



Heavy Metal Concentrations in Vegetables Cultivated and Sold in Machakos Municipality, Kenya

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ABSTRACT: Heavy metal contamination of vegetables is a key aspect of food quality assurance since vegetables form a substantial proportion of the daily human diet. Health risks in urban populations due to exposure to heavy metals are on the increase because of the consumption of vegetables irrigated with wastewater. This study analyzed the concentration of Cd, Cu, Pb, Zn and Cr in spinach and kales grown using contaminated water of the Mitheu urban stream and those sold within Machakos municipality. Vegetable samples were collected once per month for a period of four months starting from June to September 2019. The mean heavy metal concentrations obtained were 0.013 – 3.19 mg/kg, 0.468 – 1.706 mg/kg, 0.02 – 0.368 mg/kg, 5.78 – 26.7 mg/kg, and 0.104 – 14.0 mg/kg for Cd, Cu, Pb, Zn and Cr respectively in kale samples from the different sampling sites. The heavy metal mean concentrations in spinach were 0.055 – 0.575 mg/kg, 3.79 – 5.55 mg/kg, 0.098 – 1.49 mg/kg, 8.32 – 20.7 mg/kg and 0.368 – 4.43 mg/kg for Cd, Cu, Pb, Zn and Cr respectively. The mean concentrations of Cd, Pb, Zn and Cr in both spinach and kales in some of the sampling sites were above WHO permissible levels for heavy metals in vegetables for human consumption. However, the mean concentration of Cu was below WHO recommended levels. Consumption of these vegetables therefore poses a health risk to the consumers. There is need to create public awareness on the dangers of consuming contaminated vegetables. Additionally, measures to curb heavy metal pollution in Mitheu stream should be taken by the County Government of Machakos.

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Vegetables are an important source of vitamins, minerals, and fiber necessary for human nutrition and health (Wong *et al.*, 2019; Bett *et al.*, 2019). The popularity of leafy vegetable farming in urban areas of developing countries will continue to increase due to the ready market provided by the ever-increasing population (Kacholi, 2018; Kombe, 2005; Balkhair and Ashraf, 2016). However, consumption of vegetables in the urban areas has increasingly become a concern to both consumers and city authorities due to possible contamination occasioned by use of contaminated urban streams for irrigation. Studies indicate that urban effluent contains high concentration of heavy metals, which are easily taken up by vegetables thus posing a health risk to consumers (Hussain *et al.*, 2019; Shaheen *et al.*, 2019). Industrial processes such as municipal sewage and solid waste disposal, vehicular traffic, pesticide use, and inappropriate use of fertilizers contribute to increased concentration of heavy metals in the environment (Bi *et al.*, 2018).

Food contaminated by heavy metals affects human wellbeing and can drain a significant portion of the fundamental supplements in the body (Khan *et al.*, 2008; Ray and Kanti Ray, 2009).

Heavy metals are responsible for diminishing immunological resistances, degradation of intrauterine development, malfunctioning psychological faculties, disabilities associated with malnutrition and high predominance of upper gastrointestinal cancer (Arora *et al.*, 2008). Several other studies also show the potential risk of accumulation of heavy metals in plants to human health (Chauhan and Chauhan, 2014; Balkhair and Ashraf, 2016; Alghobar and Suresha, 2017). Heavy metals such as Cd and Pb have been shown to be carcinogenic (Jaishankar *et al.*, 2014). Other metals like Cu and Zn are basic supplements for human wellbeing yet can be toxic in high concentrations (Harmanescu *et al.*, 2011; Shaheen *et al.*, 2016; Ikenaka *et al.*, 2014).

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Human exposure to heavy metals is thus a public health concern all over the world and has attracted the attention of researchers, health and nutrition officers (Adedokun *et al.*, 2016). The permissible and hence safe limits of Cd, Cu, Pb, Zn and Cr by the World Health Organization (WHO) are 0.2, 10, 0.2, 5.0, and 2.3 mg/L respectively (Stan, 2009). However, their potential toxicity, persistent nature and bioaccumulation behavior necessitates a routine analysis of food items to ensure they are within permissible limits. This study focused to determine the levels of Cd, Cu, Pb, Zn and Cr in spinach and kales grown using water from Mitheu urban stream in Machakos municipality and those sold in the market and supermarkets in Machakos town. The results will be useful in raising awareness of potential health hazards of these vegetables and in highlighting the need for the County government to invest in sustainable effluent management and occupational safety and health.

