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Selected trace elements evaluation in soil from an urban farming area

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ABSTRACT

BACKGROUND AND OBJECTIVES: Urban farming makes a substantial influence on the household economy of the urban poor especially in developing countries. Urban soil the hot spot of urban farming is a natural sink for contaminants especially the trace elements derived mainly from anthropogenic activities. This study's aim was to quantify the concentrations of selected trace elements (Cr, Mn, Cu, Ni, and Zn) in topsoil (0-20 cm) and subsoil (21-50 cm) and to evaluate whether their concentration vary during dry and rainy season.
METHODS: Grid soil sampling method was used to collect soil samples and their total concentration was determined using a portable X-ray Fluorescence Spectrometer.
FINDINGS: The study revealed that the topsoil had higher concentration than sub soil. The topsoil concentration in mg/kg were 61.62, 4042.58, 30.82, 43.90 and 456.43 for Cr, Mn, Ni, Cu and Zn respectively. The subsoil concentration in mg/kg were 54.67, 3791.38, 30.32, 27.83 and 370.32 for Cr, Mn, Ni, Cu and Zn respectively. It also noted that concentration of the trace elements was higher during dry season than wet season but not significantly different ($P \geq .05$) for all the elements.
CONCLUSION: The study recommends that there is need to monitor levels of trace elements investigated in soil to ensure they do not reach detrimental levels.

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INTRODUCTION

Due to food shortages, food production in peri-urban areas is being broadly accepted as one of the basic urban occupations. In Kenya 29 % of urban households grow crops in towns (Ghosh, 2004). This practice of urban agriculture is aimed to increase food supply for health nourishment of consumers, employment and to improve environmental sustainability. To a large extent, urban farming utilizes solid and liquid waste resulting into effective waste management in cities and thus make cities green (Smit *et al.*, 2001). Irrespective of the locality of agriculture, be it in rural or urban, soil is a major resource to the environment and food production whereby it serves as the prime nutrient source for plants. Determination of soil quality is a first-rate measure of its fertility which makes it an economical way of maintaining nourished health plant leading to excellent crop productivity (Galuszka *et al*., 2015). In an urban area this need is necessitated by the fact that rural environments are less polluted than urban areas. More so from the potentially toxic trace elements, due to their emissions from traffic and burning of fossil fuels for energy and manufacturing use (Mielke *et al*., 2011). Different from soil in the countryside, natural conditions of soils in urban area undergo many changes as a result of human activities (Eghbal *et al.*, 2019). Such changes include high levels of trace elements in urban soils. Even Though such high levels may sometimes be attributed to the geology of the area, influence of anthropogenic activities that release trace elements in the environment, causing elevated content of trace elements in the soil is key (Ogunkunle *et al.*, 2017). The ever-growing number of industrial activities in cities of the developing countries has emerged to be one of the major contributors of soil pollution in urban areas (Fazel *et al.*, 2018). Hence making urban areas predominantly susceptible to trace elements pollution because of their accumulation in the soil. Soil as a constituent of the biosphere, is very important since it is a geochemical sink for pollutants, and it serves as a natural buffer regulating passage of chemical elements and other substances to the atmosphere, hydrosphere, and biota. Also, in food production, soil plays a major role thus making it a very essential component in the survival of humans. Therefore, mankind has a responsibility of maintaining the agricultural and ecological functions of soil (Kabata-Pendias, 2011). Poor soil conditions affect food security directly and indirectly. Direct effects results in poor crop yield and a deprived nutritious standard of crop produce. Nutrient imbalance in soil, caused by shortage of some and toxicity resulting from excess of others, is a primary cause of poor yield in tarnished soils that has strong undesirable influences on crop harvest (Lal, 2009). In urban areas, soil, a component of the landscape, among other functions, has recreational and esthetical roles in gardens and parks that foster safeguarding of biodiversity. Unlike other soils, urban soil is prone to be used differently hence making its connection with other compartments of the ecosystem to vary. This is especially common due to presence of anthropogenic supplies that get mixed with it hence altering its functioning (De Kimpe and Morel, 2000). Anthropogenic activities, like industrial activities, traffic emissions, waste disposal and fuel combustion in urban areas, inevitably result in soil pollution (Ajmone-Marsan and Biasioli, 2010). These anthropogenic doings have caused contamination of the soils with various pollutants. Among the pollutants, potentially toxic elements (PTEs) and heavy elements are a main cause of concern. This concern becomes eminent as a result of the closeness of soil to humans and the roles soils play (Ajmone-Marsan and Biasioli, 2010). Due to environmental pollution in cities, urban farming poses food safety concerns and public health issues (Oka *et al*., 2014). The environmental pollution is as a result of the locations of urban farming that are usually in areas of intense traffic concentration, industrial activity, and sewage effluents (Oka *et al*., 2014). Further, for high yield to be realized, pesticides and fertilizers are less utilized in rural areas than urban areas. These coupled with intensive anthropogenic activities in urban farming areas, a weighty load on the quality of the soil is imposed (Zhao *et al*., 2007). This notwithstanding, urban farming is greatly increasing in developing and developed countries around the world; however, pollution of urban farming products can exceed the permissible levels and result to human health risks due to dietary exposure to high levels of toxic trace elements, associated with soil pollution. (Ogunkunle *et al.,* 2017). This is generally because absorption of potentially trace elements by the plant on contaminated urban farms is one of the main and indirect routes of entry of trace elements to human food chains (Mahabadi, 2020) Hence, monitoring and assessment of trace elements concentrations in the urban farming soils is an excellent way of understanding and evaluating ecosystem health. (Ogunkunle *et al.,* 2017) Assessment of this nature, more so that of trace elements, provides valuable knowledge on the trace elements contents that can indicate the health of the vegetation as well as the extent of contamination in the environment (Eghbal *et al.*, 2019). The aim of the study was to quantify the concentrations of selected trace elements (Cr, Mn, Cu, Ni, and Zn) in topsoil (0-20 cm) and subsoil (21-50 cm) and to evaluate whether their concentration vary during dry and rainy season. This study was done in Ruai, an urban area within Nairobi city County Kenya in 2018.

