



The Levels of Selected Heavy Metals in Kales from Horticultural Farms in Nakuru County, Kenya

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Abstract

Kales (*Brassica oleracea*) are a staple leafy vegetable in Kenya, consumed widely for their nutritional benefits. Nakuru County is a significant horticultural hub, with numerous small to large-scale farms cultivating kales. However, the increasing use of agrochemicals, coupled with industrial activities, raises concerns about the potential contamination of soil and crops by heavy metals. Therefore, this study determined the levels of selected heavy metals in samples of kales obtained from horticultural farms in Nakuru County, Kenya. A total of 120 kales (*Sukuma wiki*) leaves were randomly collected from Njoro, Molo, Naivasha, Nakuru East, Nakuru West, Subukia, Rongai and Gilgil sub-counties within the study area and transported to University of Eldoret Chemistry lab for sample preparation. There, the leaves samples were air dried, grinded and digested. Analysis was conducted using Shimadzu AAS model SpectrAA-200. Data generated was analysed descriptively and inferentially using SPSS. The study found that the concentrations of selected heavy metals (Cr, Fe, Cu, Mn, and Zn) in kales from various horticultural farms in Nakuru County were below the WHO/FAO permissible limits. These findings suggest that kales grown in this region are safe for consumption regarding these specific heavy metals. Further, there was a significant difference in Cu, Zn, Cr and Fe across 8 regions ($P < 0.05$). The overall mean levels of heavy metals in the kales followed the order: $Cr > Fe >$



Zn > Mn > Cu, with chromium being the most prevalent. Despite the current safety, continuous monitoring is important to ensure that heavy metal levels remain within safe limits, considering the ongoing use of agrochemicals and potential industrial pollution. Also, it is recommended that local authorities and agricultural stakeholders implement regular monitoring programs to track heavy metal concentrations in kales and other vegetables.

Keywords: Heavy metals, *Brassica oleracea*, horticultural farms, Cr, Fe, Cu, Mn, and Zn

Introduction

Heavy metals are persistent environmental pollutants that can enter the food chain through contaminated soil, water, and air (Nachana'a Timothy, 2019; Ali, Khan & Ilahi, 2019; Mishra et al., 2019). The primary sources of these contaminants in agricultural settings include industrial activities, mining operations, and the use of pesticides and fertilizers containing trace metals (Alves, Reis & Gratão, 2016; Gonçalves et al., 2014). For instance, a study by Muchuweti et al. (2006) and Ratul et al. (2018) highlighted that the use of contaminated irrigation water significantly increased heavy metal levels in vegetables. Similarly, research by Khan et al. (2008) found that vegetables grown near industrial zones exhibited higher concentrations of heavy metals compared to those from rural areas.

In Kenya, there is growing concern about the safety of vegetables due to the potential accumulation of heavy metals. Studies conducted in Kenya revealed that vegetables from different regions had detectable levels of heavy metals, prompting calls for regular monitoring and stringent regulation of food safety standards (Bett et al., 2019; Inoti et al., 2012; Karanja et al., 2012).

Kale (*Brassica oleracea*) is a key dietary component in Kenya, prized for their high nutritional value, including vitamins A, C, K, and essential minerals like calcium and iron (Satheesh & Workneh Fanta, 2020; Muojiama et al., 2023). In Nakuru County, a leading horticultural region, because of its rich agricultural hinterland, Nakuru County is often referred to as the 'farmers capital' of Kenya and is famous for its agro-based industries. There is a lot of agriculture, which is practiced in the county both for food and for commercial purposes. Agriculture is, therefore, the main land use and the economic mainstay of the county (Kinambuga, 2010). Nakuru County Integrated Development Plan of 2015 showed that the total land area under agriculture in Nakuru County was about 71,400 and 243,700 ha for cash crops and food crops, respectively. A study conducted by Foeken *et al.*, (2002) showed that the three crops that stand out by household frequency (around 60%) are: kales commonly called *sukuma wiki* (*Brassica oleracea*), maize (*Zea mays*) and beans (*Phaseolus vulgaris*). Other common crops of horticultural importance



are onions (*Allium cepa*), tomatoes (*Lycopersicon escaletum*), Irish potatoes (*Solanum tuberosum*), bananas (*Musa ssp.*), cowpeas (*Vigna unguiculata*) and spider plant (*Cleome gynandra*).

