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CONCENTRATIONS OF SELECTED TRACE ELEMENTS AND THEIR TEMPORAL VARIATION IN BOREHOLE WATER, ELDORET MUNICIPALITY, KENYA

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ABSTRACT: *Water is a basic human requirement as it is extensively used in everyday life and if contaminated, it is detrimental to life and can cause health effects. This study assessed levels of trace elements; Copper, Chromium and Manganese in borehole waters in Eldoret Municipality, Kenya. Samples were collected from selected boreholes in pre-cleaned 0.5L polyethylene bottles and analysed for the trace metals using standard procedures. Statistical analysis of data was carried out using SPSS (version 12.0). Copper concentration ranged from 0.005 – 0.050 ppm, Chromium ranged from 0.04 – 0.23 ppm while Manganese concentration ranged from 0.068 – 0.291 ppm. 69% of the borehole water samples had significantly high chromium concentrations ($p < 0.05$) compared to WHO/FAO recommended values (0.1ppm). Similarly Copper concentrations in water samples from boreholes at Munyaka were significantly higher than WHO/FAO recommended values (0.036 ppm). The elevated Chromium and Copper concentrations particularly at Kipkorgot and Munyaka could be attributed to the quarry activities near the borehole and runoff water from the nearby farms where fertilizers and chemical sprays are normally used, respectively. In conclusion the concentration of the trace elements Copper, Manganese and Chromium in the study was generally lower than WHO/FAO recommended values. There were no significant temporal variations of the trace elements in studied water samples. Recommendation is made for regular monitoring of the borehole waters in the study area to ensure health and safety of consumers.*

KEYWORDS: Borehole Water, Trace elements, Concentrations, Health Effects

INTRODUCTION

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

Low concentrations of trace elements occur in natural aquatic ecosystems, but recent increases in human population, industry and peri-urban agricultural activities in 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 washing and industrial and municipal discharge (Onyari & 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 & Cockerham, 1994). 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).

Cantor (1997) stated that trace elements concentration in the environment is modified by a variety of natural processes besides deliberate and accidental human activities such as industrial and consumer waste. Commercial processes, like mining, agriculture, manufacturing and discarding of wastes in landfills lead to accumulation of these elements in the environment. Further, 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 & Mills, 1996). The Kenyan urban population is growing at 8% per annum and is now more than 27% of the country's total population according to the report by National Environment Management Authority (NEMA, 2004). In addition, generation of solid, liquid and gaseous waste has been increasing in tandem with industrial development and the diversification of consumption patterns (Onyari *et al.*, 1989). The report indicates that per capita waste generation ranges from 0.29 - 0.66 kg day^{-1} within the urban areas of the country. In case of the municipal waste generated in the urban centres, 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.

A study by (Wambui *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, 1997), 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 & Pacyna, 1988). These elements are greatly absorbed and retained in the body when given in a liquid diet (Kostial, 1983) posing public health risks. 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). The probable health effects are estimated using the risk assessment model where by the probability and the magnitude of the risk are evaluated. The study was aimed to assess the concentrations of the trace elements Cu, Mn and Cr in borehole water samples in Eldoret municipality.

MATERIALS AND METHODS

Study Area

The study was carried out in Eldoret Municipality in Uasin Gishu County, Kenya. Eldoret municipality lies with latitude $35^0 15'$ and $35^0 20'$ N and longitude $0^0 30$ and $0^0 35$ E (see figure 1) at an altitude of 2085m above sea level. The municipality covers an area of approximately 147.9 km^2 with a population of 300,000 based on 2009 national census.

Eldoret town has enjoyed rapid industrial growth attracting development and transformation from an agricultural town to an industrial centre offering employment opportunities in various industrial concerns including textile, dairy farming, cereal, vegetable oil manufacturing, steel works and tourism. Ombura (1997) 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 (Eldoret Municipal Council, 2009).

Water Sampling

A preliminary survey of the study area was carried out in October 2004 and existing water boreholes identified. The study area was divided into four zones based on geology and soils characteristics according to Ogendo (1989). The zones comprised of South Eastern (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 next zone is Southern part (designated as zone B) consisting of Elgon View, Langas, Yamumbi and Kipkaren, 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 third, Eastern part (designated as zone C) consists of Kapsoya, Munyaka, Hawai, and Kimumu. This zone is dominated by basic tuffs, basalts and phonolites which are friable, extremely deep reddish soils. The fourth, western section (designated as zone D) consisting of Huruma, King'ong and Kamukunji. This area is dominated by cambisols/pegosols/littosols which are well drained shallow reddish brown soils.

