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Heavy Metals and Essential Elements in Selected Medicinal Plants Commonly Used for Medicine in Tanzania

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Authors' contributions

This work was carried out in collaboration between both authors. Author LLN designed the study, performed the statistical analysis and literature searches and wrote the first draft of the manuscript. Author NKM supervised the analyses of the samples, reviewed the first draft and wrote the final manuscript. Both authors read and approved the final manuscript.

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ABSTRACT

Several plants in Tanzania are known to be of potential therapeutic value and are used in traditional medicine system of the country. In this paper, two medicinal plants *Moringa oleifera* (leaves and roots), and *Hibiscus sabsdariffa* (rosella calyces) were analysed for elemental concentration. Essential and non-essential heavy metals like Mg, K, Mn, Fe, Ni, Cu, Zn, Cd and Pb were quantified in selected medicinal plants by EDXRF technique. The main purpose of this study is to document the presence and the levels of heavy metals in these herbs. High Potassium contents were observed to be 20882.20 ± 253.65 mg/kg in *Moringa oleifera* roots, in *Hibiscus sabsdariffa* (rosella calyces) 15732.03 ± 191.27 mg/kg, and 14541.08 ± 206.83 mg/kg in *Moringa oleifera* leaves. Magnesium was the second abundant element with concentration (5058.13 ± 115.80 mg/kg in *Moringa oleifera* leaves, 4328.86 ± 132.85 mg/kg *Hibiscus sabsdariffa* and 1400.59.59 ± 72.09

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mg/kg in *Moringa oleifera* roots), followed by Iron (716.57 ± 48.05 mg/kg in *Hibiscus sabsdariffa*, 556.44 ± 11.77 mg/kg and 309.57 ± 8.96 mg/kg in *Moringa oleifera* roots and leaves respectively. Except Fe and Ni in all plant samples and Mg in leaves of *Moringa oleifera* and calyces of *Hibiscus sabsdariffa* as well as Mn in roots of *Moring oleifera*, the concentrations of other metals were below the permissible limits in plants set by FAO/WHO. The results presented that there is no risk associated with consumption of analysed medicinal plants. However, since Cd was not detected and it is highly toxic even at very low concentrations. Therefore, further analysis which will employ other analytical techniques and includes more samples is needed to have a definite statistical conclusion on the safety consumption of the analysed medicinal plants. The results also show that the analysed plant species are beneficial sources of appropriate and essential trace elements.

Keywords: Heavy metals; essential elements; medicinal plant; Moringa oleifera; EDXRF; Hibiscus sabsdariffa.

1. INTRODUCTION

The consumption of medicinal plants for therapeutic purposes is recognized as one of the earliest traditional forms of medical practice of mankind. These plants are also used for the prevention of diseases, sustainability of health and to cure diseases in modern medicine [1]. At the same time, they are utilized as a nutritional supplements, spice, herbal tea and taste condiment in nutrition as well as in various fields of industry (food, perfumery, cosmetics, polishes, pesticides) [2]. These uses tend to grow over the years, both in developed and developing countries [3]. Today, the number of medicinal and aromatic plants used in the world is around 20,000 according to the World Health Organization (WHO) and 4,000 of these drugs are still used widely in the World [4]. In this paper, two medicinal plants which are *Moringa oleifera* (leaves and roots), and *Hibiscus sabsdariffa* (rosella calyces) which are mostly used for medicinal purposes in Tanzania were analysed for elemental concentration.

Moringa oleifera Lam (synonym: *Moringa pterygosperma Gaertner*) belongs to an onogeneric family of shrubs and tree, Moringaceae and is considered to have its origin in Agra and Oudh, in the northwest region of India, south of the Himalayan Mountains [5]. Every plant part such as leaves, roots, fruits, bark is used for medicinal purposes as well as food because of their high nutritional value. The young leaves are edible and are commonly cooked and eaten like spinach or used to make soups and salads. They are an exceptionally good source of provitamin A, vitamins B, C and minerals (iron in particular). Powder produced from the seed is used as an effective primary coagulant for water treatment [6,7,8], and also possess the potential to remove cadmium from aqueous system [9]. Leaves and roots of *Moringa oleifera* are used for therapeutic purposes and reported to cure several disease as shown in Table 1.