The main contributing factors for prevalence of high agricultural activities in these areas include the conducive climatic conditions with adequate rains in most parts of the county, rich volcanic soils that provide great perspective for crops, well-developed road network, enabling structures available to the farming communities, readily available labor force from its high population and the availability of market for farm produce from both its own urban centers and from other major ones such as Nairobi County (Nakuru County Integrated Development Plan, 2015). Vegetables constitute essential diet components by contributing Fe, manganese, copper, chromium and other nutrients, which are usually in minute quantity (Lyimo et al., 2003). Türkdogan et al. (2003) added that they function as buffering agents during the digestion process. On the other hand, they contain both essential and toxic elements over a wide range of concentrations (Türkdogan et al., 2003).

Heavy metals accumulation in plants depends upon plant species, and the efficiency of different plants in absorbing metals is evaluated by either plant uptake or soil-to-plant transfer factors of the metals (Khan et al., 2008). Fazli (2016) reported that those vegetables, grown in heavy metals contaminated soils have higher concentration of heavy metals than those grown in uncontaminated soil. Heavy metals have been reported to pose significant health risks to humans, even at low exposure levels (Witkowska, Słowik & Chilicka, 2021). Chronic exposure to these metals can lead to severe health issues such as neurological and developmental disorders, kidney damage, bone fragility, respiratory issues, skin lesions, cardiovascular diseases, and an increased risk of cancer (Bhargava et al., 2017; Zahra & Kalim, 2017; Jaishankar et al., 2014). Studies have shown that heavy metals such as Pb, Cd, As, Hg, and Cr can accumulate in leafy vegetables, potentially causing adverse health effects when consumed over time (Gupta et al., 2019; Manzoor, Sharma & Wani, 2018; Sandeep, Vijayalatha & Anitha, 2019). The intensification of agriculture in Nakuru County, coupled with the extensive use of agrochemicals, poses significant risks of heavy metal contamination. Hence, this study assessed the levels of selected heavy metals in samples of kales obtained from horticultural farms in Nakuru County, Kenya

Methodology

Nakuru County located (0° 18' 11.1564" S and 36° 4' 48.0900" E) (Figure 1) lies within the Great Rift Valley and receives annual rainfall that averages 800 mm (Ogeto et al., 2012). The climate is strongly influenced by the altitude and physical features, particularly the Rift Valley itself.

