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Macro And Micro Elements Content Of Leaves And Seeds Of Moringa Oleifera Cultivated In Senegal: Implication For Human Health

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Abstract:
This study investigates the mineral content of the medicinal plant Moringa olifeira cultivated in Senegal, focusing on heavy metal accumulation. Metals were extracted from dried leaves and seeds samples, after calcination and digestion of the resulting ashes. Metal concentrations were determined using atomic absorption spectrometry (SAA). The predominant macro elements in the leaf and seed powders, according to SAA, were Na (132.1 and 29.4 mg/Kg), K (1121.9 and 1027.9 mg/Kg), Mg (190.1 and 845.3 mg/Kg) and Ca (422.8 and 211.4 mg/Kg). The predominant micro elements in the leaf and seed powders, according to SAA, were Cr (2.3 g/Kg for leaf), Fe (215.3 and 39.3 mg/Kg), Cu (1.1 mg/Kg for leaf), Zn (4.7 and 29.1 mg/Kg), Cd (0.3 and 0.1 mg/Kg) and Pb (3.0 mg/Kg for leaf). Ni is absent from both samples. Elevated metal concentrations in the leaves include chromium at 2.3 mg/Kg in leaves exceeding 2 mg/Kg WHO/FAO limit, iron at 215.3 mg/Kg in leaves and 39.3 mg/Kg in seeds exceeding the limit value of 15 mg/Kg WHO limit, cadmium at 0.3 mg/ kg equal to the 0.3 mg/kg WHO/FAO limit. Zinc and lead concentrations are within WHO/FAO guidelines of 50 mg/Kg and 10 mg/Kg, respectively. The target risk quotient (THQ) was less than 1 for all heavy metals in Moringa oleifera leaves and seeds, indicating that their consumption does not pose obvious non-cancer health risks, although prolonged use may lead to health risks. The overall HI for leaves and seeds remains less than 1, indicating the absence of health risks for the consumption of Moringa oleifera leaf or seed preparations. Our current results suggest that the leaves and seeds of the medicinal plant Moringa oleifera contain an acceptable amount of heavy metals and that their use is therefore beneficial in addressing macronutrient deficiencies. It is essential to organize periodic monitoring of heavy metal concentrations in Moringa oleifera extracts. The Na/K value is less than 1, which is the recommended value, in the leaves (0.12) and seeds (0.03), indicating a benefit of consuming Moringa oleifera extracts on high blood pressure. The Ca/Mg ratio value of 0.25 for seeds is within the recommended values (between 1 and 2) to be beneficial for consumers. For the leaves, the Ca/Mg ratio value is 2.22 is outside of the recommended limits. The high consumption of Moringa oleifera extracts in Senegal could cause long-term bioaccumulation of heavy metals.
Key Word: *Moringa, heavy metal, SAA, risk, health, WHO, FAO*

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I. Introduction

Moringa oleifera, belonging to the *Moringaceae* family (Padayachee & Baijnath, 2012), is the most widespread shrub species in the Moringa genus. It is a widely used plant that grows in several regions of the world [1,2]. It is found in tropical and subtropical regions and can survive in less fertile soils and is drought-resistant. It is found in Africa, South America, and Southeast Asia [3-5]. It is a medium-sized shrub. Its leaves and fruits have significant nutritional value and are used in culinary preparations [6,7]. They play the role of dietary supplements to combat malnutrition in mothers and children in many countries, particularly in African countries [8-10]. Moringa leaves are very rich in secondary metabolites such as polyphenols and flavonoids, which give it antioxidant, antimicrobial, and anticancer properties [11-14]. The leaves also contain trace elements such as selenium, zinc, and iron, which are essential for the proper functioning of the metabolism [15-17]. Moringa leaves and seeds are used in medicinal preparations to treat chronic disease, liver, high blood pressure, diabetes, fever and coughs [18-23]. Used as a medicinal plant in many parts of the world, this plant must be well studied to make its use without risks to human health. Indeed, studies have shown that dried Moringa leaves contain lead, cadmium, chromium, copper, and zinc which are toxic elements at high doses [24-26]. It has also been shown that the presence of heavy metals in crops is often linked to the contamination of the soils shown to grow these [27,28]. Water quality and the use of fertilizers can impact the presence of metals in