Hibiscus sabsdariffa also known as rosella, is an ideal crop for developing countries as it is relatively easy to grow, can be grown as part of multi-cropping systems and can be used as food and fibre. In China the seeds are used for their oil and the plant is used for its medicinal properties, while in West Africa the leaves and powdered seeds are used in meals. Additionally, it is used in the pharmaceutical and food industries. Fresh or dried calyces of *Hibiscus sabsdariffa* are used in the preparation of herbal drinks, hot and cold beverages, fermented drinks, wine, jam, jellied confectionaries, ice cream, chocolates, flavouring agents, puddings and cakes [2,10]. In the West Indies the calyces can also be used as colouring and flavouring ingredient in rum [11]. The seeds are eaten roasted or ground in meals, while the leaves and shoots are eaten raw or cooked or as a sour-flavoured vegetable or condiment [12]. In Tanzania, calyces are used for medicinal purposes and for making juice. A limited number of reviews on *Hibiscus sabsdariffa* are available for medicinal purposes as shown in Table 1.

Plants have the ability to accumulate metals such as, Mg, Fe, Ms, Zn, Cu, Mo and Ni which are essential to their growth. Some plants even have the ability to accumulate metals like Hg and Cr that have no known biological function to them. Reports have also shown that the levels of minerals in the plants depend on the soil properties and the geographical locations where the plant grows [21]; also their excessive

Table 1. Indigenous medicinal herbs used in Tanzania

Plant species and part used	Medicinal use/properties
Moringa oleifera (leaves)	Purgative, applied as poultice to sores, rubbed on the temples for headaches, used for piles, fevers, sore throat, bronchitis, eye and ear infections, scurvy and catarrh; leaf juice is believed to control glucose levels, applied to reduce glandular swelling [13,14,15,16].
Moringa oleifera (roots)	Antilithic, rubefacient, vesicant, carminative, antifertility, anti-inflammatory, stimulant in paralytic afflictions; act as a cardiac/circulatory tonic, used as a laxative, abortifacient, treating rheumatism, inflammations, articular pains, lower back or kidney pain and constipation [13,15,17,18].
Hibiscus sabsdariffa (Calyces)	Used as source of antioxidants, soothes colds, astringent, lowering blood pressure, blood lipids and for prophylaxis against cancer and liver cirrhosis especially for alcoholics, promote kidney function, helps in digestion, reduce fever, helps in cardiac and nerve diseases. It treats hangover, cough and stomach problems (indigestion). They are rich in vitamins A and C [19,20].

accumulation is toxic to most plants [22]. Studies conducted elsewhere have shown that parts of *Moringa oleifera* have been found containing high levels of Ca, Mg, K, Na, Mn, Fe, Zn, Co, Se, Pb and Cd [4,23,24]. And for the case of *Hibiscus sabsdariffa* the studies revealed that-the plant contains metals like Al, Ca, Mg, K, Na, Mn, Fe, Zn, Co, Se, P, Pb and Cd [10,25,26]. Some heavy metals like Pb, Zn, Cd, Hg and Th are of great concern because of their potential effects on human health and environment. As the concentration of metals in plants depends on the environment, it is also important to analyse medicinal plants grown and used in Tanzania. Therefore, considering this contamination issues and the uses of *Moringa oleifera* and *Hibiscus sabsdariffa* in Tanzania, this study aimed at investigating the presence of metals and elements like Mg, K, Mn, Fe, Ni, Cu, Zn, Cd and Pb in plant samples (as dry extracts) by using Energy Dispersive XRF.