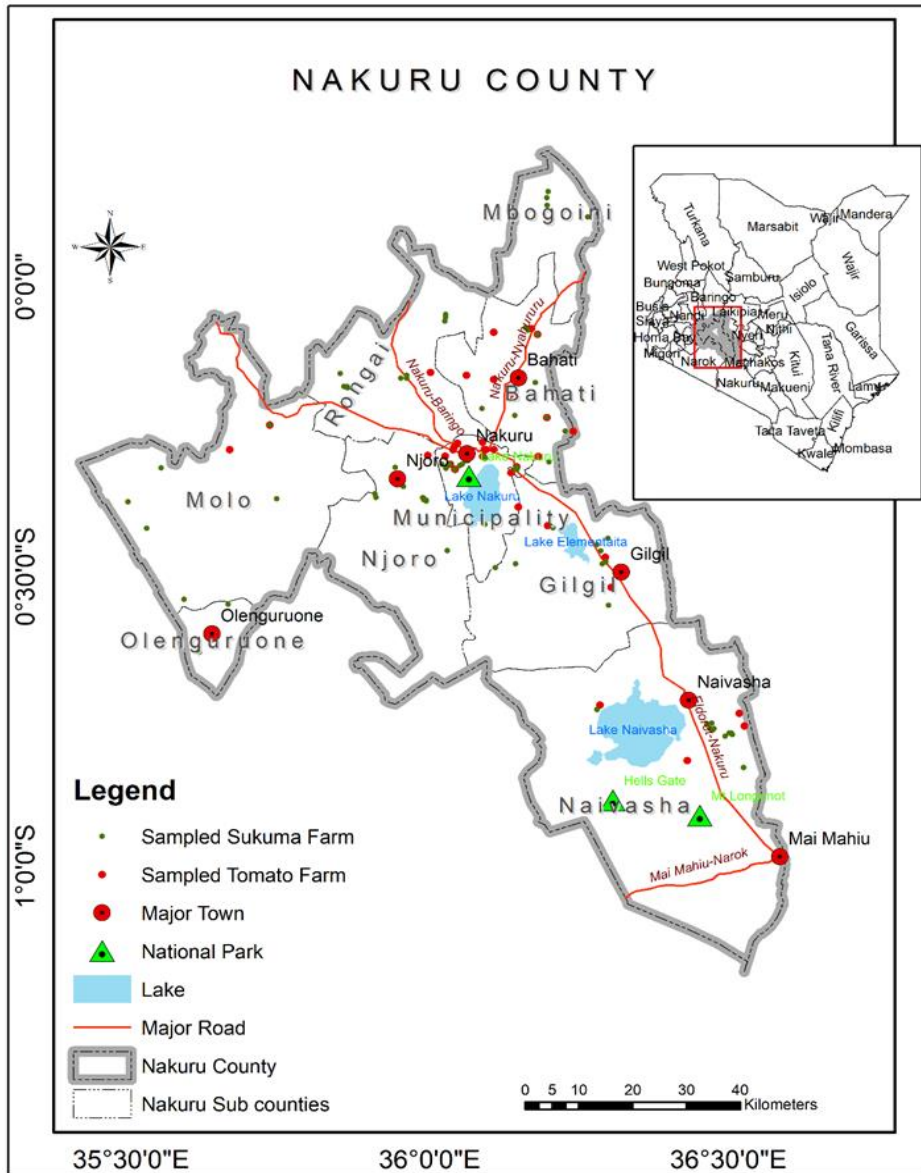


Figure 1: The map of the study area Nakuru County

There are three broad climatic zones (II, III and IV). Zone II covers areas with an altitude between 1980m and 2700 m and it receives minimum rainfall of 800 mm per annum. It covers most of the county moreso Upper Subukia, Rongai and Mau Escarpment. Zone III covers areas of altitudes of 1850 m and it receives rainfall of between 950–1500 mm per annum (Wakachala et al., 2015). This zone covers most parts of the county and is the most significant for agricultural cultivation. Zone IV occupies more or less the same elevation (900–1800m) as Zone III but it has lower rainfall of about 500–1000 mm per annum. This zone dominates Solai and Naivasha (Ogeto et al., 2012). The



county has a bimodal rainfall pattern (Wakachala et al., 2015). The short rains are experienced between October and December while the long rains between March and May. Temperatures range from 29.3°C between the months of December to March to as low as 12 °C during the month of June and July. Molo and Kuresoi Sub-Counties are relatively cold while Nakuru East, Nakuru West, Naivasha, Gilgil and parts of Rongai Sub-County experience extreme hot weather. However, with the deforestation experienced in the county's forest blocks and influence from climate change, variant rainfall patterns and higher temperatures may be experienced (Ogeto *et al.*, 2012). There are nine sub-counties in Nakuru county. These are Nakuru North, Gilgil, Nakuru, Rongai, Naivasha, Subukia, Molo, Njoro, and Kuresoi (Hussein & Wanyoike, 2015). The total population of Nakuru County was approximated at 2.162 million people in 2019 (Kenya National Population and Housing Census, 2019).

