	Downstream	WHO 2004 WHO 1993	EU 1998
	µg/l				
V	BDL	BDL	BDL		
Mn	366 ± 33^{a}	856 ± 93^{b}	496 ± 8^{c}	400	50
Fe	5132 ± 59^{a}	12402 ± 1789^{b}	8906 ± 1044^{c}	3000 (1993)	200
Co	56 ± 3^{a}	125 ± 11^{b}	102 ± 32^{b}		
Cu	BDL	BDL	BDL	2000	2000
Zn	40 ± 7^{a}	262 ± 8^{b}	336 ± 18^{c}	3000 (1993)	
Pb	BDL	BDL	BDL	10	10
Hg	BDL	BDL	BDL	1	1

Results are expressed as Means ± standard error of the mean (SEM) for four determinations. Within rows, means with different alphabets are statistically different at $p<0.05$ by ANOVA and Tukeys' test. The first site was the control site which was at a point of 300m upstream along the nearby Nairobi River from where the dumpsite was located, the second site was next to the dumpsite and the third collection point was 300m downstream from where the dumpsite was located.

BDL- Below detectable levels

4.4 Knowledge, attitude and perception of the study population on the health risks posed by Kadhodeki dumpsite

In this study it was necessary to link the health risks posed by the dumpsite to knowledge, attitude and perception of the people living in Kadhodeki village. To achieve these 323 residents of Kadhodeki were sampled and interviewed.

4.4.1 Socio Demographic Data of the participants

From the results, it is noted that the ages of the participants ranged between 18 to 83 years with a mean of 35 years and a standard deviation of 12.5. From Table 4.9 below, it is observed that the female participants were 55.4 % (179) of total number while the male participants accounted for 44.6 %. The table also shows that 47.7% of the participants had a primary education. Those who had attained secondary education accounted for 37.5% (121) while those who had some college or university education were 12.1% (39). A few of the participants (2.8%) did not have any formal education at all. Majority of the participants were married [70 % (226)].

The study sought to measure the length of time the participant had lived in the village. This is an important measure because the longer an individual is exposed to a dumpsite site and its associated health effects, the higher the level of negative impact suffered.

Table 4.9 below indicates that half of the participants (50.8 %) had lived in the village for more than 10 years while most of them (72.8%) had lived there for more than 5 years. The research sought to know the number of people living in

the participant's household. This is important since the higher the number of people living in a particular house the higher the number exposed to health risks if any. Results show a mean of 4 persons per household. More than half of the participants (74.6%) had 3 or more people living in their households at the time of the study.

The research sought to know if the participants were aware of how long the dumpsite had been in existence. This awareness is important since it may influence the participant's knowledge, attitude and perceptions of the health risks it poses. The results indicate that majority of them [44.9% (145)] did not know how old the dumpsite was. Among those who gave a positive answer only 23.8 % (77) of the participants were correct. According to a village elder, the dumpsite was started in 1986 and at the time of the interview it was the 25th year of its existence.

Table 4.9: Socio Demographic Data of the participants

	Frequency	Percentage
Gender		
Male	144	44.6
Female	179	55.4
Total	323	100
Education Level		
None	9	2.8
Primary	154	47.7
Secondary	121	37.5
College/ University	39	12.1
Total	323	100
Marital Status		
Single	75	23.2
Married	226	70
Separated	15	4.6
Windowed	7	2.2
Total	323	100
Number of years lived in the village		
< 1 Year	13	4.0
1-<5 Years	75	23.2
5- 10 Years	71	22
> 10 Years	164	50.8
Total	323	100
Years the dumpsite has been in existence		
< 5 Years	2	0.6
5-<10 Years	19	5.9
10 - < 15 Years	44	13.6
15 -< 20 Years	21	6.5
20- < 25 Years	15	4.6
> 25 Years	77	23.8
Don't Know	145	44.9
Total	323	100

4.4. 2 Sources of water for residents living in Kadhodeki village

Since the water samples collected from the three study sites was found to have a high level of manganese, iron and cobalt than what is recommended for drinking water by WHO and EU, the research sought to know the source of

domestic water for the participants and their families. This would measure the number of people who may be at risk of using contaminated water from the nearby river. The results in the Table 4.10 below show that 92.3% (298) of the participants had household taps. Although household taps were in almost all households, it was noted that the taps were dry for most days of the week. A discussion with key informants informed us that they received water on Tuesdays, Wednesdays and Thursdays at specific hours only. On the days when the taps were dry then some of the residents drew water from either a borehole or the nearby Nairobi River.

Table 4.10: Source of domestic water for the participants

Water source	**Frequency**	**Percentage**
Household tap	298	92.3
Borehole	12	3.7
Local vendors	5	1.5
Public stand point	4	1.2
Nairobi river	3	1
Others	1	0.3
Total	323	100

4.4.3 Sources of vegetables for residents living in Kadhodeki village

The vegetables collected from the study area were found to be deficient in essential elements like zinc, iron, copper and manganese. On the other hand they were found to have high levels of mercury, nickel and lead. This necessitated the research to ask the study participants where they got their vegetables from. Figure 4.1 below shows that the majority of the participants

[36.2% (117)] got vegetables from their own farms around the village, those who bought from the farms around the village were 29.1% (94) while 20.4% (66) and 14% (45) participants bought their vegetables from the nearby market and green grocers, respectively.

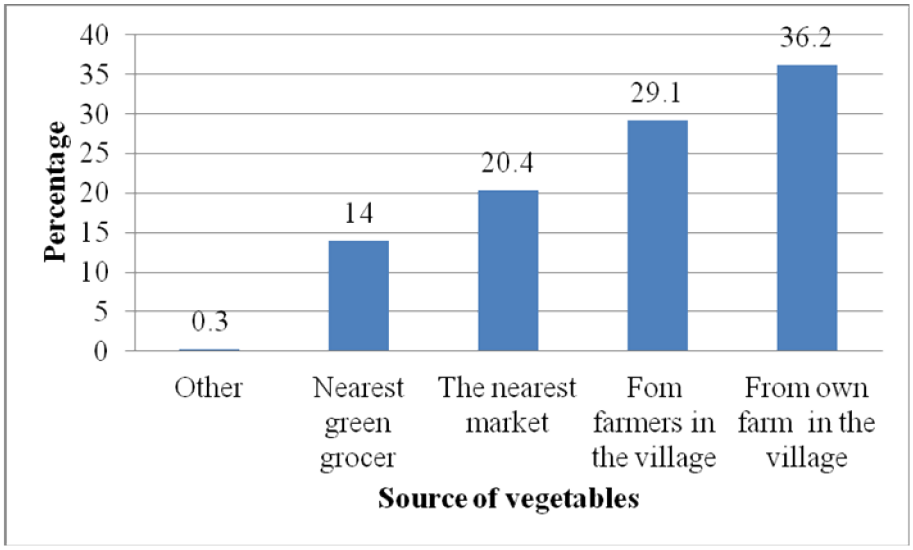

Figure 4.1: Source of vegetables for the participants

4.4.4 Knowledge, Attitude and Perception of the participants on the health risk posed by the dumpsite

The research sought to know whether the age of the participant had any influence on ones knowledge, attitude and perception. For this purpose age was quantified to two levels (not old enough and old enough). The results on Table 4.16 indicate that 143 (44.3 %) participants were said not to be old enough while 180 (55.7%) were old enough. It appears that the difference between those said to be old enough and those not old enough was not significant (χ^2 = 4.24, df = 1, p > 0.01).

The level of education is known to influence the level of knowledge, attitude and perception. For this study, any participant who had attained a primary level of education and below was treated as having inadequate education and any participant who had attained a secondary school level and above was treated as having an adequate level of education. Table 4.16 shows that half of the participants had inadequate education (50.5%) and slightly less than half (49.5%) had adequate education. Further analysis revealed that there was no significant difference between the two levels of education ($\chi^2 = 0.03$, df =1, p > 0.01)

The research also sought to find out whether the number of years one had lived in the village had any influence on knowledge, attitude and perception of the participants on the health risks posed by the dumpsite. For this purpose, anyone who had lived in the village for more than 10 years was treated to have lived long enough and one who had lived in the village for 10 years and below was treated as having not lived long enough. Table 4.16 shows that 34.7 % of the participants had lived in the village for less than 10 years while 65.3% had lived in the village for more than 10 years. From the results, it appears the differences in the number of years one had lived in the village was significant ($\chi^2 = 30.34$, df = 1 $p < 0.01$).

4.4.4.1 Knowledge of the participants on the risks posed by the dumpsite

Knowledge of the participants with regard to health risks posed by the dumpsite was measured using a dichotomous scale. Thirteen knowledge

statements were put forward to the participants. The statements ranged from common knowledge on dangers posed by uncontrolled dumpsite to specific questions on heavy metals. The analysis of the responses was such that the right answer scored 1 point and the wrong answer scored 0 point. Overall the participant who scored a total of 13 points would be said to have perfect knowledge. Of these any participant who scored 8 points and above was treated as having adequate knowledge while any participant who scored less than 8 points was treated as having inadequate knowledge.

Table 4.16 shows that the majority of the participants [91.6% (296)] had inadequate knowledge while only 8.4% (27) had adequate knowledge. From the results, it appears that the participant's knowledge about the health risks posed by the dumpsite was indeed significantly low ($\chi^2 = 224.03$, df = 1, $p < 0.01$).

Further statistical analysis (Table 4.11) showed that education level was the main factor affecting knowledge ($\chi^2 = 21.85$, df = 1, $p < 0.01$). Although the age of the participants and the number of years they had lived in the village was thought to affect knowledge, the results observed were insignificant ($\chi^2 = 0.63$, df = 1, $p > 0.01$; $\chi^2 = 0.10$, df = 1, $p > 0.01$). However some literature have shown that these factors are relevant.

Table 4.11: Relationship of knowledge with education, age and the number of year one has lived in the village

Variable	**Knowledge**		
	Inadequate	Adequate	
Education Inadequate education	161(54.4%)	2(7.4%)	χ^2 =21.85; df=1; p<0.01
Adequate education	135(45.6%)	25(92.6%)	
No. of years Not long enough	105(35.5%)	7(25.9%)	χ^2 =0.10; df=1; p>0.01
Long enough	191(64.5%)	20(74.1%)	
Age Not old enough	133(93.0%)	10(7.0%)	χ^2 =0.63; df=1; p>0.01
Old enough	163(90.6%)	17(9.4%)	

4.4.4.2 Attitude of the participants on the risks posed by the dumpsite

The attitude of the participants in regard to the health risks posed by the dumpsite was measured using a Likert scale (Likert, 1932). Fourteen statements were presented to the participants. Table 4.12 below shows that the responses were such that scores of positive statements were inversely scored to those of negative statement.

Table 4.12: Likert scale to test attitude of the participants

	Strongly Agree	**Agree**	**Disagree**	**Strongly Disagree**
Positive	5	4	2	1
Negative	1	2	4	5

The scores were tabulated and attitude quantified into positive attitude or negative attitude. Table 4.16 show that 58.2 % (188) of the participants had a positive attitude while 41.8% (135) had negative attitude. It appears that the differences in the participants attitude towards the dumpsite were significant ($\chi^2 = 8.70$, df =1, $p < 0.01$).

