Soil Concentration of Selected Heavy Metals in Chuka, Nakuru and Thika Municipal Dumpsites

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Abstract

Dumpsite waste pickers face numerous health and safety risk factors one of which is elevated concentration of heavy metals in the soil that could be a source of exposure through dusts. The purpose of this study was to determine the concentration of selected heavy metals (lead, cadmium, chromium and copper) in the top 15 cm of soil in the largest dumpsites in Tharaka Nithi, Nakuru and Kiambu counties namely; Chuka, Nakuru and Thika towns, respectively. The study was non-experimental cross-sectional ecological survey, the sampling design a herringbone pattern with 96 soil samples collected with a stainless-steel auger. Laboratory analysis was done by USEPA Method 3050B and the concentration determined by Atomic Absorption Spectrophotometer at the Department of Mines and Geology Laboratory in Nairobi. F-test was done for differences between dumpsites at a=.05 and comparison made to WHO guidance values. Significant differences between the dumpsites were detected for lead (F=44.555, p=<.001), copper (F=5.897, p=<.01), cadmium (F=4.739, p=.016) and chromium (F=6.223, p=<.01). The largest percentage of samples with concentrations above the WHO guidelines were Kiambu (97%) for lead and Nakuru with 26.7% for chromium, 66.7% for cadmium and 56.7% for copper. Chuka dumpsite had the highest proportion of samples with the lowest concentration of lead and chromium and with the lowest proportion of samples where cadmium was detected. In conclusion, Nakuru and Kiambu dumpsite were highly polluted and were a huge risk factor to the waste pickers. In the short-term, it was recommended that waste pickers should wear adequate health and safety protective equipment while on site and possibly reduce the time at the dumpsite to minimise exposure. In the long-term, waste separation should be done to ensure that heavy metal containing waste do not get to the dumpsites, waste recovery facilities adopted to minimise waste picking at dumpsites and improve recycling, and the dumpsites upgraded to sanitary landfill status.

Keywords: Heavy Metals, Waste Pickers, Waste Management, Dumpsite, Electronic Waste, KIambu, Nakuru, Tharaka Nithi

Introduction

Waste picking is prevalent in the dumpsites in many of the developing in Asia, middle east; African countries and South American Countries. It has been noted that where dumpsites are in use, source waste separation is hardly practiced and for this reason all manner of hazardous waste finds their way into the dumpsite. Consequently, waste pickers in the dumpsites are faced with many health and safety hazards among which is exposure to heavy metals due to the presence of materials such as electronic waste.

Heavy metals are known to be persistent, bioaccumulative and toxic substance present in electronic waste (Lundgren, 2012; Hassan et al., 2016) and hence are a health risk factor upon exposure to living organisms. Especially, children being particularly vulnerable to toxins because they ingest more water, food, and air per unit of body weight; their metabolic pathways are less developed to detoxify and excrete toxins; and any disruption during their growth years can easily disrupt development of their organ, nervous, immune, endocrine and reproductive systems (Cointreau, 2006).

According to Song and Li (2014) the disposal of e-waste is a major environmental problem due to the presence of heavy metal like lead and cadmium that are used in electronic devices batteries, copper in wiring and chromium as an anti-corrosion agent in circuits. In Kenya, there is limited waste separation and e-waste is a common problem in the dumpsites (NEMA, 2014). Consequently, pollution by heavy metals in the dumpsite is a matter of concern not only because of environmental pollution but also due to the fact that waste pickers operate on the dumpsite where exposure to the heavy metals by dust or fumes is likely to be higher than for the general population.

Heavy metals are common in electronic waste for instance copper is said to make up 19% of a mobile phone (Peace, 2009) while between 1994 and 2003 computers containing approximately 718,000 tonnes of lead and 1,363 tonnes of cadmium were at their end of life (Lundgren, 2012). Further, Lundgren states that a Cathode Ray Tube in older computers and television sets contain 2–3 kilograms of lead and about 1kg in newer models. Human exposure to these heavy metals is through inhalation, dust ingestion, dermal exposure and oral intake (Lundgren, 2012). In Africa, the number of lead-based batteries continue to go up as they are relied on in imported used vehicles, off-grid solar installation, uninterrupted power supply systems among others and hence the risk of the heavy metal getting to the environment will continue to increase (Gottesfeld et al, 2018).