A total of 120 kales (*sukumawiki*) leaves samples were randomly collected from Njoro, Molo, Naivasha, Nakuru East, Nakuru West, Subukia, Rongai and Gilgil sub-counties within the study area. The samples were collected in clean polythene ziplock bags and stored frozen at -10 °C. Kales (*sukumawiki*) were taken to University of Eldoret Chemistry laboratory where it washed in excess distilled water to remove any contaminants on their surface. The samples were sliced and dried to constant weight in an oven at 70 °C. They were then ground separately using an electric miller to pass through a 150-µm sieve and preserved in khaki bags for further analysis (Okalebo et al., 2002).

A 0.21 g selenium powder and 7.0 g of lithium sulfate were weighed in a clean vial then added to 175 mL of 30% hydrogen peroxide and mixed well. A 210 mL of concentrated sulfuric acid was then added with care while cooling in an ice-bath. This was then stored at 4 °C for stability. Exactly 0.3 g portions of finely ground dried vegetable samples were weighed into separate dry, clean digestion tubes. Then 4.4 mL of the digestion mixture was added to each of the tubes and also to reagent blanks for each batch of samples. The tubes were heated in block digestion at 350 °C for 2 hours. The digestion was completed when the digest became colorless. The tubes were removed from the digester and allowed to cool to room temperature. About 25 mL of distilled water was added, mixed well, and made up to 50 mL with distilled water. The contents were then transferred into a 50 mL volumetric flask and allowed to settle so that the clean solution. Analysis of Zn, Cu, Cr, Mn, and Fe by Shimadzu AAS model SpectrAA-200. Results were coded into Statistical Package for Social Science (SPSS) and analysed using descriptive and inferential statistics. The output for the least significant difference (LSD) values was obtained at $p \leq 0.05$ confidence levels.



Results

Distribution of the metal levels in kales by regions

The results for the variations in the levels of the heavy metals in kales by region are presented in Table 1 and the overall mean levels for each element depicted in Figure 2.

Table 1: Levels of heavy metals in kales from 8 regions in Nakuru County

Region	Cu (mg/kg)	Zn (mg/kg)	Cr (mg/kg)	Mn (mg/kg)	Fe (mg/kg)
Njoro	0.05±0.00	0.25±0.01	0.86±0.02	0.11±0.00	0.58±0.03
Molo	0.05±0.01	0.20±0.01	0.73±0.04	0.13±0.01	0.30±0.02
Naivasha	0.05±0.01	0.36±0.10	1.11±0.04	0.13±0.01	0.59±0.04
Nakuru East	0.05±0.02	0.25±0.05	0.80±0.08	0.11±0.00	0.89±0.06
Nakuru West	0.07±0.02	0.37±0.30	0.95±0.04	0.11±0.01	0.62±0.05
Subukia	0.07±0.02	0.24±0.55	0.90±0.10	0.11±0.01	0.53±0.12
Rongai	0.05±0.01	0.36±0.14	1.06±0.04	0.12±0.00	0.97±0.10
Gilgil	0.07±0.01	0.32±0.04	1.01±0.06	0.10±0.01	0.74±0.02
Overall	0.05±0.00	0.3±0.3	0.94±0.02	0.12±0.00	0.68±0.03

