CONCENTRATIONS OF SELECTED TRACE ELEMENTS IN BOREHOLE WATER AND THEIR IMPLICATIONS FOR HUMAN HEALTH IN ELDORET MUNICIPALITY.

BY

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ATHESIS SUBMITTED TO THE SCHOOL OF ENVIRONMENTAL STUDIES IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF M.PHIL IN ENVIRONMENTAL STUDIES (ENVIRONMENTAL HEALTH). UNIVERSITY OF ELDORET, KENYA

SEPTEMBER, 2015

DECLARATION

DECLARATION BY THE CANDIDATE

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DEDICATION

To my late father Mr. Martin Etyang Olaba Okaka Okulamong “Emorimor”. That you did not give me fish but instead showed me how to fish; this was a great heritage. God bless your soul forever.

ABSTRACT

Water is a basic human requirement as it is extensively used in everyday life and therefore if contaminated it is detrimental to life and can cause death. This study assessed levels of trace elements; Copper, Chromium and Manganese in borehole waters in Eldoret Municipality Kenya, their temporal variation and implications on human health. Samples were collected in the months of April, May, June and July in the selected boreholes and analysed for the trace metals using standard procedures. During the first visit to the selected boreholes, participants were recruited to the study. Questionnaires were administered from which a health risk assessment using exposure to the trace elements via the drinking water ingestion was worked out. The readings from Global Positioning System (GPS) taken and recorded for each of the boreholes sampled. Atomic Absorption Spectrum (AAS) was used to determine the concentrations of the trace elements and variability was then assessed using SPSS version 12.0 by comparing the results obtained to literature values by WHO/FAO. The results showed low concentration of the trace elements under investigation except for Chromium. In kipkorogot were the concentration of copper was higher than WHO/FAO recommended value and this was attributed to the quarry activities near the borehole. Also the higher Copper concentration in Munyaka was attributed to precipitation and subsequent percolation of contaminated runoff waters from the nearby farms where fertilizers and chemical sprays are normally used. Copper concentration ranged between 0.005 – 0.050 ppm, Chromium ranged between 0.04 – 0.23 ppm and Manganese concentration ranged between 0.0684 – 0.2906 ppm. In 69% of the borehole, concentration of Chromium was high and significantly different from the WHO/FAO values. The implications on the health were however not found to be significant. The health risk resulting from copper and Chromium were highest in Kipkorogot 0.005948 and 0.026813 respectively. Manganese was highest in Kipkaren with a value of 0.035303. However all the health risk values obtained were not significant. The borehole water in Eldoret Municipality needs to be monitored closely because of the variations displayed to minimize the likely health effects that can arise mainly from Copper and Chromium which displayed significant variations. In conclusion the concentration of the trace elements Copper, Manganese and Chromium in the study was generally lower than WHO/FAO recommended values. However there were exceptions which are attributed to the anthropogenic activities within the areas. The health risk implication was not significant for the trace elements studied.

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ACKNOWLEGMENTS

First and foremost I thank God almighty for the good health, blessings and guidance that has enabled me to reach this far.

I am thankful for the support and inspiration that many people have provided me over the years. I' would like to sincerely thank Dr. Gelas M. Simiyu and Dr. Kipkorir K. Kiptoo , my supervisors for their guidance throughout this work and for the many opportunities they provided me to broaden my horizon, their time and expertise. In the same tone, I acknowledge Messrs Martim, Rocky Lewela, Taratisio Ndwiga and John Ekeyya for the technical support during the analysis of the samples.

I also wish to acknowledge the moral support and encouragement from my fellow students and from the faculty members of the School of Environmental Studies throughout the study. I thank most sincerely Moi University for the partial scholarship that enabled me fulfill my financial obligations.

I am very grateful for my family: my wife Joyce Nalonja, my children Longinus, Miriam, Rose and Esther, my parents Mrs. Anjela Ichabo Etyang and the late Mr.Martin Etyang Olaba Okaka "Emorimor" who provided me with endless love and encouragement I needed to complete this work.

ABBREVIATIONS AND ACRONYMS

AAS	Atomic Absorption Spectrum
AOAC	Association of Official Analytical Chemistry
ASTM	American Society for Testing and materials
ATSDR	Agency for Toxic Substances and Disease Registry
BP	Blood Pressure
CVD	Cardiovascular diseases
ETE's	Essential trace elements
FAO	Food and Agricultural Organization
GPS	Global Positioning System
HIV	Human immunodeficiency Virus
IMDS	Isotope dilution mass spectrophotometry
IOMC	Inter Organization programme for the sound Management of Chemicals
IPCS	International Programme on Chemical Safety
ISO	Organization of International Standards
MND	Motor Neuron Disease
NEMA	National Environmental Management Authority
NHSSP	National Heath Sector Strategic Plan
PIXE	Proton induced x – ray emission
ppm	Parts per Million
ppt	Parts per trillion
SPSS	Statistical Package for the Social Sciences
UN	United Nations
WHO	World Health Organization
V/V	Volume by volume

CHAPTER ONE

INTRODUCTION

1.1 Background Information

Trace elements are inorganic chemicals that constitute less than 1% of the rocks in the earth's crust (Stumm and Morgan, 1991). They occur naturally, and cannot be biodegraded. In the human body these elements constitute less than 100mg/Kg (0.01%). The trace elements: copper, manganese and chromium are important. The elements are released to the environment naturally by weathering and volcanic activities (Flint and Skinner, 1977). These elements, depending on their concentrations and chemical forms, function as essential elements or potent toxicants to humans, animals, plants and certain bacteria.

Low concentrations of trace elements occur in natural aquatic ecosystems, but recent expansions in human population growth, industry, and peri-urban agricultural activities in African cities have led to an increase in trace element occurrence in excess of natural loads (Biney *et al*., 1994). Significant increases in some trace elements in water have been observed and attributed to anthropogenic activities such as car washes and industrial and municipal discharge (Onyari and Wandiga, 1989). Previous studies in Kenya showed that the combustion of fossil fuel (that is leaded gasoline) and the un-regulated disposal of used batteries and motor oil are important sources of trace elements pollution (Chang and Cockerham, 1994). Literatures available also show that the major factors affecting the chemical composition of natural waters in Kenya include: geological characteristics such as lithology, volcanic activity, chemical weathering and soil leaching (Davies, 1996).

Trace elements concentration in the environment is modified by a variety of natural processes and deliberate and accidental human activities such as industrial and consumer waste (Cantor, 1997). Commercial processes, like mining, agriculture, manufacturing and discarding of wastes in landfills lead to accumulations of these elements in the environment. Storm water runoff, has the potential for depositing a wide range of contaminants into urban impoundments.

The United Nations projects a rapid population growth in urban areas between 2000 and 2030, with access to safe drinking water and adequate sanitation in urban areas deteriorating in developing countries (Aggett and Mills, 1996). The Kenyan urban population is growing at 8% per annum and is now more than 27% of the country's total population in a report by National Environmental Authority (NEMA, 2004). In addition, generation of solid, liquid and gaseous wastes has been increasing in tandem with industrial development and the diversification of consumption patterns. The (NEMA, 2004) report indicates that per capita waste generation ranges between 0.29 and 0.66 kg day^{-1} within the urban areas of the country. In case of the municipal waste generated in the urban centre's, 21% emanates from industrial areas and 61% from residential areas. The large amount of waste generated particularly from the residential areas has a high potential of contaminating ground water.

Previous studies (Elizabeth *et al*. 2007) found that most people (91%) in the peri – urban Estate of Langas in Eldoret used boreholes as the main source of domestic water. With a population growth rate of 8% per annum and estimated population of over half a million people (Republic of Kenya, 2009), shortage of housing, water, congestion in health facilities, poor sewage disposal and general degradation of the environment has become a common occurrence in Eldoret. Surface and groundwater are the primary sources of water for human consumption, as well as for agricultural and industrial uses in Western Kenya (Davies, 1996). The trace element pollutants, irrespective of the source, ultimately end up in aquatic systems (Nriagu and Pacyna, 1988). These elements are greatly absorbed and retrained in the body when given in a liquid diet (Kostial, 1983) and, this therefore influences the risk in the public health. The risks of appearance of trace elements related effects on health could be influenced substantially by changes in sources of drinking water or dietary intakes (Lawrence, 1990). Any geo-chemical anomaly (enrichment or depletion) of trace element within the local environment will have a marked health influence on the well being of the inhabitants (Appleton *et al*., 1996). Ingestion of drinking water containing significant amount of trace metals may result in adverse health effect varying from shortness of breath to several types of cancers (Cantor, 1997, Calderon, 2000, Dogan et. al., 2005). These elements are important for proper functioning of biological system and biomagnifications occurs through the food chain. The probable health effects are estimated using the risk assessment model where by the probability and the magnitude of the risk are evaluated.

The potential toxic trace elements in this study Cu, Mn and Cr are identified to cause health hazards in animals. Acceptable range for Copper in drinking water is 0.05 to 1.5 ppm, Manganese 0.05 to 0.5 ppm and Chromium maximum level in drinking water is 0.05 ppm (WHO, 1996). Studies done in Georgia (U.S.A.), Copper, Manganese and Chromium were known to have beneficial health effects on heart diseases. Low – death rate could be a result of an abundance of beneficial trace elements in the soil rather than, concentrations of harmful trace elements (Shaclette *et. al*., 1972). In Florida (U.S.A) 85% of metals, 90% of oxygen demand material, more than 50% of nutrients, and 99% of suspended solids entering surface water systems were linked to storm water runoff (Livingstone and Cox 1989).

1.2 Statement of the Problem

In Eldoret Municipality up to 91% of the people living in peri - urban estates use borehole water as the main source of domestic water, Elizabeth *et al*. (2007). Most of the factories in Eldoret are either for wood treatment or textiles which use large quantities products from Copper, Manganese and Chromium either as preservatives or dyes. Residues from heavily contaminated areas leak into ground water supplies and contaminate them (Butchet and Lison, 2000). Also stone mining (quarry) are common. During precipitation these elements which through spillages or residues in wastes end up in the environment are then easily washed into ground water systems, by percolation and infiltration thus increasing the chances of contaminating the borehole waters. Further Eldoret fall in a volcanic area, weathering of the parent rock and during precipitation the residues are washed into ground water system/boreholes hence contaminating the same with trace elements. Most studies have focused on microbial quality of water and left out the inorganic quality which is equally important and is the subject of this study. This study set to establish the level of contamination in the boreholes waters in the wake of the increased anthropogenic activities. If higher than normal levels of the trace elements concentration is established in borehole waters then the risks involved will be high due to the population that is exposed.

1.3. Objective of the Study

1.3.1 Overall objective

To assess the concentration levels of selected trace elements in borehole water and assess health risks to consumers in Eldoret Municipality

1.3.2 Specific study objectives

(a) To determine the concentration levels of trace elements, Chromium, Copper and Manganese in borehole waters in Eldoret Municipality.

(b) To assess temporal and spatial variation of trace elements in borehole water in Eldoret Municipality.

(c) To determine drinking water consumption levels

(d) To estimate the Exposure and potential health risks to consumers in Eldoret.

1.4 Hypothesis

(i) $H_{o\ 1}$ The concentration of the trace elements Copper, Manganese and Chromium in the borehole water is not significantly different from WHO/FAO guideline values.

(ii) $H_{o\ 2}$ The temporal variation in concentrations of the selected trace elements in the study area is not significantly different.

(iii) $H_{o\ 3}$The trace elements Chromium, Copper and Manganese concentrations studied in boreholes waters supplies do not pose adverse health implications to the consumer population of Eldoret Municipality.

1.5 Justification of the Study

Water is a basic requirement for life and is extensively used in everyday life. The human body is 70 – 80 % water by weight, with 99.5 % of all molecules containing water. Water is the delivery system that carries nutrients to the cells, maintains energy production, and removes toxic wastes from the body. Biological processes including circulation, digestion, absorption, and excretion depend on water to function properly. If contaminated water has capacity to transmit many diseases, but most routine reports on domestic water analysis only give the microbial quality and ignore concentration of trace elements (Inorganic quality).

The choice for the three trace elements was because of their beneficial health effects, (Shaclette et. al, 1972) availability and affordability of the reagents.

1.6 Significance of the Study

The findings of the study will impact such that the quality of the borehole water will be known and the consumers will make informed decision about the water they drink. This will create a basis for advocacy in improving the quality of the borehole waters if the quality is found wanting. This will lead to improvement in the quality of human health and hence the productivity of the consumers.

1.7 Study Area

The study was carried out in Eldoret Municipality in Uasin Gishu County, Kenya. Uasin Gishu County has six divisions: - Ainabkoi, Moiben, Soi, Turbo, Kesses and Central. Uasin Gishu one of the 47 counties in Kenya borders other counties which include: Trans Nzoia, Kakamega, Nandi, Elgeyo Marakwet , Baringo and Kericho as shown in Figure 1. The County has a total area 3218 Km^2 constituting only 2% of the former Rift Valley Province.