MATERIALS AND METHODS

Study Area and Sampling Sites: This study was carried out in Machakos municipality in Kenya. The vegetable farms are located along Mitheu stream as indicated in figure 1. Much of the domestic and municipal effluent generated within the town is drained into Mitheu stream. As would be expected, much of the vegetable grown along this stream is sold from the municipal open-air markets. Four vegetable sampling sites were selected along Mitheu stream and three market outlets within Machakos town (i.e the main open-air market (OAM) and two selected supermarkets (SPM 1 and SPM 2). The open-air market and the supermarkets are retail markets for different types of food items. Sampling sites along the stream were site A, site B, site C and site D. Site D was farms upstream of Mitheu stream where the Machakos town wastewater sewer lines were vandalized releasing raw sewage directly into Mitheu stream. Site C was at farms adjacent to the wastewater treatment plant, site B was farms just downstream of the treatment plant while farms further downstream was site A. Irrigation of vegetables using wastewater is actively taking place at the four sampling points along the stream.

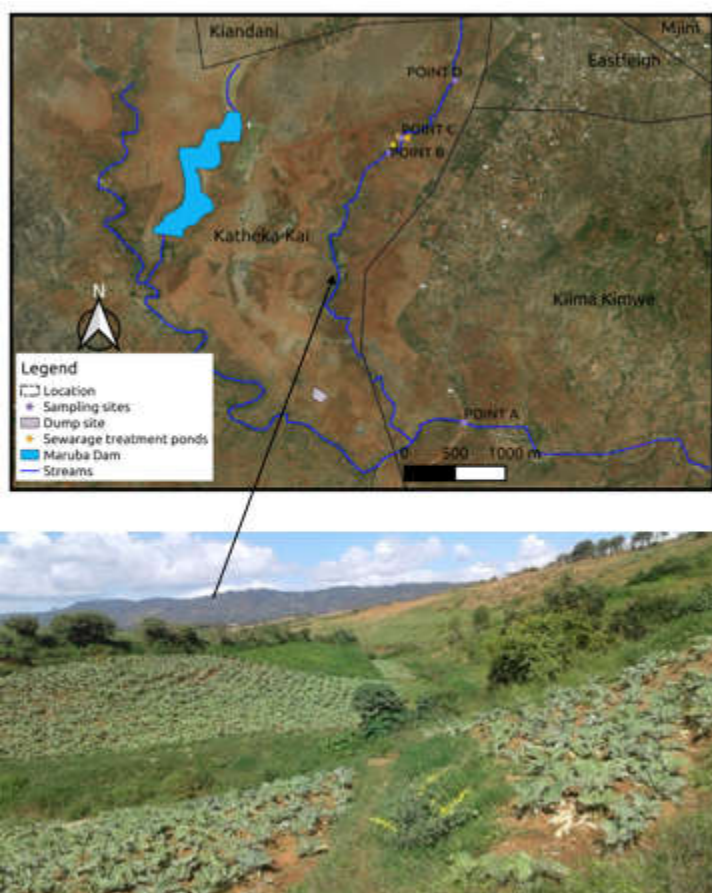


Fig 1: Map of the study area showing sampling sites and vegetable farms

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Sampling: Vegetable samples of spinach (*Spinaciaoleracea*) and kales were randomly bought from the farmers farming in the selected sites along the urban stream and from the selected market sites. The samples were put in clean polyethylene bags, well-labeled to indicate the site and date of sampling and transported to Kenya Plant Health Services (KEPHIS) Chemistry and Analytical certified laboratory, Nairobi for heavy metals analysis. Sampling was done once each month for a period of four months from June 2019 to September 2019.