The overall mean levels of heavy metals in kales decreased in the order: Cr > Fe > Zn > Mn > Cu. Copper concentration ranged between 0.05±0.00 mg/kg and 0.07±0.01 mg/kg. Nakuru West, Gilgil, and Subukia had the same mean of 0.07±0.02 mg/kg which was the highest concentration, whereas Njoro had the lowest of 0.05±0.00 mg/kg compared with other regions. Zinc concentration ranged between 0.20±0.01 mg/kg and 0.37±0.30 mg/kg. The zinc level was highest in Nakuru West with a mean of 0.37±0.30 mg/kg, while Molo recorded the lowest levels of 0.20±0.01 mg/kg. Chromium concentration ranged between 1.11±0.04 mg/kg and 0.73±0.04 mg/kg. Naivasha recorded the highest of 1.11±0.04 mg/kg, while Molo recorded the lowest 0.73±0.04 mg/kg compared with other regions. Manganese mean concentration ranged between 0.10±0.01mg/kg and 0.13±0.01 mg/kg. Naivasha and Molo regions had the highest mean concentrations of 0.13±0.01mg/kg, whereas Gilgil had the lowest concentration of 0.10±0.01 mg/kg compared with other regions. Iron concentration ranged between 0.30±0.02 mg/kg and 0.97±0.10 mg/kg. Rongai region had the highest of 0.97±0.10 mg/kg, while the Molo region had the lowest concentration of 0.30±0.02 mg/kg compared to other regions.



Comparisons of metals levels in kales among regions

One-way analysis of variance was then conducted to determine the existence of any significant differences in the spatial distribution of the heavy metals in kales and the results presented in Table 2.

Table 2: One-way ANOVA for the concentrations of heavy metals in kales from 8 regions

	Sum of Squares	Df	Mean Square	F	Sig.
Cu	.010	7	.001	8.471	.000
Zn	.427	7	.061	2.988	.007
Cr	1.548	7	.221	6.671	.000
Fe	3.854	7	.551	7.859	.000
Mn	.008	7	.001	1.320	.247

According to the analysis of variance of the results in Table 2, the *p* values of Cu, Cr, and Fe were all 0.000, while Zn was 0.007. They were below 0.05 significance level indicating a significant difference at 95% in the heavy metals content. The *p* values of Mn were 0.247. It was above the 0.05 significance level indicating insignificance in the content of heavy metals in kales in the different regions from Nakuru County.

Comparison of heavy metal levels in kales with the WHO/FAO allowable levels

The obtained levels of selected heavy metals in kales were compared with standards recommended by both the WHO and FAO and the results of this comparisons are presented in Table 3.

Table 3: Comparison of selected heavy metals in kales with the WHO/FAO/RDA standards

Sample	Element	Elements levels (mg/kg)	
		Current work	WHO/FAO/RDA
Kales	Cr	0.94	1
	Cu	0.05	20
	Fe	0.68	48
	Mn	0.12	0.2
	Zn	0.3	60

The results showed that the concentration of heavy metals, that is, Cr, Fe, Cu, Mn, and Zn in kales from Naivasha, Gilgil, Rongai, Subukia, Nakuru West,



Nakuru East, and Molo were recorded as within the permissible limits of WHO/FAO for these metals.

Discussion

In kales, the overall mean concentration of Cu was 0.05 ± 0.00 mg/kg with the highest levels of 0.07 ± 0.01 mg/kg Cu being reported in Nakuru West, Nakuru East, and Gilgil regions, this could be attributed to the high use of agrochemicals in these areas, which have high agricultural productive compared to other regions. Njagi (2013) during the evaluation of heavy metal levels in Kadhodeki dumpsite Nairobi reported high Cu levels in *Spinacia oleracea* to be 1.13 ± 0.19 mg/kg. Elsewhere, Uwah et al., (2011) also reported high Cu concentrations of 0.81 mg/Kg in spinach grown in certain sites in Nigeria. The results of both studies showed higher Cu contamination than those reported in the present study. The levels of Cu in kales were within the accepted level of 20.00 mg/kg (WHO/FAO, 2001). Nonetheless, one-way ANOVA indicated that the difference in the concentration of Cu in kales was statistically significant ($p < 0.05$). This difference in the levels of Cu could be attributed to different agricultural practices employed by farmers in each of the regions. The high Cu levels in Nakuru West, Nakuru East, and Gilgil regions were attributed to the application of fertilizers and other horticultural chemicals used in farming. Also, high levels could be attributed to industrial waste discharge from manufacturing industries like the now-defunct Eveready Batteries Ltd production industry located in the central business district of Nakuru town. Besides municipal waste such as e-waste that is uncontrollably disposed of among the major urban centers.