In order to get as regular sampling grid as possible the study area was further divided into approximately 2 km rectangular squares (4 km^2 blocks), which gave rise to 37 (147.5 km^2/4 km^2 sampling blocks. For normal distribution, a sample size of 30% of the total population is required (Mugenda & 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
- nf = The sample size

Therefore nf= 12/ (1+12/37) = 15.9. This was approximated to 16 sampling blocks.

Boreholes in each of the sampling blocks were assigned unique numbers, from which one borehole was randomly selected. A total of 16 boreholes were selected for study (Figure 1). The 4 km^2 study blocks design assumed that the geology of each block was fairly uniform and therefore the one borehole picked at random was representative of the studied block. Duplicate borehole water samples were collected in polyethylene bottles once monthly for four months starting from April to July 2005. The sampling followed standard sampling procedure for trace metal analysis (Arnold *et al.*, 1992).

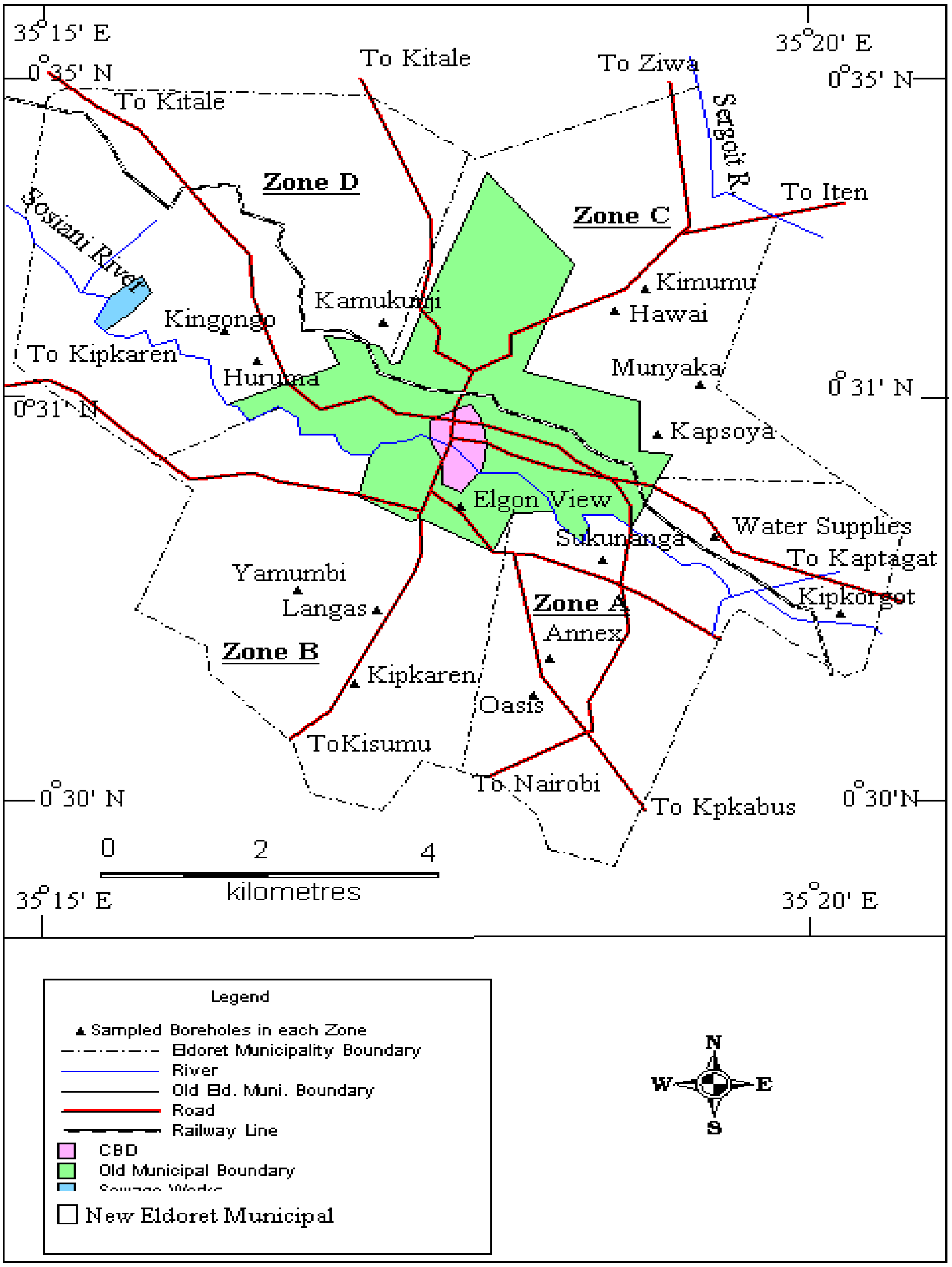

Figure 1: Location of studied boreholes in respective study zones within Eldoret Municipality

Laboratory Methods

Digestion procedure

A 50 ml aligot from each borehole water sample was measures into digestion tubes and digested using aqua regia. The digestion was done to remove the organic matter and expose the inorganics / the trace elements. The digest filtered into a 50 ml volumetric flask through 0.45µm filter paper and topped to the mark with de-ionized distilled water before analysis. The filtrates were analyzed for Copper, Manganese and Chromium using AAS (Varian Spectra AA 200) after calibrating the equipment with respective standard solutions.

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.

RESULTS AND DISCUSSION

Copper