Further statistical analysis showed that although factors such as education level, age of the participants and the length of stay in the village were thought to influence attitude, it was not the case (Table 4.13). An insignificant association between level of education and attitude was revealed $\chi^2 = 1.21$, df = 1, $p > 0.01$). Similarly the age of the participants and the number of years one had lived in the village did not influence their feelings towards the health risks posed by the dumpsite ($\chi^2 = 0.16$, df = 1, $p > 0.01$; $\chi^2 = 3.43$, df= 1, $p > 0.01$).

Table 4.13: Relationship of attitude with education, age and the number of years one has lived in the village

Variable	**Attitude**		
	Negative	Positive	
Education			
Inadequate education	73(54.1%)	90(47.9%)	χ^2 =1.21; df=1; p>0.01
Adequate education	62(45.9%)	98 (52.1%)	
No. of years			
Not long enough	39(28.9%)	73(38.8%)	χ^2 =3.43; df=1; p>0.01
Long enough	96(71.1%)	115(61.2%)	
Age			
Not old enough	58(40.6%)	85(59.4%)	χ^2 =1.16; df=1; p>0.01
Old enough	77(42.8%)	103(57.2%)	

4.4.4.3 Perception of the participants on the risks posed by the dumpsite

Perception of the participants regarding their understanding and or insight to the risks posed by heavy metals was measured using a Likert scale. Five statements dealing with perception were presented to the participants. Table 4.14 shows that the analysis of the responses was such that scores of positive statements were inversely scored to those of negative statement.

Table 4.14: Likert scale to test the perceptions of the participants

	Strongly Agree	**Agree**	**Disagree**	**Strongly Disagree**
Positive	5	4	2	1
Negative	1	2	4	5

Overall, one with a perfect high risk perception would score 21 points. Of these any respondent who scored 13 points and above was treated as having a high

risk perception while those who scored 12 points and below were treated has having a low risk perception.

From the results, it appears that the participants perception about the health risks posed by the dumpsite were not significantly different ($\chi^2 = 3.80$, df = 1, $p > 0.01$). Table 4.16 shows that 55.4 % (179) of the participants perceived themselves to be at a high health risk from the dumpsite while 44.6 % (144) viewed themselves to be at low risk.

Statistical analysis on table 4.15 showed that the level of education was the main factor affecting perception ($\chi^2 = 18.73$, df = 1, $p < 0.01$). Those participants who had an adequate level of education were more likely to perceive themselves at a higher risk of the dangers posed by the dumpsite. The number of years one had lived in the village and the age of the participants were thought to influence perception but statistical analyses revealed that it was not the case ($\chi^2 = 0.05$, df = 1, $p > 0.01$; $\chi^2 = 0.26$, df = 1, $p > 0.01$) respectively. Some literature has however shown that these two factors are relevant.

Table 4.15: Relationship of perception with education, age and the number of years one has lived in the village

Variable	**Perception**		
	High risk	Low risk	
Education			
Inadequate education	71 (39.7%)	92(63.9%)	χ^2 =18.73; df=1; p<0.01
Adequate education	108(60.3%)	52(36.1%)	
No. of years			
Not long enough	63 (35.2%)	49(34.0%)	χ^2 =0.05; df=1; p>0.01
Long enough	116(64.8%)	95 (66%)	
Age			
Not old enough	77(53.8%)	66(46.2%)	χ^2 =0.26; df=1; p>0.01
Old enough	102(56.7%)	78(43.3%)	

Table 4.16: Chi square of proportionality of the study variables

	Frequency	Percentage
Level of education $\chi^2 = 0.03$, df = 1, p>0.01		
Inadequate education	163	50.5
Adequate education	160	49.5
Total	323	100
Age $\chi^2 = 4.24$, df = 1, p>0.01		
Not old enough	143	44.3
Old enough	180	55.7
Total	323	100
Number of years lived in the village $\chi^2 = 30.34$, df =1, p<0.01		
Not long enough	112	34.7
Long enough	211	65.3
Total	323	100
Knowledge $\chi^2 = 224.03$, df = 1 p<0.01		
Inadequate Knowledge	296	91.6
Adequate Knowledge	27	8.4
Total	323	100
Attitude $\chi^2 = 8.70$, df = 1, p<0.01		
Negative attitude	135	41.8
Positive attitude	188	58.2
Total	323	100
Perception $\chi^2 = 3.79$, df = 1, p>0.01		
High risk perception	179	55.4
Low risk perception	144	44.6
Total	323	100

4.4.4.4 Self reported symptoms of the participants

To be able to further explore the health risks posed by the dumpsite, the participants were asked to indicate whether they or members of their households had certain symptoms in the past six months. Several symptoms related to metal deficiency and toxicity were presented to the participants. They included: increased irritability, unexplained mood swings, vision problems such as blurred vision, chronic fatigue, stomach pain, abnormally low or high blood pressure, chest pain or racing heartbeat, rashes, itching and acne,

chronic heartburn, uncontrollable twitching, memory loss and confusion, chronic insomnia and waking up tired, persistent pain in the joints, unexplained depression, dizziness and/or motion sickness.

Figure 4.2 below shows symptoms that had the highest frequencies. Chest pain like symptoms were indicated by 92 (28.5%) participants followed by stomach problems indicated by 75 (23.2%). Rashes, itching and acne were indicated by 62 participants, chronic heart burn by 54 while persistent pain in the joints was indicated by 47 participants.

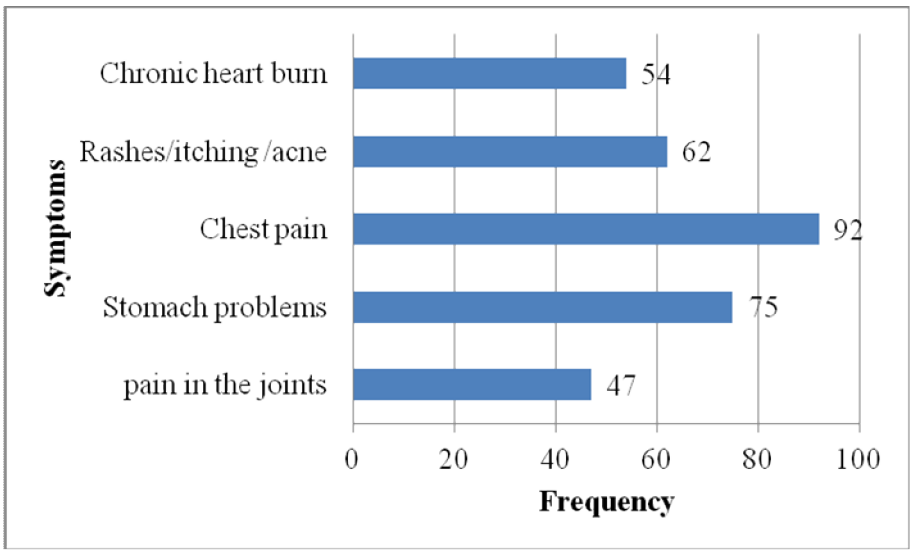

Figure 4.2: Symptoms with the highest frequency

The research further sought to quantify the self reported symptoms**.** Each of the fifteen symptoms was scored on a yes or no scale (dichotomous scale). The analysis of the responses was such that a yes answer (indicating that the participant or their family had suffered from the symptom) scored 1 point and a

No answer scored 0 point. Overall the participant who scored any point would be said to have poor health, while those who did not score any point overall (0 points) was said to have good health. Further analysis of the scores revealed that 172 (53.3%) of the participants had good health while 151(46.7%) had poor health.

Table 4.17 below shows a significant relationship between the reported health status and the number of persons in the participants household ($\chi^2 = 14.66$, df = 1, $p < 0.01$). Similarly a significant association was revealed between the reported health status of the participant and their attitudes towards the health effects posed by the dumpsite ($\chi^2 = 10.18$, df = 1, $p<0.01$).

Table 4.17: Relationship of reported health status with the number of persons living in the households and the participant's attitude

Variable	**Reported health status**		
	Good health	Poor health	
No. of people			
Few	97(64.7%)	53(35.3%)	χ^2 =14.66; df=1; p<0.01
Many	75(43.4%)	98(56.6%)	
Attitude			
Negative	86(63.7%)	49(36.3%)	χ^2 =10.18; df=1; p<0.01
Positive	86(45.7%)	102(54.3%)	

CHAPTER FIVE: DISCUSSION

5.1 Metal content in soils, vegetables and water samples

In this study the mean metal concentrations of iron in the soils ranged between 22.01 mg/kg to 525.50 mg/kg. This is within the ranges reported by Akubugwo *et al*. (2012) who recorded an iron metal content in the soils ranging between 73.62 mg/kg to 226.39 mg/kg. Similarly Tsafe *et al*. (2012) reported a value of 195.25 mg/kg in the soils studied. Other studies have reported higher values than those of this study. Awokunmi *et al*. (2010) reported values between 1100 to 10,920 mg/kg while McGrath *et al*. (2001) reported an iron metal content of 80000 mg/kg and Kimani, (2007) reported a mean concentration of 57100 mg/kg on uncontaminated soil. The transfer factor of iron between the soil and the vegetables was only significant for those vegetables grown at the control site.

The daily metal intake estimates of iron calculated for vegetables in this study was below the recommended RDI of 8-18 mg/day in all the vegetables studied. The vegetables had a mean metal level of 0.39±0.19 to 2.74 ± 0.12 mg/kg. Similar results with those in this study were reported by Aweng *et al* (2011) which recorded an iron content of 0.65 - 2.76 mg/kg in the fruit vegetables.

Other studies have reported much higher values of iron in the leafy vegetables. Tsafe *et al.* (2012) reported an iron content of 54.05 mg/kg while Uwah *et al*. (2011) reported an iron content of 15.96 ± 0.18 mg/kg in *Amaranthus caudatus* vegetables and values of 42.84 ± 0.27 mg/kg in *Lactuca sativa* vegetables.

Akubugwo *et al*. (2012) reported an even higher iron metal content of up to 147.41±0.01 mg/kg in the *Amaranthus hybridus* vegetables.

The rate of metal uptake by the vegetables could have been affected by other factors such as plant age, plant species, soil pH, nature of soil and climate and this in turn would affect the content of heavy metal recorded (Alloway and Ayres, 1997; Uwah, *et al.,* 2009). Variations in transfer factor may also have contributed to the differences in the element uptake by different vegetables hence the different metal contents (Cui *et al.,* 2004; Zheng, *et al.,* 2007).

Iron levels in all water samples were higher than the 200µg/l recommended by EU (1998) in drinking water. The works of Raji *et al*. (2010) revealed that the iron levels that were much lower than those of this study with values between 460 - 610 µg/l. In contrast the studies of Laniyan *et al*. (2011) recorded higher iron values ranging between 11 -21675 µg/l.

The mean metal concentrations of copper in the soils in this study ranged between 143.02 and 2089.61 mg/kg. Apart from soils found on the control site the other values are above those reported in literature for uncontaminated soils. Kabata-Pendias and Pendias (1992), Haluschak *et al*. (1998), McGrath *et al.* (2001) and EPA, (1995) reported soils with the higher limits of 140 mg/kg, 68 mg/kg, 100 mg/kg and 750 mg/kg, respectively for copper in uncontaminated soils. Awokunmi *et al*. (2010) reported even higher levels of copper from 95 to 6726 mg/kg from soils collected from several dumpsites in Nigeria.