Copper is described as a hazardous substance upon ingestion, inhalation or eye contact and in mammals its toxicity can result to inhibition of intracellular enzymes, oxidative stress and mitochondrial swelling. Whereas chromium (III) is recognised as an essential trace element Chromium (VI) compounds are toxic and carcinogenic. The carcinogenic effect is expressed in the respiratory system with the bronchial tree being the major target organ (WHO, 2000). Exposure to Cadmium has been associated with kidney and bone damage with the metal being also identified as a potential human carcinogen, causing lung cancer. (WHO, 2007)

Lead (Pb) has been reported as the number two most hazardous substance after arsenic, based on the frequency of occurrence, toxicity and the potential for human exposure in the United States with long-term exposure leading to memory deterioration, prolonged reaction times and reduced ability to understand (Ding et al., 2013). Lead poisoning has also been reported to cause anaemia, encephalopathy, arthritis, and muscular depression (Kondo et al., 2013). WHO (2007), identifies lead as a well-known neurotoxin with

exposure resulting to neuro-behavioural effects on foetuses, infants and children, and elevated blood pressure in adults.

The USEPA hazard concentration level for lead in the soil for residential use is 400mg/kg (Gottesfeld et al, 2018). In Finland, the health risk level for soil lead concentration is 200mg/kg (Tóth et al 2016) which is the same for Tanzania (Kibassa et al, 2013). The WHO safe soil concentration limit for lead is 100mg/kg whereas the limit by Canadian Environmental Quality Guidelines (CEQG) for both agricultural and residential uses is 70mg/kg for agricultural and 140mg/kg for residential land (Bongoua-Devisme *et al*, 2018). The United States Centre for Disease Control and Prevention reports that an increase of 1000mg/kg of soil concentration of lead would result to a rise of 3-7 µg/dL in blood lead concentration (Gottesfeld et al, 2018).

USEPA requires clean-up of soils with chromium concentration of at least 230mg/kg while limits considered safe for various uses is 100mg/kg in Tanzania (Kibassa et al., 2013), 70mg/kg by WHO and 64mg/kg by CEQG for both agricultural and residential uses (Bongoua-Devisme et al, 2018). Concerning copper, the safe soil limit in Tanzania is 200mg/kg, the WHO limit 100mg/kg and is 63mg/kg by CEQG for both agricultural and residential uses (Bongoua-Devisme, 2018). The USEPA guidance level for sites polluted Cadmium and requiring clean-up is 70mg/kg soil. On the other hand, the lower guideline value for ecological risk in Finland is 10mg/kg (Tóth et al., 2016) and in Tanzania (Kibassa et al., 2013) the safe soil concentration is 1 mg/kg. WHO guideline for cadmium is 0.35mg/kg and by CEQG it is 1.4 mg/kg and 10mg/kg for agricultural and residential land, respectively (Bongoua-Devisme, 2018).

In this regard, the purpose of the present study was to determine the concentration of lead, copper, cadmium and chromium in the top 15 cm of soil which could easily become airborne and a health risk factor to the waste pickers in the named dumpsites.

Materials and Methods

The Physical Location, Climate and Economic Activities of the Study Area

The study area comprised the counties of Nakuru, Kiambu and Tharaka Nithi (Figure 1). The largest dumpsite in each of the three counties was selected for the study and were located in Chuka, Thika and Nakuru Towns respectively.