MATERIALS AND METHODS

Study Area

The study was carried out in Ruai ward, Ruai sewage area, which is in Nairobi East Kasarani constituency, Kasarani Sub County. The area is approximately 30 km east of Nairobi City Centre off Kangundo road (Fig. 1) and its geographical coordinates are 1° 18' 0" South, 36° 55' 0" East. (Opijah *et al.*, 2007). The rainfall is bimodal with long rains occurring between March and May while the short rains are in August to November. The rainfall ranges between 750mm to 1500 mm, with a mean annual rainfall of 1250mm. The temperature varies from 17 ^{0}C to 27 ^{0}C. June and July are the months with lowest temperature while the hottest months are January and September with temperature from 25 ^{0}C to 27 ^{0}C. (Opijah *et al.*, 2007). The area is drained by Athi River and its tributaries which flow northeastwards and eastwards. Athi River has several seasonal tributaries which have water during the rainy seasons and immediately after, otherwise they are normally dry most part of the year. The geology of the area generally contains Nairobi volcanic sheltered by black cotton clay soils. The area is generally flat with Nairobi River at the north Eastern region of the area (Opijah *et al.*, 2007).

Selection of study site and sampling points

Domestic and industrial wastes in Nairobi city are transported to Ruai for treatment. These wastes have pollutants from the municipal drainage or the industrial drainage that are either dissolved in sewage water or attached to suspended matter. These pollutants eventually get into the treatment plant

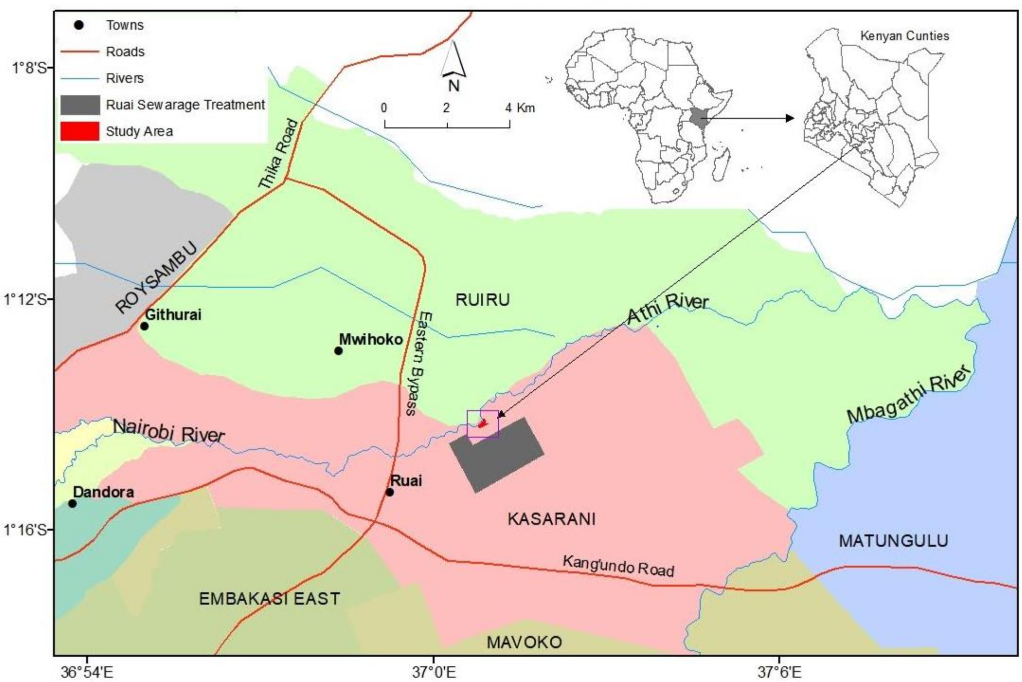

Fig. 1: Map of Nairobi showing Location of Ruai Sewage treatment plant in the study area.