On the other hand, the overall mean zinc levels in kales from the 8 regions was 0.3 ± 0.3 mg/kg. Zinc levels were highest in Nakuru West with a mean of 0.37 ± 0.30 mg/kg. The results of this study were similar to those reported by Njagi (2013) and by Muhammad et al. (2008) who reported Zn levels of 0.38–2.43 mg/kg and 0.461 mg/kg in certain leafy vegetable including: spinach, cabbage and cauliflower. Nonetheless, somehow higher values of Zn (1.06 ± 0.02 – 2.82 ± 0.01 mg/kg) were previously reported by Akubugwo et al., (2012) in *Amaranthus hybrid* vegetables. High Zn content in vegetable, especially from Nakuru West could be attributed to anthropogenic activities such as industrial waste and municipal waste disposal and hydrogeological translocation into the farmlands in low-lands surrounding the saline Lake Nakuru. One-way ANOVA indicated significant difference ($F = 2.988$, $df = 7$, $p = 0.007$) in concentration of Zn in kales. This is attributed to the same levels of Zn in the parent rocks.

As for Fe, the overall mean concentration in kales from the 8 regions was 0.68 ± 0.03 mg/kg and Fe levels were highest in Rongai (0.97 ± 0.10 mg/kg)



whereas the lowest levels (0.30 ± 0.02 mg/kg) as shown in Table 1 occurred in Njoro and in Molo. Results recorded by Aweng et al., (2011)_reported Fe content of 0.65–2.76 mg/kg in vegetables which were similar to those of the current study. One-way ANOVA indicated significant difference ($F=7.859$, $df=7$, $p=0.000$ in concentration of Fe in kales. Differences in Fe distribution between the regions of the current study area is attributed to different in soil type influencing the pH and the pH affects absorption of iron. Rongai area is known for its planosolic soils while Njoro and Molo for latosolic soils. Similarly, different agricultural practices employed by farmers in each region and different distribution of Fe in parent rock could cause variations in Fe availability and uptake by plants in those regions.

The overall mean concentration for chromium in kales was 0.94 ± 0.02 mg/kg. The concentrations of chromium in kales were within acceptable limits of 1 mg/kg as per WHO/FAO (2001) requirements. Chromium concentration ranged between 1.11 ± 0.04 (mg/kg) in Naivasha and 0.73 ± 0.04 (mg/kg) in Molo. Studies by Alamin et al., 2007 indicated higher Cr concentrations in cabbages (1.39 mg/kg) than in carrots (0.35 mg/Kg) in Libya. Hellen & Othman, (2014) recorded 20.00 mg/Kg concentrations of Cr in tomatoes. One-way ANOVA indicated the difference in concentration of chromium in kales for the 8 regions which were statistically significant ($p < 0.05$). Again, variation in Cr levels between regions could be attributed to partly different geological distribution of parent rock and partly to differences in leaching due to varying climatic conditions and annual rainfall. The overall mean concentration for Mn in kales on the other hand, was 0.12 ± 0.00 mg/kg and Naivasha and Molo recorded the highest concentration of Mn 0.13 ± 0.01 (mg/kg) as compared with other regions. In this case, Gilgil had the lowest Mn concentration with a mean of 0.10 ± 0.01 (mg/kg). One-way ANOVA indicated no difference in concentration of manganese in kales which was not statistically significant ($p > 0.05$). This is attributed to the same levels of Mn in the parent rocks.