Sample Analysis: The vegetable samples were oven-dried at 100°C then ground into powdered form. Portions of 1.5g of vegetable powder sample were digested in 15 mL tri acid mixture (65% HNO₃, 70% HClO₄, 34.37% HCl, 5:1:1 ratio) at 150 °C in a microwave oven until a transparent solution appeared. The digests were then passed through a pre-washed filter and 15 mL of the filtrate made up to 250 mL (Mohsin *et al.*, 2019). The filtrate of vegetables was then analyzed for Cd, Pb, Cr, Zn, and Cu concentrations using inductively coupled plasma mass spectrometer (ICP-MS).

Statistical Analysis: The data obtained was analyzed using Minitab Statistical software, version 19. The significant difference ($p \leq 0.05$) of heavy metal concentrations in vegetables among the different sampling sites was tested using one way-analysis of variance (ANOVA). The heavy metal concentrations obtained were compared with WHO limits to inform

the suitability of the vegetables for human consumption.

RESULTS AND DISCUSSION

Heavy Metal Concentration in Spinach: Cadmium: Concentration of Cd in spinach samples from the different market sampling sites ranged between 0.055 ± 0.08 mg/kg and 0.172 ± 0.18 mg/kg. All Cd values in spinach were within 0.2 mg/kg WHO permissible levels (Stan, 2009). The level of Cd in spinach in the farming sites varied between 0.575 ± 1.01 mg/kg and 0.013 ± 0.02 mg/kg (Table 1). Spinach at site A exceeded WHO set limit for Cd in leafy vegetables while at site B, C, and D were within WHO safe limits. This is an indication that spinach at site A are likely to have adverse health implications concerning Cd. Cadmium in vegetables is transferred to the human body by ingestion and subsequently distributed by the circulation system to many body organs such as the liver, kidney, lungs and finally bringing harm to these organs (Shi *et al.*, 2020). The concentration of Cd recorded in this study is lower than the concentration of Cd in spinach ($3.89 \pm 0.17 - 4.13 \pm 0.14$ mg/kg) recorded in a previous study of spinach vegetables in Saudi Arabian markets (Ali and Al-Qahtani, 2012). Lower values of Cd concentration in vegetables (0.0018 – 3.6580 mg/kg) were also reported in a study carried out in polluted areas in China (Shi *et al.*, 2020). Values of Cd recorded by Heshmati *et al.*, 2020 for a study in western Iran agree with the levels recorded in this study. (Khan *et al.*, 2019) also reported levels of Cd (0.203 – 1.575 mg/kg) that are comparable to Cd values obtained in this study.

Table 1: Mean \pm standard deviation of heavy metal concentration (mg/kg) in spinach and WHO limits

Sampling Site	N	Mean \pm Std Dev (mg/Kg)				
		Cadmium (Cd)	Copper (Cu)	Lead (Pb)	Zinc (Zn)	Chromium (Cr)
SPM 1	4	0.172 \pm 0.18	4.70 \pm 4.41	0.439 \pm 0.51	20.7 \pm 24.70	4.43 \pm 9.72
SPM 2	4	0.055 \pm 0.08	4.93 \pm 2.97	0.098 \pm 0.22	12.14 \pm 11.31	1.80 \pm 3.87
OAM	4	0.106 \pm 0.09	3.923 \pm 2.16	0.867 \pm 1.16	17.94 \pm 15.49	4.24 \pm 8.90
Site A	4	0.575 \pm 1.01	7.56 \pm 6.58	0.367 \pm 0.30	8.32 \pm 10.50	1.24 \pm 1.47
Site B	4	0.069 \pm 0.14	3.79 \pm 2.02	0.439 \pm 0.63	17.94 \pm 14.88	0.368 \pm 0.59
Site C	4	0.013 \pm 0.03	4.50 \pm 2.16	0.243 \pm 0.19	8.99 \pm 7.57	0.497 \pm 0.87
Site D	4	0.127 \pm 0.23	5.55 \pm 4.05	1.49 \pm 2.68	12.42 \pm 6.78	3.49 \pm 4.60
WHO Set		0.2	10.0	0.3	5.0	2.3
p-value		0.469	0.229	0.773	0.923	0.908