The transfer of copper from the soils to the vegetables in this study was almost zero. This could be because copper contents do not mobilize in plants and remain stagnant in roots, which would explain the lower content of the metal in leaves as compared to the soils (Bakere *et al*., 1994). Yang *et al*. (2002) showed that copper mainly accumulated in roots while a small fraction (10%) of absorbed copper was transported to the shoots. The results by Bakere *et al*. (1994) and Yang *et al.* (2002) could explain why there were similar copper levels among the three sites in all the vegetables. Indeed, when copper ends up in soils, it strongly attaches to organic matter and minerals. As a result, it does not travel very far after release and consequently copper tends to accumulate in soil (Slooff *et al.,* 1989; Alloway, 1990; Lenntech, 2009). Perhaps this explains why the soil had high levels of copper while the vegetables had very little.

All the vegetables in this study had a DImetal value less than the RDI for copper of 0.9mg/day (FNB, 2001). The DIMetal values ranged from 0.15 - 0.69 mg/day. Mean concentrations for copper in the vegetables ranged from the lowest value of 0.38±0.19 mg/kg to 1.72±0.11 mg/kg. Similar results have been reported by Uwah *et al*. (2011) who recorded copper values of between 0.81 mg/kg and 1.75 mg/kg in spinach and lettuce grown in Nigeria, respectively. Akubugwo *et al*. (2012) and Muhammad *et al*. (2008) also show similar results in the ranges of 1.20 to 3.42 mg/kg and 0.25 mg/kg to 0.92 mg/kg, respectively, in vegetables studied.

Copper and iron are required for the proper functioning neurovascular system. It is a component of several enzymes, cofactors, and proteins in the body. In particular, copper functions as an electron transfer intermediate in redox reactions. As well as a direct role in maintaining cuproenzyme activity, changes in copper status may have indirect effects on other enzyme systems that do not contain copper. The level of copper in the body are affected by the levels of zinc as it appears to exert an antagonistic effect on copper status through the induction of metallothionein synthesis by zinc in mucosal cells in the intestine. Metallothionein bound copper is not available for transport into the circulation and is eventually lost in the faeces (Gyorffy and Chan, 1992; Barone *et al*., 1998; Zahir *et al*., 2009).

Lower copper uptake in human consumption can cause a number of symptoms which include growth retardation, skin ailments, and gastrointestinal disorders. Copper deficiency impinges on iron metabolism, causing an anemia that does not respond to iron supplementation. Interactions between iron and copper seem to be impaired utilization of one in the absence of the other. Copper deficiency also exerts an effect on iodine metabolism resulting in hypothyroidism, at least in animal models (Michael *et al*., 2009)

The natural range of zinc in soils is 10 – 300 mg/kg (Eddy *et al*., 2004). The soil concentration of zinc in this study was within these natural ranges with values ranging between 128.11 mg/kg to 289.27 mg/kg. These results also compare with those of several studies done by different workers. Kabata-

Pendias and Pendias (1992), Haluschak *et al*. (1998), McGrath *et al*. (2001), and Kimani (2007) reported the following values of zinc in different countries 300 mg/kg, 230 mg/kg, 200 mg/kg and 133 mg/kg, respectively, for uncontaminated soils. Awokunmi *et al*. (2010) reported zinc levels in soils higher than those of this study ranging between 350-3052 mg/kg.

Results show that the transfer of zinc from the soil to the vegetables was more significant than that of copper. These findings agree with Barrg and Clark (1998) who reported that zinc is more actively mobilized than copper from roots to shoots.

The daily metal intake of zinc was found to be below the recommended RDI of 8-11mg/day (FNB, 2001). The vegetables had DIMetal values ranging between 0.15 - 0.97 mg/day. Results show that the levels of zinc in the vegetables studied had a range of 0.38±0.19 mg/kg to 2.43±0.15 mg/kg. Results from this study compare with studies done by Akubugwo *et al*. (2012) on *Amaranthus hybridus* vegetables which reported values of zinc of 1.06 ± 0.02 to 2.82 ± 0.01 mg/kg. Muhammad *et al*. (2008) also reported the amount of zinc in leafy vegetable samples as 0.461(spinach), 0.705 (coriander), 0.743 (lettuce), 1.893 (radish), 0.777 (cabbage) and 0.678 (cauliflower) mg/ kg, respectively.

Zinc levels in the water samples collected from the three sites were below the 3000 µg/l recommended by WHO (1993). Raji *et al*. (2010) reported zinc levels similar to those of this study with values ranging between 200 - 250 µg/l.

On the other hand, Laniyan *et al*. (2011) recorded zinc levels lower than those of this study, ranging from 4.1 - 73.7 µg/l.

Zinc is required by protein kinases that participate in signal transduction processes and as a stimulator of transducting factors responsible for regulating gene expression. Zinc plays an important role in the immune system and is an antioxidant *in vivo* (Blumberg, 1997; Demirezen and Aksoy, 2006 ; Michael *et al*., 2009; Strachan, 2010).

Zinc deficiency can disturb zinc maintenance in human body. The clinical manifestations of zinc deficiency in humans are growth retardation, neuropsychiatric disturbances, dermatitis, alopecia, diarrhoea, increased susceptibility to infections, and loss of appetite (Demirezen and Aksoy, 2006; Michael *et al*., 2009).

The permissible range for the concentration of manganese in soils is 200 to 9,000 mg/kg (Eddy *et al*., 2004). The soils analysed in this study had a mean metal concentration ranging from 5490.60 - 14419.10 mg/kg. Studies carried out by Kabata-Pendias and Pendias (1992) and Haluschak *et al*. (1998) reported manganese values within the ranges similar to those of this study. McGrath *et al*. (2001), Kimani (2007) and Awokunmi *et al*. (2010) reported lower levels than those of this study. The transfer ratio for manganese between the soils and vegetables in this study was virtually zero.

The recommended RDI for manganese is between 1.8- 2.3 mg/day with a tolerable upper limit of 11mg/day (FNB, 2001). In this study the DIMetal

values ranged from 0.30 - 3.47 mg/day. Although the value 3.47 mg/day is higher than the RDI, it is below the tolerable upper intake levels limit of 11mg/day (FNB, 2001).

In this study, the mean metal concentrations of manganese in the vegetables ranged from 0.75 ± 0.22 to 8.66±0.57 mg/kg. This agrees with a study carried out by Harmanescu *et al*. (2011) who reported manganese values of between 1.38 to 10.47 mg/kg in the vegetables studied. Uwah *et al*. (2011) reported similar values of 5.23 ± 0.06 to 11.75 ± 1.04 mg/kg in the vegetables.

The levels of manganese in the water samples collected at the control site were within the recommended 400 µg/l in drinking water by WHO (2004) but they were above the EU (1998) recommendation of 50 µg/l. Downstream and midstream levels were above the recommended values by both WHO and EU. Raji *et al*. (2010) recorded values in a similar range of 550 µg/l to 930 µg/l while Laniyan *et al*. (2011) recorded lower values of 7 µg/l to 184.6 µg/l manganese.

A study comparing nervous system status between those exposed for many years to high (50 - 2160 µg/l) and low (≤ 50 µg/l) manganese levels in drinking water detected no difference in nervous system functioning between the two groups (Environmental fact sheet, 2006). Indeed, Longe and Enekwechi (2007) reported that concentrations of manganese in excess of 200 µg/l makes

water distasteful to drinking with no specific toxic effects (Longe and Enekwechi, 2007).

Manganese is required as a catalytic cofactor for mitochondrial superoxide dismutase, arginase, and pyruvate carboxylase. It is also an activator of glycosyltransferases, phosphoenolpyruvate carboxylase, and glutamine synthetase. Symptoms of manganese deficiency include impaired growth, skeletal abnormalities and defects in lipid and carbohydrate metabolism. Iron-manganese interactions have been demonstrated whereby iron deficiency increases manganese absorption, and high amounts of dietary iron inhibit manganese absorption, possibly by competition for similar binding and absorption sites between nonheme iron and manganese (Michael *et al*., 2009).

Global input of nickel to the human environment is from natural and anthropogenic sources including emissions from fossil fuel consumption, industrial production, use, and disposal of nickel compounds and alloys (Kasprzak *et al*., 2003). Soils in this study recorded concentrations that were higher than those reported in literature with values ranging from 5250.62 – 11968.76 mg/kg which may account for the high metal content found in the vegetables. Literature report values of 450 mg/kg, 98 mg/kg, 100 mg/kg, 1650 mg/kg and 2360mg/kg recorded by Kabata-Pendias and Pendias (1992), Haluschak *et al*. (1998), McGerath *et al*. (2001), Awokunmi *et al*. (2010) and Adefemi and Awokunmi, (2009), respectively.

Farm soils contain approximately 3 to 1000 mg/kg of nickel, but the concentration can reach up to 24,000 to 53,000 mg/kg in soil near metal refineries and in dried sludge, respectively (Denkhaus and Salnikow, 2002; Sutherland and Costa, 2002). Some areas of the United States may contain natural levels as high as 5000 mg/kg (ATDSR, 2005). Although literature shows that nickel in plants is highly mobile and is likely to accumulate in both leaves and seeds, in this study the transfer ratio of nickel between the soil and the vegetables was virtually zero.

Srinivas *et al*. (2009) reported that vegetables have more nickel than animal products. According to ATSDR (1999) the acceptable range of nickel daily intake is 3-7 mg/day. In this study all the vegetables grown at the control site were within the reported safe range of 3-7 mg/day. The vegetables grown at the other two sites had values above 7 mg/day with the highest DIMetal value of 14.10 mg/day.

The mean metal concentration of nickel in the vegetables ranged from 13.02±0.54 to 35.23±1.04 mg/kg. Similarly, Premarathna *et al.* (2011) reported nickel levels ranging from 2.3 to 37.80 mg/kg in the various vegetables. Okoronkwo *et al*. (2005) reported values of between 22.59 mg/kg and 24.47 mg/kg in the vegetables under study. On the other hand, Naser *et al.* (2009) in Bangladesh reported lower levels of nickel than those of this study of 5.369 mg/kg in the vegetables.

Nickel in plants is highly mobile and is likely to accumulate in both leaves and seeds (Sengar *et al*., 2008). There is also evidence of uptake and accumulation in certain plants (ATSDR, 2005a). Intake of too large quantities of nickel by humans from plants grown on nickel rich soils has higher chances of inducing the development of cancers of the lung, nose, larynx and prostrate as well as inducing respiratory failures, birth defects and heart disorders (Duda-Chodak and Blaszczyk, 2008; Lenntech, 2009).

Studies have shown that heavy metals such as nickel can stimulate cell growth in estrogen receptor (ER) positive breast cancer cells (Martin *et al*., 2003). Indeed, Ionsescu *et al*. (2006) found highly significant nickel accumulation in 20 breast cancer tissue biopsies compared to controls. Although nickel is a toxic metal, it plays a role as a coenzyme in different enzymes (ATSDR, 1999a; Lyaka *et al*., 2005).

The mean metal concentration of cobalt recorded from the soils in this study was high compared with those found in literature with values ranging from 2767.91- 6003.90 mg/kg. Awokunmi *et al*. (2010) reported levels of cobalt in the soils ranging from 110- 2200 mg/kg in soil from dumpsites in South West Nigeria.

Literature reports that while cobalt may be taken up from soil by plants, the translocation of cobalt from roots to above-ground parts of plants is not significant in most soils; the transfer coefficient for cobalt is generally 0.01-0.3

(Smith and Carson, 1981; Mascanzoni, 1989; Mermut *et al*., 1996). Indeed, the transfer factor of cobalt in this study had values of 0.1 for the vegetables grown at the control site while others sites had virtually zero values.