The mean concentration of Copper was significantly ($p < 0.05$) different among the studied boreholes. Duncan statistical posthoc test showed that water samples from Oasis, Annex, Sukunanga, Kipkrogot, Munyaka and Langas were relatively more elevated compared to other sites is evidenced in Table 1. T-test analysis indicated that copper concentration (Copper = 0.0498 ppm) in water samples from Kipkorogot in Zone A was significantly higher ($P<0.05$) than the WHO/FAO (1993) recommended standards (copper = 0.036 ppm) for drinking water. The elevated copper in Kipkorogot could be attributed to the quarrying activities in this zone. According to Idris *et al*. (2014), blasting in quarry sites causes rocks fracture which during precipitation leads to leaching of minerals such as copper to the underlying aquifers. Depending on the abundance of the metal in the rock, borehole waters harvested from such aquifers have high trace metal content. 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 study carried out in Thika, Davies (1992) found copper concentration varying from 0.01 – 0.057 pm in borehole water depending on the geochemistry of the area.

Table 1: Mean concentrations of Copper, Manganese and Chromium in studied boreholes in comparison with WHO standards (0.036, 1.5 and 0.1)

Zone	borehole	Depth (m)	Cu (ppm)	Mn (ppm)	Cr (ppm)
A	Oasis	4.60	0.0323±0.0050	0.0784±0.0127	0.1754±0.1391
	Annex	8.50	0.0356±0.0047	0.0684±0.0104	0.1685±0.0903
	Sukunanga	12.2	0.0281±0.0106	0.0811±0.0088	0.0618±0.0337
	KCC	7.60	0.0145±0.0129	0.0953±0.0163	0.0296±0.0122
	Kipkrogot	13.7	0.0498±0.0087	0.1213±0.0130	0.2323±0.2969
B	Elgon view	7.60	0.0115±0.0070	0.0795±0.0089	0.1147±0.0960
	Langas	7.60	0.0320±0.0067	0.0684±0.0079	0.1966±0.3345
	Kipkaren	15.2	0.0169±0.0090	0.2906±0.0251	0.1063±0.1080
	Yamumbi	3.00	0.0054±0.0054	0.0846±0.0072	0.1375±0.1411
C	Munyaka	6.10	0.0426±0.0081	0.0929±0.0123	0.2279±0.2855
	Kimumu	7.60	0.0054±0.0060	0.0639±0.0064	0.1339±0.1141
	Hawai	6.10	0.0058±0.0066	0.1908±0.0107	0.2179±0.2473
	Kapsoya	9.10	0.0073±0.0078	0.1203±0.0094	0.1829±0.2531
D	Kamukunji	2.40	0.0083±0.0089	0.1071±0.0192	0.0826±0.1313
	Kingo'ngo	10.7	0.0073±0.0058	0.0768±0.0183	0.2208±0.2387
	Huruma	6.10	0.0086±0.0080	0.1113±0.0142	0.0494±0.0507