and finally to the sludge. Therefore, the area was considered for the study because some potentially toxic trace elements are prone to be in the sewage sludge and consequently into the soil.

Sample Collection

A 50 m by 50 m grid was constructed over the site. 15 sampling points were identified within the area using grid soil sampling pattern according to Wollenhaupt and Wolkowski, (1994). At each sampling point topsoil (0-20 cm) and sub soil (21-50 cm) samples were collected with an auger from five cores within a 2-meter radius and pooled into two buckets, one for topsoil and the other for subsoil. The samples were then thoroughly mixed in the buckets using a trowel. About 50 g of the sample was subsampled into labeled plastic bags respectively to form a total of thirty soil samples. All the labeled thirty soil samples were individually sealed into polythene bags to avoid cross contamination and thereafter transported to the World Agroforestry (ICRAF) laboratories in Nairobi for preparation and analysis. Sampling and transfer of samples was done on the same day. Sampling was done during the dry and wet season.

Sample Preparation and analysis

Soil samples were air-dried, mechanically crushed using a stainless-steel roller and sieved through 2-mm sieves. About 10 grams was then subsampled by coning and quartering and further milled to attain a particle size of between 20 - 75 µm using a Retsch RM 200 mill (Retsch, Düsseldorf, Germany) automated milling machines. About 3g homogenized sample was loaded into special XRF cups made from 4µm (0.16 mil) polypropylene XRF film free from irregular surfaces and contamination. Elemental concentration of the loaded soil samples was done using Bruker Tracer 5i pXRF instrument (900F4473) with Rhodium tubes. The units had resolutions (full width height maximum, or FWHM) of 135 eV at the Manganese K-alpha line. Soil samples were analyzed with a voltage of 30 kV and a current of 50 µA for 60 seconds with filter (Ti 25µm: Al 300µm).

Data Analysis

Results obtained were collated and statistically analyzed using R Version 3.3.3. Soil elemental concentration between the seasons and depths were subjected to analysis of variance using R version 3.3.3. The variation in elemental concentration due to depth and seasons were subjected to t-test to test the difference between the seasons and depths.

RESULTS AND DISCUSSIONS

Trace elements in topsoil (0-20cm)

Chromium

The study revealed that the concentration of Chromium in topsoil (0-20 cm) showed variation during the study period (Table 1), the concentration ranged from 54 mg/kg to 77.5 mg/kg (Table 1). The mean concentration of Chromium in topsoil (0-20 cm) was 61.62 mg/kg. Levels of Chromium in soil has been reported to vary according to area and the degree of contamination from anthropogenic activities (Kabata-pendias and Henryk, 2001; Kamaludeen *et al.*, 2003). Another aspect that has been reported to influence level of Chromium in soil is the amount that has been removed through volatilization, surface runoff, leaching and Phyto-uptake. Due to farming coupled with irrigation of wastewater at the sampling location, variation of

Table 1: Concentration of the five trace elements of topsoil (0-20 cm) and subsoil (21- 50 cm) for both season from the fifteen plots.

Elements (mg/kg)	Cr		Mn		Ni		Cu		Zn	
	Topsoil (0-20 cm)	Subsoil (21-50 cm)	Topsoil (0-20 cm)	Subsoil (21-50 cm)	Topsoil (0-20 cm)	Subsoil (21-50 cm)	Topsoil (0-20 cm)	Subsoil (21-50 cm)	Topsoil (0-20 cm)	Subsoil (21-50 cm)
Mean ± SD	61.62 ± 6.14	54.67 ± 5.85	4042.58 ± 380.45	3791.38 ± 572.11	30.82 ± 1.21	30.32 ± 1.37	43.90 ± 12.05	27.83 ± 12.54	456.43 ± 71.61	370.32 ± 74.42
Range	54.00 - 77.50	47.00 - 74.00	3320.00 - 4752.50	2865.00 - 4627.00	28.50 - 33.00	27.50 - 32.50	22.00 - 69.00	9.50 - 68.50	363.00 - 590.00	271.50 - 567.50
P -value	< .001		.052		.140		< .001		< .001	

chromium concentration in soil is expected as was revealed in the study (Avudainayagam *et al.*, 2003). The mean concentration of Chromium from the study area (61.62 mg/kg) is slightly below what has been reported on a worldwide basis on Cr concentration in urban soil of 66.08 mg/Kg (Su, *et al.*, 2014). A study in Iran, revealed a mean concentration of 28.7 mg/kg that was much lower than what was found in the current study (Maleki *et al.*, 2014). Further, a study in Varanasi, India, reported a mean concentration of 56.3 mg/kg (Mishra and Tripathi, 2008).