2. MATERIALS AND METHODS

2.1 Sampling and Post Harvesting Treatment of Plant Material

Moringa oleifera and *Hibiscus sabsdariffa* were identified as herbal plants mostly used in Tanzania for healthcare. Five (5) plants of *Moringa oleifera* and seven (7) plant of *Hibiscus sabsdariffa* (Calyces) were collected from different parts of Tanzania. The parts of the plant mostly recommended and/or used for medicine purposes were washed to remove surface deposition then sun dried for a week. Then the samples were dried into oven at 48℃ for 4 days. And finally were grinded and sieved through a 2 mm-sieve into powder, packed and stored into the desiccator for a week to attain a constant weight before analysis.

A dry weight of 12 grams of *Moringa oleifera* root sample with 2.7 grams of cellulose binder were put into a bowl together with four spherical balls, each with 3 mm radius and fixed to a pulveriser machine which was further ground and homogenized. The machine was set at a speed of 150 revolutions per minute (rpm) for 15 minutes. The analyte was placed into a polished, lapped thrust piece with a smooth surface and fixed into hydraulic press machine. A pellet in tablet form was obtained by applying an average pressure of 12.5 tons. The same processes were applied to 12 grams of *Moringa oleifera* (leaves) and *Hibiscus sabsdariffa* (calyces) samples. Each pellet was labeled and subsequently placed in a transparent plastic sample holder ready for measurements in Energy Dispersive X-Ray Fluorescence (EXRDF) Machine.

2.2 Sample Analysis

The elemental analyses of samples were conducted using a bench top energy dispersive X-ray spectrometer of Tanzania Atomic Energy Commission (TAEC) in Arusha. The machine which is operated by automated turbo-quant X-lab Pro^{TM} software uses a 0.003 beryllium window X-ray tube with copper body anode and ceramic envelope with palladium target. The X-ray tube was operated at a power of 50 W and 50kV voltage. The florescent X-rays were collected by a Si (Li) detector having a resolution (FWHM) at MnK_{α} ≤ 160 eV.

The excitation of elements in the sample was carried out using three secondary targets. Light elements from Na-V were excited using high oriented pure graphite (HOPG) target (intense monochromatic polarized X-Rays). The Elements from Cr-Zr and Pr-U were excited using Mo secondary target (intense monochromatic non-polarized X-Rays). The high energy elements Y-Ce were excited using Barkla target (Al2O3) (intense polychromatic polarized X-Rays) [27]. The spectrum was generated after 20 min and it gave a good continuity statistics and resolution of the peaks.

Concentrations of elements in the samples were calculated by the inbuilt software called X-lab Pro^{TM} with Turboquant (Tq 9232) algorithm for matrix effect correction [28]. The software corrects for the matrix effects (*Mi*) and the interference effects (*Ki*) basing on fundamental parameter methodology. The software corrects also for the background effect on a spectral line intensity (*Ii*), given as counts per second (cps). After all the corrections, the software converts the intensity into concentration of the element using Equation below [29].

$$C_i = K_I \times I_I \times M_a \quad (1)$$

Where *Ci* is the concentration of a given element *i*; Ma is the correction factor for matrix effects. *Ki* is the constant of proportionality; *Ii* is the intensity of the fluorescent radiation from the element *i.*

2.3 Quality Control

Quality control was carried out using two IAEA reference materials for Trace and Minor Elements. The first one was Cabbage coded as IAEA 359 [30]. And the second was Soil coded as IAEA-Soil 7 [31]. Both were analyzed simultaneously with the samples. As Table 1 shows, the experimental values were all in good agreement with the recommended values and there were also within 95% confidence interval given in the reference sheets except for Cd only.

3. RESULTS AND DISCUSSION

The results of EDXRF system confirming the presence of several chemical elements including Mg, K, Mn, Fe, Ni, Cu, Zn, Cd and Pb in all analysed medicinal plants at a wide range of concentrations. As seen in Table 2, it can be observed a variation in the concentration of the quantified elements both essential and non-essential or heavy metals. However, it was not possible to establish any reason about this difference as all the plant samples were from rural areas. The discussion part of this paper will be based on permissible limit given by FAO/WHO and the related organisations.