Figure 1: Position of Nakuru, Kiambu and Tharaka Nithi counties in Kenya

Source: Maps of Kenya (2018)

Nakuru County covers an area of 7,495.1 km² and lies within longitude 35^0 28′ and 35^0 36′ East and latitude 0^0 13′ and 1^0 10′ South (RoK, 2013a). The temperatures range between 10^0C during the cold months (July and August) to 20^0C during the hot months (January to March) and receives between 700mm and 1200mm pa. The county's population is

about 1.6 million with agriculture and tourism being major economic activities (County Government of Nakuru, 2014). Nakuru town, with a population of 307, 990, is the largest town in the county and fourth largest in Kenya. It is located 165 km northwest of Nairobi, the capital city of Kenya (County Government of Nakuru, 2014; KNBS, 2009). The main dumpsite, commonly known as Gioto and established in 1975 is situated about 3km to the northwest of Nakuru town, along Nakuru-Kabarak road on the slopes of Menengai crater and on a higher elevation than Nakuru town. Administratively it is located on London ward in Nakuru subcounty, about 25 acres (10ha)

Tharaka Nithi County has a total area of 2661.1 km^2 and a population of 365,330. It lies within latitude 00^0 07′ and 00^0 26′ South and longitudes 37^0 19′ and 37^0 46′ East and the altitude ranges from 5200m on top of Mt Kenya to 500m in the lowlands. The high-altitude areas experience reliable rainfall while middle and lower regions receive medium and unreliable rainfall, respectively. The key economic activities revolve around crop farming (Tharaka Nithi County Strategic Plan 2012-2017, RoK, 2013b). Chuka dumpsite is located less than 2km from Chuka town in Karingani ward in Meru South subcounty. It is quite small, occupying about one acre (0.41ha) for the main dumpsite area and a peripheral area of 0.71 acres where waste could overflow to but no vehicle could access. It is along the highway of Chuka-Meru and was accessed through a murram road that branched off from the highway. The dumpsite is located on a steep ground that was elongated along the murram road.

Kiambu County is located in the central region of Kenya and covers a total area of 2,543.5 Km^2. It lies between latitudes 0^0 25′ and 0^0 20′ South of the Equator and Longitude 36^0 31′ and 37^0 15′ East (County Government of Kiambu, 2013). The county population according to the 2009 census was 1,673,785 which was highly urbanised with 61% of the population being urban and 39% being rural. Thika town is the largest town in Kiambu county with a population of 139,853 (KNBS, 2009). The town is about 40km away from Nairobi city.

It is one of the major industrial towns in Kenya (County Government of Kiambu, 2013). Kiambu municipal dumpsite, commonly called Kang'oki is located on the lower side of Thika town about 7 km from the central business district. It is administratively in the Kamenu ward in Thika subcounty. Of the three dumpsites, it is the most extensive occupying an area of about 192 acres (78 hectares).

Study Design

The study was non-experimental and the design a cross-sectional ecological survey. A key concept of cross-sectional survey is that data is collected once from the subject/area which is what was done in the present study.

Sample Size

Nathanail et al, (2002) formula for calculating the number of sampling points was used. According to this formula:

$N = kA/a$

Where:

k= shape constant, whereby: k = 1.08 (for circular hotspot), 1.25 (plume shaped), 1.8 (Elliptical) and 1.5 where there is no information on hotspot shape.

In this study, k = 1.5 as there is no information on hotspot shape.

N=is the number of sampling points,

A=total dumpsite area,

a = hotspot area

The study was based on assumption of one hotspot of 5% of the total dumpsite area. This is based on the fact that the distribution of the pollutants within the sampling area was assumed to be generally uniform due to limited or no source separation of waste in most of Kenya (NEMA, 2014). Consequently, in this study each dumpsite was regarded as one continuous hotspot and hence an area of 5% within the dumpsite is not likely to be missed.

According to this formula, with a 5% hotspot area and with the shape constant (k) taken as 1.5, a total of 30 sampling points was sufficient for each dumpsite, irrespective of the differences in dumpsite area of the three sites. This gave the total sampling points of all the dumpsites to 90.