The high levels of cobalt in the soil of this study could be attributed to indiscriminate disposal of cobalt containing wastes on the dumpsite. Cobalt enters the air through burning of oil and cobalt compounds that are used as colorants in glass, ceramics, as paint driers, trace element additives in agriculture, medicine and the production of petroleum and tyres (ATSDR, 2004b; Nagpal, 2004). After it enters the air cobalt is associated with particles which will settle to the ground within few days. Food and drinking water are the largest sources of exposure to the general population (Udeh, 2004).

The daily recommended range of cobalt in human diet is 0.005 mg/day (ATSDR, 2004b). In this study, the DIMetal recorded was above the recommended RDI; however, the DImetal values were less than 30 mg/day which can cause digestive and skin disorders in humans (ATSDR, 2004 b). The mean metal concentrations of cobalt in the vegetables under study ranged from 17.42 ±0.08 to 26.13 ±0.20 mg/kg.

Though international standards for cobalt in drinking water are not available, other works have recorded values of cobalt in drinking water close to those found in this study. Greathouse and Craun (1978), Meranger *et al*. (1981) and Smith and Carson (1981) recorded levels of cobalt in drinking water in the

ranges of 2.6 - 107 µg/l. Raji *et al*. (2010) recorded cobalt levels higher than those of this study with values ranging from 370 - 530 µg/l.

Cobalt has been confirmed to be a carcinogen in animal studies and is considered a possible carcinogen in humans. Symptoms of cobalt toxicity include fatigue, nausea, vertigo and problems with balance, poor memory and cognitive function, tinnitus and hearing problems, blindness, headaches, cardiomyopathy, hypothyroidism, peripheral neuropathy with tremors and loss of coordination, rashes, kidney failure, anxiety and irritability (Adams, 2011).

Vanadium is widely distributed in the earth's crust at an average concentration of 100 mg/kg (Byerrum, 1991; ATSDR, 2009). In this study, the mean soil concentrations ranged from 337.05 to 5077.95 mg/kg. Krishna and Govil (2007) reported vanadium concentrations lower than those of this study with a range of 141.9 to 380.6 mg/kg in India. Kabata-Pendias and Pendias (1992), Haluschak *et al*. (1998) and McGrath *et al.* (2001) reported values of 115 mg/kg, 455 mg/kg and 250 mg/kg, respectively, of vanadium in uncontaminated soils. On the other hand, Molatlhegi (2005) reported values as high as 5340mg/kg vanadium in South Africa.

Martin and Kaplan (1998) reported that uptake of vanadium into the roots and upper parts of plants does not change significantly suggesting reduced bioavailability over time as a result of binding to soil materials. Binding of vanadium to soil materials may account for its high levels in the soil and low

levels in the vegetables. This may be the reason why there was a virtually zero transfer ratio for vanadium in the vegetables in this study.

The tolerable upper limit intake level of vanadium is 1.8 mg /day since there is insufficient data to establish a RDI (FNB, 2001; EGVM, 2003). In this study, the vegetables had DIMetal values lower than the upper limit apart from those grown next to the dumpsite. The mean metal concentration of vanadium in the four vegetables ranged from 0.46±0.23 to 14.26±2.50 mg/kg. Molatlhegi (2005) reported higher vanadium values than those of this study of between 31 to 35 mg/kg in plants. Due to plants' relatively high accumulation ability in respect of vanadium, this element is always present in food products (Sperling *et al*., 2000).

Although vanadium has not been shown to be essential for humans and has no nutritional value, its compounds have been shown to mimic the action of insulin in isolated cell systems, animal models and diabetic patients and therefore, their use in the therapy of diabetes mellitus has been considered (Shechter, 1990; Shamberger, 1996).

Lead is one of the more persistent metals and is estimated to have a soil retention time of 150 to 5000 years (Sobolev and Begonia, 2008). This study reported a mean level ranging from 19.79 to 60.22 mg/kg. This is within ranges of soils studies by Premarathna *et al.* (2011) who reported a range of 15 to 311 mg/kg. Similarly Kabata-Pendias and Pendias (1992), Haluschak *et al*. (1998),

McGrath *et al*. (2001) and Kimani (2007) reported lead values of 189 mg/kg, 55 mg/kg, 80 mg/kg and 34.5 mg/kg, respectively in uncontaminated soils. However Awokunmi *et al.* (2010) reported very high levels of lead from soils collected from various dumpsites ranging between 3500-6860 mg/kg. Aluko *et al*. (2003) also reported high values of lead in soil at Ibadan ranging from 1340 - 1693 mg/kg.

The high levels of lead in both vegetables and soils could be attributed to the dumpsite and the busy Uthiru / Kawangare Road. This is because in the past lead was used in gasoline and hence a major contributor to lead in soil, and automotive exhaust emitted when gasoline contained lead. Luilo and Othman (2006) found high levels of lead in both soil and couch grass grown along the road in Dar es Salaam. Lead is released into the air during burning oil, or waste. Lead is removed from the air by rain and by particles falling to land or into surface water. Once lead falls onto soil, it sticks strongly to soil particles and remains in the upper layer of soil (ATSDR, 2007).

Although the lead values were within the permissible levels for agricultural soils, the transfer factor of this metal to the vegetables was significant and this could explain why the vegetables had higher than permissible levels of lead. Indeed, lead accumulation in many plants can exceed several hundred times the threshold of maximum level permissible for human (Wierzbicka, 1995).

In this study, the mean metal concentrations of lead in the four vegetables ranged from 0.39±0.20 to 1.59±0.03 mg/kg. Orisakwe *et al.* (2012), Naser *et*

al. (2009) and Akubugwo *et al*. (2012) reported lead levels in the vegetables in ranges similar to those of this study. They reported values of between 0.35 to 3.89 mg/kg, 0.49 to 1.97 m/kg and 0.13 to 0.73 mg/kg, respectively. Other works show that lead metal levels in spinach, coriander, lettuce, radish, cabbage and cauliflower were 2.251, 2.652, 2.411, 2.035, 1.921 and 1.331 mg/ kg, respectively (Muhammad *et al*., 2008). According to the maximum allowable limit for lead in vegetables of 0.5 mg/kg used by Harmanescu *et al*. (2011) and WHO/FAO (2011), it was only those vegetables grown upstream that were below this limit.

Lead has no beneficial biological function and is known to accumulate in the body (Zurera-Cosano *et al*., 1984; Ellen *et al*., 1990; Yargholi and Azimi, 2008). Lead exposure can cause adverse health effects, especially in young children and pregnant women, since lead is a neurotoxin that permanently interrupts normal brain development. It also accumulates in the skeleton and its mobilization from bones during pregnancy and lactation causes exposure to foetuses and breastfed infants (ATSDR, 2007; WHO, 2004). Lead on a cellular and molecular level may enhance carcinogenic events involved in DNA damage, DNA repair and regulation of tumor suppressor and promoter genes (Silbergeld, 2003).

Mercury in the soils analysed for this study ranged from 7.43 - 436.70 mg/kg. Kimani (2007) reported mercury levels of between 18.6 to 46.7 mg/kg in the studied soils. Plants can develop a tolerance to high concentrations of mercury

on contaminated sites, with corresponding elevated concentrations in edible parts compared with natural soils (Kabata-Pendias and Mukherjee, 2007).

The transfer factor of mercury from the soil to the vegetables was significant. Indeed, several studies have reported the accumulation of mercury in plant roots, although translocation within the plant to other parts including shoots and seeds will also occur (Schlüter, 1993; ATSDR, 1999b; Kabata-Pendias and Mukherjee, 2007; Environment Agency, 2009).

The high values of mercury in the vegetables and soil may be as a result of mercury contamination from the dumpsite. This is because the dumpsite site, had evidence of broken thermometers, used paint cans and batteries all of which contain some form of mercury. Furthermore, metallic mercury used in thermometers is liquid at room temperature and evaporates and forms mercury vapours, which when blown by the wind and combine with compounds such as chlorine, sulphur, or oxygen to form inorganic forms of mercury which may contaminate other areas when it rains or when the dust settles in other previously uncontaminated grounds (ATSDR, 1999b).

A maximum allowable limit of 0.5 mg/kg is used for mercury (CODEX, 2010; Choi, 2011). In this study, all the vegetables grown at the control site recorded mean concentration of less than 0.5 mg/kg with the lowest levels of 0.38 ± 0.19 mg/kg. The highest level recorded for mercury was 2.68± 0.08 mg/kg. Abbas *et al*. (2010), Lee *et al*. (1972) and Orisakwe *et al*. (2012) reported values

lower than those of this study of 0.02 to 0.03, 0.001 to 0.02 mg/kg and 0.02 to 0.03 mg/kg in vegetables, respectively.

Mercury is a neurotoxin and long-term, low-level exposure to elemental mercury vapor, like eating food contaminated with organic mercury, affects the nervous system most adversely, causing depression, anxiety, insomnia, constant fatigue, tremor, and behavioural disturbance (ATSDR, 1999b).

5.2 Knowledge, attitude and perception of the study population on the health risks posed by Kadhodeki dumpsite

This survey involved 179 female and 144 male participants. The ages ranged between 18 to 83 years (mean = 35, SD = 12.5). More than half of the participants were aged 30 and above, this implies that more than half of them were adults who could speak authoritatively on behalf of their family members. Age did not statistically influence the participant's knowledge, attitude or perceptions of the health risks posed by the dumpsite. Studies done by Coffie (2010) and Grasmuck, *et al*. (2005) reported similar findings.

Further analysis indicates that 49.5% of participants had attained secondary education and above which is in line with Kenya demographic and health survey of 2008-2009 report that states that only 53% of the population have secondary education and above (KDHS, 2010).

Furthermore, more than half of the households had 4 and above members increasing the number of people who are at risk of heavy metal contamination. Olorunfemi (2009) reported that the more the number of people in the household the more people are at risk of suffering from the negative impact of the dumpsite. Indeed results indicate that households that had more people reported a higher number of self reported symptoms ($\chi^2 = 14.66$, df = 1, $p < 0.01$).

More than half of the participants had lived in the village for more than 5 years. It seems to be crucial that the risk in Kadhodeki is caused by contaminated soil, as a result of the dumpsite which has been in existence for several years; indeed the longer someone has been living in the contaminated area, the more likely it is that he or she suffers from the associated health risks (Olorunfemi, 2009).

More than half of the participants either grew their own vegetables or bought them from the farms around the dumpsite which meant that they were at a direct risk of consuming contaminated vegetables grown around the dumpsite. Furthermore since no one is sure where the green grocers or those who sold the vegetables in the market bought their products from, then one can assume that there may be risks of eating contaminated vegetables bought from the farms around the dumpsite. This increases the number of participants who may be at risk of consuming contaminated vegetables. Since the majority had 3 or more persons living with them, then the number of those at risk becomes higher.

Objectively, though people consuming local produce and people who are exposed for longer periods of time are more at risk than are others, It is likely that people who are initially less concerned about the risks involved are more likely to consume or to continue consuming vegetables or fruits grown in their own garden or grown by local producers.

Although 92.3% of the participants had household taps, the said taps were dry four days in a week. The participants then drew water from either a borehole or the nearby Nairobi River. Therein lies the risk of contamination.