The observed mean concentrations of the mineral elements in *Moringa oleifera* leaves (Table 2) were 5058.13 ± 116.80 mg/kg, 14541.08 ± 207.83 mg/kg, 73.47 ± 3.51 mg/kg, 309.57 ± 8.96 mg/kg, 2.25 ± 0.46 mg/kg, 4.35 ± 0.68 mg/kg, 19.88 ± 0.22 mg/kg and 0.35 ± 0.01 mg/kg for Mg, K, Mn, Fe, Ni, Cu and Zn respectively. For heavy metal, Pb was 0.35 ± 0.01 while Cd was not detected. As expected, except for Mg and Cu, the root samples of *Moringa oleifera* had highest level of metal concentration than its leaves. As seen in Table 2, Mg was higher in *Hibiscus sabsdariffa* followed by K and Fe. Also Cd was not detected and Pb recorded high concentration of 6.62 mg/kg when compared to the concentration of Pb found in leaves and roots of *Moringa oleifera.* However, it was below the permissible limits set by FAO/WHO.

Magnesium (Mg), the concentration of Mg in analysed plants herbs ranged from 4748.79 - 6346.55 mg/kg, 1372.42 - 1477.53 mg/kg and 3232.76 - 4480.26 mg/kg for leaves and roots of *Moringa oleifera* and *Hibiscus sabsdariffa* (calyces) respectively. With a mean concentration of 5058.13 ± 115.80 mg/kg, 1400.59.59 ± 72.09 mg/kg in leaves and roots of *Moringa oleifera* and 4328.86 ± 132.85 mg/kg in *Hibiscus sabsdariffa*. The lowest concentration was observed in roots of *Moringa oleifera* (Table 2). The concentration levels in leaves were higher than the reported values in Nigeria, India and Thailand [23,24,32]. Also, the concentration level of Mg in roots of *Moringa oleifera* from this study was higher compared to the reported level from Nigeria [2]. In this study, the concentration levels of Mg in *Hibiscus sabsdariffa* were compared to that reported in Gabon, the mean value was within the range reported (2469 – 4579 mg/kg). However, the reported mean concentration of Mg in present research was higher compared to that reported from Libreville in Gabon [25]. The permissible limit of Magnesium set by WHO in plants was 2000 mg/kg, while its daily intake is set to be 350 mg/day for men and 300 mg/kg for women [33]. After comparison, except for Mg levels in roots of *Moringa oleifera*, Mg concentration levels in the

Table 2. Experimental and recommended values (mg/kg) of reference material trace and minor elements (K, Mn and Ni) in cabbage [30] and minor elements (Mg, Fe, Cu, Zn, Cd and Pb) in IAEA-Soil 7 [31]

Elements	Experimental values	Recommended values	95 % confidence Interval from the data sheet
Mg	76.36	60.00	49 – 77
K	32800	32500	31810 – 33190
Mn	32.3	31.9	31.3 – 32.5
Fe	150.00	148.00	144.1 - 151.9
Ni	1.09	1.05	1.00 – 1.10
Cu	5.48	5.67	5.49 - 5.85
Zn	36.77	38.60	37.9 – 39.3
Cd	0.09	0.12	0.115 – 0.125
Pb	55.44	60.00	55 – 71

studied medicinal herbs were above the permissible limit set by FAO/WHO in plants. The leaves of *Moringa oleifera* and calyces of *Hibiscus sabsdariffa* contains unsafe levels of Mg and hence might be detrimental to consumers' health.

Mg is required in the plasma and extra cellular fluid, where it helps in maintaining osmotic equilibrium. It is required in many enzyme catalyzed reactions, especially those in which nucleotide participate where the reactive species is the magnesium salt, e.g. $MgATP^{2-}$. Lack of Mg is associated with abnormal irritability of muscle and convulsions and excess Mg with depression of the central nervous system.