Copper: The results of copper concentration in spinach vegetables in the different sampling sites are presented in Table 1. The mean concentration of Cu in spinach for the market sites ranged between 3.923 ± 2.16 mg/kg and 4.93 ± 2.97 mg/kg. Mitheu urban stream sites recorded levels of Cu ranging from 3.79 ± 2.02 mg/kg to 7.56 ± 6.58 mg/kg. The values of Cu in spinach from all the market sites and all the farm sites were within WHO permissible limits hence the spinach grown and sold in the market sites had no health risk exposure to the consumers. Spinach

showed the highest concentration of Cu at site A. Continued irrigation over a long period could further have laced the soils with Cu contributing to the high Cu content in spinach grown downstream. The presence of copper in the vegetables could be attributed to sewage used in irrigating the vegetables, fertilizers and pesticides applied in the growing of the vegetables and some Cu naturally occurring in the soil in form of minerals. Values obtained in this study are similar to values obtained in previous studies; (2.39 – 10.19 mg/kg) in Lagos metropolis, Nigeria for

vegetables in different markets (Adedokun *et al.*, 2016) and 0.041 – 0.829 mg/kg for vegetables in Tehran supermarkets (Alimohammadi *et al.*, 2018). Sayo *et al.*, 2020 reported similar concentrations of Cu in spinach vegetables (1.372 ± 0.180 - 4.084 ± 0.353 mg/kg) irrigated with wastewater in Embu, Kenya. Results in this study are much higher than those recorded (0.81-0.98 mg/kg) in Sahiwal, Pakistan (Mohsin *et al.*, 2019).

Lead: The concentration of lead in spinach ranged from 0.098 ± 0.22 mg/kg to 0.867 ± 1.16 mg/kg for the market sites. The level of Pb in spinach from SPM 1 and the open-air market exceeded WHO acceptable limits while Pb in spinach from SPM 2 was within WHO set limit. Concentration of lead in spinach grown along the urban stream varied between 0.243 ± 0.19 mg/kg and 1.49 ± 2.68 mg/kg. The highest concentration of Pb in spinach was at site D and the lowest Pb concentration at site C. Based on these findings it can be stated that spinach from SPM 1 and the open-air market had hazardous health implications to the consumers. The level of Pb in spinach from sites A, B and D all exceeded WHO acceptable limit thus the spinach from those sampling points were not fit for human consumption. This indicated that irrigation farming of spinach along Mitheu stream produced heavily contaminated vegetables unfit for human consumption. Excess intake of Pb has been associated with cardiovascular, kidney, nervous and bone diseases (Shaheen *et al.*, 2016; Chauhan and Chauhan, 2014; Stan, 2009). Pb in the vegetables could be emanating from different sources such as use of wastewater to irrigate the vegetables, petroleum products and automobile emissions. A study on heavy metal concentration in vegetables in the local market of Jordan recorded similar levels (0.072-0.289 mg/kg) of Pb in spinach (Osaili *et al.*, 2016). Comparable Pb values (0.063 – 0.75 mg/kg) were also reported for spinach vegetables grown in Pakistan (Mohsin *et al.*, 2019). On the contrary, lower Pb values (0.022 – 0.04 mg/kg) were reported in a study carried out in western Iran which were within WHO recommended levels. Results obtained in this study are higher than those recorded by Sayo *et al.*, 2020 for spinach (0.02 – 0.168 mg/kg) irrigated with wastewater in Embu, Kenya.

Zinc: Zn concentration in spinach ranged from 12.14 ± 11.31 mg/kg to 20.7 ± 24.7 mg/kg from the market sites. On the other hand, the levels of Zn in spinach for the different sampling sites along Mitheu stream were 8.32 mg/kg, 17.94 mg/kg, 8.99 mg/kg and 12.42 mg/kg. Concentration of Zn among Mitheu stream sampling sites decreased as; site B > site D > site C > site A. Concentration of Zn in spinach from the market sites and those from Mitheu stream sites

exceeded WHO safe limit and thus spinach from these sites were likely to have harmful health effects occasioned by Zn poisoning. Zinc is an essential nutrient for body growth and development when used in the recommended proportions. Excessive intake of zinc as determined in this study could lead to stomach cramps, nausea, vomiting and diarrhea (Saskatchewan, 2007; Wei *et al.*, 2019). The presence of Zn in the vegetables could be associated with the use of wastewater for irrigation, contaminated soil and fertilizers and pesticides used in vegetable growing. Results in this study indicated lower zinc levels when compared with those recorded in a previous study (23.8 – 89.8 mg/kg) carried out in Maun market, Botswana (Bati *et al.*, 2016). Lower values of Zn (3.77 – 16.3 mg/kg) than those obtained in this study were reported in a previous study in Banat County, Romania (Harmanescu *et al.*, 2011). Higher Zn concentrations in spinach grown 2.31 - 9.4 mg/kg and 1.141 – 3.57 mg/kg were also reported by Mohsin *et al.*, (2019) and Sayo *et al.*, (2020) respectively.