Sampling Procedure

Sampling was a non-targeted approach which is non-biased and able to eliminate hotspots of a given size at a given confidence level (95% in this study), allow for determination of mean concentration and standard deviation and the determination of spatial distribution of the pollutants (Nathanail et al, 2002). Within this approach, the herringbone sampling pattern was used, which is systematic, stratified, unaligned and easy to set out on site. In this pattern, a square grid is drawn and in the first line, every other point is offset by a quarter of a unit, in the second line every point is offset by a quarter of a unit with regard to the first, and the third and fourth line mirror the first and second lines and subsequent lines follow the same pattern (Figure 2). According to the Department of Environment (DOE) a good spatial sampling design should meet four conditions: stratified, each stratum to carry one sampling point, systematic and sampling points not to be aligned. DOE further observes that herringbone approach satisfies all these conditions while simple random sampling satisfies only one condition (nonalignment of sampling points) whereas grid sampling does not satisfy the condition on nonalignment of sampling points.

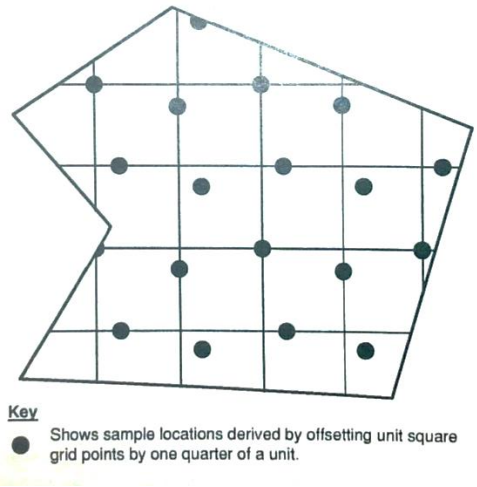

Figure 2: Setting Out a Herringbone Design (Nathanial et al., 2002)

Field Data Collection

Before data collection an application was made to the National Commission for Science and Technology and a permit was given. The permit was presented to the director of environment in each of the three counties before proceeding to the field for data collection. Field collection of samples involved some activities done before going to the field for instance labelling of collection containers. The soil samples were collected at 0-15 cm depth by use of a stainless-steel soil auger. This depth is deemed appropriate where the focus is to human health with regard to direct ingestion and inhalation (Nathanial et al., 2002). The container for soil collection was sturdy polythene bags which was used for transportation and storage. After collection from one sampling point, the soil attached to the surface of the auger was carefully scraped with a wooden device to avoid contaminating the soil from the next sampling point. The coordinates of each sampling site were recorded during collection.

Laboratory Analysis for Heavy Metals

Laboratory analysis for heavy metals was carried out in Department of Mines and Geology Laboratory in Nairobi and concentration determined by Atomic Absorption

Spectrophotometer (AAS). Determination of heavy metals was carried out as per United States Environmental Protection Agency Method 3050B (USEPA, 1996; Dean, 2007). In the laboratory, the soil samples were air dried by opening up the polythene bag and allowing it to dry to constant weight under the ambient room temperature. Each sample was homogenised using a mortar and pestle after which a 5mm sieve was used to get the fine soil appropriate for analysis. The soils were then digested with strong Nitric Acids. According to USEPA (1996) strong acids dissolve almost all elements that could become biologically available. After digestion and cooling, filtering was done and digestate transferred into 100ml volumetric flasks where dilution is done to 100ml for the analysis. The concentrations were then determined as described by Dean 2007.

Data Analysis

Statistical Package for Social Science (SPSS version 20) was used for data analysis. Concentration of heavy metal from the study was compared across the three dumpsites by F-test whereas qualitative comparison was done with secondary sources and reference values from WHO.

Results and Discussions

Lead was detected in all the samples tested (Table 1). Most of the samples from Chuka (72.7%) had concentrations less than 70ppm, 97% had concentrations below 200ppm and 3% had concentrations higher than 400ppm. The mean concentration in Chuka was 89.27±35.77ppm with a minimum of 7.43 and a maximum of 1214.91ppm. In Kiambu, only 3% of the samples had less than 70ppm concentration, 54.5% had concentrations of 200-400 and 42.4% had concentrations above 400ppm. The mean concentration in Kiambu was 397.80±22.47ppm with a minimum of 50.76 and a maximum of 680.67ppm. In Nakuru, 36.7% of the samples had less than 70ppm of concentration, 23.3% with a concentration of 100-400 and 23.3% with greater than 400ppm. The mean concentration

in Nakuru was 292.33±66.51ppm with a minimum of 27.34 and a maximum of 1479.3 ppm. Significant differences were determined between all sites.