Manganese

Manganese content of the topsoil (0-20 cm) depicted a concentration range of 3320.00 – 4752.00 mg/kg with a mean concentration of 4042.58 mg/kg (Table 1). The total concentration of Manganese in surface soil has been reported to vary greatly ranging from less than 7 mg/kg to more than 9000 mg/kg (Hooda, 2010). Most of the soil manganese is from the parent material and other minor sources include atmospheric deposition, irrigation water and the use of sewage sludge (Hooda, 2010). High manganese content is reported for soils over mafic rocks, soils from arid or semi-arid regions and soils rich in organic matter (Hooda, 2010; Kabata-pendias and Henryk, 2001). Fixation of organic matter in topsoils is the reason why it tends to accumulate more on top soils (Kabata-pendias and Henryk, 2001).

The observed levels of Manganese could be attributed to Manganese content of the parent material, fixation of organic matter and anthropogenic activities around the area that include Irrigation of wastewater and atmospheric deposition. The range of Manganese of 3320.00 – 4752.00 mg/kg is high compared with various ranges that have been reported from similar studies that include; a study on urban soil contamination conducted in the city of Novokuybyshevsk in Russia had a range of 125.7 mg/kg to 270.6 mg/kg (Galitskova and Murzayeva, 2016). A study in Penas Albas, Spain, revealed a concentration range of 751 mg/kg to 1850 mg/kg (Couce and Vega, 2015). Further, a study in Manaila, Romania, revealed a concentration range of between 161 mg/kg to 1258 mg/kg (Simona *et al.,* 2015).

Nickel

The mean total Nickel concentration was 30.82 mg/kg in topsoil (0-20 cm) with a range from 28.50mg/kg to 33.00 mg/kg (Table 1). Though the range is within the reported broad world-wide range of 0.2 mg/kg to 450 mg/kg, the concentration mean of topsoil was higher than the soil world calculated mean of 22 mg/kg (Kabata-pendias and Henryk, 2001). However, the study location being an urban area that has a high possibility of being contaminated, the concentration mean of Nickel is prone to be higher than its reported world calculated mean. Typically, the mean concentration of Nickel from contaminated urban soil has been reported to be 29.14 mg/kg (Su *et al*., 2014). Nickel concentration mean of 30.82 mg/kg for topsoil was higher compared to the reported world mean of contaminated urban soils which is 29.14 mg/kg (Su *et al*., 2014). This shows the location has been highly contaminated in the previous period or the background concentration level of Nickel was higher for the site. The likely sources of pollution could be the sewage sludge and industrial dust to the area. In a similar study done in India, it was observed that constant application of untreated and treated sewage water to the soil led to elevated concentrations of trace elements in the soil (Mishra and Tripathi, 2008). A similar study on urban soil contamination conducted in the city of Novokuybyshevsk Russia had a range of 16.5 mg/kg to 35.25 mg/kg (Galitskova and Murzayeva, 2016). A study in the city of Tabriz Iran, revealed a concentration range of 2.50 mg/kg to 72.50 with a mean of 38.73 mg/kg (Taghipour *et al.*, 2013).

Copper

Copper content of the topsoil (0-20 cm) showed a range concentration of 22 mg/kg to 69 mg/kg with a mean concentration of 43.90 mg/kg (Table 1). Copper typically accrues in the topsoil, a phenomenon explained by the bioaccumulation of the element and existing anthropogenic activities (Kabata-Pendias, 2001). Like other elements investigated, variation in total elemental concentrations of copper was revealed. This variation could be attributable to differences in parent materials and to local pedologic and anthropogenic influences (Towett *et al.,* 2015). The revealed mean concentrations of Copper from the study is above the reported world mean that vary from 13 to 24 mg/kg (Kabata-pendias and Henryk, 2001). Therefore, copper levels were high as per the findings of the study in comparison to other global findings. The high concentration of copper could be attributed to particulates of copper that are released into the atmosphere by wind-blown dust and influence of other anthropogenic sources (Nazir *et al.,* 2015). A similar study on urban soil contamination conducted in the city of Novokuybyshevsk Russia had a range of 4.6 mg/kg to 27.75 mg/kg (Galitskova and Murzayeva, 2016). A study in the city of Tabriz Iran, revealed a concentration range of 13.17 mg/kg to 265.67 with a mean of 101.25 mg/kg (Taghipour *et al.*, 2013). A study in Varanashiindia, revealed a concentration range of 32.3 mg/kg to 123.6 mg/kg with a higher mean concentration of 77.8 mg/kg (Mishra and Tripathi, 2008). A study in China revealed a concentration range of 22.2 mg/kg to 93.0 mg/kg with a slightly lower mean of 42.4 as compared to the present study (Guo *et al.,* 2013)