The results of this study reveal that the participant's education level influenced their knowledge on the health risks posed by the dumpsite ($\chi^2 = 21.86$, df=1, $p < 0.01$). Indeed, Olorunfemi (2009) reports that high level of literacy is considered advantageous for the fact that knowledge plays a significant role in impact studies. Other studies have reported otherwise; a survey on secondary school teachers indicated that there was a low a low level of environmental knowledge (Mansaray *et al*., 1998). In this study the age and number of years which the participant had lived in the village did not affect their knowledge on the health risks posed by the dumpsite ($\chi^2 = 0.63$, df = 1, $p > 0.01$; $\chi^2 = 0.10$, df = 1, $p > 0.01$).

The results of this study show that education had no association with what the participants felt were the risks posed by the dumpsite ($\chi^2 = 1.21$, df = 1 $p > 0.01$). Furthermore, a study done in Nigeria among secondary school teachers

who have a higher level of education than most in a general population showed that negative environmental attitudes were also found to be prevalent among the three categories of teachers interviewed (Mansaray *et al*., 1998).

Similarly, the age and number of years the participant had lived in the village did not influence the participants feelings on the dangers posed by the dumpsite ($\chi^2 = 0.16$, df = 1, $p > 0.01$; $\chi^2 = 3.43$, df = 1, $p > 0.01$), respectively. Though the factors mentioned above did not influence the participants attitudes, the difference between those who had a positive attitude and those who had a negative attitude was significant ($\chi^2 = 8.70$, df = 1, $p < 0.01$).

The results indicate that the more educated the participants were, the more likely they were to perceive themselves at a high risk posed by the dumpsite ($\chi^2 = 18.73$, df = 1, $p < 0.01$). A fact supported by Kariyawasam *et al.* (2006) who showed that the level of education had a significant association with consumer attitudes and perceptions. Similarly, Scholz and Weber (2001) show that the increase in knowledge through being given new information increases participants' risk ratings. However, a survey by Coffie (2010) showed that the participant's perception towards waste disposal issues was not influenced by their educational level, income or age. Indeed, the results of this study reveal that participants age did not influence their perceptions ($\chi^2 = 0.26$, df = 1, $p > 0.01$).

The number of years one had lived in the village were similarly shown not to influence ones perception on the risks posed by the dumpsite ($\chi^2 = 0.05$, df = 1,

$p > 0.01$). This agrees with Grasmuck *et al*. (2005) who revealed an insignificant relationship between risk perception and the duration of the exposure. Though objectively, the people who have lived in the village for a long time are more at risk than are others.

Health risk perception plays an ongoing role in the public response to environmental exposures (Dupler, 2001). Essentially, relationships between an environmental contaminant and health are mediated by perceptions of the 'exposure' which are in turn influenced by a host of individual and contextual factors (Ferner, 2001).

The fact that more than half of the participants perceived themselves at high risk and that there was a significant association between education and perception may be because of the documentaries in television stations about vegetables grown on raw sewage and the debates about relocations of Dandora dumpsite which may have influenced their perceptions. Elliott (1998) reports that worries and concern about environmental and health has increased steadily over the past two decades and that the increase is associated with widely publicized environmental disasters.

Results indicate that the more the number of people in a household the more the self reported symptoms ($\chi^2 = 14.66$, df=1, $p < 0.01$). Indeed, Olorunfemi (2009) states that the more the number of people in the household the more the risk of suffering from the negative effects of the dumpsite. Similarly, the way

the participants felt about the health risks posed by the dumpsites significantly influenced how they answered the question on self reported symptoms ($\chi^2 = 10.18$, df = 1, $p < 0.01$).

Although biases and confounding factors cannot be excluded as explanations for these findings, the results may indicate real risks associated with residence near certain dumpsites. An increase in self-reported health outcomes and symptoms has been found consistently in health surveys around sites where local concerns were evident (Zupancic, 1997). Similarly, Vrijheid (2000) reported that, it is difficult to conclude whether these symptoms are an effect of direct toxicological action of heavy metals present in dumpsite, an effect of stress and fears related to the dumpsite, or an effect of reporting bias.

Although a substantial number of studies have been conducted, risks to health from dumpsites are hard to quantify. Exposure information and effects of low-level environmental exposure in the general population are by their nature difficult to establish (Zupancic, 1997).

CHAPTER 6: SUMMARY, CONCLUSION AND RECOMMENDATION

6.1 SUMMARY

Cities reveal aspects of waste-management problem such as heaps of uncontrolled garbage, roadsides littered with refuse; streams blocked with rubbish and inappropriately disposed toxic waste and disposal sites that constitute a health hazard to residential areas, (Kibwage, 2002; Rotich *et al*., 2006; Ebong *et al*., 2008). Open dumps are a source of various environmental and health hazards. Abandoned waste dumpsites have been used extensively as fertile grounds for cultivating vegetables though research has indicated that the vegetables are capable of accumulating high levels of heavy metals from contaminated and polluted soils (Garcia *et al*., 1981; Xiong , 1998; Cobb *et al*., 2000; Benson and Ebong, 2005).

Heavy metal pollution of the environment, even at low levels, and their resulting long-term cumulative health effects are among the leading health concerns all over the world (Oluyemi *et al*., 2008). Furthermore, heavy metals are non-biodegradable and can accumulate in soils to toxic concentrations that affect plant and animal life (Karatas *et al*., 2006 ; Adjia *et al*., 2008).

Heavy metals from waste dumpsites can accumulate and persist in soils at an environmentally hazardous level (Alloway, 1996; Amusan *et al*., 2005). Studies have shown municipal refuse may increase heavy metal concentration in soil and underground water (Albores *et al*., 2000; Okoronkwo *et al*., 2005b; Okoronkwo *et al*., 2006). This may have effects on the host soils, crops and human health (Smith *et al*., 1996; Nyle and Ray, 1999).

Nairobi city faces solid waste management challenges. The use of open dumps for municipal solid waste in Kenya makes environmental pollution highly probable. This study set to determine the level of heavy metal contamination of soils, vegetables and water sources found near Kadhodeki dumpsite. The study further assessed the knowledge, attitudes and perceptions of people living around the study area on whether the dumpsite posed any health risk to them.

This study was carried out in Kadhodeki Village in, Waithaka Sublocation, Dagoretti Division, Nairobi County, Kenya. The study was carried out in two phases whereby the first phase involved analytical methods that were geared to analyse the mean heavy metal concentrations in soil samples and edible vegetables collected on and around the dumpsite, downstream and upstream along the nearby Nairobi River. Samples of water upstream, on the dumpsite and further downstream after the dumpsite were also collected and analysed to measure the impact of the dumpsite on water and the dilution effect.

Four samples each of *Spinacia oleracea*, *Solanum villosum, Brassica oleracea Acephala* and *Amaranthus spp* of vegetables growing along transect lines in the three study sites were collected and prepared for laboratory analysis. Likewise soil samples were collected along transect lines at a depth of 15cm at the three study sites and also prepared for laboratory analysis (Melville and Welsh, 2001). Water samples from the three study sites were also collected using depth integrated sampling techniques and the samples were mixed together to produce a composite sample (Afullo, 2009). Heavy metal determination was

carried out using X-ray Fluorescence Spectroscopy technique whereby the following nine elements were quantified; V, Mn, Fe, Co, Ni, Cu, Zn, Hg and Pb.

In an attempt to provide answers for the second phase, a descriptive cross section survey was carried out. In this a pre-tested questionnaire and a face-to-face interview were used to capture data on the respondent's knowledge, attitude and perceptions on whether the dumpsite posed any health risk to them. Using households as sampling units, a total of 323 households were randomly picked from a computerized list of households.

Data collected from the analytical methods was analysed using Microsoft excel to get the mean and standard error of the mean of the heavy metal quantified from the various samples. This was then subjected to statistical tests of significance using ANOVA ($p<0.05$). The results that were found to be statistically different were subjected to a Tukeys post hoc analysis test. Mean heavy metal results were also extrapolated to calculate the estimate for calculated daily intake of metal (DIMetal) and transfer factorsfrom the soil to the plant. Statistical analysis for the cross sectional survey was carried out using Predictive Analytic Software for windows version 16 where inferential statistics were made using Chi square to test for associations between the different variables. Descriptive statistics such as frequencies and percentages were used to summarize the data in the questionnaires while tables and graphs were used to present the results.

6.2 CONCLUSIONS

This study showed that the vegetables under study may pose a health risk to the people who consume them as they were found to be deficient of essential metals such as iron, zinc, copper and manganese. On the other hand, they were found to have higher than allowed levels of metals like cobalt, vanadium and nickel. Furthermore, the vegetables were also found to have high levels of toxic metals such as mercury and lead.

The soils samples studied were found to have higher than allowed levels of vanadium, copper, cobalt, nickel, mercury, manganese and lead than is permissible for agricultural soils. The soils were deficient in iron and zinc whose levels were lower than the permissible levels for agricultural soils.

Analysis of water samples revealed that vanadium, copper, lead and mercury metals were below the detection limits. Iron metal levels in all water samples were higher than the 200µg/l recommended by the European Union in drinking water. Manganese level from the control site were within the recommended 400 µg/l in drinking water by WHO (2004) but they were above the EU recommendation of 50 µg/l. Downstream and midstream levels were above the recommended values by both WHO and EU. While international standards for cobalt in drinking water are not available, other works have recorded values of cobalt in drinking water close to those found in this study. Zinc levels in all the sites were below the 3000 µg/l recommended by World Health Organization. It was found that the dumpsite indeed directly contributed to the

pollution of the river by the fact that the concentrations of manganese, iron and cobalt metals increased at midstream (next to the dumpsite) and decreased downstream (away from the dumpsite).

The people living in Kadhodeki village were found to have inadequate knowledge about the health risks posed by the site which was found to have a significant association with the level of education. On the other hand, factors such as the age of the participant and the number of years one had lived in the village were found not to influence ones knowledge. Slightly above half of the participants were found to have a positive attitude which was not influenced by their level of education, their age or the number of years they had lived in the village. Those who perceived themselves at high risk were more than half the number of participants and a significant association between level of education and perception was revealed. However, the age of the participant and the number of years he or she had lived in the village did not significantly influence their perceptions on the health risks posed by the dumpsite.

The study also showed a significant relationship between the reported health status and the number of persons in the participant's household. Similarly, a significant association was revealed between the reported health status of the participant and their attitudes towards the health effects posed by the dumpsite. This study and others have shown that the health risks associated with dumpsites are significant. The area used for dumping and in this case was

easily accessible to people and especially children, who are vulnerable to the physical and chemical hazards posed by wastes.

6.3 RECOMMENDATIONS

1. That the soils were found to have a deficiency in some essential minerals, excesses in some essential metals, and high levels of non essential heavy metals than is allowed for agricultural soils. As such the farmers growing edible crops around the site should be advised to stop doing so.

2. That the vegetables grown around the dumpsites were deficient in essential minerals and on the other hand they had a high level of toxic heavy metals coupled with the fact that the residents had low knowledge on the health risks posed by the dumpsite. As such, the ministries of Public Health and Sanitation and that of Agriculture should come up with health education programmes for the general population on the dangers of consumption of crops grown in and around the waste disposal sites.

3. That the dumpsite was shown to directly contribute to the pollution of the soils, vegetables and river water in the village and the fact that it is an illegal entity, as such dumping should be stopped and the site properly closed.

4. As a result of the above, the government should put in place certain monitoring processes and empower NEMA and the relevant institutions such as the ministry of Local governments that deal with solid waste disposal management at the city council and municipal levels, to be able to assess solid waste disposal practices and impose penalties if good practices are not followed in the disposal of solid waste.