Table 1: Concentration of Lead in the Dumpsites

Site	Concentration (PPM)*	Frequency distribution		Descriptive					
		F	%	N	Min	Max	Mean	Std Error	Std. Dev.
Chuka	≤ 70	24	72.7	33	7.43	1214.91	89.27[a]	35.77	205.47
	70 - 100	4	12.1						
	100 - 200	4	12.1						
	>400	1	3.0						
	Total	33	100.0						
Kiambu	≤ 70	1	3.0	33	50.76	680.67	397.80[b]	22.47	129.10
	200-400	18	54.5						
	>400	14	42.4						
	Total	33	100.0						
Nakuru	≤ 70	11	36.7	30	27.34	1479.30	292.33[c]	66.51	364.26
	70 - 100	5	16.7						
	100 - 200	1	3.3						
	200-400	6	20.0						
	>400	7	23.3						
	Total	30	100.0						

*categories based on maximum allowed limits by various authorities; [a,b,c] means with different superscripts are significantly different (F-test).

The USEPA hazard concentration level for lead in the soil for residential use is 400ppm (Gottesfeld *et al* 2018) with sites above this concentration requiring clean up. From the result, each of the dumpsite had samples that had exceeded this level which were > 20% in Nakuru, > 40% in Kiambu and 3% in Chuka. In Finland, the health risk level for soil lead concentration is 200mg/kg Tóth et al., 2016) which is the same for Tanzania (Kibassa et al., 2013). The WHO safe soil concentration limit for lead is 100ppm whereas the limit by CEQG for both agricultural and residential uses is 70ppm for agricultural and 140ppm residential land (Bongoua-Devisme et al, 2018). Ninety-seven percent of samples from Kiambu, 46.6% in Nakuru, 15.1% in Chuka and had exceeded the WHO guideline.

Results from a study of lead concentrations in areas around lead recycling plants in Kenya Gottesfel et al, (2018) indicated that out of 10 samples four had concentration between 400-600ppm, three samples between 600 and 1000ppm, two samples between 1000 and 2600 and two samples less than 50ppm. The mean concentration of lead in municipal dumpsite in Calabar Metropolis, Nigeria was reported to be 1489.1mg/kg (Ediene and Umoetok, 2017) which is 3.5 times the concentration in Kiambu dumpsite. In Manila dumpsite, Philippines the mean lead concentration was reported as 15.47ppm whereas in Uyo, Nigeria it was 43.28ppm for the municipal dumpsite and 18.57ppm for a rural dumpsite (Ebong et al, 2008). In Bonoua Dumpsite, Ivory Coast the concentration was 118ppm (Bongoua-Devisme et al, 2018).

This shows that the levels of lead are very high and it is a real hazard in the dumpsites. This especially so in Kiambu where almost all samples were above the WHO limit. On the basis of these results alone, the dumpsites are very unsafe for the waste pickers to work in. This might necessitate the use of breathing masks at all times to minimise the risk.

Copper was detected in all samples from Kiambu, Nakuru dumpsites and in most samples from Chuka at 81.8% (Table 2). Most of the samples in Chuka (63.6%) and Kiambu (87.9%) had concentrations of up to 100ppm whereas in Nakuru most of the samples had more than 100ppm. The highest mean concentration of copper was recorded in Nakuru (227.86±52.12) followed by Chuka (193.37±110.91) and Kiambu (113.23±52.31). there were significant differences between Chuka and Nakuru and between Nakuru and Kiambu but none between Chuka and Kiambu.