Chromium: Spinach vegetables from the market sites showed varying Cr concentrations of 1.80 ± 3.87 mg/kg to 4.43 ± 9.72 mg/kg. This study revealed that spinach from SPM 1 and OAM had accumulated Cr level higher than the WHO permissible level. Cr levels in spinach grown along the Mitheu urban stream ranged from 0.368 – 3.49 mg/kg. Cr concentration in Spinach from site A were within the WHO safe levels while those from sites B, C and D exceeded the WHO acceptable limits. This study showed that spinach from sampling sites that exceeded the recommended Cr limits were not safe for human consumption and human health risks were thus inevitable with the consumption of these vegetables. Various scientists have also reported elevated levels of Cr in wastewater irrigated vegetables. The results obtained in this study showed similar Cr contents in spinach to those reported by Pan *et al.*, (2016) and Osaili *et al.*, (2016), who also reported that Cr concentration in spinach (0.057 – 3.51 mg/kg) exceeding the recommended international standards. A similar level of Cr (1.96 mg/kg) was also found in wastewater irrigated spinach samples collected from western region of Saudi Arabia. In contrast, a lower concentration of Cr was found (0.27 mg/kg) in wastewater irrigated spinach in Sao Paulo state, Brazil (Guerra *et al.*, 2012).

Heavy Metal Concentration in Kales: **Cadmium:** The mean and standard deviation of Cd concentration in the kale samples in the different sampling sites were; 0.113 ± 0.11 mg/kg in SPM 1, 0.013 ± 0.03 mg/kg in SPM 2 while kale from OAM had Cd below detectable limit (BDL). The mean concentration of Cd in kales in the market sites varied in the order SPM 1 > SPM 2 >

Open air market. All Cd mean values in kale collected from the market sites were within 0.2 mg/kg WHO set limit (Stan, 2009), implying they were not contaminated with Cd and were thus safe for human consumption. The mean concentration of Cd in kale from the Mitheu urban stream sites ranged from 0.058 ± 0.09 mg/kg to 0.319 ± 0.56 mg/kg (Table 2). Site D had the highest Cd concentration in kales while site A had the lowest level of Cd (BDL). All the mean values of Cd in kales were within WHO acceptable standards except for kale collected from site D which slightly exceeded the WHO limit for Cd in leafy vegetables. High level of Cd at site D could be associated with the

raw sewage that drains to the Mitheu stream from vandalized sewer lines. There was no significant variation of Cd concentration in the different sampling sites ($p > 0.05$). Concentration of Cd obtained in this study agrees with Cd levels reported for kale grown in Jos, Nigeria (0.061 ± 0.03 mg/kg) and 0.18 – 0.29 mg/kg reported in Koka and Wonji farms in Ethiopia (Lapshak *et al.*, 2019; Eliku and Leta, 2017). Higher Cd concentrations (0.34 – 3.5 mg/kg) were however reported in a similar study in Kitui, Kenya (Wambua *et al.*, 2018) and 0.67 mg/kg in Harar town, Ethiopia (Alamnie *et al.*, 2020).