Potassium (K), as seen from Table 2, K was the most abundant element present in all analysed medicinal herbs. The levels ranged from 12091.05-17234.11 mg/kg in leaves, 17600.36-21211.10 mg/kg in roots of *Moringa oleifera* respectively, and 10537.02-15919.70 mg/kg in calyces of *Hibiscus sabsdariffa*. The mean concentrations of K were 14541.08 ± 206.83 mg/kg in *Moringa oleifera* leaves, 20882.20 ± 253.65 mg/kg in *Moringa oleifera* roots and 15732.03 ± 191.27 mg/kg in *Hibiscus sabsdariffa*. The highest value was observed in root of *Moringa oleifera* (Table 2). The mean value of K in *Moringa oleifera* leaves and roots were higher than 8010 mg/kg and 4750 mg/kg respectively, reported from Nigeria [4]. In *Hibiscus sabsdariffa*, concentration of K was much higher than 5326 mg/kg reported from Libreville in Gabon [25].

K is important in for its diuretic nature and helps in the proper function of the brain as well as nerves, thereby preventing stroke. It plays part in acid-base and water regulation in the blood and tissues. K has been reported that a high-potassium diet lowered blood pressure in individuals with raised blood pressure [34]. In addition to its contribution to the electrolytes and function of the nerves in the human body, K has been linked to bone health and osteoporosis prevention according to studies of intake of 2500 mg/day done in United Kingdom [35].

The concentrations observed for Manganese (Mn) in this study ranged from 59.81 to 84.08 mg/kg in *Moringa oleifera* leaves, with its mean value of 73.47 ± 3.51 mg/kg. This concentration range of Mn in *Moringa oleifera* leaves in the present study falls within the concentration range reported in the previous studies (50-90 mg/kg) [36]. For roots of *Moringa oleifera*, Mn ranged from 196.20-317.23 mg/kg with mean concentration of 308.46 ± 10.27 mg/kg. In *Hibiscus sabsdariffa*, Mn ranged from 12.07-27.09 mg/kg and the mean value was 24.16 ± 1.00 mg/kg. The reported mean value of Mn in leaves of *Moringa oleifera* in this study was the same as that reported in Nigeria [23] but higher when compared to 48.73 mg/kg reported from Thailand [24]. In roots of *Moringa oleifera*, the levels of Mn were much higher than 78.9 mg/kg reported from Nigeria [4]. *Hibiscus sabsdariffa* had low concentration of Mn, when compared to 453.71 mg/kg reported from Serbia [10]. The permissible level set by FAO/WHO in medicinal plants is 200 mg/kg, and a daily intake is 11 mg/day [37]. In the present study, except for Mn levels in roots of *Moringa oleifera*, Mn concentration levels in the studied medicinal herbs were below the permissible limit set by FAO/WHO in medicinal plants. The roots of *Moringa oleifera* contain higher levels than the permissible limits set for Mn in plants. Hence, they contain unsafe levels of Mn and might be detrimental to consumers' health. Manganese (Mn) is a trace element necessary for plant,

animal and human as enzyme cofactor [38]. However, the deficiency of manganese in humans may lead to immunodeficiency disorder, rheumatic arthritis in adults, disorder of bony cartilaginous growth in infants, as well as myocardial infarction and other cardiovascular diseases [39].