Table 2: Copper Concentration in the Dumpsites

Site	Concentration (mg/kg)*	Frequency distribution		Descriptive					
		F	%	N	Min	Max	Mean	Std Error	Std. Dev.
Chuka	≤ 100	21	63.6	27	1.40	3032.66	193.37 [a]	110.91	576.28
	100-200	2	6.1						
	>200	4	12.1						
	Not detected	6	18.2						
	Total	33	100.0						
Kiambu	≤ 100	29	87.9	33	5.93	1279.34	113.23 [a]	52.31	300.52
	100-200	2	6.1						

	>200	2	6.1							
	Total	33	100.0							
Nakuru	≤ 100	13	43.3	30	2.07	1245.83	227.86 [b]	52.12	285.48	
	100-200	8	26.7							
	>200	9	30.0							
	Total	30	100.0							

*categories based on maximum allowed limits; [a,b,c] means with different superscripts are significantly different (F-test).

With regard to copper the maximum soil concentration deemed safe in Tanzania is 200mg/kg. The allowed soil concentration limit of copper by WHO is 100ppm and 63ppm by CEQG for both agricultural and residential uses (Bongoua-Devisme et al, 2018). The percentage of samples that had exceeded 200ppm was 12.1% in Chuka, 6.1% in Kiambu and 30% in Nakuru. Further, the percentage of samples that exceeded the WHO guidelines was 57% in Nakuru, 3% in Chuka and 12% in Kiambu. In Uyu, Nigeria copper concentration were reported as 33.7ppm for the municipal dumpsite and 56.33ppm for a rural dumpsite (Ebong et al, 2008). In Bonoua dumpsite, Ivory Coast copper concentration were reported as 9.5ppm (Bongoua-Devisme et al 2018) and 26.08ppm while in Calabar Metropolis, Nigeria municipal dumpsite (Ediene and Umoetok, 2017).

Copper pollution appear to be quite widespread in Nakuru as compared to the other two sites and is also quite high in comparison to the studies elsewhere. Exposure to Copper is upon ingestion, inhalation or eye contact. In this regard, use of protective equipment would be necessary to minimise risk.

In a majority of samples from Chuka (91%) and Kiambu (66.7%) cadmium was not detected whereas in Nakuru it was detected for a majority (66.7%) of the samples (Table 9; Appendix 3). In all the samples where detection was positive, the concentration was above 1mg/kg. The highest concentration was recorded for Nakuru (4.77±.48ppm) with

a minimum of 1.67 and a maximum of 9.06 ppm. Chuka had the lowest mean concentration of (3.41±0.87ppm) with a minimum of 1.73 and a maximum of 4.62ppm. Significant differences were detected only between Nakuru and Kiambu only.

Table 3: Cadmium Concentration

Site	Concentration (PPM)*	Frequency distribution		Descriptive					
		F	%	N	Min	Max	Mean	Std Error	Std. Dev.
Chuka	1-5	3	9.1	3	1.73	4.62	3.41[ab]	.87	1.50
	Undetected	30	90.9						
	Total	33	100.0						
Kiambu	1-5	10	30.3	11	1.08	12.20	2.99[a]	.97	3.21
	10-15	1	3.0						
	Undetected	22	66.7						
	Total	33	100.0						
Nakuru	1-5	11	36.7	20	1.67	9.06	4.77[b]	.48	2.13
	5-10	9	30.0						
	Undetected	10	33.3						
	Total	30	100.0						

*categories based on maximum allowed limits; [a,b,c] means with different superscripts are significantly different.

The guidance level for Cadmium is 70mg/kg soil concentration by USEPA for sites requiring clean up. On the other hand, the lower guideline value for ecological risk in Finland is 10mg/kg (Tóth et al., 2016) whereas in Tanzania (Kibassa et al., 2013) the safe soil concentration is 1 mg/kg. WHO guideline is 0.35ppm and by CEQG it is 1.4 ppm and 10ppm for agricultural and residential land, respectively (Bongoua-Devisme et al, 2018).