6.4 SUGGESTIONS FOR FURTHER RESEARCH WORK

1. Biological samples of people living in Kadhodeki village should be taken for analysis to determine heavy metal levels.
2. Samples of the air and the other water sources not tested (borehole, tap water) in this study should also be analysed to ascertain the level of heavy metal.
3. Other crops such as cereals and tubers grown around dumpsites should be analysed to determine heavy metal levels

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APPENDICES

APPENDIX 1

Table A1: ANOVA results for the four vegetable samples

	Spinacia oleracea		***Solanum villosum***		***Amaranthus spp***		***Brassica oleracea Acephala***		
	F	**P**	**F**	**P**	**F**	**P**	**F**	**P**	**Df**
Pb	1.32	$p > 0.05$	1.59	$p > 0.05$	1.32	$p > 0.05$	8.34	$p < 0.05$	(2,9)
Zn	2.19	$p > 0.05$	2.85	$p > 0.05$	2.19	$p > 0.05$	9.19	$p < 0.05$	(2,9)
Cu	0.26	$p > 0.05$	2.22	$p > 0.05$	0.26	$p > 0.05$	3.55	$p > 0.05$	(2,9)
Fe	3.89	$p > 0.05$	7.16	$p < 0.05$	6.84	$p < 0.05$	7.07	$p < 0.05$	(2,9)
Hg	7.27	$p < 0.05$	19.64	$p < 0.05$	10.17	$p < 0.05$	11.44	$p < 0.05$	(2,9)
Ni	17.60	$p < 0.05$	4.91	$p < 0.05$	42.67	$p < 0.05$	3.25	$p > 0.05$	(2,9)
Co	9.07	$p < 0.05$	5.15	$p < 0.05$	12.59	$p < 0.05$	6.14	$p <0.05$	(2,9)
Mn	13.10	$p < 0.05$	5.73	$p < 0.05$	14.12	$p < 0.05$	2.33	$p > 0.05$	(2,9)
V	21.58	$p < 0.05$	9.05	$p < 0.05$	5.34	$p < 0.05$	4.44	$p > 0.05$	(2,9)

APPENDIX 2

Table A2: ANOVA results for soil samples

	F VALUE	P VALUE	Df
Lead	0.70	$p > 0.05$	(2,9)
Zinc	2.05	$p > 0.05$	(2,9)
Cobalt	3.95	$p > 0.05$	(2,9)
Iron	10.09	$p < 0.05$	(2,9)
Mercury	6.02	$p < 0.05$	(2,9)
Nickel	4.57	$p < 0.05$	(2,9)
Copper	94.43	$p < 0.05$	(2,9)
Manganese	9.31	$p < 0.05$	(2,9)
Vanadium	41.10	$p < 0.05$	(2,9)

APPENDIX 3

Table A 3: ANOVA results for water samples

	F value	P value	Df
Lead	N/A	N/A	N/A
Mercury	N/A	N/A	N/A
Vanadium	N/A	N/A	N/A
Copper	N/A	N/A	N/A
Iron	36.41	$p < 0.05$	(2,9)
Zinc	65.61	$p < 0.05$	(2,9)
Nickel	42.67	$p < 0.05$	(2,9)
Cobalt	12.84	$p < 0.05$	(2,9)
Manganese	78.89	$p < 0.05$	(2,9)

APPENDIX 4: QUESTIONNAIRE IN ENGLISH

SECTION 1: SOCIO DEMOGRAPHIC DATA

1. Age in years of the respondent……..

2. Gender (observe then record)

Female…… Male…….

3. Highest level of education completed (please tick one)

a) None….....
b) Primary……..
c) Secondary.....
d) College/ University……

4. Marital status (please tick one)

a) Single…….
b) Married……..
c) Divorced…….
d) Separated……
e) Widowed……
f) No comment.....

5. What is the nature of your occupation? (Please tick one)

a) Casual employment……
b) Permanent and pensionable….
c) Contract employment…….
d) Self employed…….
e) None……

6. What is your religion (please tick one)

a. Catholics……..

b. Protestants……

c. Muslims……

d. Seventh Day Adventist (SDA)…

e. Others (Specify)……

7. Number of persons in the household……

8. How long have you and your family lived in Kadhodeki village? Tick against the period.

a) < 1 year
b) 1-< 5 years
c) 5- 10 years
d) > 10 years

9. According to you, for how many years has this dumpsite been in existence? (Please tick one)

a) 0-4 years…….
b) 5-9 years……..
c) 10-14 years…….
d) 15-19 years……..
e) 20-24 years……..
f) More than 25 years…
g) Don't know……..

10. What is your source of information on the answer given for question **9** above? (Please tick one)

a) Neighbors …….
b) Local leaders…….
c) Television…….
d) Land owners where the dumpsite is located
e) Internet ……
f) Born here……
g) Found the dumpsite when I moved to this place
h) Others (specify)……..

GENERAL FACTS

1. What is the source of family vegetables? (Please tick one)

a) The nearest green grocer……
b) The nearest market …….
c) Buy from the farmers near here…
d) From own farm around here……
e) Others (specify)……...

2. What is the source of family's domestic water? (Please tick one)

a) Public standpoint……

b) Household tap……

c) Local vendors specify (tankers, cart pullers, water kiosks)...

d) Nairobi River……

e) Borehole……

f) Not sure where water comes from……

g) Others (specify)…….

SECTION 2: KNOWLEDGE, ATTITUDE AND PERCEPTION

KNOWLEDGE

Please react to the following statements by either ticking **yes (Y) or no (N)**

1. Do you know that dumpsites can cause blockage of drains and pipes of the surrounding environment?
2. Do you know that dumpsites cause bad smell/ smoke/ fires?
3. Do you know that dumpsites cause pollution of the soils in the surrounding environment?
4. Do you know that crude dumpsites cause rodent and other animal infestations of the surrounding environment?
5. Do you know that dumpsites cause breeding of mosquitoes and other insects?
6. Do you know that crude dumping cause diseases and illness to the surrounding people?
7. Do you know that dumpsites can cause pollution of water sources by heavy metals?
8. Do you know that heavy metals can be found in the dumpsite and the surrounding environment?
9. Do you know that toxic chemical and other harmful substances can be found in the dumpsite and the surrounding environment?
10. Do you know that vegetables grown on or near a dumpsite can have high levels of heavy metals which can be harmful to human health when eaten?
11. Do you know that there are essential trace elements which can be found in the dumpsite and the surrounding environment?

12. Do you know that if such essential trace elements if in excess amounts in vegetables can be harmful to human health?
13. Do you know that effects of heavy metal toxicity take many years to show themselves?

ATTITUDE

Please indicate your reaction to the following statements, using these statements:

Strongly Agree (SE), Agree (A), Disagree (D), Strongly Disagree (SD)

1. The vegetables grown in Kadhodeki village are healthy to eat.
2. Kadhodeki dumpsite is beneficial to this village
3. Dumping of waste is not good for people living around Kadhodeki dumpsite.
4. It is okay to grow vegetables around the dumpsite.
5. It is okay for people to eat vegetables grown around the dumpsite
6. The water of Nairobi River is clean to use at home.
7. The soil around the dumpsite is good for planting crops.
8. Litter affects your quality of life in Kadhodeki.
9. Littering is okay every once in a while
10. Seeing litter in Kadhodeki DOES upset you personally
11. Kadhodeki dumpsite pollutes your environment
12. Kadhodeki dumpsite is a can be a health hazard to you
13. Kadhodeki dumpsite is a safety hazard to you

PERCEPTION

Please indicate your reaction to the following statements, using these statements:

Strongly Agree = SA, Disagree = D, Agree = A, Strongly Disagree = SD.

	Strongly agree	Agree	Disagree	Strongly disagree
Dumpsites increase heavy metal concentrations in the environment				
Dumpsites increase heavy metal concentrations in the vegetables planted near them				
Heavy metals can pass from the dumpsites to the human body through eating vegetables grown on or around the site				
If these heavy metals accumulate in the human body, they can cause diseases.				
The harmful effects of the dumpsite on the human body take long to show themselves.				

Self-reported symptoms of heavy metal toxicity.

Have you or any member of your family member experienced any of the following symptoms in the last six months? (You can tick more than one)

1. Increased irritability …….
2. Unexplained mood swings……. …….
3. Short term memory loss and mental confusion……
4. Vision problems such as blurred vision ……..
5. Chronic fatigue …….
6. Stomach Pain…….
7. Abnormally low or high blood pressure…….
8. Chest Pain or Racing Heartbeat…….
9. Rashes, itching and acne……..
10. Chronic Heartburn……..
11. Uncontrollable Twitching……..
12. Chronic Insomnia and waking up tired……
13. Persistent pain in the joints…….
14. Unexplained Depression …….
15. Dizziness and/or Motion Sickness…….

APPENDIX 5: INFORMED CONSENT FOR THE HOUSEHOLD SURVEY

Introduction and purpose of the research

Good morning/afternoon/evening. My name is _____.

I am student of Kenyatta university. Am conducting a research on Assessment of Heavy Metal Concentration in the Environment and Associated Health Risks: the Case of Kadhodeki Dumpsite in Dagoretti Kenya.

Objectives of the study

This study aims to know whether the dumpsite around kadhodeki area has a health risk to the community living around. I will do the following to try and establish this.

I will take the soil, water samples and various vegetables and analyze their of heavy metal concentrations.

I will ask various questions to determine whether the community around here is knowledgeable about the health risks the dumpsite posses.

I will have a focused group discussion with the farmer to discuss the quality of the food (vegetables) they grow on and around the dumpsite.

Why am I inviting you to participate in the study

I request you to be a participant in my study because your home is located within the area of study. Your house was chosen randomly from all households in the area. I will include around 330 households in this study.

What is expected from the participants of the research study

If you agree to participate you will answer or fill in a questionnaire with questions regarding the above topic

Risks and benefits

Your participation will help me to understand/ gain knowledge on whether the community is aware of the health risks possessed by vegetables grown on and around dumpsites.

Gain knowledge on whether the community is aware of the health risks possessed by using the water from Nairobi River downstream after the dumpsite for domestic purposes.

Gain an understanding on what the community feels about the presence of the dumpsite in their area.

I am aware you could be uncomfortable answering some of the questions in the questionnaire; however we do not expect any harm to come to you or your family because of this process.

Rights not to participate

Participation is voluntary.

Privacy, anonymity and confidentiality

I will not require you to write your name or address or phone number on any part of the questionnaire.

This research is for academic purposes and any findings will never be traced back to you. The data and information will be kept in a locked cabinet. No name will appear or be mentioned during presentations made on the findings regarding this research.

Future use of data

Information collected will only be used for the purposes stated earlier. No further use.

In case of any publications made from findings of this research, the community of Kadhodeki will be acknowledged (blanket acknowledgement)

Principle of compensation

You do not to pay me or my research assistant for taking part in this study. Similarly we will not pay you money for participating in the study

If you agree to participate in this study please sign below

The interview will last approximately 30 minutes.

Signature ……..date……..