Table 2: Mean ± standard deviation of heavy metal concentration (mg/kg) in kales and WHO recommended levels

Sampling Site	N	Mean ± StDev (mg/Kg)				
		Cadmium (Cd)	Copper (Cu)	Lead (Pb)	Zinc (Zn)	Chromium (Cr)
SPM 1	4	0.113 ± 0.11	1.706 ± 1.47	0.331 ± 0.57	17.86 ± 18.13	0.112 ± 0.25
SPM 2	4	0.013 ± 0.03	0.971 ± 1.40	0.236 ± 0.44	26.7 ± 24.00	14.0 ± 26.90
OAM	4	BDL	0.971 ± 0.89	0.156 ± 0.19	11.06 ± 11.34	0.280 ± 0.56
Site A	4	BDL	0.468 ± 0.94	BDL	15.4 ± 24.10	0.104 ± 0.21
Site B	4	0.058 ± 0.09	1.630 ± 2.05	0.368 ± 0.56	19.28 ± 14.54	2.86 ± 4.19
Site C	4	0.067 ± 0.08	1.630 ± 2.14	BDL	16.15 ± 13.30	BDL
Site D	4	0.319 ± 0.56	1.085 ± 1.26	0.020 ± 0.04	5.78 ± 6.74	BDL
WHO Set		0.2	10.0	0.3	5.0	2.3
P-value		0.391	0.571	0.577	0.934	0.497

Key: SPM: supermarket, OAM: open-air market, WHO: critical levels, BDL: Below detectable limit

Copper: Concentration of copper in kales in the market sites ranged between 0.971 ± 0.89mg/kg and 1.706 ± 1.47 mg/kg. Farming sites along the urban Mitheu stream recorded levels of Cu ranging from 0.468 ± 0.94mg/kg to 1.630 ± 2.14 mg/kg. The highest mean Cu concentration in kale from the farm sites was recorded at site C, a farm along Mitheu stream just after sewage treatment plant. The level of concentrations of Cu in kale from all the different sampling sites was within WHO permissible level thus the kale sold in the market sites and that grown along Mitheu stream was not contaminated with Cu and had no health risk hazard to the consumers. Results showed no significant difference in Cu concentrations among the sampling sites ($p > 0.05$). Concentration of Cu in kale recorded in this study compares well with previous Cu concentration (0.48 mg/kg) in kale in Makongeni market, Thika (Maina *et al.*, 2019). Zhang *et al.*, (2018) also recorded similar Cu levels for kales grown in Pearl River Delta, South China. Contrarily, Lapshak *et al.*, (2019) recorded higher Cu concentration (1.892±0.01 mg/kg).

Lead: The mean concentration of Pb in kales from the three market sampling sites ranged from 0.156 ± 0.19 mg/kg to 0.33 ± 0.57 mg/kg. Pb concentration in kales from SPM 2 and the open-air market was within WHO safe limit while Pb in kales from SPM1 exceeded WHO permissible limit for Pb in leafy vegetables. It is thus deducible that kales from SPM 1 were not safe for consumers as they exposed the consumers to unsafe Pb

levels. On the other hand, mean concentration of lead in kale grown along Mitheu urban stream was 0.02±0.04 mg/kg in site D and 0.368±0.56 mg/kg in site B. However, the level of Pb in kale from site A and site C was below detectable limit. Kale had the highest concentration of Pb at site B and the lowest at site D. The level of Pb in kale from site B exceeded WHO acceptable limit thus the kale from sampling site B were contaminated with Pb and were likely to have health implications. Concentration of Pb in the various sampling sites did not show any significant variation ($p > 0.05$). Similar Pb concentrations (0.37 – 0.45 mg/kg) were reported in Koka and Wonji farms, Ethiopia (Eliku and Leta, 2017). Higher mean Pb values (0.25 – 6.125 mg/kg) were reported for kale sold in markets and supermarkets of Semarang city (Inandin and Arminsih, 2020). Wambua *et al.*, (2018) also reported higher mean Pb levels (12.37 – 20.33 mg/kg) for kale irrigated with wastewater in Kitui county, Kenya.