Zinc

Concentration of Zinc of the topsoil (0-20 cm) exhibited a concentration range of 363.00 mg/kg to 590.00 mg/kg with a mean concentration of 456.43 mg/kg (Table 1). The overall Zn content of soils is reported to vary greatly with a reported range of 10 to 300 mg/kg (Haluschak *et al*., 1998), while background levels of uncontaminated soils are 17 to 125 mg/kg on a world-wide basis (Kabata-pendias and Henryk, 2001). Anthropogenic sources of zinc are substantial to its elevated levels that majorly arise from industrial activities, waste combustion and steel processing. The world's Zn production is increasing, and manufacturing applications tend to scatter Zinc extensively in the environment, resulting to concentration levels that are above pre-industrial levels in soil, water and air. The mean content of Zinc of the site was high compared to concentrations recognized for soils on the globe (Kabata-pendias and Henryk, 2001) and soils from polluted urban areas (Su *et al*., 2014). The high Zn content is a typical characteristic of contaminated sites whose Zn level together with other trace elements could be high and has been reported to range from 443 to 1112 mg/kg (Kabata-Pendias and Mukherjee, 2007). In addition, the elevated concentration of Zinc may be due to anthropogenic activities that are prone to influence its level, especially in the top horizon of soil. A similar study on urban soil contamination conducted in the city of Novokuybyshevsk Russia had a range of 34.75 mg/kg to 73.5 mg/kg (Galitskova and Murzayeva, 2016). A study in the city of Tabriz Iran, revealed a concentration range of 49.80 mg/kg to 163.80 with a mean of 98.27 mg/kg (Taghipour *et al.*, 2013). A study in Varanashiindia, revealed a concentration range of 86.4 mg/kg to 158.3 mg/kg with a mean concentration of 122.3 mg/kg. (Mishra and Tripathi, 2008). A study in China revealed a concentration range of 31.2 mg/kg to 213.6 mg/kg with a lower mean of 129.9 as compared to the present study (Guo *et al.,* 2013).

Trace elements in sub soil (21-50cm)

Chromium

Chromium concentration of sub soil (21-50 cm) had a concentration mean of 54.67 mg/kg with a range varying from 47 mg/kg to 74 mg/kg (Table 1). From a worldwide basis, Cr mean concentration in urban soil has been reported to be 66.08 mg/kg (Su *et al*., 2014). A study carried out in Niger Delta; Nigeria reported a mean concentration of Chromium in subsoil to be 23.4 mg/kg with a range of less than 0.002 mg/kg to 34.2 mg/kg (Iwegbue and Iwegbue, 2015). A study in Hangzhou, China revealed a mean concentration of Chromium in sub soil of 43.91 mg/kg with a range of 22 mg/kg to 80.4 mg/kg (Ji *et al.,* 2012).

Manganese

Sub soil (21-50 cm) concentration of Manganese from the study revealed a concentration range that varied from 2864.00 mg/kg to 4627.00 mg/kg with a concentration mean of 3791.38 mg/kg (Table 1). This concentration is low compared to that of topsoil (Table 1). This trend is expected due to fixation of organic matter in topsoils that makes it to accumulate more on top soils (Kabata-pendias and Henryk, 2001). A study carried out in Niger Delta; Nigeria reported a mean concentration of Manganese in subsoil of 169.0 mg/Kg with a range of less than 53.67 mg/kg to 539.4 mg/kg (Iwegbue and Iwegbue, 2015). A similar study carried out in Germany, revealed a mean concentration in sub soil of 821 mg/kg with a range that varied from 433 mg/kg to 4501 mg/kg (Reiss and Chifflard, 2015).