Conclusion and Recommendation

The results reported in the present study showed that concentration of heavy metals Cr, Fe, Cu, Mn and Zn in kales from Naivasha, Gilgil, Rongai, Subukia, Nakuru West, Nakuru East and Molo were below the WHO/FAO permissible limits for these metals. These findings suggest that kales grown in this region are safe for consumption regarding these specific heavy metals. The overall mean levels of heavy metals in the kales followed the order: $Cr > Fe > Zn > Mn > Cu$, with chromium being the most prevalent. Despite the current safety, continuous monitoring is essential to ensure that heavy metal levels remain within safe limits, considering the ongoing use of agrochemicals and potential industrial pollution. The study recommends that local



authorities and agricultural stakeholders implement regular monitoring programs to track heavy metal concentrations in kales and other vegetables. Additionally, educating farmers on best practices for the use of agrochemicals and promoting organic farming methods could help minimize future contamination risks. Policymakers should also consider establishing more stringent regulations and providing resources for soil and water management to safeguard against heavy metal accumulation.

References

- Akubugwo, E. I., Obasi, A., Chinyere, G. C., Eze, E., Nwokeoji, O. and Ugbogu, E. A. (2012). Phytoaccumulation effects of *Amaranthus hybridus* L. grown on buwaya refuse dumpsites in Chikun, Nigeria on 105 heavy metals. *Journal of Biodiversity and Environmental Sciences (JBES)*, 2(5), 10–17.
- Alamin, M.B., Mhapes, A.A., Bejey, A.M., Sadek, A., Atweer, R.H., Dubali, K., and Saad, D.M., (2007), Determination of essential and toxic elements in Libyan foodstuff using instrumental neutron activation analysis (INAA). *Journal of Radioanalytical and Nuclear Chemistry* 271, p. 247–250
- Ali, H., Khan, E., & Ilahi, I. (2019). Environmental chemistry and ecotoxicology of hazardous heavy metals: environmental persistence, toxicity, and bioaccumulation. *Journal of chemistry*, 2019.
- Alves, L. R., Reis, A. D., & Gratão, P. L. (2016). Heavy metals in agricultural soils: from plants to our daily life (a review).
- Aweng, E. R., Karimah, M., and Suhaimi, O. (2011). Heavy metals concentration of irrigation water, soils and fruit vegetables in Kota Bharu area, Kelantan, Malaysia. *J. Appl. Sci. Environ. Sanit*, 6(4), 463–470.
- Bett, L., Ongera, G., Wangila, P., & Mule, S. (2019). Determination of some heavy metals in soils and vegetables samples from Kericho West Sub-County, Kenya.
- Bhargava, P., Gupta, N., Vats, S., & Goel, R. (2017). Health issues and heavy metals. *Austin J Environ Toxicol*, 3(1), 3018.
- County, N. (2015). Nakuru County Integrated Development Plan 2013–2017.
- Foeken, D. W. J., Owuor, S. O., & Klaver, W. (2002). *Crop cultivation in Nakuru town, Kenya: Practice and potential*.
- Gonçalves Jr, A. C., Nacke, H., Schwantes, D., & Coelho, G. F. (2014). Heavy metal contamination in brazilian agricultural soils due to application of fertilizers. *Environmental risk assessment of soil contamination*, 4(1), 105-135.
- Gupta, N., Yadav, K. K., & Kumar, V. (2015). A review on current status of municipal solid waste management in India. *Journal of environmental sciences*, 37, 206-217.
- Hellen, L. E., and Othman, O. C. (2014). Levels of selected heavy metals in soil, tomatoes and selected vegetables from Lushoto district-Tanzania. *International Journal of Environmental Monitoring and Analysis*, 2(6), 313–319.
- Inoti, K. J., Fanuel, K., George, O., & Paul, O. (2012). Assessment of heavy metal concentrations in urban grown vegetables in Thika Town, Kenya. *African Journal of Food Science*, 6(3), 41-46.
- Jaishankar, M., Tseten, T., Anbalagan, N., Mathew, B. B., & Beeregowda, K. N. (2014). Toxicity, mechanism and health effects of some heavy metals. *Interdisciplinary toxicology*, 7(2), 60-72.
- Karanja, N. N., Njenga, M., Mutua, G. K., Lagerkvist, C. J., & Okello, J. J. (2012). Concentrations of heavy metals and pesticide residues in leafy vegetables and implications for peri-