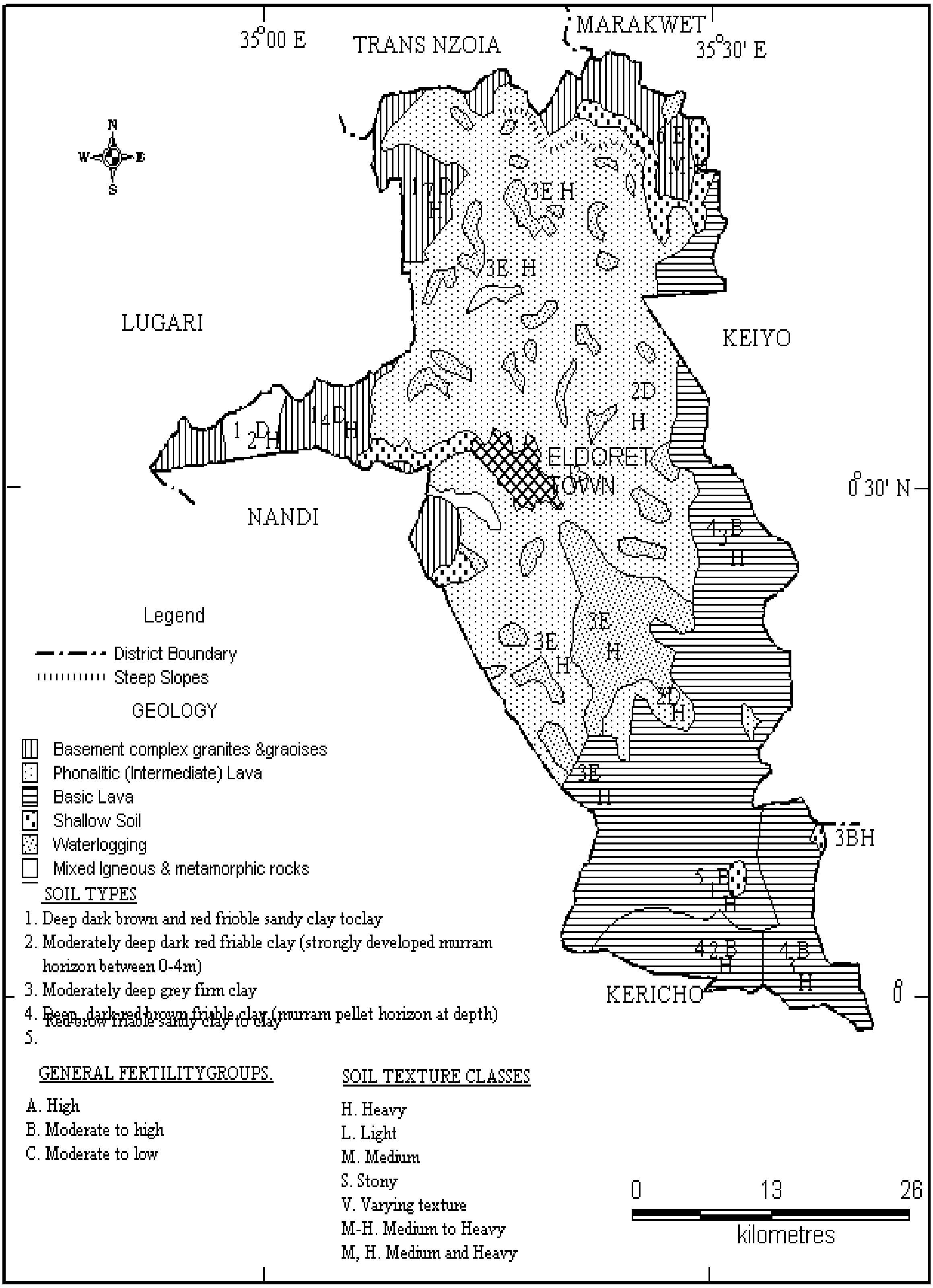

Figure 1: ***Map of Uasin Gishu County showing its Geological layout***

(Source*: Adapted from Eldoret Municipal Council Annual Report, Eldoret 2009)*

1.7.1 Physiography

Eldoret Municipality, where the study was done falls within the central Division of Uasin Gishu County. It traverses latitude $0^{0}31$'North, $35^{0}16$'East longitude with altitude of about 2085M above sea level and the municipality covers an approximate area of 147.9 Km^{2}. Figure 1 shows the map of Uasin Gishu County where Eldoret Municipality is with its geological layout. The town has grown over years and has become one of the most important and fastest growing agricultural, commercial and industrial towns in Kenya with an average growth rate of 7-8% per annum.

1.7.2 Relief and Drainage

Eldoret Municipality is located on the Uasin Gishu plateau which is dissected into two by river Sosiani, which flows westward from Elgeyo escarpment to join Turbo River and later Kipkaren River. The land rises from river Sosiani Valley both northwards and southwards from about 1800 M in the extreme northwest and beyond 2160 M contour line. The northern part of Eldoret is marked by a steep slope which forms an escarpment wall extending East of Sergoit road and north of Kipchoge Stadium.

1.7.3 Climate

The maximum daily temperature ranges from 23.7^{0}C to 25^{0}C normally in February and mean maximum ranges from 9^{0}C to 9.5^{0}C in July. The rainfall distribution is approximately bimodal with two peaks in the months of May and August. The short rains that amount to between 900-1200 mm starts in July and is higher than the long rains during May/ June, however the mean annual rainfall range from 1000 mm to 1124 mm.

1.7.4 Soils and Geochemistry

The soils in Eldoret Municipality are categorized into four groups according to their localities. The soils on bottom lands are mainly vertical and poorly drained moderately deep and dark grey in colour. These are found mainly to the south eastern part of Eldoret Municipality. The second type of soils is those found on plateaus. They are ferralsols and are well drained dark red and dominantly used for arable agriculture, livestock and wattle plantations (Republic of Kenya, 1997). The soils on the hills and minor scarps form the third groups of soils; they are well drained, shallow, reddish brown and viciously known as cambisols, pegosols or lithosols (Ogendo, 1989). These types of soil occupy the western section and partly south eastern parts of Eldoret Municipality. Finally the soils on upper middle level uplands found to the east of Eldoret Municipality region form the fourth category. They are developed on older basic igneous rocks, particularly basic tuffs, basalts and phanolites. They are friable, extremely deep reddish and well drained (Republic of Kenya, 1997).

Geologically, Eldoret municipality falls under the tertiary volcanic period. The rocks are mainly of alkaline type including basalts, phonolites, nephelinites, trachytes, alkali rhyolites and their pyroclastial equivalents.

1.7.5 Socio – Economic Activities

Eldoret municipality developed as a result of activities of European settlers in the then Uasin Gishu District during the colonial period specifically in 1909. Over the years municipal boundaries have been extended from the initial 25 km^2 to 50 km^2 in 1974 and 147.9 km^2 in 1988 with corresponding population increased from 8193 in 1948 to over 300,000 at present (CBS, 2006). The population growth in Eldoret has been attributed to natural growth, rural – urban immigration from rural areas, municipal extension and rapid industrial growth. The town plays a significant role in the wholesale and retail trade in agricultural commodities such as wheat, maize and livestock products and sales and servicing of farm tools, machinery and other agricultural inputs. Horticultural crops are also common due to availability of nearby markets. The town offers administrative, banking and entertainment services. Further it is a major dynamic regional administrative, commercial, educational and industrial centre. The town has also a vibrant informal sector that offers employment to many of its residents. The roads cover about 240 km and over the years motorized transport has increased with rising economic activity resulting in increased road – related pollution increasing the trace elements burden. Also mining for murram and building stones are common on unoccupied hills and this contribute to environmental degradation and increase in trace elements load in the environment.

Rapid industrial growth attracted development, as the town was transformed into an industrial centre offering employment opportunities in various industrial concerns including textile, dairy farming, cereal, vegetable oil manufacturing, steel works and tourism. Ombura, (1999) noted that Eldoret had conflicting land uses such as mixing of heavy Industrial manufacturing and processing plants with residential areas and over development plots which lead to degradation of environmental and hence release of trace elements to the environment. The use of fertilizers, herbicides and sprays to control pests and ticks also contribute to the trace element burden in the environment. Also the rapid growth of population has led to shortage of housing, health facility, water, poor sewage disposal and general degradation of environmental quality. This in turn has strained the municipality in provisions of these services (Eldoret Municipality Council, 1985).

CHAPTER TWO

LITERATURE REVIEW

2.1 Diseases associated with trace elements in the study

2.1.1 Cancer

Cancer is becoming a leading cause of death in old age. The gradual elimination of other fatal diseases combined with rising life expectancy, means that the risks of developing cancer are steadily growing. Diet or nutrition are well recognized to be major factors determining some part of the human cancer incidence. About 10 – 70%, (mean 35%) of all human cancer may be associated with dietary factors (Lawrence 1990). The latest studies (WHO, 1997) have provided evidence that cancer and heart diseases are related to trace elements deficiencies. In mortality study conducted in a populated area with high trace element chromium concentrations in domestic/borehole waters in the People's Republic of China, there were increased incidences of lung and stomach cancer (Zhang et. al, 1997)

In previous studies conducted at Moi Teaching and Referral Hospital by (Wakhisi, *et al*., 2006), Esophageal cancer associated with trace elements was rated as the ninth most common cancer in the world, and the fifth most common cancer in developing countries, with approximately 300,000 newly diagnosed patients every year. The dietary intakes and drinking water supplies were considered as major sources of the trace elements. The study further reported an increase in the cancer cases recorded at the Hospital, from Jan. 1994 to May 2001. It showed that the cancer incidence was 2% per 100,000 per year. Kenyatta National Hospital recorded the overall country incidence as 6.7% per 100,000 per year over the same period.

Epidemiological studies have indicated the importance of the quality of portable waters and other environmental factors in human cancer. Information on the association between occurrence of trace elements and esophageal cancer is explained in studies by Appleton e*t al (*2006). It was observed that trace element deficiency was a factor in the aetiology of esophageal cancer in the Linxian and Cixian regions of the People's Republic of China. That in vitamin trials done in the Linxian area, it was found that combined supplementation with β-carotene, vitamin E and trace element Selenium reduced the mortality rate. To further explain the role of trace elements, the distribution in cultivated top-soils, grain, human hair and drinking water of Selenium was studied in 15 villages in the Cixian area of the People's Republic of China. In the 1980–1990's Cixian area had one of the highest mortality rates from esophageal cancer in the world. The study demonstrated that total Selenium concentrations in drinking water, soil, grain and hair increase from the low esophageal cancer area to the high esophageal cancer area, contrary to the expected trend.

2.1.2 Hypertension and Cardiovascular Diseases

Data from (WHO, 2002) indicate that hypertension is the third most important contributor to the global disease burden among the six risk factors of underweight, unsafe sex, hypertension, unsafe water, tobacco and alcohol (IMCR, 2002). That by 2020 hypertension will be the commonest cause of death in developing Countries (WHO, 2002). In Africa – Caribbean blocks the prevalence of hypertension being as high as 50% over the age of 40 years (Ramsay *et al*., 1999). Studies (WHO, 1997) have provided evidence that cancer and heart diseases are related to trace element deficiencies. Knowledge of levels of trace elements in domestic water sources is important in understanding any association that may be in existence. The trace elements that allegedly have beneficial effects on cardiovascular function include manganese, chromium, and copper (Massironi, 1996). Table 1 shows the maximum acceptable and guideline value of some trace elements in water systems.

Table 1: Guidelines values for health related inorganic constituents (WHO, 1984)

Parameter	**Limits MG/L**
Arsenic	0.05
Asbestos	No value set
Barium	No values set
Beryllium	No values set
Cadmium	0.005
Chromium	0.05
Cynide	0.1
Floride	1.5
Hardness	No health related value set
Lead	0.05
Mercury	0.005
Nickel	No values set
Nitrate(of N)	10(=44 mg/l NO3)
Selenium	0.01
Silver	No value set
Sodium	No value set
Copper	1.0

(Source: Adapted from Fresenius,1988)

2.1.3 Other Diseases caused by Trace Elements

Trace elements Manganese, Copper and Chromium amongst others have effects on human body organs especially the brain, kidney and the skin (Tucker, 1972). Peli-Ba (1998), analyzed 20 trace elements including Copper, Chromium and Manganese in samples from 60 boreholes located in the upper east and west regions of Ghana and found out that most trace elements concentrations were high as compared to concentrations found in natural water. Potential health risks that high concentration levels in borehole waters could pose range from decrease in human heath to succumbing to the associated illness.

Obiri, (2007) studied concentrations of trace elements in the four of the operational borehole at Dumasi in the Wassa West District of the Republic of Ghana. He recorded the concentrations of the trace elements manganese and chromium in the ground water from Dumasi borehole and found that they were relatively high compared to WHO recommended values. He observed that resident adults and children who entirely used water from the boreholes were at serious risk from exposure to health hazards associated with exposure to the above metals. Obiri also observed that his results could be applied to other mining communities, which lie on the Birimian and Tarkwaian rock system, and that the residents were at serious risk from exposure to toxic metals from drinking water from the boreholes.

Pollution studies on surface waters of Thika found out that concentrations Copper and Chromium were within the safe limits for drinking water as per WHO standard, whereas Manganese was in excess (Davies, 1992). The study attributed the pollution of rivers to untreated or partially treated effluent from factories, sewage treatment plants, solid waste dumps and run-off from agricultural lands. The study however did not establish whether the trace elements levels in the surface waters was also the case in borehole waters that is a common source of domestic waters for most urban/ rural communities without piped water.

Simiyu in, 2000 assessed the concentrations of trace elements, Zinc, Lead, Copper, Cadmium, Boron, Mercury, and Arsenic in geothermal fluids at Olkaria power plant and influence of fluids levels of the elements in sediment and plants. He observed that their concentration levels exceeded the WHO recommended limits for drinking water. He further observed that geothermal fluids had adverse implication to environmental health of human and animals at the top of the food chain. He however concentrated his research work on trace elements on geothermal fluids.

Marginal deficiency trace elements have been shown to exist in all segments of societies both in developed and underdeveloped countries (Fishbein, 1981). In contrast to the toxic trace elements where dose – effect relationship exist, trace elements copper, manganese and chromium both increases and decreases of daily intake can induce adverse effects (Fishbein, 1981). Dietary excess of one trace element may have a detrimental effect on one or more of the essential elements particularly if the latter is present at a minimal level. An excess of one essential trace element may decrease the bioavailability of another. Bioavailability of these elements is influenced by factors such as dietary intake, host and environmental factors which might affect its use.

Trace elements regarded as essential for human health care include: Copper, and Chromium, (WHO, 1988, 1996). Those considered as probable essential trace elements include: Manganese (WHO, 1996). Table 2 shows maximum acceptable concentrations of some of the trace elements in Marine, fresh and drinking waters by WHO standard. For a particular essential trace element, its absence or deficiency from diet produces either functional or structural anomaly that the abnormality may lead to a consequence of specific biochemical change that can be reversed by the presence of the essential metal (WHO, 1996).