Nickel

Sub soil (21-50 cm) concentration of Nickel had a mean concentration of 30.32 mg/kg with a range that varied from 27.5 mg/kg to 32.50 mg/kg (Table 1). Though the range is within the reported broad world-wide range of 0.2 mg/kg to 450 mg/kg, the mean of sub soil was higher than the soil world calculated mean of 22 mg/kg (Kabata-pendias and Henryk, 2001). Also, this mean of sub soils was higher compared to the reported world mean of contaminated urban soils which is 29.14 mg/kg (Su *et al*., 2014). The high Nickel mean content as compared to the world mean can be credited to the parent material as Nickel concentration of soils is extremely reliant on its concentration in background material (Kabata-Pendias, 2011). Nevertheless, higher content of Nickel in soils indicates the added impact of anthropogenic factors and soil-forming processes. A study carried out in Niger Delta; Nigeria reported a mean concentration of Nickel in subsoil to be 26.5 mg/kg with a range of less than 11.9 mg/kg to 37.9 mg/kg (Iwegbue and Iwegbue, 2015). A study in Hangzhou, China revealed a higher mean concentration of Nickel in sub soil of 32.88 mg/kg with a range of 22.1 mg/kg to 58.6 mg/kg (Ji *et al.,* 2012)

Copper

Concentration of Copper in subsoil (21-50 cm) revealed a range of between 9.50mg/kg to 68.50 mg/kg with a concentration mean of 27.83 mg/kg (Table 1). As expected, this concentration mean was lower compared to that of topsoil (0-20 cm) that was 43.90 mg/kg (Table 1). Copper is said to be associated with organic matter (Iwegbue and Iwegbue, 2015), hence, subsoil samples tend to have smaller amounts of Cu in comparison with topsoil samples, perhaps owing to presence of less organic substances in the subsoil and because at the topsoil is where biological activities mainly occur (Abollino *et al*., 2002).A study carried out in Niger Delta; Nigeria reported a mean concentration of Copper in subsoil to be 5.50 mg/kg with a range of less than 0.002 mg/kg to 15.0 mg/kg (Iwegbue and Iwegbue, 2015). A study in Hangzhou, China revealed a higher mean concentration in sub soil of 37.49 mg/kg with a range of 16.7 mg/kg to 70.9 mg/kg (Ji *et al.,* 2012)

Zinc

From the study, Zinc concentration in sub soil (21-50 cm) revealed a concentration range of between 271.00 mg/kg to 567.50 mg/kg with a concentration mean of 370.32 mg/kg (Table 1). Zinc concentration in soil is said to be subject to organic matter, the type of parent material, texture, and pH, and its world-wide range is from 10mg/kg to 300 mg/kg with a projected average of 64 mg/kg (Kabata-Pendias, 2001). A study carried out in Niger Delta; Nigeria reported a mean concentration of Zinc in subsoil of 30.8 mg/Kg with a range of less than 8.67 mg/kg to 48.0 mg/kg (Iwegbue and Iwegbue, 2015). A study in Hangzhou, China revealed a mean concentration of Zinc in sub soil of 120.90 mg/kg with a range of 72.5 mg/kg to 215.0 mg/kg (Ji *et al.,* 2012). Like in the top soil (0-20 cm), the mean concentration of Zinc in sub soil (21-50 cm) from the study was high compared to concentrations reported for soils on a world-wide basis (Kabata-pendias and Henryk, 2001) and those from contaminated urban areas (Su *et al*., 2014). The high Zn content is a distinctive characteristic of contaminated sites whose Zn level may be quite high, from 443 mg/kg to 1112 mg/kg (Kabata-Pendias and Mukherjee, 2007). In addition, anthropogenic source of Zinc may greatly influence its high contents and are most likely responsible for the observed elevated levels of Zn (Kabata-Pendias and Mukherjee, 2007).

Elemental concentration in topsoil compared to sub soil

All the elements; Cr, Mn, Ni, Cu and Zn depicted a higher concentration in the topsoil (0-20 cm) than in the sub soil (21-50 cm) (Table 1) (Fig. 2). The higher concentrations of these elements in topsoil could be due to fixation by soil organic matter (Kabata-Pendias, 2011). These observations is similar to what has been reported by other researches who indicated elemental concentration in soil tends to decrease with depth (Adugna, 2015; Jobbágy and Jackson, 2014). Also, it has been reported that the observed elemental differences between soils horizons is due to the influence of predominating pedogenic and anthropogenic processes (Abbaslou *et al*, 2014; Kabata-pendias and Henryk, 2001). To establish if the difference of topsoil and sub soil were significant or not, student T-Test were done. Results revealed significant differences ($p \leq 0.05$) for Cr, Cu and Zn whereas for Mn and Ni there were no significant differences ($p \geq .05$) (Table 2).

Soil Trace elements concentration during dry and wet seasons

For all the elements investigated (Cr, Mn, Ni, Cu and Zn), their soil mean concentration during dry season was higher than wet season (Table 2) (Fig. 3).