The observed concentration levels of iron (Fe) in analysed medicinal plants ranged from 89.02–553.46 mg/kg, 246.44–572.81 mg/kg to 380.56 – 798.43 mg/kg for leaves and root of *Moringa oleifera* and in *Hibiscus sabsdariffa*, respectively. Highest levels of Fe were reported in *Hibiscus sabsdariffa* (716.57 ± 48.05 mg/kg) followed by concentration in roots (556.44 ± 11.77 mg/kg) and then in leaves (309.57 ± 8.96 mg/kg) of *Moringa oleifera* (Table 2). The Fe concentration levels in *Hibiscus sabsdariffa* in present study was higher than the levels reported from Turkey, Serbia, Gabon and Nigeria [2,10,25,26]. The obtained Fe level of 309.57 ± 8.96 mg/kg in the leaves of *Moringa oleifera* was slightly higher to that reported in Nigeria [40]. But much higher when compared to that reported in Thailand [24]. Also a similar study, reported a range of 203.1 to 376 mg/kg [41] which was closer to that of the present study. WHO permissible limits for Fe specifically in medicinal plants is 20 mg/kg, while its daily intake is 10-28 mg/day [37]. After comparison, Fe levels in all studied medicinal herbs were above the permissible limits set by WHO in medicinal plants. Generally, the analysed medicinal plants contain unsafe levels of iron. Iron overdose is associated with symptoms of dizziness, nausea and vomiting, diarrhea, joint pain and liver damage [42,43]. Iron has several key functions in human body including oxygen supply, energy production and immunity. Deficiency of Fe may result in anaemia.

The concentration levels of Nickel raged between 0.09–4.89 mg/kg, 0.33–3.08 mg/kg and 0.98–2.15 mg/kg in *Moringa oleifera* leaves, roots and *Hibiscus sabsdariffa*, respectively. With a mean concentration of 2.25 ± 0.46 mg/kg, 2.28 ± 0.88 mg/kg and 1.98 ± 0.06 mg/kg in *Moringa oleifera* leaves, roots and *Hibiscus sabsdariffa*, respectively. In this study, the concentration levels of nickel (Ni) in *Moringa oleifera* leaves and roots were higher than that in calyces of *Hibiscus sabsdariffa*. Ni in *Moringa oleifera* leave was almost the same as the value (2.56 mg/kg) reported in Thailand [24]. The permissible limits for Ni in medicinal plants established by WHO is 1.5 mg/kg [44]. It was also reported that FAO/WHO set the permissible limits to 1.63 mg/kg [45] for edible plants. Nickel concentrations in all analysed plant samples in the present study were above the permissible limits set for both medicinal plants and edible plants (Table 2). Therefore, the results show that all analysed medicinal plants contain unsafe levels of nickel and this might cause toxic effects to human health. The Ni toxicity in human is not a very common occurrence because its absorption the body is very low [46]. The most common ailment arising from Ni is an allergic dermatitis known as nickel itch, which usually occurs when the skin is moisture state [47]. Nickel has been also identified as carcinogen and adversely affects lungs and nasal cavities [47]. Ni is required in minute quantity for body as mostly in the pancrease and hence plays an important role in the production of insulin. Its deficiency results into liver disorder [46]. The daily intake of Ni is recommended to be less than 1 mg/day, beyond this it's a toxic [48].

The copper (Cu) concentration varied from 1.58 - 6.22 mg/kg, 1.20 - 3.79 mg/kg and 0-0.42 mg/kg in *Moringa oleifera* leaves, roots and *Hibiscus sabsdariffa*, respectively. The mean concentrations of Cu were 4.35 ± 0.68 mg/kg, 3.26 ± 0.50 mg/kg and 0.33 ± 0.13 mg/kg in *Moringa oleifera* leaves, roots and *Hibiscus sabsdariffa*, respectively. The mean levels of Cu in *Moringa oleifera* leaves in this study was higher to 1.02 ± 0.08 mg/kg reported in Nigeria [23] but the reported value (6.63 mg/kg) from Sam Phran, Thailand was higher than the levels of Cu in present study [24]. Also the concentration levels of Cu in root of *Moringa oleifera* reported from Nigeria and India were very low compared to that of this study [32, 49].However, for *Hibiscus sabsdariffa* the levels were much lower when compared to that reported from Turkey, Serbia and Nigeria [2, 10, 26]. WHO permissible limits in Cu for medicinal plants is 10 mg/kg, while its intake in food is 2-3 mg/day [44]. Also, the permissible limit set by FAO/WHO in edible plants is 3 mg/kg. China and Singapore had set limits for Cu in medicinal plants at 20 mg/kg and 150 mg/kg respectively [50]. In the present study, the concentrations of Cu in all medicinal plants were below the permissible limits set by FAO/WHO in both medicinal plants and edible plants. The results of from this study have shown that copper concentration is not a matter of concern from the toxicity point of view for the observed herb.