Table 2: Maximum Acceptable concentration of some Trace elements in fresh water, marine and drinking water

Metal	Fresh water	Marine water	Drinking water
Arsenic	0.05	0.05	0.05
Cadmium	0.0004	0.005	0.01
Chromium	0.1	1.0	0.05
Copper	0.036	0.1	1.0
Manganese	1.5	0.1	0.05
Mercury	0.00005	0.0001	0.002
Nickel	0.1	0.1	_
Silver	0.0003	0.0003	0.05
Selenium	1.5	-	0.01

(Source: WHO, 1986)

2.2 The selected Trace Elements

2.2.1 Copper

Copper is a reddish metal that occurs naturally in rock, soil, water, sediment and at low levels in air. Sources of copper include natural sources (such as volcanoes, decaying vegetation, forest fires etc) and anthropogenic sources such as smelters, power stations, combustion in municipal incinerators and agricultural use of copper products. Much of copper that enters environmental waters, do so either through natural weathering or anthropogenic soil disturbance, 6.8% of releases of copper to water is estimated to derive from these processed. Copper surface use presents 13% of releases to water and urban runoff contribute 2% (Perwak *et al*. 1980). In the absence of specific industrial sources, runoff is the major factor contributing to elevated copper levels in river water (Nolte, 1988). In the EPA-sponsored National urban runoff programme, in which 86 samples of runoff from 19 cities throughout the

United States were analyzed, copper was found in 96% of samples at concentrations of 1-100 mg/l (ppb) with a geometric mean of 18.7 mg/l (Cole *et al*., 1984). Copper is released to the atmosphere in association with particulate matter and it's removed by gravitational settling and dry decomposition. Its average concentration in the earth's crust is about 50 ppm. Copper levels in surface water range from 0.5 to 1,000 ppb (Davies and Bennett, 1985). Excess copper in the body is excreted via the bile (Turnlund *et al*, 1998). The control of copper body load is by changes in the efficiency of absorption and biliatry excretion, (Turnlund *et al.*, 1998). The cations ETE's are absorbed very efficiently usually greater than 70% and total body burden regulated by renal excretion. In the general population, the highest exposures to copper come from drinking water and food. At times the concentration of copper in tap water may exceed 1.3 ppm, the EPA drinking water limit. The estimated intakes of copper in the general population are 0.15 mg/day from drinking water, and approximately 2 mg/day from food. The dietary intake of copper can be increased from the regular consumption of certain foods, such as shellfish, organ meats (e.g., liver and kidney), legumes, and nuts. The recommended total daily intake of copper is 1 – 12 mg/day for adults (WHO, 1996). Copper levels in fresh water of 1-20 µg/L are found in uncontaminated areas.

Deficiency and excess exposure to copper at levels within the acceptable range of oral intake (AROI) for general population (1.0 ppm maximum allowable concentration and 0.3 ppm permissible concentration in drinking water), may cause disorders such as Wilson's Diseases, prevalence of 1 in 30,000) or Menke's disease (sex-linked, kinky-hair neurological disorder in infants) which has been suggested since 1972 (Fishbein, 1981). The fundamental defect being impaired billiard excretion of copper resulting in copper accumulation in most organs of the body e.g. liver, brain and kidney which provide the most apparent clinical manifestations. Menke's disease on the other hand is an x-linked recessive disorder of copper metabolism (IPCS, 1998). The other adverse health effects associated with copper include; anaemia and bone abnormalities, vomiting, nausea, diarrhea, headache, respiratory difficulty, liver and kidney failure, massive gastro-intestinal bleeding and death (IPCS, 1998). There are numerous reports of acute gastrointestinal effects in humans after ingestion of large amount of copper in drinking water or beverages (Araya *et al*., 2001). A significant increase in the incidence of nausea was observed at 4 ppm copper (0.01mg cu/kg) and higher. At 6 ppm a significant increase in the incidence of vomiting was also observed. Abdominal pain, nausea, and/or vomiting were observed in women drinking water containing 5 ppm (0.096 mg cu/kg) copper sulfate or copper oxide (Pizarro *et al.*, 2001). For copper deficiency we have defective connective tissue synthesis and oesteogenesis, nutropena and iron-resistant anaemia (WHO, 1996). Low copper intake results in decreases in ceruloplamin levels and superoxide dismatese (SOD) (IPCS, 1998). Single acute or repeated ingestion of large doses of copper may induce gestrointestial toxicity followed by naematuria, jauntice and multiple organ failure and death. Chronic exposure to high doses of copper can result in liver damage (IPCS, 1998). Death and disease related have been documented for copper (WHO, 1996).

Copper has the potential for a variety of interactions with other nutrients particularly other ETE'S which may be regulated, in part or fully, by the processes of gastrointestinal absorption. The relationship with zinc being the best characterized. Both elements compete for similar binding in tissue. High zinc intakes (50 mg or more per day) inhibit absorption of copper by competing directly for serosal transport in the gut or by inducing metallothionein in the intestinal cells. Zinc is a good inducer of metallothionein but copper has a higher affinity for the protein. Zinc and copper may co-exist on metallothionein and the zinc induced metallothionein may sequester the copper and retard its transport across the serosal membrane. Consequences of the high affinity of copper for Zinc-induced metallothionein can be both negative (i.e. excessive ingestion of Zinc may promote copper deficiency) or positive (i.e. use of high zinc level as atherapeutic agent in treatment of wilson's disease (IPCS, 1998). High plasma copper levels with low levels of plasma zinc have been reported in some sickle cell anemia patients and in zinc-deficient dwarfs from the Middle East (Rose, 1990).

In a study of ground water and surface waters throughout New Jersey USA in which less than1000 wells and 600 surface sites were sampled, the medium copper level in groundwater and surface water were 5.0 and 3.0 ppb, respectively (Rose, 1990). The respective 90^{th} percentile and maximum levels were 64.0 and 2,783.0 ppb for groundwater and 9.0 and 261.0 ppb for surface water. The patterns of contamination in surface water correlates with light hydrocarbons, while that in groundwater correlates with trace elements. This suggests that the sources of contamination of surface water and groundwater are different. The copper concentration in some bodies of water evidently varies with season.

In another study of a small pond in Messachusetts from April of 1971 to March 1972, the concentration of copper was found to vary decreasing during the spring and early summer to less than 10-30 ppm in early August and then increasing when the pond was under the cover of ice to maximum values of 80-105 ppb in later January and early February (Kimball, 1973). Similar seasonal variations were noted in the epilimnion of the offshore waters of Great Lakes (Nriagu *et al*., 1996). In both cases, the cycling in copper concentrations is thought to be a response to biological reed and copper uptake during the growing season and its subsequent release from seasonal die-off and delay of biota.

A case report by (Spitalny *et al.,* 1984) examined the effect of repeated exposure to copper. Recurrent, acute symptoms, including nausea, vomiting and abdominal pain, were reported by three of four family members shortly after drinking juice, coffee, or water in the morning. An early morning water sample contained 7.8 ppm copper. A study by (Buchanan *et al.,* 1991) also examined individuals with elevated levels of coper in household water reported similar symptoms. Acute renal failure was reported in 5 of 125 individuals intentionally ingesting large doses of copper sulfate (Ahasau *et al.*, 1994). Hematuria, glylosuria, lylindruria and proteinuria, indicateive of renal tubular damage, were observed in a child who drank a solution containing approximately 3g of copper sulfate (Walsh *et al.,* 1997). A number of studies confirm that the kidney is target of copper toxicity. Renal toxicity as a result of copper loading follows a specific time course (Haywood *and Loughran*, 1985).

2.2.2. Manganese

Manganese is one of the most abundant trace elements in the environment. Some manganese compounds can dissolve in water and low levels of these compounds are normally present in water bodies. Manganese can change from one compound to another (either by natural or anthropogenic process), but it does not break down or disappear in the environment. Also manganese is an essential trace element for all species and is necessary for good health. It is an essential component of enzymes that are used for the carbohydrate, protein and fat metabolism. The human body typically under normal circumstances controls these amounts so that neither too little or too much is present. Due to accumulation fish can have up to 5 ppm and mammals up to 5 ppm in their tissues although the normal value is around 1ppm.

Manganese effects occur manually in the respiratory tract and in the brains. It causes Parkinson disease, lung embolism and bronchitis. Longer period exposure for men may cause impotence. Symptoms of poisoning include hallucinations, forgetfulness and nerve damage. On the other hand chronic manganese poisoning symptoms include: languor, sleepiness, weakness, emotional disturbances, spastic gait, recurring leg cramps, and paralysis. Manganese substances do cause lung, liver and vascular disturbances, declines in blood pressure, failure in development of animal fetuses and brain damage. A syndrome that is caused by manganese has symptoms such as schizophrenia, dullness, weak muscles, headaches and insomnia. Up take of manganese through the skin can cause tremors and coordination failures while severe manganese poisoning causes tumor development in animals. Insufficient manganese leads to interference of normal growth, borne formation and reproduction. Also other health effects such as, fatness, glucose intolerance, blood clotting, skin problems, lowered cholesterol levels, skeleton, disorders, birth defects, changes of hair color and neurological symptoms are experienced. The children who consumed higher manganese concentrations performed more poorly on WHO neurobehavioral score test than the control children. Furthermore the blood and hair manganese concentrations of exposed children were significantly higher than those of the contained population. The negative results on the test were correlated with hair manganese concentration. The children with increased manganese exposure also performed more poorly in school (as measured by mastery of the native language, mathematics and overall grade average), and their serum levels of serotonin, norepinephrine, dopamine, and acetylchloninesterace were significantly decreased compared to controls (Zhang *et al.*, 1995).

In one study in Japan by Kawamura (1994), death occurred in two adults who ingested drinking water contaminated with high levels, 14 mg/l of manganese. A manganism like neurological syndrome was also noted in an aboriginal population living on an island near Australia where environmental levels of manganese are high (Kilburn, 1987). Symptoms included weakness abnormal gait ataxia, muscular hypotonicity, and fixed emotionless face.

In another study (Kondakis *et al.*, 1989) reported that chronic intake of drinking water containing elevated levels of manganese (1.8 – 2.3 mg/l) led to an increased prevalence of neurological signs in the elderly residents (average age 67 years) of 2 small towns in Greece. Effects in these residents were compared with effects in similarly aged residents in a town where manganese levels were 0.004 – 0.015 mg/l and 0.082 – 0.25 mg/l. Also (Ite et al., 1994, Zhang *et al.*, 1998) have reported adverse neurological effects in children (Aged 11 – 13) who were exposed to excess manganese in well water and in foods fertilized with sewage water. The exposed population drank water with manganese levels of 0.241 mg/l on average. The control group drank water containing 0.04 mg manganese/l

In the study (Ite *et al.*, 1994), 92 children aged 11 -13 years who drank water containing manganese at average levels of at least 0.24 ± 0.051mg/l for 3 years or more and who also ate food stuffs (Wheat flour) with excess manganese (due to the high concentration of the metal in sewage water used to irrigate/fertilize the fields were compared to 92 children from a nearby village whose manganese concentration in water did not exceed 0.040 ± 0.012 mg/l (Controls).

2.2.3 Chromium

Chromium is a nitrous, brittle, hard metal commonly found in the environment. People can be exposed to Chromium through breathing, eating, or drinking and through skin contact. Chromium (III) is an essential element for organisms that can disrupt the super metabolism and cause related cardiovascular abnormalities including impaired glucose tolerance, elevated circulating insulin, glycosuria, impaired growth, decrease longevity, decreased fertility and sperm count among other conditions when the daily dose it too low. Chronic inhalation studies provide evidence that chromium (IV) is carcinogenic in animals and mainly toxic to organism; it can alter genetic materials and cause cancer in animals. The lethal oral dose in human adults is 50-70 mg of soluble chromates per kg body weight. At this level of ingestion, chromium causes poisoning of blood-forming organs. Chronic toxicity can be observed in several other mammalian species, with hexavelant chromium in concentrations of more than 5 mg/L (WHO, 1988). Chromium can also cause respiratory problems, weakened immune systems, birth defects, infertility and tumor formation. Other health effects include: skin rashers, dizziness, headache, nausea and vomiting upset stomach and ulcers, kidney and liver damage, lung cancer and death. In studies by (Lucas and Kramkowski 1975), workers exposed to mean concentration of 0.004 mg/m^3 chromium (IV) reported symptoms of stomach pains, duodenal ulcers, gastritis, stomach cramps and indigestion.

All the hexavalent chromium (more toxic form) in the environment arises from human activities, industries are major sources of chromium in waterways through industrial effluents (WHO, 1988). Chromium can make fish more susceptible to infection. It is possible for aquatic animals to accumulate high and ultimately lethal concentrations of trace elements over long periods from extremely low water concentrations. High concentrations can damage and or accumulate in various fish tissues and invertebrates such as snails and worms. Other factors influence the availability of chromium and therefore, its toxicity include the presence of other minerals and organic pollutants, and the temperature of the environment. Hexavalent chromium is accumulated by aquatic species by passive diffusion (US EPA, 1978). In the Illinois River the concentration of chromium in the muscles of omnivorous fish was found to be appreciably greater than that in the muscles of carnivorous fish although again the concentrations were less than that of the river sediment (Borgono *et al*, 1977).

Studies done in the United States and other developed countries where there is generally a large consumption of processed foods have associated high incidences of diabetes and cardiovascular problems to suboptimal dietary chromium. It is important to note that processing removes a large percentage of trace elements in foods. Examples of processed foods that have noted to have suboptimal levels of chromium are refined sugars and carbohydrates (Rose *et al.*, 1986). Some processed foods such as sucrose stimulate urinary excretion of chromium and thereby deplete chromium stores.