Zinc: Results showed mean concentration of Zn in kale from the market sites varied from 11.06 ± 11.34 mg/kg to 26.7 ± 24.00 mg/kg. Farm sites along Mitheu stream recorded Zn mean concentration of 15.4 mg/kg, 19.28 mg/kg, 16.15 mg/kg, and 5.78 mg/kg in sampling sites A, B, C, and D respectively. Concentration of Zn among the sampling sites decreased as; site B > site C > site A > site D. Concentrations of Zinc in kale both grown and sold in the different sampling sites exceeded WHO

permissible levels for Zn in leafy vegetables. This indicated that the kale had high zinc concentration exposing the consumers to harmful health effects. Compared to previous studies, mean concentrations of Zn in kale obtained in this study were higher compared to Zn values reported in previous studies; 4.85 mg/kg for kale sold in Makongeni market in Thika (Maina *et al.*, 2019), 4.61 – 5.13 mg/kg for kale grown in Koka and Wonji farms, Ethiopia (Eliku and Leta, 2017) and 0.0154 ± 0.007 mg/kg for kale grown in farms along river Moiben, Uasin Gishu (Akenga *et al.*, 2020).

Chromium: Kale samples from the market sites showed mean Cr concentrations in the range 0.112 ± 0.25 mg/kg to 14.0 ± 26.9 mg/kg. The level of concentration of Cr in kale from SPM 2 was higher than the recommended Cr levels in leafy vegetables. The mean Cr concentration levels in the kale grown along the Mitheu urban stream were; 0.104 ± 0.21 mg/kg at site A and 2.86 mg/kg at site B. Kales grown at sites A and D did not have detectable concentrations of Cr, the concentration was possibly below detectable limit (BDL). Kales from sites A, C and D were safe for

human consumption with regard to WHO recommended levels of Cr in leafy vegetables. Kale vegetables from site D exceeded WHO standard limits and thus were not fit for consumption. Lapshak *et al.*, (2019) recorded comparable Cr levels (0.511±0.01 mg/kg) to those obtained in this study. A similar study in farms along Moiben River recorded lower Cr means (0.00141 mg/kg) in kales compared to Cr levels recorded in this study (Akenga *et al.*, 2020).

Correlation of heavy metal concentration in Kales and Spinach: Pearson correlation was applied to explore the degree of association of the heavy metals in the vegetables (Table 3). Cd in kales was found to be positively and significantly correlated to Pb in spinach (r = 0.772, p = 0.042). There was a significant positive correlation in Pb in kales and Zn in spinach (r = 0.821, p = 0.024). Zn in kales showed positive significant correlation to Cr in kales (r = 0.772, p = 0.042). Cd in spinach also significantly correlated to Cu in spinach (r = 0.882, p = 0.009). On the other hand, Pb in spinach had a negative significant correlation to Zn in kales (r = 0.889, p = 0.007).

Table 3: Pearson correlation of heavy metals in spinach and kales

	Cd kales	Cu kales	Pb kales	Zn kales	Cr kales	Cd spinach	Cu spinach	Pb spinach	Zn spinach	Cr spinach
Cd kales	1									
Cu kales	0.215	1								
Pb kales	-0.208	0.513	1							
Zn kales	-0.615	0.149	0.538	1						
Cr kales	-0.301	-0.154	0.343	0.772*	1					
Cd spinach	-0.198	-0.682	-0.349	-0.143	-0.286	1				
Cu spinach	0.046	-0.722	-0.587	-0.143	-0.110	0.882*	1			
Pb spinach	0.772*	-0.138	-0.292	-0.889*	-0.464	-0.041	0.017	1		
Zn spinach	0.027	0.509	0.821*	0.025	-0.098	-0.338	-0.643	0.146	1	
Cr spinach	0.327	-0.045	0.127	-0.426	-0.218	-0.033	-0.114	0.546	0.566	1

*. Correlation is significant at the 0.05 level (2-tailed).

The results showed that Cd, Pb, Zn, Cu and Cr could be associated to each other and might originate from common sources. Heavy metals do not degrade and cannot disintegrate into less toxic constituent and thus accumulate where they are deposited or released (Lapshak *et al.*, 2019). Leafy vegetables grown in heavy metal contaminated areas accumulate higher amounts of heavy metals as they are said to be good absorbers of the heavy metals (Bett *et al.*, 2019).

Conclusion: This current study revealed there was significant heavy contamination of kales and spinach grown along Mitheu stream and those sold in Machakos municipality largely due to concentration of Cd, Cr, Pb and Zn that were above WHO critical values. There is thus need for regular monitoring of heavy metal contamination in vegetables within Machakos town and its environs to prevent human

health risks associated with consumption of vegetables grown in urban areas.

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