- urban farming in Nairobi, Kenya. *Journal of Agriculture, Food Systems, and Community Development*, 3(1), 255-267.
- Khan, S., Cao, Q., Zheng, Y. M., Huang, Y. Z., & Zhu, Y. G. (2008). Health risks of heavy metals in contaminated soils and food crops irrigated with wastewater in Beijing, China. *Environmental Pollution*,
- Kinambuga, D. (2010). *Evaluation of the constraints to profitable smallholder dairying; a case of nakuru county kenya* (Doctoral dissertation, Egerton University).
- Lyimo, M., Temu, R. P. C., & Mugula, J. K. (2003). Identification and nutrient composition of indigenous vegetables of Tanzania. *Plant Foods for Human Nutrition*, 58, 85-92.
- Manzoor, J., Sharma, M., & Wani, K. A. (2018). Heavy metals in vegetables and their impact on the nutrient quality of vegetables: A review. *Journal of plant Nutrition*, 41(13), 1744-1763.
- Mishra, S., Bharagava, R. N., More, N., Yadav, A., Zainith, S., Mani, S., & Chowdhary, P. (2019). Heavy metal contamination: an alarming threat to environment and human health. *Environmental biotechnology: For sustainable future*, 103-125.
- Muhammad, F., Anwar, F. and Rashid, U. (2008). Appraisal of Heavy Metal Contents in Different Vegetables Grown in the Vicinity of an Industrial Area. *Pakistan Journal of Botany*, 40(5), 2099–2106
- Muojiama, S. O., Nwune, U. C., Ugo, G. O., Ezeh, M. C., & Ukwu, U. N. (2023). Growth performance and nutritional concentrations of two kale (*Brassica oleracea* var *Acephala*) varieties in response to fertilizer types in Awka, Southeast Nigeria. *International Journal of Recycling Organic Waste in Agriculture*, 12(4), 723-733.
- Nachana'a Timothy, E. T. W. (2019). Environmental pollution by heavy metal: an overview. *Chemistry*, 3(2), 72-82.
- Njagi, J.M. (2013). *Assessment of Heavy Metal Concentration in the Environment and Perceived Health Risks by the Community around Kadhodeki dumpsite, Nairobi County*. (Msc) Kenyatta University.
- Ratul, A. K., Hassan, M., Uddin, M. K., Sultana, M. S., Akbor, M. A., & Ahsan, M. A. (2018). Potential health risk of heavy metals accumulation in vegetables irrigated with polluted river water. *International food research journal*, 25(1).
- Sandeep, G., Vijayalatha, K. R., & Anitha, T. (2019). Heavy metals and its impact in vegetable crops. *Int J Chem Stud*, 7(1), 1612-21.
- Satheesh, N., & Workneh Fanta, S. (2020). Kale: Review on nutritional composition, bio-active compounds, anti-nutritional factors, health beneficial properties and value-added products. *Cogent Food & Agriculture*, 6(1), 1811048.
- Uwah, E. I., Ndahi, N. P., Abdulrahman, F. I. and Ogugbuaja, V.O. (2011). Heavy metal levels in spinach (*Amaranthus caudatus*) and lettuce (*Lactuca sativa*) grown in Maiduguri, Nigeria. *Journal of Environmental Chemistry and Ecotoxicology*, 3(10), 264–271.
- WHO/FAO, Codex Alimentarius Commission (2001). *Food additives and contamination*. Joint FAO/WHO Food Standards programme; p 45 – 48.
- Witkowska, D., Słowik, J., & Chilicka, K. (2021). Heavy metals and human health: Possible exposure pathways and the competition for protein binding sites. *Molecules*, 26(19), 6060.
- Zahra, N., & Kalim, I. (2017). Perilous effects of heavy metals contamination on human health. *Pakistan Journal of Analytical & Environmental Chemistry*, 18(1), 1-17.