In a cross section study conducted in 1965 of 155 villagers whose well water contained 20 mg chromium (IV)/L as a result of pollution from an alloy plant in the people's Republic of China, associations were found between drinking water and oral ulcer, diarrhea, abdominal pains, indigestion and vomiting. The 20 mg chromium (IV)/L concentration is equivalent to a dose of 0.57 mg chromium (IV)/kg/day, using a default reference water consumption rate and body weight value of 2L/Day and 70 kg respectively. Three separate studies showed that at least 50 percent of the subjects showed significant improvements in their impaired glucose tolerance after chromium supplementation (Fishbein, 1981). Other studies however revealed little difference after subjects were treated with placebo and chromium.

Other effects of chromium are observed in a retrospective mortality study conducted on a population who resided in a polluted area near an alloy plant that smelted chromium in the people's republic of China, it was found that increased incidences of lung and stomach cancer in the study the population from 1970 to 1978 when the study was conducted. The adjusted mortality rates of the exposed population ranged from 71.89 to 92.66 per 100,000, compared with 65.4 per 100,000 in the general population of the District. The adjusted mortality rates from lung cancer ranged from 13.17 to 21.39 per 100,000 compared with 11.21 per 100,000 in the general population. The adjusted mortality rate for stomach cancer ranged from 27.67 to 55.17 per 100,000 which were reported to be higher than the average rate for the whole District. The higher cancer rates were found for those who lived closer to the dump site (Zhang and Li 1987). The exposed population was by all environmentally relevant routes (i.e. Air, drinking water, food and soil)

CHAPTER THREE

METHODOLOGY

3.1. Reconnaissance

A preliminary survey of the study area was carried out in October 2004. The Peri – Urban Estates of Eldoret Municipality were visited and listed upon acceptance by the owner to be enrolled in the study. A Questioner (see Appendix VI) was administered to obtain information on drinking water source and Consumption levels. The estimate number of 200 ml glasses consumed in a day based on the 24 hour recall were recorded. Only participants who admitted using borehole water for drinking were included in the study. The GPS coordinates reading for the borehole picked was then taken using the GPS meter (Figure 2). The existing information on geology and soils (Ogendo, 1989) was used to divide the area into four zones. South Eastern part was designated as zone A which consists of the Oasis, Annex, Sukunanga, Kipkrogot and KCC. This area is dominated by poorly drained moderately deep and dark grey soils in colour. The Southern part consisting of Elgon View, Langas, Yamumbi and Kipkaren, was designated as zone B. The area is dominated by ferralsols/Soils found in plateaus. The soils here are well drained dark red soils dominantly used for arable agriculture, livestock and wattle plantations. The Eastern part consists of Kapsoya, Munyaka, Hawai, and Kimumu. This was designated as zone C. This zone is dominated by basic tuffs, basalts and phonolites which are friable, extremely deep reddish soils. Finally the western section consisting of Huruma, King’ong and Kamukunji, was designated as zone D. This area is dominated by cambisols/pegosols/littosols which are well drained shallow reddish brown soils. The sampled boreholes in each of the zones are shown in Figure 2.

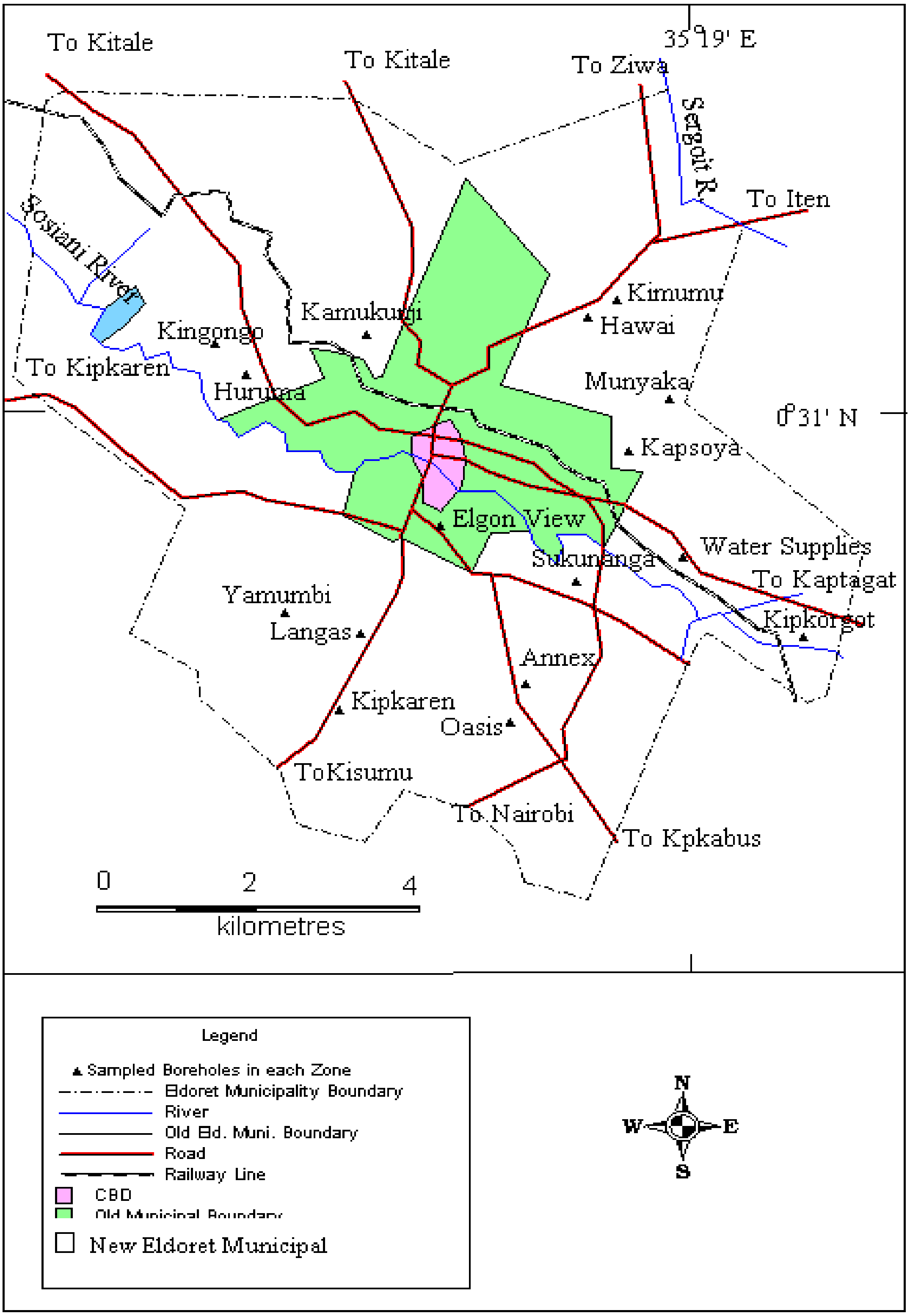

Figure 2: ***Eldoret Municipality showing the sampled boreholes in of the Zones.***

(**Source:** ***Self-generated from GIS Readings***)

3.2 Sample Size Estimation

In order to get as regular sampling grid as possible the study area was divided into approximately 2 km rectangular squares (147.9 km^2 / 4 km^2) to obtain 37 sampling blocks. For normal distribution, a sample size of 30% of the total population is required (Mugenda and Mugenda, 1999). Therefore, 30% of 37 gives 12 and since the population is < *10,000*, the formula

$n_f = n/(1+n/N)$ was used to estimate the sample size.

Where: N = Study population

n = Desired sample size

n_f = The sample size

Therefore $n_f = 12/(1+12/37) = 15.9$. This will be approximated to *16* sample areas.

Boreholes in each of the sampled areas were assigned unique numbers, from which then one borehole was picked at random for the study; see appendix V. The geology of the sampled areas was fairly uniform; see figure 1 and it was assumed one sample from the area picked at random will be representative. The GPS coordinates reading for the borehole picked was then taken using the GPS meter see figure 2. Sampling techniques as well as laboratory analytical methods were then reviewed and equipments assembled. The sixteen boreholes were then sampled, between 15^{th} to 20^{th} day of each month for four months starting April to July to give a total of 64 samples.

3.3 Sampling and Equipments

Sampling was done at two levels; by use of questioners to obtain information on source of drinking water and consumption levels and sampling water for trace elements analysis from the selected boreholes.

3.4.0 Questionnaires

Unique numbers were assigned to the nearby houses to the selected boreholes from which then one house was selected. The first adult person met by the researcher and who identified him or herself as a user of borehole water for drinking was requested to fill the questionnaire (appendix VI). The participant was asked to declare personal information including gender, residence, education, and as well information on drinking water consumption level. The consumption level was estimated from the number of the standard glasses (200ml) of water consumed during the day and including while away from home based on 24 hour recall information.

However, since contamination levels were not known in the water from borehole or water drunk away from home and daily consumption level, assumptions were made;

(i) The contamination levels for water both at home and away were equal

(ii) The consumption level obtained from the 24 hour recall was same for other days.

The mean body weights for the population of respondants studied was assumed as 70kgs for Men and 60kgs for Women as per WHO

3.4.1 Exposure and risk assessment

(i) Carcinogenic Risk

In order to estimate the daily exposure of an individual, USEPA (2005) suggested the Life time Average Daily Dose (LADD) as the exposure metric. Using the equation below:

$$CDI = (C \times DI) / BW$$

Where CDI is the chronic daily intake (mg/kg/d), C is the drinking water contaminant concentration (mg/l), DI is the average daily intake rate of drinking water (l/d), and BW is body weight in (kg). The standard body weight for an average man and woman respectively of 70 kg and 60 kg as per WHO standard was used.

Risk was then worked out using the equation:

$$R = CDI \times SF \text{ (Patrick, 1994)}$$

Where, R is the probability of developing cancer over a lifetime as a result of exposure to the contaminant and SF the slope factor of the contaminant (mg/kg/d).

(ii) Non Carcinogenic Risk

To estimate non carcinogenic risk, the Hazard Quotient (HQ) was calculated using the equation;

$$HQ = CDI/RfD \text{ (USEPA, 1999).}$$

Where RfD is the reference dose (mg/kg/d) and values for SF and RfD are obtained from WHO. The average daily intake rate was obtained by converting the number of standard (200ml) glasses of water drunk per day to liters and averaged to calculate individual DI.

3.4.2 Sampling Design for Water Samples

Borehole water sampling followed standard water sampling procedure (Arnold, 1992). Boreholes in Steep slopes were avoided; Water bucket only dedicated for sampling and attached on a loop rope was used to lift water from boreholes. Contamination of water within the site was minimized by use of disposable gloves. The bucket was then lowered, filled up and then lifted while avoiding contact with the sides of the borehole. The water samples were collected in duplicate in 500 ml pre-cleaned plastic bottles. The plastic rather than the glass bottles were used in order to take precaution against the absorption of the trace elements by the glass bottles (Arnold et. al, 1992). The bottles were cleaned by soaking overnight in a mixture of concentrated nitric and hydrochloric acids (Zhang, 1988) and rinsed three times in distilled water. At the sampling sites, the bottles were further rinsed three times with the water sample before being filled up. The samples were preserved by acidification to less than a pH of 2 using 2 ml of concentrated nitric acid immediately after sampling. The samples were stored in a cool box and transported to the School of Environmental Studies (SES) laboratory and stored in the fridge at $0^{o}C$ awaiting the laboratory analysis.

3.5 Laboratory Methods

3.5.1 Digestion Procedure

The duplicate water samples were thoroughly mixed. After mixing well, 100 ml from each sample was pipetted into a conical flask and 5 ml of concentrated sulphuric acid (H_2SO_4) was added and shaken for 2 minutes. Later 3 ml of concentrated nitric acid (HNO_3) was added and the mixture heated for 2 hours on a hot plate. 5 ml of concentrated nitric acid was added to the mixture to avoid complete dryness during the digestion period. The digestion was done to remove the organic matter and expose the inorganics / the trace elements.

After digestion the mixture was cooled and later filtered through 0.45µm filter paper and topped to 50 ml with distilled water in a volumetric flask before analysis. Using digestion the procedure was repeated for the blanks using de-ionised water as sample.