Research assistants name ……..…signature ……..date ……

In case of any questions regarding this research contact

Joan Murugi Njagi

Department of Environmental Health

Kenyatta University

P.O Box 43844- 00100

Nairobi, Kenya

APPENDIX 6: HOJAJI

SEHEMU YA I

1. Umri wa mtafitiwa ……

2. Jinsia (angalia na ujaze) Mwanamke: ….. Mwanamume: ……

3. Kiwango cha juu zaidi cha elimu ya mtafitiwa (Tafadhali chagua moja)

a) Hujawahi kusoma shuleni……

b) Elimu ya msingi……..

c) Elimu ya sekondari……

d) Chuo……

4 Hali ya ndoa (tafadhali chagua moja)

a) Single .....

b) Ndoa .....

c) ya Hati .....

d) Kinachotenganishwa .....

e) mjane .....

f) Hakuna maoni .....

5. Unafany kazi aina gani (tafahdali chagua moja)

a) Kibarua…….

b) Kazi ya kudumu hadi umri wa kustaafu……..

c) Kandarasi……

d) Biashara……..

e) Hakuna……

6. Unashiriki dini gani? (Tafahdali chagua moja)

a) Katoloki……

b) Protestanti……

c) Muislamu…… .

d) Sabato……. .

e) Nyinginezo (Bainisho)……..

7. Familia yako ina watu wangapi? ……..

8. Wewe na familia yako mmeishi katika kijiji cha Kadhodeki kwa muda gani? (Tafahdali chagua moja)

a) Chini ya mwaka mmoja…….. .

b) Mwaka mmoja hadi chini ya miaka mitano…….

c) Miaka mitano hadi chini ya miaka kumi……

d) Miaka minne hadi chini ya miaka sita…….

e) Miaka kumi na zaidi…….

9. Kulingana nawe, jaa hili limekuwepo kwa muda gani? (Tafadhali jibu moja)

a) Miaka mine au michache…….

b) Kati ya miaka 5 hadi tisa……

c) Kati ya miaka 10 hadi 14……..

d) Kati ya miaka 15 hadi 19……..

e) Kati ya miaka 20 hadi 24…….

f) Zaidi ya miaka 25……

g) Sijui …….

10. Uliyapata wapi maelezo kuhusu swali la 9 ? (Tafadhali chagua moja)

a) Majirani……..

b)Viongozi wa eneo hili……

c) Televisheni…….

d) Wanaomiliki mashamba pale jaa hili linapatikana……

e) Mtandao……

f) Mzaliwa wa hapa …….

g) Nililikuta nilipo hamia mahala hapa …….

h) Kwingineko (Bainisha)…….

<u>MASWALA MUHIMU</u>

1) Asili ya Mboga (Sukumawiki, Spinachi, Managu na Terere) unazotumia nyumbani kwako ni zipi? (Tafadhali chagua moja)

a)Vibanda vya kuuza mboga vilivyo karibu……

b) Soko lililoko karibu……...

c) Mashamba yaliyo karibu……

d) Shamba lako lililo karibu……

e) Kwingineko (Bainisha)……..

2. Maji kwa matumizi ya nyumbani unayapata wapi? (Tafadhali chagua moja)

a) Bwawa la wanajamii…….

b) Mfereji wa nyumbani……

c) Wauza maji (magari ya maji, mikokoteni, vioski vya maji)……..

d) Mto Nairobi ……

e) Huna hakika yanatoka wapi ……

g) Kwingineko (bainisha)……..

SEHEMU YA PILI

A. Utambuzi

Tafadhali andika Utambuzi wako kuhusiana na usemi ufuatao, ukibainisha Ndio (Y) au La (N)

a) Unafahamu kwamba Jaa hili linafunga mifereji na mitaro ya maji

b) Unafahamu kwamba Jaa hili husababisha harufu mbaya

c) Unafahamu kwamba Jaa hili lina chafua mazingira

d) Unafahamu kwamba Jaa hili lina wanyama waharibifu huja kuishi hapo kama vile panya

e) Unafahamu kwamba Jaa hili lina mbu huzalia hapo

f) Unafahamu kwamba Jaa hili lina huleta majonjwa

g)Unafahamu kuwepo kwa madini yoyote hatari yanayopatikana kwenye jaa la taka na maeneo ya karibu?

h) Kuna vitu vyovyote vyenye madhara ambavyo viko katika jaa la takataka au kwenye maeneo yanayokaribiana na jaa hilo?

i) Je, unajua kwamba madini madhara inaweza kudhuru afya ya binadamu wakati kuliwa katika mboga?

j) Unafahamu magonjwa yoyote yanayosababishwa na madini hatari yanayopatikana katika jaa hilo.

k) Unafahamu kuwa kuna madini muhimu kwa afya ambayo yanapatikana katika jaa hili na maeneo yanayolizingira

l) Unafahamu kuwa madini hayo yakizidi viwango fulani katika mwili wa binadamu husababisha magonjwa?

m) Unafahamu kuwa athari ya vitu vyenye madhara kwenye mwili huchukua muda kabla ya kujihirisha waziwazi katika mwili wa binadamu

MIELEKEO

Tafadhali andika mielekeo au hisia zako kuhusiana na usemi ufuatao, ukibainisha

Nakubali kabisa (NK), Nakubali (N), Nakana (Na), Nakana kabisa (Nak)

1. Mboga zinazo kuzwa katika kijiji cha Kadhodeki ni safi
2. Jaa la taka la Kadhodeki lina manufaa kwa kijiji hiki
3. Utupaji wa takataka hapa kunadhuru wakazi wa eneo la karibu na jaa la Kadhodeki
4. Ni sawa kukuza mboga karibu na jaa hili
5. Ni sawa kula mboga zinazokuzwa karibu na jaa hili
6. Maji ya mto Nairobi ni safi kwa matumizi ya nyumbani
7. Hakuna tatizo kutupa takataka katika jaa la Kadhodeki
8. Takataka huathiri hali ya maisha katika
9. Kutupa takataka hapa mara chache hakuna madhara
10 Naudhiki nikiona takataka Kadhodeki
11. Jaa la taka la Kadhodeki huharibu mazingira
12. Jaa la taka la Kadhodeki linakudhuru kiafya
13. Jaa la taka la Kadhodeki linadhuru usalama wako

MTAZAMO

Tafadhali dhihirisho mtazamo na hisia zako kuhusiana na usemi huu

Nakubali kabisa (NK), Nakubali (N), Nakana (NA), Nakana kabisa (NAK)

	Nakubali kabisa	Nakubali	Nakana	Nakana Kabisa
Majaa ya taka huongeza kiasi cha madini hatari katika mazingira				
Majaa ya taka huongeza kiasi cha madini hatari katika mboga zilizopadwa karibu				
Vitu vyenye madhara ambavyo viko katika majaa ya taka hujipenyeza				

katika mwili wa binadamu kwa njia ya kula mimea iliyokuzwa kwenye majaa au karibu nayo				
Ulaji wa vitu vyenye madhara kwa wingi kunaweza kusababisha magonjwa				
Athari ya vitu vyenye madhara kwenye mwili huchukua muda kabla ya kujihirisha waziwazi katika mwili wa binadamu				

Maelezo ya kibinafsi kuhusu dalili za athari ya madini katika mwili

Kwa miezi sita iliyopita, wewe au jamaa zako wamewahi kupata dalili zifuatazo (unaweza kuchagua zaidi ya moja)

a) Kuudhika haraka bila sababu maalum

b) Kupata na kukosa raha kupita kiasi

c) Tatizo la kusahausahau

d) Kuchanganyikiwa

e) kutoona vizuri

f) Kuhisi kitefutefu

g)Uchovu mwingi

h) Kuumwa na tumbo

i) Damu kwenda mbio au polepole kupita kiasi

j) Roho kupiga kwa utaratibu usiofaa/ Kuumwa na kifua

k) Kuwashwa na mwili na vipele

l) Kiungulia

m) Kutingika katika sehemu yoyote ya mwili

n) Uchovu mwingi

o) Kuumwa na viungo mara kwa mara

p) Huzuni usiokua na sababu

q) Kizunguzungu

APPENDIX 7 : RUHUSA YA KUFANYA UTAFITI MANYUMBANI

Utangulizi na sababu ya utafiti

Habari ya asubuhi / jioni? Jina langu ni _____

Mimi ni mwanafunzi wa chuo kikuu cha Kenyatta. Nafanya utafiti kuhusu utambuzi wa kiwangu cha madini hatari katika mazingira na athari za madini haya katika jaa la Kadhodeki, Dagoretti, Kenya.

Maelezo ya utafiti

Utafiti huu hunanuiwa kuchunguza iwapo jaa la taka lilioko eneo la kadhodeki lina athari za kiafya kwa wakazi wa eneo hilo. Katika juhudi za kutambua haya,nitafanya yafuatayo,

1.Nitachukua mchanga,sampuli ndogo ya maji na mboga ili kupima au kuchambua kiasi cha madini hatari kilichomo.

2. Nitauliza maswali machache kwa wakazi wa hapa ili nijue iwapo wanatambua hatari za kiafya zinazohusiana na jaa hili.

3. Nitakuwa na majadiliano na wakulima wa hapa kuhusu hali ya mboga wanazokuza katika jaa hili au karibu jaa hili.

Sababu za kukualika katika ushiriki katika utafiti huu

Nakuomba uwe mshirika wangu katika utafiti wangu kwa sababu unaishi katika eneo la utafiti wangu. Mbinu bahatishi ilitumika katika kuchagua nyumba yako miongoni mwa nyingine. Nitashirikisha nyumba 330 katika utafiti huu.

Kinachotarajiwa kutoka kwa washiriki wa utafiti

Ukikubali kushiriki, utajibu maswali ama ujaze hojaji lililo na maswali yanayohusisha mada hii.

Madhara na manufaa

Ushiriki wako utaniwezesha:-

1.Kutambua iwapo wakazi wa eneo hili wanafahamu athari za kiafya zinazotokana na ulaji wa mboga zilizokuzwa katika jaa la taka hili au karibu na jaa la taka hilo.

2. Kutambua iwapo wakazi wa eneo hili wanafahamu madhara ya kiafya yanayotokana na matumizi ya maji katika mkondo wa maji katika mto Nairobi chini ya jaa hili.

3. Kutambua hisia na mielekeo za wakazi wa hapo kuhusu jaa hili.

Nafahamu kuwa kuhisi ugumu katika kujibu maswali yaliyomo kwenye hojaji hii, hata hivyo, hakuna madhara yoyote kwako na familia yako yanayoweza kutokana na ushiriki wako.

Haki za washiriki

Ushiriki ni wa kujitolea. Hakuna kulazimishwa.

Kuweka usiri

Usiandike jina lako, anwani, au nambari yako ya simu popote katika hojaji hio. Utafiti huu unafanywa kwa manufaa ya kisomi. Hakuna mtu atakayetoa habari hizi kwa mtu mwingine. Majina ya mshiriki hayatatajwa wakati wa kuwasilisha matokeo ya utafiti huu.

Matumizi ya baadaya ya deta hii

Deta itakayokusanywa haina matumizi mengine isipokua tu kwa sababu zilizotajwa awali. Iwapo machapisho yoyote yatafanywa kuhusiana na matokeo ya utafiti huu, wakaazi wa Kadhodeki watajulishwa.