Manganese

Mean concentrations of Manganese in borehole water samples studied ranged from 0.0639±0.0064 ppm (in water samples from Kimumu borehole) to 0.2906±0.0251ppm (in water samples from Kipkaren borehole). Apparently Manganese water concentration in studied boreholes was significantly ($P < 0.05$) below WHO/FAO (1993) recommended value (1.5 ppm) in drinking water (Table 1). In Kipkaren borehole Manganese concentration was relatively higher than other sampled sites (0.2906). This was the deepest (13.72 m) bore hole in the study. Regression of depth against Managanese concentrations showed a positive correlation coefficient (0.179) as is evidenced in Figure 3. The water in this borehole could be interacting with the igneous rocks deep in the ground to give the results recorded. Further, the Mangase concentration could be due to geochemistry of the area (Davies, 1994). Wen (2002) observed that sorption uptake process of Manganese by mineral phases suspended in the water could also lead to low concentration of Manganese in the water as was the case in majority of the studied borehole water.

Chromium

Mean concentration of chromium in 11 (69%) of the borehole samples studied was significantly ($P < 0.05$) higher than WHO/FAO (1993) recommended values for drinking water (Table 1). The relatively high Chromium concentration (0.2323±0.2969) was recorded in water samples collected from Kipkorogot borehole. Here is also where copper concentration was high. Anthropogenic quarrying activities could be contributing to the elevated chromium levels (Idris *et al.*, 2014).