3.5.2 Preparation of Standards

Copper

The standard for copper was prepared by dissolving one gram of copper wire in 50% nitric acid (v/v) and diluted to 1 litre to give 1000 ppm of copper. A working standard was then prepared from 1000 ppm; 10 ml was then diluted 10 times to make 100 ppm. The 100 ppm working standard was further diluted to make 0.5, 1 and 1.5 ppm calibrating standards respectively. The standards were then run in AAS to give the calibration curve shown in: Figure 3

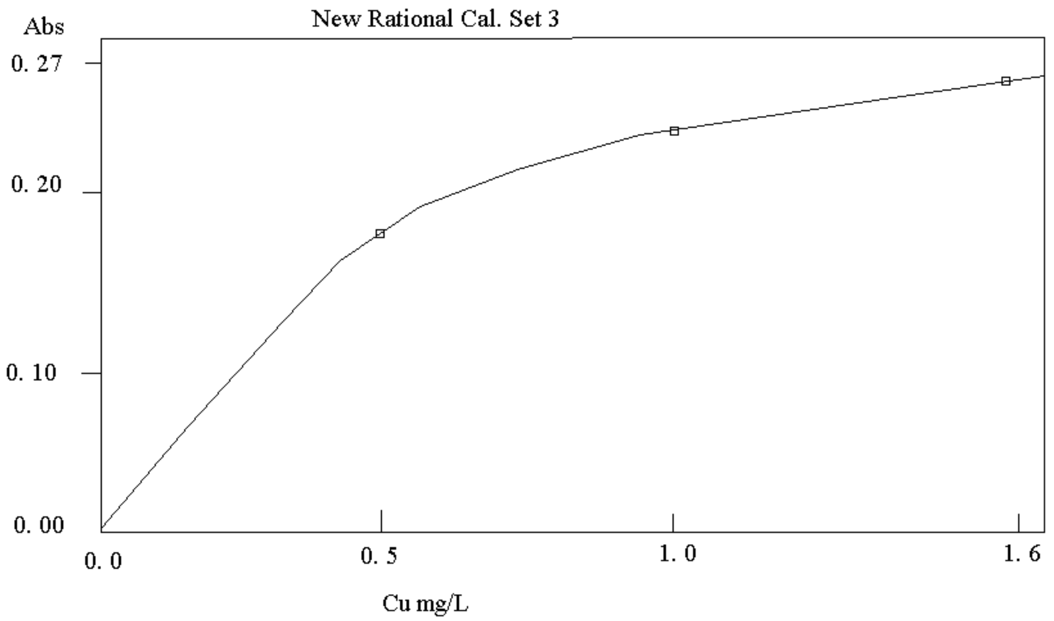

Figure 2: ***Calibration curve for the trace element copper***

Manganese

The standard for manganese was prepared by dissolving one gram of manganese wire in 50% nitric acid (v/v) and diluted to 1 litre to give 1000 ppm of manganese (Mn). A working standard was then prepared from 1000 ppm; 10 ml was then diluted 10 times to make 100 ppm of Mn. The 100 ppm working standard was further diluted to make 0.5, 1 and 1.5 ppm (Mn) calibrating standards respectively. The standards were then run in AAS to give the calibration curve shown in: Figure 4

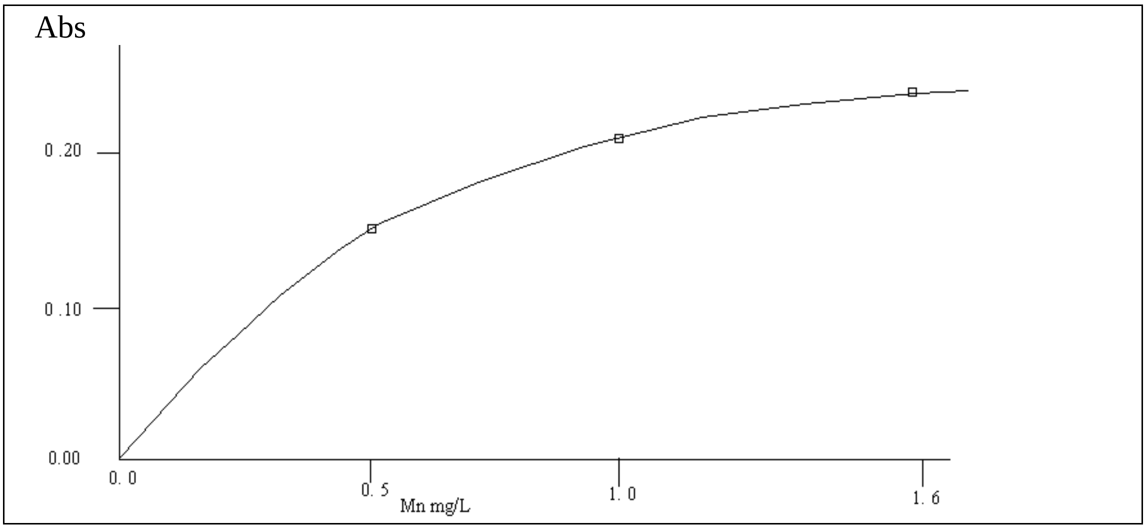

Figure 3: ***Calibration curve for the trace element manganese***

Chromium

The standard for chromium was prepared by dissolving one gram of chromium wire in 50% nitric acid (v/v) and diluted to 1 litre to give 1000 ppm of chromium (Cr). A working standard was then prepared from 1000 ppm; 10 ml was then diluted 10 times to make 100 ppm (Cr). The 100 ppm working standard was further diluted to make 1, 3 and 5 ppm (Cr) calibrating standards, respectively. The standards were then run in AAS to give the calibration curve shown in figure 5.

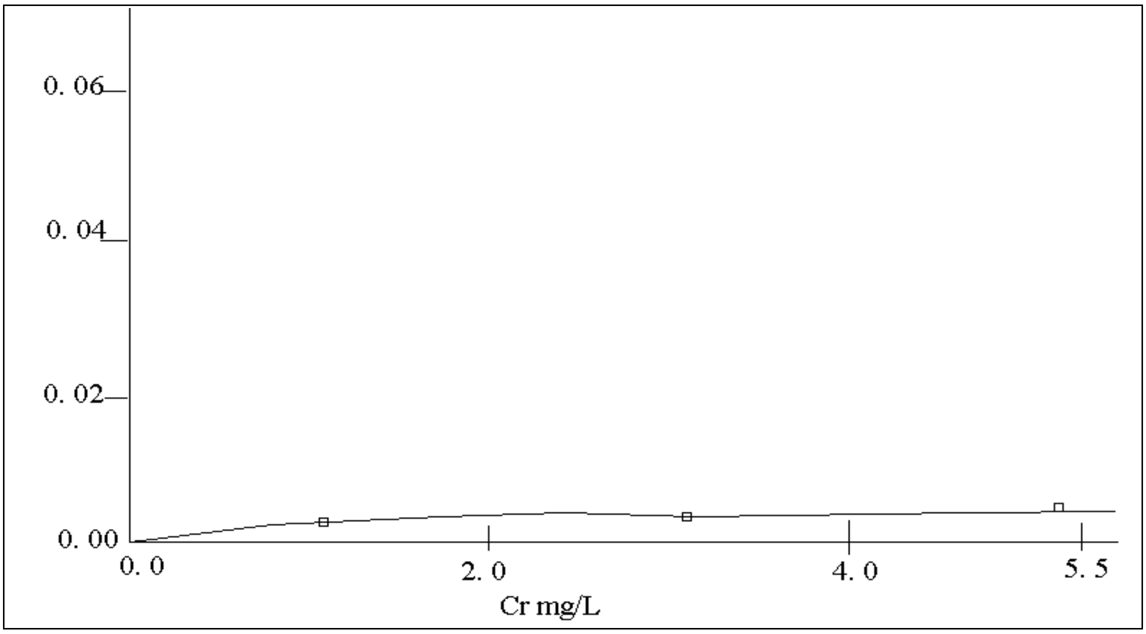

Figure 4: ***Calibration curve for the trace element chromium***

3.5.3 AAS Calibration and Sample Analysis

The AAS was calibrated using (0.5, 1 and 1.5 ppm) standards for copper and manganese while chromium was calibrated using (1, 3 and 5 ppm) standards. The calibrating conditions were applied as indicated in table 3.

Table 3: ***Calibration conditions for Copper, Manganese and Chromium***

Condition	**Copper**	**Manganese**	**Chromium**
Lamp current	7 mA	7 mA	7 mA
Fuel	Acetelylene	Acetelylene	Acetelylene
Support	Air	Air	Air

The readings from the atomic absorption spectrometer (AAS) were then taken. The AAS was chosen because of its availability, high accuracy, and high precision and sufficiently low detection limits for most trace elements in the environment (Reynolds *et al.*, 1970).

3.6 Reliability

Reliability of the instrument was ensured by running the blanks and calibrating the AAS after running every 10 samples. If the deviation was found to be > 10 %, the device was recalibrated. Taking duplicate samples at each sampling point and also repeating the process four times during the months of April, May, June and July (2005), which are Months with the peak rain season was done to replicate and record differences if any with time.

3.7 Data Analysis

The data obtained was entered into SPSS version 12.0 and subjected to kolmogorov smirnov test (test for normal distribution). At each borehole, means of concentrations of Copper, Chromium and Manganese were obtained and comparisons to WHO/FAO done to a certain if there were significant differences with the standard. With reference to the objectives of the study, variations of the concentration of the selected trace elements were determined and compared to WHO/FAO acceptable guideline using a one sample t-test. P-value less than 0.05 were considered significant. All the statistical analyses were done in SPSS.

CHAPTER FOUR

RESULTS

4.1 Copper

The mean concentration of Copper was significantly different in 12 of the 16 (75%) boreholes studied were $p < 0.001$; this is illustrated in table 4.1. In the boreholes in KCC, Elgon view, Kipkaren, Yamumbi, Kimumu, Hawai, Kapsoya, Kamukunji, Kingo'ngo and Huruma had Copper concentration of 0.0145, 0.0115, 0.0169, 0.0054, 0.0054, 0.0058, 0.0073, 0.0083, 0.0073 and 0.0086 respectively. The concentration of copper was significantly less than what is recommended as per the WHO/FAO guideline value of 0.036. The boreholes with lower than recommended Copper concentration were spread in all the zones as follows; zone A one, zone B three, zone C three and zone D three. In the boreholes in Kipkorogot (zone A) the concentration of copper (0.0498) was significantly higher from WHO/FAO standards with $P = 0.003$ and $t = 4.472$. Concentration of copper in the boreholes in Oasis (0.0323), Annex (0.0356), Sukunanga (0.0281), Langas (0.0320) and Munyaka (0.0426) were not significantly different from the recommended WHO/FAO guideline value with $p > 0.05$.

Highest recorded concentration of copper in zones; A, B C and D was in the Month of June below 0.02 ppm while the lowest was in the Months of April and July. Figures: 6, 7, 8 and 9 illustrate this observation.

There was no significant variation in the concentration of Copper by month within the Zones, $p > 0.05$ and this is shown in Table 4.1 Also there was no significant correlation between borehole dept and concentration of copper, $p > 0.05$ as shown in Table 4.8. The correlation of copper and Manganese is -.229 and significance is .431.

The correlation of Copper and Chromium is .257 and significance is .374. The correlation of Copper to borehole depth is .256 and significance is .377.

Table 4.1: ***Mean concentration of copper for each borehole in the study areas in comparison to WHO standards (0.036)***

Locality	Depth (ft)	copper (ppm)	t-value	p-value
Oasis	15	0.0323±0.0050	2.118	0.072
Annex	28	0.0356±0.0047	0.223	0.830
Sukunanga	40	0.0281±0.0106	2.093	0.075
KCC	25	0.0145±0.0129	18.606	**<0.001**
Kipkrogot	45	0.0498±0.0087	4.472	**0.003**
Elgon view	25	0.0115±0.0070	9.914	**<0.001**
Langas	25	0.0320±0.0067	1.679	0.137
Kipkaren	50	0.0169±0.0090	6.043	**0.001**
Yamumbi	10	0.0054±0.0054	15.895	**<0.001**
Munyaka	20	0.0426±0.0081	2.312	**0.054**
Kimumu	25	0.0054±0.0060	14.556	**<0.001**
Hawai	20	0.0058±0.0066	13.037	**<0.001**
Kapsoya	30	0.0073±0.0078	10.479	**<0.001**
Kamukunji	8	0.0083±0.0089	8.11	**<0.001**
Kingo'ngo	35	0.0073±0.0058	14.14	**<0.001**
Huruma	20	0.0086±0.0080	9.723	**<0.001**

For Health risk assessment using the linear multistage model, the chronic daily intake (CDI), Risk and Hazard Quotient (HQ) for each sampling site were worked out and are shown in Table 4.2. The total number of females who responded to the questionnaire was 7 and the males were 9. The mean drinking water intake per day was 1.87litres for female and 1.93litres for males, with the average for both at 1.9 liters. The concentration of Copper did not differ between the gender categories (p >

0.5). This information was obtained from the questionnaire by averaging the water intake. The reference dose (RfD) for copper being 0.036 (WHO standard).

Substituting the values to the equations CDI = (C x DI) / BW, R = CDI x SF and HQ = ADD / SF. The concentration of Copper was highest in Kipkorogot and so was the risk and hazard quotient 0.005797 and 0.04348, respectively. The risk for cancer for the females is 0.002031 and males 0.002351. The hazard quotient is 0.015232 for females and 0.017632 for males.

Table 4.2: ***Risk assessment values for copper (Cu)***

Locality	**Sex of person Interviewed**	**CDI**	**Risk**	**HQ**
Oasis	F	0.000915	0.003390	0.025421
Annex	M	0.001130	0.004187	0.031397
Sukunanga	F	0.000773	0.002864	0.021481
KCC	M	0.000394	0.001458	0.010933
Kipkrogot	M	0.001565	0.005797	0.043476
Elgon view	F	0.000345	0.001278	0.009583
Langas	F	0.001120	0.004148	0.031111
Kipkaren	M	0.000566	0.002095	0.015714
Yamumbi	F	0.000198	0.000733	0.005500
Munyaka	M	0.001443	0.005344	0.040079
Kimumu	M	0.000131	0.000486	0.003643
Hawai	M	0.000130	0.000483	0.003619
Kapsoya	F	0.000243	0.000901	0.006759
Kamukunji	M	0.000166	0.000615	0.004611
Kingo'ngo	M	0.000188	0.000695	0.005214
Huruma	F	0.000244	0.000903	0.006769

4.2 Manganese

The concentration of manganese ranged between 0.0684 – 0.1908 mg/l and the mean was significantly different in all the boreholes studied in comparison to WHO/FAO with $P<0.001$ as shown in Table 4.3. The highest recorded concentration was in the month of June (> 0.1) while the lowest was in July (< 0.1), however there was no significant variation in the concentration of Manganese within the zones; this is illustrated in Figures 6, 7, 8 and 9. Also there was no significant correlation between dept of borehole and concentration of Manganese, $p > 0.05$ as shown in Table 4.7.

The correlation of Manganese and Copper was -.229 and significance of .431, Chromium -.162 and significance of .580, altitude .086 and significance of .769.