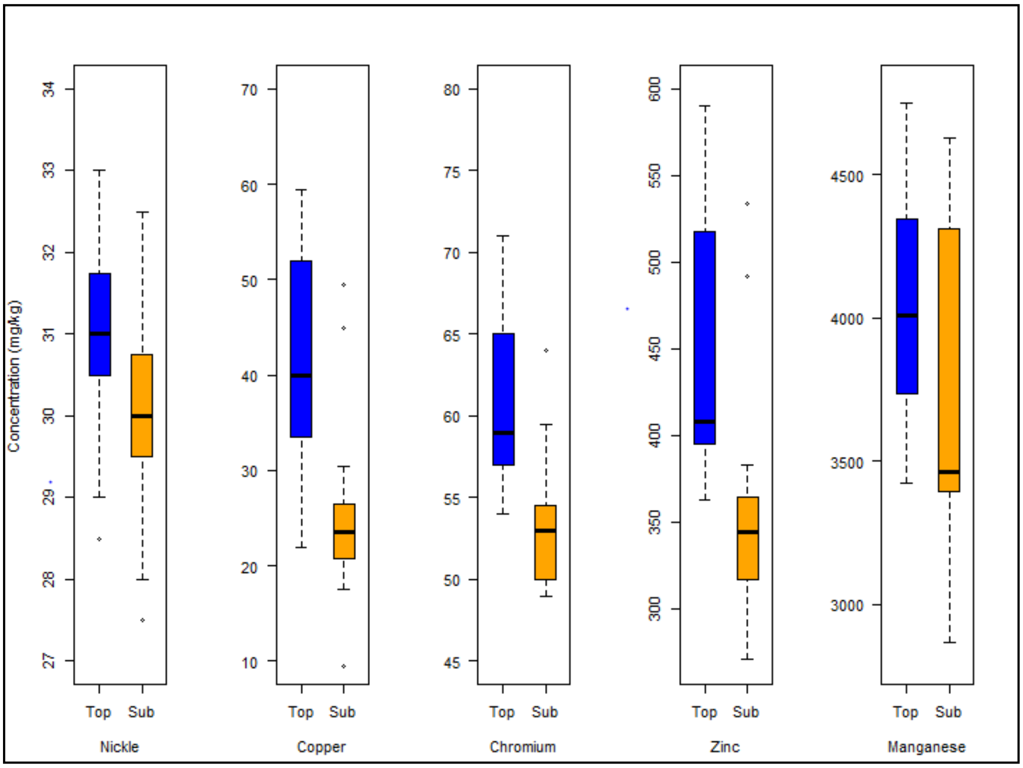

Fig. 2: Box plots of soil elemental concentration of Topsoil and sub soil during Wet season

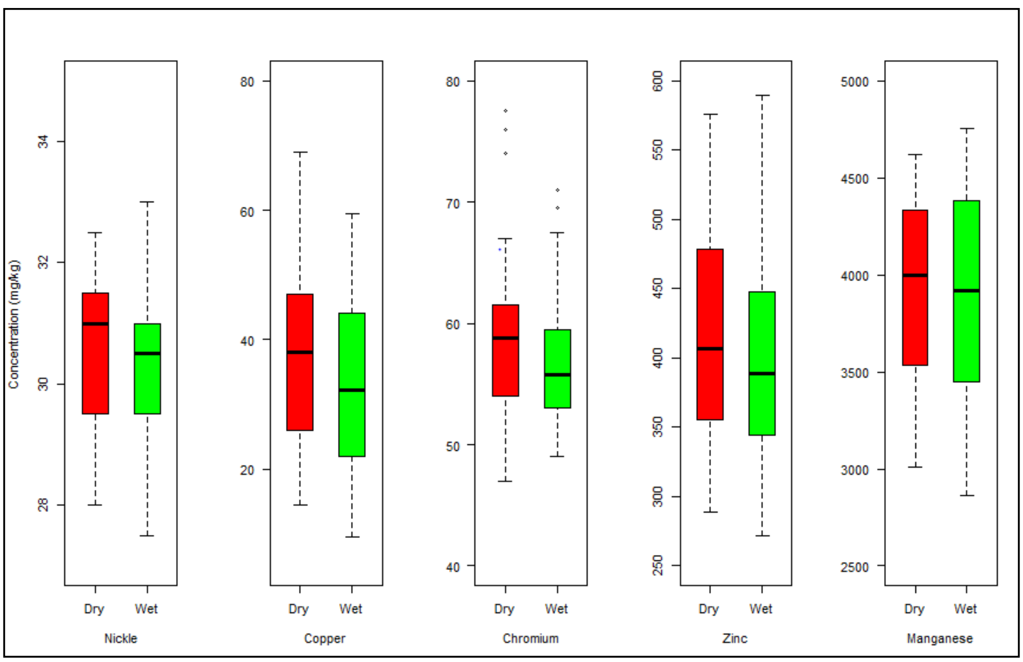

Fig. 3: Box plots of elemental concentration in soil during Dry and wet seasons

Table 2: Basic statistics of elemental concentration in soil during wet and dry season.