Compared to the WHO maximum allowed limit, all samples in the study that tested positive had a higher concentration. However, all the samples had concentrations that were lower than the minimum required by USEPA for clean-up.

In Uyo Nigeria, the soil concentration in the municipal dumpsite was 9.25 and 14.1 for the rural dumpsite (Ebong *et al* 2008). Bongoua-Devisme *et al* (2018) reported quite a high concentration of 81ppm in Bonoua Dumpsite, Ivory coast and 1.04ppm was reported for Calabar Metropolis, Nigeria (Ediene and Umoetok, 2017).

Cadmium is a pollutant of concern in Nakuru having been detected in two thirds of the samples. Since cadmium is highly toxic being associate with kidney ad bone damage and a potential carcinogen (WHO, 2007) this implies that the waste pickers in Nakuru are highly exposed this pollutant. This might call for efforts to minimise exposure through dust ingestion.

Chromium was detected in 100% of all samples except for Kiambu where it was detected for 63.6% of the samples (Table 5). Most of the samples had concentration of up to 70ppm. The highest mean concentration was recorded in Nakuru of 87.65±23.12 with a minimum of 2.8 and a maximum of 573.47ppm followed by Kiambu (209.13±41.91ppm) and the lowest in Chuka (28.54±3.62ppm). Significant differences were determined between Chuka and Nakuru as well as between Nakuru and Kiambu.

Table 4: Chromium Concentration

Site	Concentration (PPM)	Frequency distribution		Descriptive					
		F	%	N	Min	Max	Mean	Std Error	Std. Dev.
Chuka	≤ 70	31	93.9	33	7.69	112.47	28.54[a]	3.62	20.78
	70 - 100	1	3.0						
	100 - 200	1	3.0						
	Total	33	100.0						
Kiambu	≤ 70	17	51.5	21	5.53	209.13	41.91[a]	12.24	56.11
	70 - 100	1	3.0						
	100 - 200	2	6.1						
	> 200	1	3.0						
	Undetected	12	36.4						
	Total	33	100.0						
Nakuru	≤ 70	22	73.3	30	2.80	573.47	87.65[b]	23.12	126.62
	70 - 100	2	6.7						
	100 - 200	3	10.0						
	> 200	3	10.0						
	Total	30	100.0						

[a, b] Significant differences exist between means that do not share same superscript

Soil concentration of Chromium of 230ppm require clean up as per USEPA. In Nakuru 3 samples had more than this guideline level with concentrations of between 300 and 600ppm whereas in the other dumpsites the levels were less than 230ppm. Maximum soil concentration for chromium considered safe for various uses is 100ppm in Tanzania (Kibassa et al., 2013), 70ppm by WHO and 64ppm by CEQG for both agricultural and residential uses (Bongoua-Devisme et al 2018). The number of samples above the WHO guidelines were zero in Chuka, four in Kiambu (12.1%) and eight in Nakuru (26.7%).

When compared to similar places, mean concentration of chromium in Bonoua dumpsite in Ivory Coast was 130.1ppm (Bongoua-Devisme et al, 2018). In Calabar Metropolis, Nigeria the mean concentration in the municipal dumpsite was reported as 120.28 ppm (Ediene and Umoetok, 2017).

Chromium pollution was less widespread than lead. Chromium toxicity depends on the presence of chromium VI whereas chromium III is not toxic. Due to this fact the overall risk may be less since the toxic chromium VI is only a portion of the total chromium in the soil. Nevertheless, chromium toxicity is associated with cancer of the respiratory system and as such exposure would need to be minimised.

Conclusion and Recommendation

In conclusion, Nakuru and Kiambu dumpsite were highly polluted and were a huge risk factor to the waste pickers. In the short-term, it is recommended that waste pickers should wear adequate health and safety protective equipment while on site and possibly reduce the time at the dumpsite to minimise exposure. In the long-term, waste separation should be done to ensure that heavy metal containing waste do not get to the dumpsites, waste recovery facilities adopted to minimise waste picking at dumpsites and improve recycling and, the dumpsites upgraded to sanitary landfill status.

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