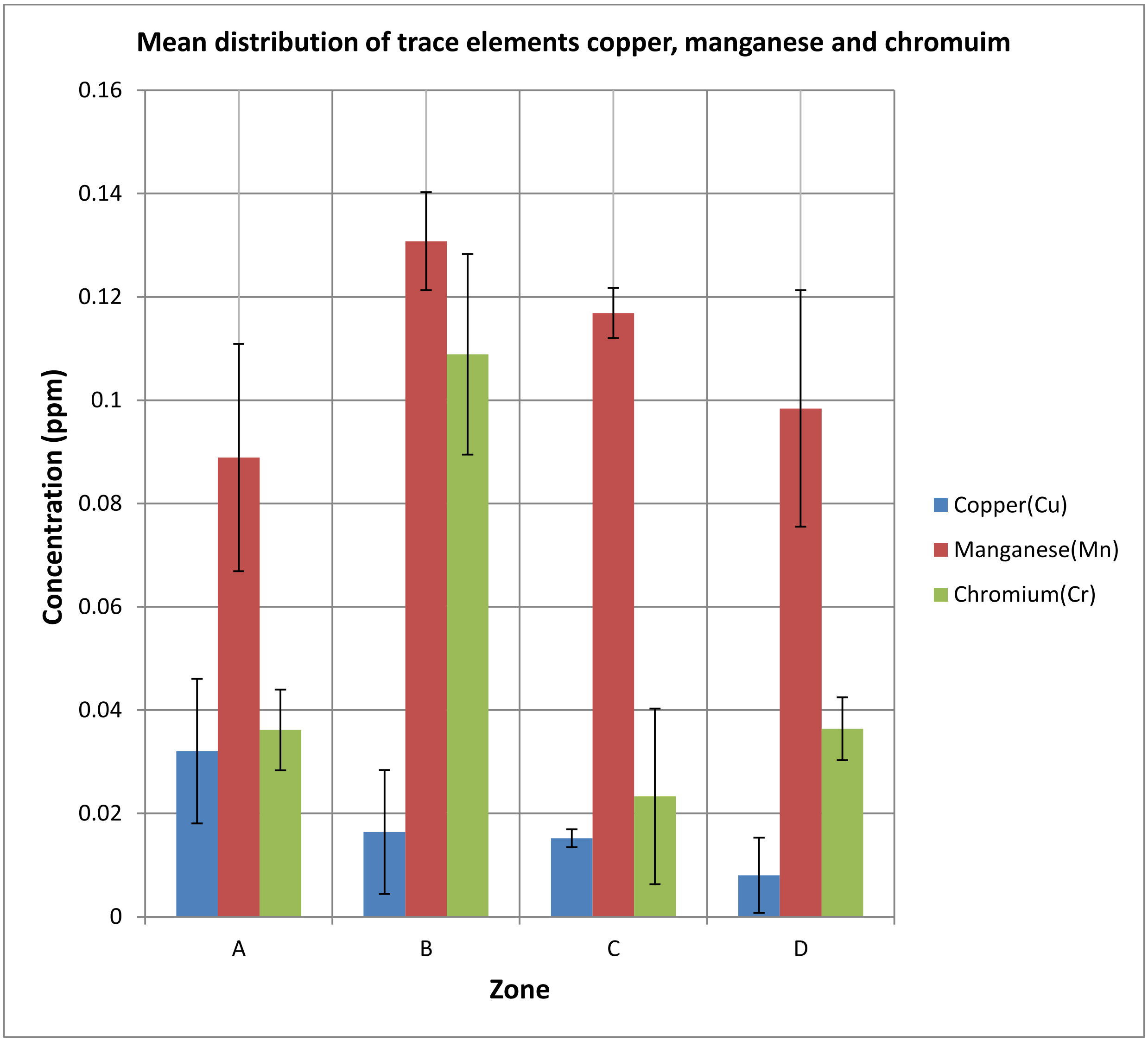

Figure 2: Mean distribution of trace elements (Cu, Mn & Cr) in the Zones

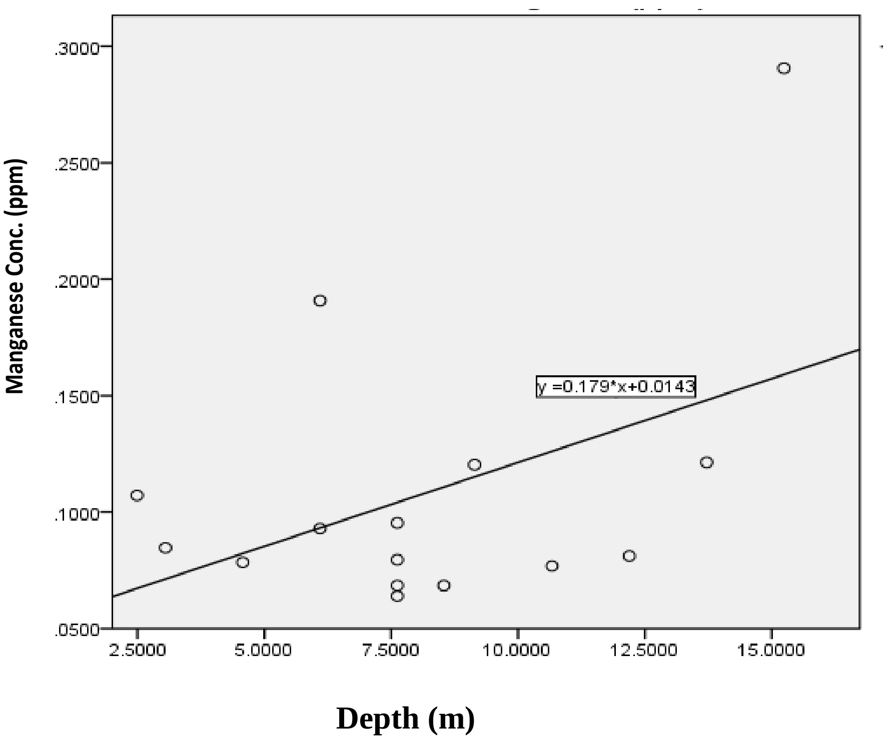

Figure 3: Relationship between Depth and Manganese concentrations in water samples from selected boreholes in Eldoret Municipality, Kenya

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. The high Chromium concentration in the borehole water could be associated to the geochemistry of the area and also the quarrying activities. The heavy metal concentrations were not influenced by seasonal variability analysis of variance results showed no significant ($P > 0.05$) variation. Recommendation is made for regular monitoring the borehole waters in the study area to ensure health safety of consumers in relation to observed relatively elevated copper and chromium in some borehole water samples.

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