Malipo

Hutalipa wala kulipwa ili ushiriki katika utafiti huu

Ikiwa utakubali kushiriki tafadhali tia sahihi hapa. Mahojiano yatachukua takribani dakika 30

Wasaidizi katika utafiti: _

Sahihi: _____ Tarehe: _____

Iwapo una maswali kuhusiana na utafiti huu tafadhali julisha

Joan Murugi Njagi

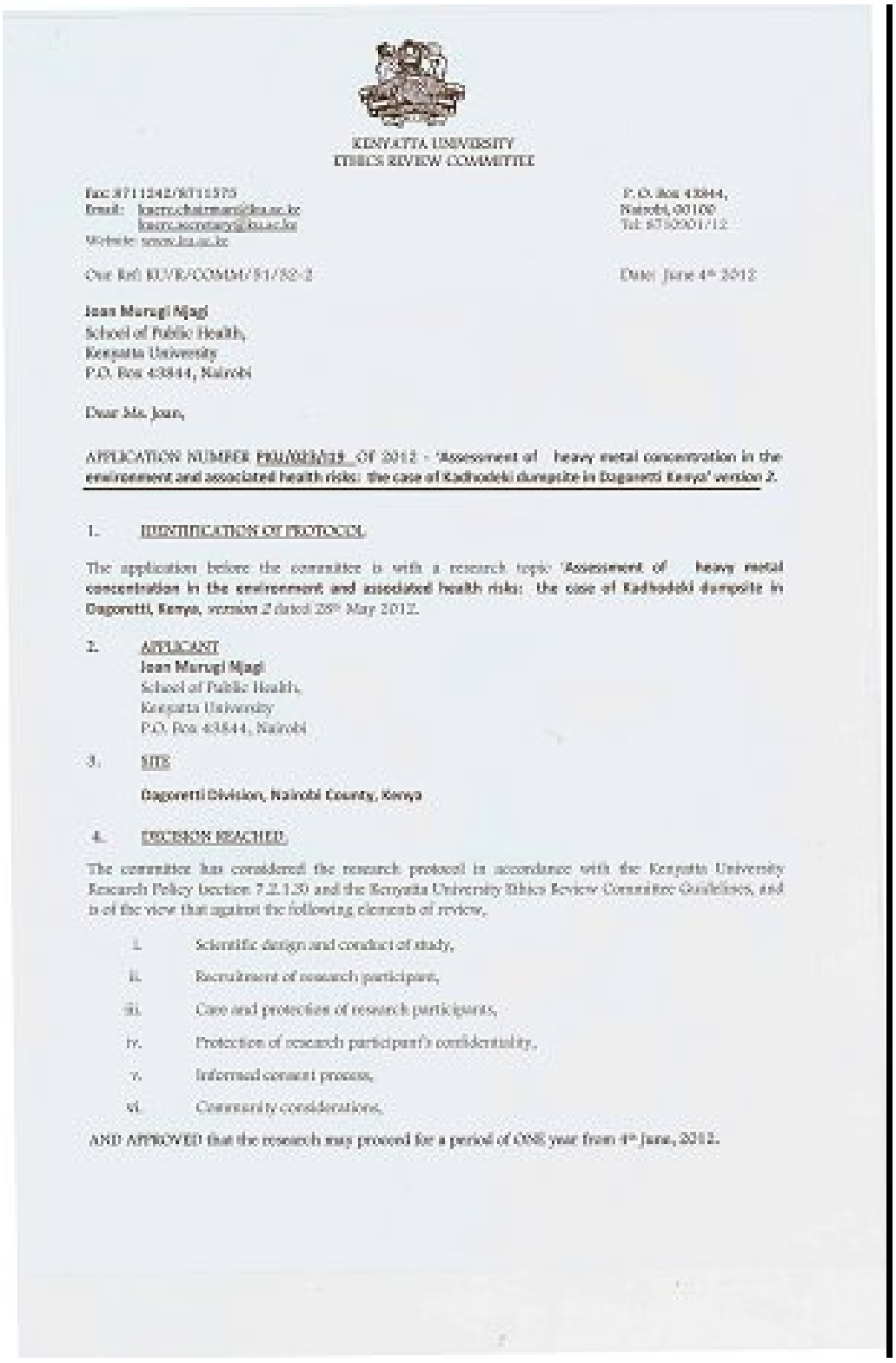
Idara ya Environmental Health (ya mazingira)

Chuo kikuu Cha Kenyatta

S.L.P. 43844-00100

Nairobi – Kenya

Appendix 8: Kenyatta University ERC Research Permit



KENYATTA UNIVERSITY
ETHICS REVIEW COMMITTEE

Fax: 8711242/8711575
Email: kuerc.chairman@ku.ac.ke
kuerc.secretary@ku.ac.ke
Website: www.ku.ac.ke

P.O. Box 43844,
Nairobi, 00100
Tel: 8710901/12

Our Ref: KUERC/COMM/51/52-2 Date: June 4th 2012

Joan Murugi Mjagi
School of Public Health,
Kenyatta University
P.O. Box 43844, Nairobi

Dear Ms. Joan,

APPLICATION NUMBER PHI/0034/09 OF 2012 - 'Assessment of heavy metal concentration in the environment and associated health risks: the case of Kadhodeki dumpsite in Dagoretti Kenya' version 2.

1. IDENTIFICATION OF PROTOCOL

The application before the committee is with a research topic 'Assessment of heavy metal concentration in the environment and associated health risks: the case of Kadhodeki dumpsite in Dagoretti, Kenya, version 2 dated 28th May 2012.

2. APPLICANT
Joan Murugi Mjagi
School of Public Health,
Kenyatta University
P.O. Box 43844, Nairobi

3. SITE

Dagoretti Division, Nairobi County, Kenya

4. DECISION REACHED

The committee has considered the research protocol in accordance with the Kenyatta University Research Policy (section 7.2.1.3) and the Kenyatta University Ethics Review Committee Guidelines, and is of the view that against the following elements of review,

i. Scientific design and conduct of study,
ii. Recruitment of research participant,
iii. Care and protection of research participants,
iv. Protection of research participant's confidentiality,
v. Informed consent process,
vi. Community considerations,

AND APPROVED that the research may proceed for a period of ONE year from 4th June, 2012.

9. ADVICE/CONDITIONS

i. Progress reports are submitted to the KU-ERC every six months and a full report is submitted at the end of the study.

ii. Serious and unexpected adverse events related to the conduct of the study are reported to this board immediately they occur.

iii. Clearance must be obtained for transportation of any biological material out of the country i.e. Kenya.

iv. Notify the Kenyatta University Ethics Committee of any amendments to the protocol.

v. Submit to KU-ERC the soft copy of the approved proposal.

When replying, kindly quote the application number above.

If you accept the decision reached and advice and conditions given please sign in the space provided below and return to KU-ERC a copy of the letter.

PROF. NICHOLAS K. GIRONGO
CHAIRMAN ETHICS REVIEW COMMITTEE

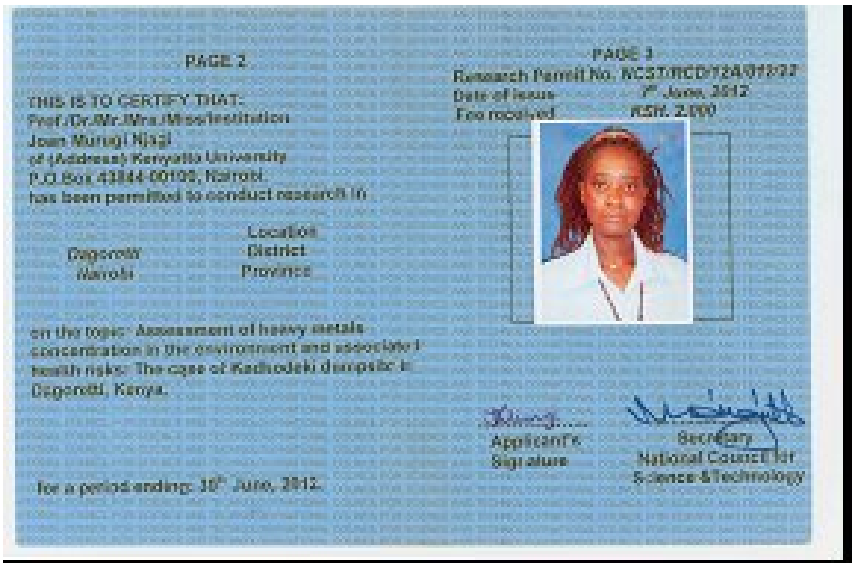
I ..... accept the advice given and will fulfill the conditions therein.

Signature ..... Dated this day of ..... 2012.

cc. Vice-Chancellor
Director: Institute for Research Science and Technology

cc. Vice-Chancellor
Director: Institute for Research Science and Technology

Appendix 9: National Council for Science and Technology Research Permit



PAGE 2

THIS IS TO CERTIFY THAT:-
Prof./Dr./Mr./Mrs./Miss/Institution
Joan Mungi Njagi
of (Address) Kenyatta University
P.O.Box 43844-00100, Nairobi
has been permitted to conduct research in

Location
Dagoretti
Nairobi
District
Province

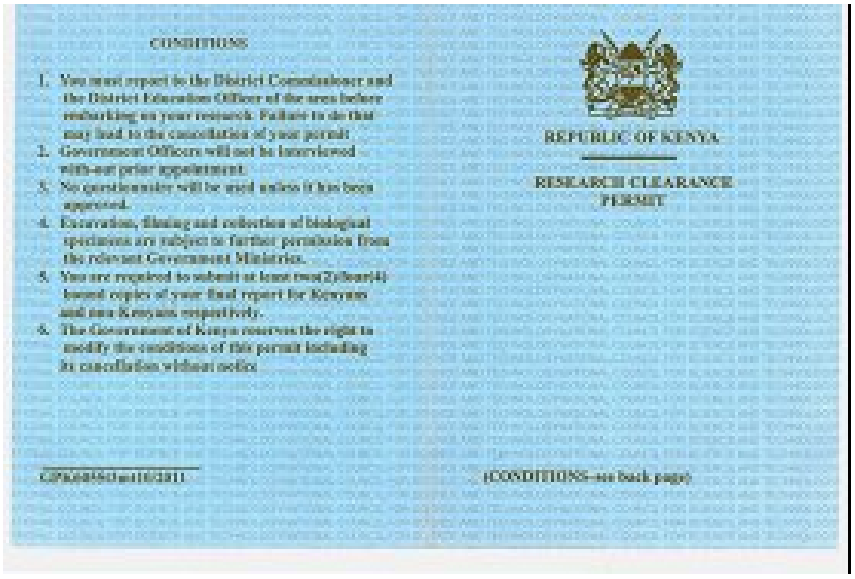
on the topic: Assessment of heavy metals concentration in the environment and associated health risks: The case of Kadhodeki dumpsite in Dagoretti, Kenya.

for a period ending: 30th June, 2012.

PAGE 1
Research Permit No. NCST/RCD/12A/012/22
Date of issue: 7th June, 2012
Fee received: KSH. 2,000

Applicant's Signature

Secretary
National Council for Science & Technology



CONDITIONS

1. You must report to the District Commissioner and the District Education Officer of the area before embarking on your research. Failure to do that may lead to the cancellation of your permit
2. Government Officers will not be interviewed with-out prior appointment.
3. No questionnaire will be used unless it has been approved.
4. Excavation, filming and collection of biological specimens are subject to further permission from the relevant Government Ministries.
5. You are required to submit at least two(2)/four(4) bound copies of your final report for Kenyans and non Kenyans respectively.
6. The Government of Kenya reserves the right to modify the conditions of this permit including its cancellation without notice

REPUBLIC OF KENYA

RESEARCH CLEARANCE PERMIT

CONDITIONS-see back page)