Table 3. The average concentration of heavy metals (mg/kg ± SD) in selected medicinal plants

Elements	Concentrations of heavy metals in (mg/kg ± SD)		
	Moringa oleifera **(leaves), n = 5**	***Moringa oleifera*** **(roots), n = 5**	***Hibiscus sabsdariffa*** **(calyces), n = 7**
Mg	5058.13 ± 116.80 (4748.79-6346.55)	1400.59 ± 72.09 (1372.42-1477.53)	4328.86 ± 132.85 (3232.76 - 4480.26)
K	14541.08 ± 207.83 (12091.05-17234.11)	20882.24 ± 254.65 (17600.36-21211.10)	15732.03 ± 191.27 (10537.02-15919.70)
Mn	73.47 ± 3.51 (59.81-84.08)	308.46 ± 10.27 (196.20-317.23)	24.16 ± 1.00 (12.07-27.09)
Fe	309.57 ± 8.96 (89.02-553.46)	556.44 ± 11.77 (246.44-572.81)	716.57 ± 48.05 (380.56 – 798.43)
Ni	2.25 ± 0.46 (0.09-4.89)	2.28 ± 0.88 (0.33-3.08)	1.98 ± 0.06 (0.98 – 2.15)
Cu	4.35 ± 0.68 (1.58-6.22)	3.26 ± 0.50 (1.20-3.79)	0.33 ± 0.13 (0 - 0.42)
Zn	19.88 ± 0.22 (8.67-23.54)	25.95 ± 0.85 (15.51-27.13)	12.67 ± 0.35 (7.09 – 15.08)
Cd	BDL	BDL	BDL
Pb	0.35 ± 0.01 (0.01-0.07)	0.77 ± 0.19 (0.36-1.05)	6.62 ± 0.13 (2.32-8.74)

Note: The values in bracket represent the range
BDL = Bellow Detection Limits

Copper is essential to the human body since it forms a component of many enzyme systems, such as cytochrome oxidase, lysyl oxidase and ceruloplasmin, an iron-oxidizing enzyme in blood. Copper deficiency results in anemia and congenital inability to excrete copper resulting in Wilson's disease [51]. However, copper could be toxic depending on the dose and duration of exposure [42].

The concentration of Zn in the analysed plant samples raged between 8.67-23.54 mg/kg, 15.51-27.13 mg/kg and 7.09 – 15.08 mg/kg in *Moringa oleifera* leaves, roots and *Hibiscus sabsdariffa*, respectively. With a mean concentration of 19.88 ± 0.22 mg/kg, 25.95 ± 0.85 mg/kg and 12.67 ± 0.35 mg/kg. The mean concentration levels in leaves and roots of *Moringa oleifera* were high compared to the levels reported in Nigeria [4,49] and in Salem, Tamil Nadu- India [32]. Also the concentration level of Zn in *Hibiscus sabsdariffa* was low to that reported in Turkey, Serbia and in Adama State in Nigeria [2,10,26]. FAO/WHO set the permissible limit for Zn in medicinal plat to be 50 mg/kg, while its intake in food is 11 mg/day [44]. Also in 1984, FAO/WHO recommended that the permissible limit of Zn in edible plant to be 27.4 mg/kg [33]. Therefore, the levels of Zn in all analysed medicinal herbs were below the permissible limits of both medicinal and edible plants set by FAO/WHO. Medicinal plants evaluated contained safe level of zinc as far as the permissible levels in edible plants and in medicinal plants are concerned. Zinc is essential trace element necessary for proper growth, blood clotting, thyroid function and protein and DNA synthesis. Zinc intake beyond permissible limits produces toxic effects on the immune system of the body and disrupts copper levels [52].