Table 4.3: ***Mean concentration of Manganese (Mn) for each borehole in the study areas in comparison to WHO standards (1.5)***

Locality	Depth (ft)	manganese (ppm)	t-value	p-value
Oasis	15	0.0784±0.0127	316.493	**<0.001**
Annex	28	0.0684±0.0104	391.227	**<0.001**
Sukunanga	40	0.0811±0.0088	458.249	**<0.001**
KCC	25	0.0953±0.0163	243.515	**<0.001**
Kipkrogot	45	0.1213±0.0130	298.905	**<0.001**
Elgon view	25	0.0795±0.0089	450.006	**<0.001**
Langas	25	0.0684±0.0079	513.148	**<0.001**
Kipkaren	50	0.2906±0.0251	136.190	**<0.001**
Yamumbi	10	0.0846±0.0072	555.251	**<0.001**
Munyaka	20	0.0929±0.0123	323.597	**<0.001**
Kimumu	25	0.0639±0.0064	632.312	**<0.001**
Hawai	20	0.1908±0.0107	346.503	**<0.001**
Kapsoya	30	0.1203±0.0094	414.833	**<0.001**
Kamukunji	8	0.1071±0.0192	205.333	**<0.001**
Kingo'ngo	35	0.0768±0.0183	219.820	**<0.001**
Huruma	20	0.1113±0.0142	276.42	**<0.001**

For Manganese, the values for health risk assessment using the linear multistage model are shown in Table 4.4 below. The highest risk 0.03752 with hazard quotient 0.006642 was in Kipkaren. In the study female respondents were 7 while the males were 9.The mean drinking water intake per day was 1.87litres for female and 1.93litres for males, with the average for both at 1.9 liters. The risk for the females is 0.010475 while that for the males is 0.012903. The hazard quotient for females is 0.01854 and males 0.02284. This information was obtained from the questionnaire by averaging the water intake. The reference dose (RfD) for Manganese being 1.5 (WHO standard). For the Kipkaren site which had the highest concentration of manganese, the risk and hazard quotient were 0.037522 and 0.006642 respectively.

Table 4.4: ***Risk assessment values for Manganese (Mn)***

Locality	**Sex of person Interviewed**	**CDI**	**Risk**	**HQ**
Oasis	F	0.002253	0.008483	0.001502
Annex	M	0.002664	0.008600	0.001522
Sukunanga	F	0.000773	0.008345	0.001477
KCC	M	0.002955	0.009537	0.001688
Kipkrogot	M	0.004448	0.014357	0.002542
Elgon view	F	0.000345	0.008982	0.001590
Langas	F	0.001120	0.009016	0.001596
Kipkaren	M	0.011624	0.037522	0.006642
Yamumbi	F	0.000198	0.011682	0.002068
Munyaka	M	0.003850	0.012428	0.002200
Kimumu	M	0.001791	0.005780	0.001023
Hawai	M	0.003816	0.012318	0.002181
Kapsoya	F	0.000243	0.014938	0.002644
Kamukunji	M	0.002499	0.008067	0.001428
Kingo'ngo	M	0.002328	0.007515	0.001330
Huruma	F	0.000244	0.011876	0.002102

4.3 Chromium

The mean concentration of chromium was significantly different in 11 of the 16 boreholes (68.75%) studied with P<0.001 as illustrated in Table 4.5. The concentration of chromium in Annex, Kipkorogot, Munyaka, Hawai and Kapsoya was significantly higher than WHO/FAO recommended guideline value 0.1685, 0.2323, 0.2279, 0.2179 and 0.1829 respectively against 0.1. However the concentration of chromium in Sukunanga, KCC, Elgon view, Kimumu, Kamukunji and Huruma was significantly lower than WHO/FAO recommended guideline value 0.0618, 0.0296, 0.1147, 0.1339, 0.0826 and 0.0494 respectively. In the boreholes in Oasis (0.1754), Langas (0.1966), Kipkaren (0.1063), Yamumbi (0.1375) and Kingo'ngo (0.2208) the concentration of chromium was not significantly different from the recommended WHO/FAO guideline value with P>0.05. There was no significant variation in the concentration of Chromium within the zones; this is illustrated in Figures 6, 7, 8 and 9. Concentration of Chromium was highest in April > 0.02 and lowest in July < 0.02 and this was the case in all the zones. Also there was no significant correlation between borehole depth and concentration of Chromium, P > 0.05 as shown in Table 4.8. The correlation of Chromium and Copper was .257 and significance of .374, Manganese -.162 and significance of .580, borehole depth .098 and significance of .740.

Table 4.5: ***Mean concentration of Chromium for each borehole in the study areas in comparison to WHO standards (0.1)***

Locality	Depth (ft)	chromium (ppm)	t-value	p-value
Oasis	15	0.1754±0.1391	0.009	0.993
Annex	28	0.1685±0.0903	28.888	**<0.001**
Sukunanga	40	0.0618±0.0337	8.802	**<0.001**
KCC	25	0.0296±0.0122	4.716	**0.002**
Kipkrogot	45	0.2323±0.2969	74.945	**<0.001**
Elgon view	25	0.1147±0.0960	20.593	**<0.001**
Langas	25	0.1966±0.3345	0.751	0.477
Kipkaren	50	0.1063±0.1080	0.165	0.874
Yamumbi	10	0.1375±0.1411	0.380	0.715
Munyaka	20	0.2279±0.2855	8.802	**<0.001**
Kimumu	25	0.1339±0.1141	8.735	**<0.001**
Hawai	20	0.2179±0.2473	38.765	**<0.001**
Kapsoya	30	0.1829±0.2531	125.643	**<0.001**
Kamukunji	8	0.0826±0.1313	53.590	**<0.001**
Kingo'ngo	35	0.2208±0.2387	0.779	0.462
Huruma	20	0.0494±0.0507	104.899	**<0.001**

For Chromium, the values for health risk assessment using the linear multistage model are shown in Table 4.6 below. The risk and hazard quotient arising from the exposure to Chromium through drinking water was highest in Kipkorogot 0.02704 and 0.07301 respectively. In the study female respondents were 7 while the males were 9.The mean drinking water intake per day was 1.87litres for female and 1.93litres for males, with the average for both at 1.9 liters. The risk for the females is 0.013959 while that for the males is 0.016356. The hazard quotient for females is 0.042111 and male's 0.044271.The risk is highest in Kipkorogot 0.02704 and hazard quotient 0.07301. This information was obtained from the questionnaire by averaging the water intake. The reference dose (RfD) for Chromium being 0.1 (WHO standard).

Table 4.6: ***Risk assessment values for Chromium (Cr)***

Locality	Sex of person Interviewed	CDI	Risk	HQ
Oasis	F	0.004970	0.018408	0.049697
Annex	M	0.005536	0.020507	0.055364
Sukunanga	F	0.001648	0.006104	0.016480
KCC	M	0.008034	0.002976	0.008054
Kipkrogot	M	0.007301	0.027042	0.073009
Elgon view	F	0.003441	0.001275	0.034410
Langas	F	0.006881	0.025487	0.068810
Kipkaren	M	0.003645	0.013499	0.036446
Yamumbi	F	0.005042	0.018674	0.050417
Munyaka	M	0.008139	0.030148	0.081393
Kimumu	M	0.003252	0.012045	0.033519
Hawai	M	0.003735	0.013836	0.037354
Kapsoya	F	0.006097	0.022582	0.060967
Kamukunji	M	0.001652	0.006119	0.016520
Kingo'ngo	M	0.005678	0.021030	0.056777
Huruma	F	0.001400	0.005184	0.013997

The test for linear trends was done to assess the variations. The Figures 6, 7, 8 and 9 respectively for zones A, B, C and D show the results of the test for the variation in linear trends between the months of April to July. The results show variation which turned out not to be significant when subjected to ANOVA (Analysis of Variance) test as shown in Table 4.7 where $P > 0.05$.

Zone A

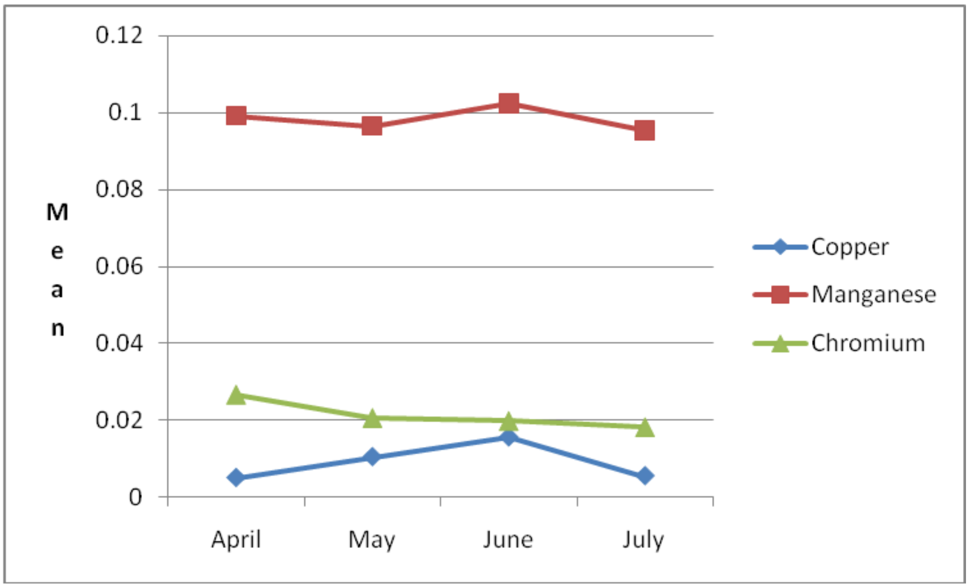

Figure 5: ***Temporal distribution of trace elements copper, manganese and chromuim in Zone A***

Zone B

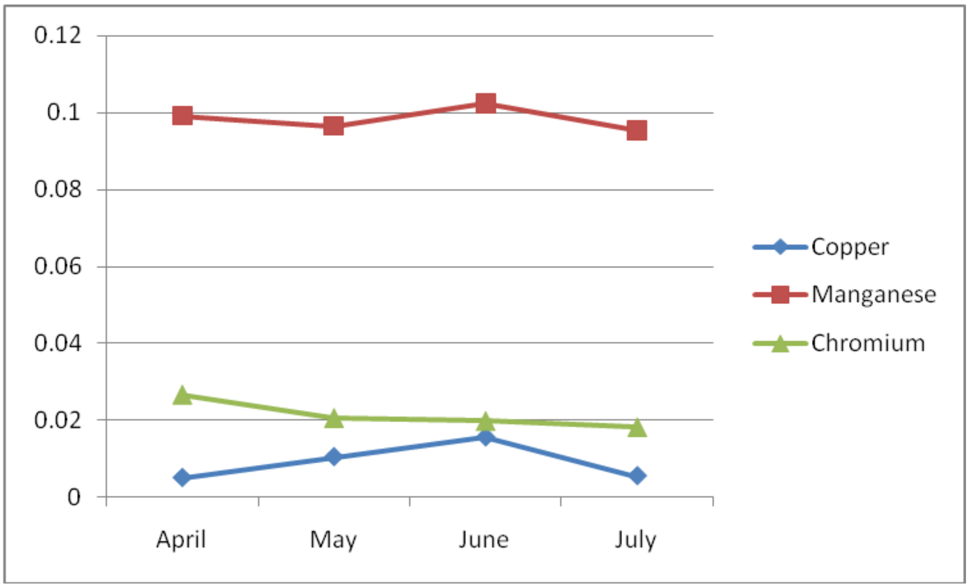

Figure 6: ***Temporal distribution of trace elements copper, manganese and chromium in Zone B***

Zone C

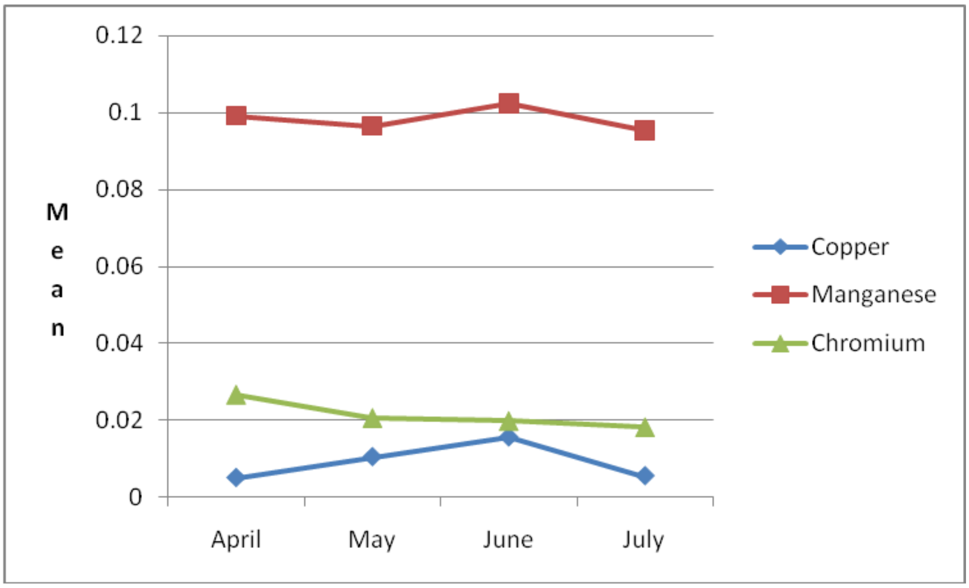

Figure 7: ***Temporal distribution of trace elements copper, managene and chromium in Zone C***

Zone D

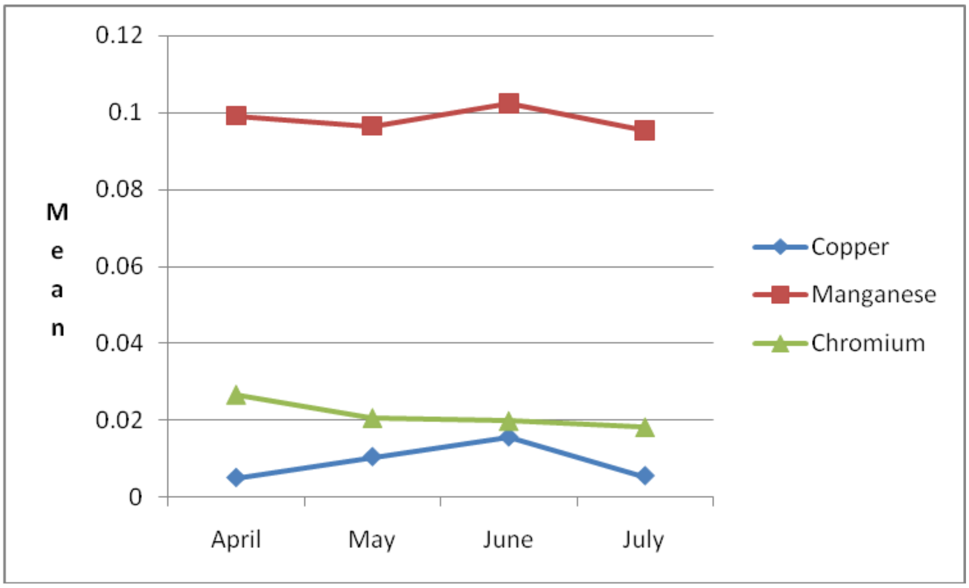

Figure 8: ***Temporal distribution of trace elements copper, manganese and chromium in Zone B***

Table 4.7: ***Analysis of variance by zone for trace elements copper, manganese and Chromium***

Area	F-value	P-value
Zone A		
Copper	0.535	0.661
Manganese	0.148	0.930
Chromium	2.441	0.080
Zone B		
Copper	0.447	0.722
Manganese	0.047	0.986
Chromium	1.269	0.304
Zone C		
Copper	0.232	0.873
Manganese	0.035	0.991
Chromium	1.027	0.395
Zone D		
Copper	2.765	0.156
Manganese	0.105	0.957
Chromium	2.074	0.136

The analysis of variance indicated that there was no significant temporal variation in mean concentration of the trace elements (Copper, Manganese and Chromium) in the borehole water by month (All $p>0.05$) table 4.7.