Elements Mg/kg	Cr	Mn	Ni	Cu	Zn
Wet season soil Mean	57.07±6.11	3903.02±500.35	30.50±1.41	33.63±13.46	404.42±83.91
Wet season Range	49.00-71.00	2865.00-4752.50	27.50-33.00	9.50-59.50	271.50-590.00
Dry season soil Mean	59.22±7.56	3930.95±503.92	30.63±1.22	38.10±15.64	422.33±85.42
Dry season Range	47.00-59.22	3008.50-4619.00	28.00-32.50	14.50-69.00	289.00-576.00
P - value	.167	.826	.373	.161	.346

Table 3: Correlation coefficient (r) of the trace elements in soil (n = 60)

	Cr	Mn	Cu	Zn	Ni
Cr	1.000				
Mn	0.426	1.000			
Cu	0.920	0.239	1.000		
Zn	0.937	0.262	0.966	1.000	
Ni	0.610	0.286	0.507	0.661	1.000

Statistically, concentration levels of these elements were found to be of no significant difference between the dry season and wet season ($p \geq 0.05$). Other researchers have reported that during wet season trace elements tend to be significantly lower compared to dry season (Osobamiro and Adewuyi, 2015; Teutsch *et al,* 1999), The differences tend to be as a result of precipitation that has an effect on depletion and enrichment trends of trace elements in soils(Teutsch *et al*., 1999). Plant uptake, precipitation, discharge and erosion could be responsible for the reduction in trace elements levels in wet season as compared to dry season (Osobamiro and Adewuyi, 2015; Teutsch *et al*., 1999).

Correlation analysis of the Trace elements concentration in soil

The relationship that exist between elements in the soils is generally due to parent material, effect of pedogenic process and influence of anthropogenic activities (Cheng *et al.,* 2015). Data analysis for the five trace elements (Cr, Mn, Ni, Cu and Zn) showed that there were positive correlations(Table 3) among the five trace elements, implying that the five trace elements in the soils have the same source (Cheng *et al.,* 2015; Ding *et al.,* 2018). However, Manganese had the least correlation with the rest of the elements an indicator that its major source could be different as compared to the rest of the elements. This is substantiated by the fact that generally most of the soil manganese is from the parent material with minor sources that could be from anthropogenic activities (Hooda, 2010).

CONCLUSION

The urban area is predominantly susceptible to trace elements pollution because of their accumulation in the soil. Nevertheless, urban farming is unceasingly being practiced in major cities including Nairobi and hence adverse effects by these pollutants is inevitable. This notwithstanding, the importance of urban farming cannot be overlooked as it leads to provision of basic foodstuffs to urban residents. It is therefore of essence to have access to accurate, simple and rapid means for their detection in soils to contribute to the understanding of trace elements levels in soil in an urban farming area. The findings of the study revealed that all elements (Cr, Mn, Ni, Cu and Zn) depicted a higher concentration in topsoil than sub soil probably due to fixation by soil organic matter and influence of pedogenic processes and anthropogenic activities. For all the elements investigated, their soil mean concentration was higher during dry season than wet season. Of the elements investigated, all were above the reported mean on a worldwide basis except for chromium. This indicates that the site is highly contaminated, a fact that was proved by a decrease of elemental concentration between topsoil and subsoil. Nonetheless, the available guidelines seem to be insufficient in assessment of soil contamination for farming as they lack site specific factors like bioavailability of the element, plant type and soil properties that have a great influence on phytotoxicity. These findings recommend a further controlled experiment that could take account of specific factors like bioavailability of trace elements, uptake of various species, presence of other trace elements and soil properties. Such a controlled study would aid in the understanding of bioavailability of trace elements from contaminated soil.

AUTHOR CONTRIBUTIONS

H.O. Nyandika and E. Kitur conceived and designed the experiment. H.O. Nyandika sampled, performed the experiment, analyzed the data, and wrote the paper. J.K. Nzeve revised the draft manuscript. All authors read and approved the final manuscript.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy have been completely observed by the authors.

ABBREVIATIONS

%	Percentage
^0C	Degree centigrade
cm	centimeter
Cr	Chromium
Cu	Copper
eV	electron volt
FWHM	Full width height maximum
ICRAF	International center for research in Agroforestry
m	meter
mg/kg	milligram per kilogram
mm	millimeter
Mn	Manganese
Ni	Nickel
PTE	Potentially toxic elements
PXRF	Portable X-ray fluorescence
XRF	X – ray fluorescence
Zn	Zinc
µA	Microampere
µm	micrometer

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