Cadmium is a nonessential element with uncertain direct functions in both plants and humans [53]. In this study, Cd was not detected in all plant samples (Table 2). However, metals like Cd might be highly toxic even at very low concentrations [54]. WHO recommended limit for medicinal plants is 0.3 mg/kg [55]. Similarity, permissible limits in medicinal plants for Cd set by Canada was 0.3 mg/kg in raw medicinal plant material and 0.006 mg/day in finished herbal products [44]. It is also reported that the lowest level of cadmium which can cause yield reduction in plants is 5 to 30 mg/kg and the maximum acceptable concentration for foodstuff is about 1 mg/kg [56]. Cadmium accumulates in human body and damages mainly the kidneys and liver. Higher levels of Cd pose serious toxicological impacts on human health and it gets into human body through food ingestion, especially plant-based foodstuff. The kidney, liver and other internal organs, especially the renal tract, is the critical organ of intoxication after exposure to Cd. Excretion is slow, and it

accumulates in human kidney and renal, resulting in an irreversible impairment in the re-absorption capacity of renal tubules [43,57].

In all analysed plant samples, lead (Pb) ranged from 0.01-0.07 mg/kg and 0.36-1.05 mg/kg with mean concentration value of 0.35 ± 0.01 mg/kg and 0.77 ± 0.19 mg/kg for *Moringa oleifera* leaves and roots respectively. The mean concentration value of Pb in the leaves was low while the mean value in roots was high than the reported mean concentration levels of Pb in the same plant samples from Keshere, Gombe state in Nigeria [49]. In *Hibiscus sabsdariffa*, the concentration of Pb ranged from 2.32- 8.74 mg/kg with mean value of 6.62 ± 0.13 mg/kg. The Pb in *Hibiscus sabsdariffa* recorded highest level compared to Pb levels in leaves and roots of *Moringa oleifera* (Table 2). The reported concentration levels of Pb in analysed medicinal plants were below the permissible limits of 10 mg/kg [55]. It was reported that the permissible limits of Pb in edible plants was 0.43 mg/kg, while the dietary intake was set to 3 mg/week [33]. Except for *Moringa oleifera* leaves, lead concentrations in other analysed plant samples were higher than the permissible limit set in edible plants. Pb is non-essential trace element having functions neither in human's body nor in plants. Its exposure may have an adverse effect on the blood, nervous, renal, skeleton muscular, reproductive and cardiovascular systems causing poor muscle coordination [58]. The study revealed that lead (Pb) concentration is not a matter of concern from the toxicity point of view for the observed medicinal herb as far as permissible level in medicinal plants is concerned.

4. CONCLUSION

Most of people in Tanzania believe that herbal medicines are safe and non-toxic unlike modern chemotherapeutic agents and they are unaware of toxic potential of these medicinal plants. Therefore, the present study gives a new perspective about the presence of heavy metals and essential elements in the medicinal plants. The above results showed that except for Mg, Mn, Fe and Ni, all other concentrations of heavy metals and essential elements including K, Cu, Zn, Pb and Cd in *Moringa oleifera* roots and leaves and calyces of *Hibiscus sabsdariffa* samples were found within permissible limits set for medicinal plants or the permissible limits of metals in edible plants. It was determined that leaves and roots of *Moringa oleifera* and calyces of *Hibiscus sabsdariffa* in the present study were probably unsafe for human consumption because of Mg, Mn, Fe and Ni concentrations. However, some metals especially for Cd and Pb are toxic heavy metals and their presence even at very low concentration causes toxic effects to human health [59]. Also essential elements like Cu, Fe, and Zn, their excessive concentrations in herbal plants can cause toxicity in consumers [60[. These essential elements interact with some organic compounds such as flavonoids, influencing their biological activity so they must be removed if they are in excess. Hence, people should be aware of the daily consumption of heavy metals accumulated in analysed medicinal plants. Therefore, further analysis which will include more samples is needed to have a definite statistical conclusion on the safety consumption and to assess their long-term cumulative risk on consumer health.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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