Table4.8: ***Correlations between altitude and elements concentration***

Control Variables			copper	Manganese	Chromium	Borehole depth
Depth	copper	Correlation	1.000	-.229	.257	.256
		Significance (2-tailed)	.	.431	.374	.377
		df	0	12	12	12
	Manganese	Correlation	-.229	1.000	-.162	.086
		Significance (2-tailed)	.431	.	.580	.769
		df	12	0	12	12
	Chromium	Correlation	.257	-.162	1.000	.098
		Significance (2-tailed)	.374	.580	.	.740
		df	12	12	0	12
	Borehole depth	Correlation	.256	.086	.098	1.000
		Significance (2-tailed)	.377	.769	.740	.
		df	12	12	12	0

Controlling for the depth of the borehole, there was no significant correlation between the altitude and trace elements concentration ($p>0.05$), though the correlation was positive meaning the higher the altitude the higher the concentration and vice versa (Table 4.8).

CHAPTER FIVE

DISCUSSION

5.1 Discussion of Results

From the results, concentration levels for the trace elements varied in most boreholes and mostly the levels were below WHO/FAO recommended levels. This result compare well with results in a study in Izmir Turkey by Demirak et. al, 2005. The mean concentration for Cu (0.0736) and Mn (0.0134) were all below WHO value. The drinking water consumption level was found to be 1.9 liters' per day and this was not significantly different from the WHO value of 2 liters' per day. Also the daily water intake in Izmir was 1.95 l/d which is half a litre greater than the value recorded in this study. However the daily drinking water intake in this study agreed with the intake of the American adults (USEPA, 1997) and is also in agreement with values reported in literature. Deterministic approach was used to access carcinogenic and noncarcinogenic risks attributed to the trace element (Cu, Mn and Cr). Risk values greater than one in a million (10^{-6}) are generally considered unacceptable by the USEPA. The Health risk assessment values obtained were low tables 4.2, 4.4 and 4.6. This means that the risks arising from the exposure to the selected trace elements is not significant.

5.1 Copper

Most of the Copper entering the environmental waters do so either through natural weathering or anthropogenic soil disturbances. The estimated intake of Copper in drinking water is 0.15mg/day. According to the prescribed guideline by WHO/FAO (0.036), it was found that most boreholes were free from Copper. Only 2 of the 16 boreholes had copper concentration above the WHO/FAO guideline value. The boreholes were the ones in Kipkorogot (0.0498) and Munyaka (0.0426). In Kipkorgot it was 39% excess Copper. The borehole waters in KCC, Elgon view, Kipkaren, Yamumbi, Kimumu, Hawai, Kapsoya, Kamukunji, King'ongo and Huruma which form 69% had less copper than recommended by WHO/FAO values as shown in table 4.1. Excess of Cu concentration in humans causes "Wilson disease", hypertension and Copper is also known to have an antioxidant enzyme activity (Buzadzic et. al, 2002). The other adverse effects include: anemia and bone abnormalities, nausea, respiratory difficulty, liver and kidney failure, massive gastro-intestinal bleeding and death (IPCS, 1998 and Fishbein, 1981). Hemoglobin contains Copper and excess Copper promotes iron bacteria in water. Some Swedish studies have suggested that excess copper might cause diarrhea in young children, but statistical associations has not been demonstrated. The high copper concentration in Kipkorogot borehole water could be due to geological and geographical factors. There is a quarry (stone mining) that takes place in this area, this could be a reason for the high copper concentration in the borehole water but this requires further investigation. However, in Munyaka, the borehole sampled was in a swampy area and so the high levels of copper could be due to sipping of runoff waters.

The Health risk assessment resulting from drinking of the borehole water in Kipkorogot was calculated and the risk was found to be 0.005797 with the hazard quotient of 0.043476. For non carcinogenic risk if; HQ > 1 means adverse non – carcinogenic effects of concern and HQ < 1, means acceptable level (no concern). With Cancer Risk > 10^{-6} carcinogenic effects and Cancer Risk < 10^{-6} Acceptable level (no concern). From the findings, although the concentration of Copper is above WHO recommended value for Kipkorogot and Munyaka, the Cancer risk > 10^{-6} and this is of concern and the Hazard quotient < 1, means acceptable level (no concern).

The mean drinking water intake in the study was 1.9 l/d which compared well with the study in Izmir which had a mean of 1.95 l/d, and are also in agreement with values reported in literature.

The water in these boreholes however needs to be treated before being consumed. One way of treating this water will be by increasing the pH to result in an overall decrease in metal concentrations for example, increasing the pH of water from 7.5 to 8.5 in distribution lines decreased copper concentration by 50% (Yannoni and piorkowski, 1995). Also there is a need for close monitoring of the trace elements concentration in this borehole in Kipkorogot to avoid a scenario where by the level go much higher than WHO and cause adverse health effects.

In the boreholes in KCC, Elgon view, Kipkaren, Yamumbi, Kimumu, Hawai, Kapsoya, Kamukunji, King'ongo and Huruma, the concentration of copper was lower than recommended by WHO and this finding compare well with similar studies done by (Davies, 1994) on concentration of copper in natural waters of the Kerio valley area and water in the Nzoia River (appendix IV). The mean concentration was 0.03mg/l with a range of 0.01 to 0.08mg/l in July 1992 in the same study in July 1993, the mean concentration of copper was found to be 0.02mg/l and a range of 0.01 to 0.04mg/l. In River Nzoia the mean concentration of copper was found to be 0.06mg/l with arange of 0.01 to 0.2mg/l.

In a study done in upper east and west regions of Ghana (Kortatsi, 2007) on 60 boreholes, the concentration of copper was found to range between 0.0 – 0.211mg/l with a mean of 0.013mg/l. In Izmir Turkey, Copper concentration in borehole was found to be below the WHO recommended level, Demirak (2005). In both studies, the concentration of Cu was below the WHO/FAO guideline value (0.036mg/l) and this is consistent with the findings of this study in 87% of the boreholes. The Copper Concentration range 0.0054 – 0.036 mg/l. However in the 2 of the boreholes (13%) in Kipkorgot and Munyaka the concentration of copper was 0.05 and 0.043mg/l respectively and this contradicted the findings of the study in Ghana.

For the concentration of Copper, the findings agree with findings from similar studies except in the two bore in Kipkorogot and Munyaka where the copper concentration was high 0.05 and 0.043 mg/l, respectively. From this finding, there are no significant effects arising from wastes and spillages from the textile industries and the wood treatment plants. The Copper concentration in the borehole water in Kapsoya, KCC, Kipkaren and annex which are nearby the textile and wood treatment plants should have been high but this was not the case.

The variation of the concentration of copper within each zone from April to July was not significant. The p – value for zone A,B,C & D respectively being 0.661, 0.722, 0.873 and 0.156 all >0.05. This contradicts the findings by Kimball, 1973 in U.S.A who found copper concentration varying with seasons. In a study in Massachusetts from April of 1971 to March 1972, the concentration of Copper was found to decreasing during spring and early summer (August) to lows of < 10 – 30 ppm and then increasing to maximum values of 80 - 105 ppm in late January and early February Kimball, 1973. Similar seasonal variations were also recorded by Nriagu et al, 1996.

5.1.1 Implications of Anomalous Copper Concentration on Human Health

The estimated intakes of copper in the general population are 0.15mg/day from drinking water and approximately 2mg/day from food, with recommended limit of 10 – 12 mg/day for adults (WHO, 1996). The lower concentration of copper recorded could have significant health implications however from the health risk assessment figures and the hazard quotient, this is not the case. Severe copper deficiency for example can result in defective connective tissue synthesis and oestrogenesis, natropena and Iron resistant anemia (WHO, 1996). Low copper intake results in decreases in ceruloplasmin levels and superoxide dismutase (SOD) (IPCS, 1998)

Wilson’s disease (prevalence of 1 in 30,000) and Menkes disease (prevalence of 1 in 200,000) are heredity disorders of copper metabolism that resembles a copper deficiency state regardless of the level of copper intake above the AROI for the general population. It results from a defect in the gene coding for ATPase, resulting in a marked reduction in the first phase of copper transport (IPCS, 1998).

5.2 Manganese

Concentration of Manganese in all the boreholes studied was low, below 1.5 ppm recommended value by WHO/FAO. The p-values were all < 0.05 in the boreholes studied, table 4.3, and therefore significant. This finding agrees with findings of the study by Shabanda I. S. et al, 2014 in Aliero, Kebbi State, Nigeria. Manganese concentration in borehole water was found to average 0.100 ± 0.0001ppm which is below the maximum limit of WHO standards (1, 5 ppm). Recommended manganese intake is 5mg/day however range of 1 to 10mg/day is established. In Kipkaren borehole with the highest recorded manganese concentration, the health risk and the hazard quotient respectively were 0.03752 and 0.006642. The hazard quotient is < 1 which means acceptable level (no concern). There is therefore no significant health risk expected to arise from the manganese in the drinking water. The high manganese concentration recorded in the Kipkaren borehole. This borehole was the deepest compared to others and may the igneous rock is contributing to the high manganese concentration recorded or could be because of the contamination from the surrounding factories; Rivatex and Pyramid.

In the study by Davies, (1994), the manganese mean concentration was found to be less than 0.2mg/l and this agrees with the observations for all the boreholes studied table 5, $p < 0.05$. In Nyando River with the source in the Rift valley, Davies found the mean concentration of manganese to be 1.5mg/l this value agrees with the recommended WHO/FAO value for fresh water's Table 2.

The variation of the Manganese concentration within each zone between April to July was not significant. The p – value for zones A, B, C & D respectively being 0.930, 0.986, 0.991 and 0.957 which is > 0.05 in all the cases.

5.2.1 Implications of Anomalous Manganese Concentration on Human Health

In a study by (Iwami *et al*., 1994) on the metal concentrations in rice, drinking water and soils in Horara, a small town on the Kii peninsula of Japan, the town had a high incident of motor neuron disease (MND). The findings of the study observed that a significantly increased manganese content in local rice and a decreased concentration of magnesium in drinking waters were positively correlated with the incidence of MND in Horara ($r^2 = 0.99$). The lower manganese concentration observed in this study in the borehole waters could result to cases of MND. The results for the health risk assessment and hazard quotient values obtained show no significant risk.

5.3 Chromium

Concentration of chromium in 11 (Annex, Sukunanga, KCC, Kipkorgot, Elgon View, Langas, Munyaka, Kimumu, Hawai, Kapsoya; Kamukunji, Kingo'ngo and Huruma) of the 16 boreholes (69%) was significantly different from the WHO/FAO guideline value table 4.5. The concentration of chromium was higher than WHO/FAO guideline value in these boreholes. The highest Chromium concentration was in Kipkorogot (0.2323±0.2969) with the health risk value of 0.027042 and hazard quotient of 0.073009, table 4.6. The risk assessment values obtained are low and hence the water in Kipkogot borehole does not pose a health risk to the population. The generally high Chromium concentration in other boreholes can be attributed to anthropogenic activities around. This could include contamination from the wastes and spillages from the textile factories and the wood treatment plants. Also dissolution of naturally occurring minerals containing Chromium in the soil zone could explain the concentration levels recorded. Concentration of chromium in Oasis, Langas, Kipkaren, Yamumbi & Kingo'ngo was however not significant as $P > 0.05$.

Chromium is required for normal carbohydrate metabolism with its biological function closely associated with that of insulin. Previous studies associated high Chromium concentration in drinking water to increased incidence of lung and stomach cancer. Oral ulcer, diarrhea, abdominal pains, indigestion and vomiting have been associated to chronic exposure.

The variation of Chromium concentration within the zones A, B, C & D between April to July was not significant. The p – value for zones A, B, C & D respectively being 0.080, 0.304, 0.395 and 0.136.

5.3.1 Implications of Anomalous Chromium Concentration in Human Health

In a study by (Davies, 1994), the mean concentration of chromium was found to be 0.11 mg/l in 1992 and 6.03 mg/l in 1993 in Kerio Valley area In River Nzoia the mean concentration was found to be 0.07 mg/l in July 1993. The findings for the two studies show lower chromium levels than recommended.

Previous study by Lucas and Kramkowski, 1975, found, mean concentration of 0.004 mg/l chromium in drinking waters which led to symptoms of stomach pains, stomach cramps, indigestion, duodenal ulcers and gastritis. In this study the concentration of Chromium was high in 5 of the boreholes and this could lead to similar health problems as reported above. In another study in the Republic of China conducted in 1965 of 155 villages whose well water contained 20 mg chromium (VI)/l as a result of pollution, associations were found between drinking the contaminated water and oral ulcers, abdominal pain, indigestion and vomiting (ASTDR). In another study done between 1970 and 1978 in chromium polluted areas in the Republic of China, increased incidences of lung and stomach cancer were observed (Zhang and Li, 1997).

This study, found that there will be some effects of high concentration of chromium in borehall waters. The values obtained were above (0.1 ppm) WHO recommended except for Sukunanga,KCC, Elgon View, Kimumu, Kamukunji and Huruma. The likely health effects of the higher chromium levels in borehole waters include; stomach pains, stomach cramps, indigestion, duodenal ulcers, and gastritis, heart and diabetes diseases. Lung and stomach cancers are also possibilities. However from the health risk assessment value and hazard quotient this indicates otherwise.

5.4 Temporal Variations of the Trace Elements

From the results, no significant temporal variation in the concentration of the trace elements was recorded. This means null hypothesis (iii) therefore stands. The four months period within which this study was carried out may be a short time for the temporal variations in the concentrations of the trace elements to come out. A longer period for this kind of study is recommended to confirm or reject hypothesis (iii).

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Concentrations of the trace elements copper and manganese in most borehole waters in the study area were lower than the guideline value by WHO/FAO. Only Kipkorogot and Munyaka boreholes had Copper concentration higher than guideline value by WHO/FAO. This high values can be explained by the anthropogenic activities; the quarry in Kipkorogot and the wash off as run off of chemicals sprays and fertilizers to the borehole in Munyaka. Concentrations of Manganese were found to be lower than WHO/FAO recommended value. Concentrations for Chromium were high in Annex, Kipkorogot, Munyaka, Hawai and Kapsoya and low in Sukunanga, KCC, Elgon View, Kimumu, Kamukunji and Huruma table 4.5. The high Chromium concentration in the borehole water could be associated to the anthropogenic activities particularly affluent and spillages from the textile industries and wood treatment plants.

From the use of the test for linear trends, the analysis of variance indicates no significant temporal and spatial variation in the concentration of the trace elements for all the months $P > 0.05$. That the concentrations of the trace elements studied did not show any significant variation within the period of the study. For both copper and manganese, peak concentration was in the month of June and for chromium the month of April.

The low concentration of manganese in borehole waters could result to health conditions such as slowed blood clotting, skin problems, changes in hair color, lowered cholesterol levels and other alterations in metabolism, interfere with normal growth, borne formation or skeletal disorders, birth defects, reproduction, fatness, glucose intolerance, neurological symptoms and skin problems. Also low copper in borehole waters could result to medical conditions such as menke's disease, anaemia, born abnormalities, slowed blood clotting, skin problems, changes in hair color, lowered cholesterol levels and other alterations in metabolism, interfere with normal growth, borne formation or skeletal disorders, birth defects, reproduction, fatness, glucose intolerance and neurological symptoms. However the health risk established from values obtained does not result in significant health effects.

6.2 Recommendations

(i) Boreholes in the study area should be treated for the trace elements. In Kipkorogot water, increasing pH has an effect of decreasing Copper Concentration (Yannoni and Piorkowski, 1995)

(ii) Constant monitoring of the quality of the borehole waters in Eldoret Municipality. Many of the environmental health problems are a result of long-term low-level exposure to trace metals in drinking water. Monitoring therefore will provide basis for the treatment of the water.

(iii) There is a need by Eldoret Municipality to increase access to piped water so us to reduce pressure on borehole water. Also should be alert and enforce approved methods of waste disposal.

(iv) The borehole at Kipkorogot should be secured to check on the quarry dust gaining access. Also the quarry management requires to control the dust emission to a void contamination of the water. The higher Copper concentration in the borehole water is suspected to be resulting from the quarry activity.

(v) Further studies needs to be done to compare the variation through the year. From the findings, there is no significant temporal variation of the trace elements studied and this mean that concentration within the season is stable.

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APPENDICES

Appendix I: ***Hydro chemical data for natural waters of the Kerio Valley area, recorded during July 1992 and July 1993***

Parameter	1992		1993		International average for freshwater[ж]	Maximum Permissible level in drinking water[ж]
	Range	Arithmetic Mean	Range	Arithmetic Mean		
T (^{0}C)	18 - 30	26	17 - 25	23	NS	NS
PH	6.0 – 7.9	7.2	7.1 – 9.5	8.7	6.5 – 8.5 (R)	6.5 – 8.5 (R)
Turbidity (NTU)	8 – 620	255	5 – 620	94	NS	5
EC (µS cm^{-1})	76 – 812	217	42 – 336	141	10 – 1000 (R)	NS
Hardness (mgl^{-1} $CaCO_3$)	8 – 46	21	10 – 126	45	NS	500
Alkalinity (mgl^{-1} $CaCO_3$)	26 – 414	109	26 – 262	96	NS	NS
TDS (mgl^{-1})	110 – 760	253	180 – 335	274	< 100	1000
TSS (mgl^{-1})	5 – 280	134	0 – 220	48	150	NS
BOD (mgl^{-1} $CaCO_3$)	0 – 66	14	0 – 66	9	2.0	3.0
COD (mgl^{-1} $CaCO_3$)	0 – 80	20	0 – 80	14	< 200	44
F (mgl^{-1})	1.6 – 305.5	33.0	0.8 – 212.6	26.6	0.1	1.5
Cl (mgl^{-1})	11 – 48	19	11 – 27	14	3.9	250
SiO_2 (mgl^{-1})	16.4 – 64.8	43.0	32.6 – 67.4	43.9	10.8	NS
NO_3 (mgl^{-1})	0.01 – 0.07	0.04	0.01 – 0.30	0.06	0.10	50
SO_4 (mgl^{-1})	22.8 – 55.0	39.5	29.4 – 66.0	40.7	4.8	400
PO_4 (mgl^{-1})	0.02 – 0.36	0.11	0.01 – 0.36	0.12	0.01	5
Fe (mgl^{-1})	0.2 – 0.8	0.4	0.1 – 0.4	0.3	0.05	0.3
Mn (mgl^{-1})	-	< 0.2	-	< 0.2	0.01	0.5
Cr (mgl^{-1})	0.02 – 0.84	0.11	0.01 – 0.12	0.03	0.0001	0.05
Cu (mgl^{-1})	0.01 – 0.08	0.03	0.01 – 0.04	0.02	0.0014	2.0

R = range, NS = not specified [ж] WHO (1984, 1992), CCREM (1987), CEC (1980), Sayre (1988), Meybeck (1988), Schiller and Boyle (1985, 1987), Meybeck and Helmer (1989), Chapman and Kimstach (1992), Davies (1994).

Appendix II ***Selected Hydrochemical data for surface waters of the Thika area recorded during the period October 1990 to August 1992***

Parameter	Range	Arithmetic mean	International average for freshwater[ж]	Maximum permissible level in drinking water[ж]
PH	5.5 – 9.5	7.6	6.5 – 8.5 (R)	6.5 – 8.5 (R)
EC	70 – 4420	526	10 – 1000 (R)	-
Hardness	20 – 48	32	-	500
TDS	105 - 390	205	<100	1000
TSS	1 - 46	22	150	-
BOD	5 - 990	177	2.0	3.0
COD	8 – 1088	0.194	<200	44
Cd	0.01 – 0.004	0.002	0.000001	0.003
Cr	0.01 – 0.265	0.020	0.0001	0.050
Cu	0.01 – 0.057	0.010	0.0014	2.0
Fe	0.400 – 2.500	0.883	0.050	0.300
Mn	0.001 – 2.976	0.442	0.010	0.500
Pb	0.001 – 0.026	0.007	0.00004	0.01
Zn	0.010 – 0.163	0.056	0.0002	3.0

R = range, Cd, Pb and Zn in mgl^{-1} , [ж]Source WHO (1984, 1992)

Appendix III: ***Mean values of water quality parameters of the Migori / Gucha River***

Parameter	Arithmetic mean	International average for freshwater[ж]	Maximum permissible level in drinking water[ж]
PH	7.6	6.5 – 8.5	6.5 – 8.5
TDS	137	< 100	1000
EC	119	10 – 1000	NS
NO_3	0.02	0.1	10
SO_4	30.8	4.8	400
Cl	21	3.9	250
F	1.02	0.1	1.5
Fe	0.4	0.05	0.3
Mn	0	0.01	0.1
Cr	0.04	0.0001	0.05
Cu	0.04	0.0014	1.0
TSS	64	150	NS
BOD	26.3	2.0	3.0

, [ж]Source WHO (1984, 1992), NS = not specified

Appendix IV: ***Hydrochemical data for River Nzoia, recorded during June and July, 1993***

Parameter	Range	Arithmetic mean	International average for fresh water	Maximum permissible level in drinking water[ж]
PH	6.63 – 8.81	7.7	6.5 – 8.5 (R)	6.5 – 8.5 (R)
Turbidity	7 – 66	31.9	NS	5
EC	85 – 3232	879.4	10 -1000 (R)	NS
Hardness	6 - 98	45.1	NS	500
Alkalinity	30 - 236	74.9	NS	NS
TDS	115 – 1500	556.7	< 100	1000
TSS	5 – 1100	225.3	150	NS
BOD	0 – 320	46.5	2.0	3.0
COD	0 – 400	60.3	< 200	44
F	0.68 – 1.20	0.90	0.1	1.5
Cl	11 – 786	185	3.9	250
SiO_2	30.8 – 63.4	47.3	10.8	NS
NO_3	0.01 – 0.13	0.05	0.10	10
SO_4	29.9 – 66.7	47.9	4.8	400
PO_4	0.01 – 0.43	0.13	0.01	5
Fe	0.2 – 0.4	0.25	0.05	0.3
Cr	0.01 – 0.19	0.07	0.0001	0.05
Cu	0.01 – 0.20	0.06	0.0014	2.0

(Source: ***WHO (1984, 1992), NS = not specified)***

Appendix V: ***List of the peri – urban Areas / Estates in Eldoret Municipality and total number of boreholes identified***

Zone	Areas	
A	1. Oasis (11) 2. Annex (15) 3. Sukunanga (8) 4. KCC (5) 5. Kipkrogot (10) **(49)**	6. Seruiyot 7. Limo 8. Islamic centre
B	1. Elgon View (18) 2. Langas (44) 3. Kipkaren (7) 4. Yamumbi (22) 5. CBD **(91)**	6. Racecourse 7. Hill School 8. Veterinary Quarters 9. West Indies 10. Kapyemit
C	1. Kapsoya (28) 2. Munyaka (24) 3. Hawaii (17) 4. Kimumu (16) 5. Airstrip 6. Railway Station **(85)**	7. Boarder farm 8. Kemboi farm 9. Chepkoilel 10. Prison
D	1. Huruma (33) 2. Kingongo (18) 3. Kamukunji (15) 8. Bacon 5. Kakhoya **(66)**	6. Kipkenyo 7. Mile nne 8. Mwenderi

(291)

Appendix VI:

Questionnaire

Serial number --

Introduction

I am a student from the School of Environmental Studies, University of Eldoret carrying out research on the Concentration of Trace Elements in Borehole water and their Implication for Human Health. This is only for academic purpose as a requirement for M-phil degree. I request your participation in the study and I also assure you of privacy and confidentiality of all the information that you will disclose to me. Thank you.

Interviewer--- Time ----------------------------

(1) Peri – urban Estate --

(2) Sex: (tick one)
1. Male ☐ 2. Female ☐

(3) How old are you? -------------------------------

(4) Family role
(a) Father ☐
(b) Mother ☐
(c) Child ☐
(d) Worker ☐
(e) Visitor ☐
(f) Others (Specify) ---------------------------------------

(5) Are you a resident here?
` 1. Yes ☐ 2. No ☐

(6) For how long have you been residing here?
(a) Less than one Month ☐
(b) Three Months ☐

(c) Six Months ☐
(d) One year ☐
(e) Three years ☐
(f) Others (Specify) ----------------------
----

(7) What level of Education did you attain?
(a) None ☐
(b) Primary ☐
(c) Secondary ☐
(d) Tertiary ☐

(8) What work do you do?
(a) Laborer ☐
(b) Work in an office ☐
(c) Unemployed ☐
(d) Self Employed ☐
(e) Retired ☐
(f) Business owner ☐
(g) Others (Specify) ----------------------
----

(9) What is your marital status?
(a) Married ☐
(b) Single ☐
(c) Separated ☐
(d) Divorced ☐
(e) Widowed ☐

(10) Please put a tick against your source of water for drinking
(1) Spring ☐
(2) Dam ☐
(3) River ☐
(4) Tap ☐
(5) Borehole ☐
(6) Others (Specify) -------------------------------
----

(11) If your answer above is 5, do you treat the water before drinking?
1. Yes ☐ 2. No ☐

(12) How many times do you take water in a day?
(a) Not at all ☐
(b) Once ☐
(c) Twice ☐
(d) Three times ☐
(e) Four times ☐
(f) Others (Specify) -------------------------------
--

(13) If not (a) above, at what time did you take most of the water

(1) Morning ☐
(2) Afternoon ☐
(3) Evening ☐
(4) At night ☐
(5) Others (Specify) ------------------------------------

(14) Yesterday, approximately how many 200ml glasses of water did you take?

(1) None ☐
(2) Two ☐
(3) Four ☐
(4) Six ☐
(5) Eight ☐
(6) Ten ☐
(7) Others (Specify) ----------------------------------

(15) How many meals did you take yesterday?

1. One ☐
2. Two ☐
3. Three ☐
4. Four ☐
5. Others (Specify)

Remarks: (Give any general information and feelings relevant to the study)

Signature of the person collecting data ---