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plants [29-31]. The accumulation of metals in plants can occur through root absorption or deposition on aerial surfaces. The widespread use of *Moringa oleifera* leaves and seeds observed in recent years has attracted the attention of researchers who are raising questions related to safety and health risks for consumers due to the presence of heavy metals [32,33]. Prolonged exposure of consumers to heavy metals exceeding guideline values is associated with the development of several serious diseases such as neuropathy, cancers, kidney failure, liver and pancreatic diseases, and mental retardation in children [32, 34-36]. It therefore appears essential to monitor the mineral composition of crops consumed both for food and for the preparation of medicines because elements such as lead, cadmium, mercury, and arsenic, non-essential elements, are very toxic to humans, even at low concentrations. In this study, we propose to evaluate the risks to human health of the consumption of leaves and seeds of *Moringa oleifera* cultivated in Senegal due to the presence of macro (Na, K, Mg, Ca) and microelements (Cr, Fe, Ni, Cu, Zn, Cd, Pb).

II. Materials And Methods

Instrumentation

All experiments were carried out using a Thermo Fischer Atomic Absorption 3000. The samples were run in triplicates and the values reported are mean of triplicates. Analytical conditions, limits of detection and the calibration variables obtained for the studied elements are given in Table 1.

Reagents and standards

All solutions were prepared with distilled-deionized water (18MΩcm, Milli-Q, Millipore, Bedford, MA, USA). Sulfuric acid (H_2SO_4 , 98%), perchloric acid ($HClO_4$, 70%) and nitric acid (HNO_3 65%), from Sigma-Aldrich France, were used in the procedure of digestion of the samples. The analytical solutions were prepared from standard solution dilutions 1000 μgmL^{-1} of Na, K, Mg, Ca, Cr, Fe, Ni, Cu, Zn, Cd and Pb (Aldrich, France). All materials used were decontaminated in nitric acid solution 10% v/v by 24 h. Leaves and seeds of *Moringa oleifera* were harvested from a rural area in Senegal.

Extraction of heavy metals from leaves and seeds of Moringa oleifera

Five grams of leaves or seeds of *Moringa oleifera* were weighed and collected in a Kjeldahl flask. Wet digestion was carried out with an acid mixture (3:2:1 nitric acid, perchloric acid and sulfuric acid) for 4 hours to obtain a clear solution. The samples were cooled to room temperature and the volume was made up to 100 mL with ultra-pure water [37]. They are stored in the refrigerator in food grade polyethylene bottles previously washed with a 6N nitric acid solution.

Table 1: Analytical conditions and calibration curves for Na, K, Mg, Ca, Fe, Ni, Cu, Zn, Cd and Pb analysis by Atomic Absorption Spectroscopy.

Mineral	Wavelength (nm)	Range of detection (mg/L)	Correlation coefficient (R^2)	Calibration curve equation
Sodium	598	0.02-0.8	0.9960	y = 123.66x +14.846
Potassium	766.5	0.03-1.6	0.9969	y = 0.1621x + 0.0096
Magnesium	285.2	0.003-0.6	0.9955	y = 0.5648x + 0.0109
Calcium	422.7	0.005-4	0.9918	y = 0.0052x - 0.0018
Chromium	357.9	0.03-10	0.9966	y = 0.0133x +0.0029
Iron	248.3	0.05-0.8	0.9979	y = 0.0310x + 0.0042
Nickel	232	0.09-8	0.9906	y = 0.0451x + 0.0173
Copper	324.8	0.01-4	0.9975	y = 0.1418x + 0.0078
Zinc	213.9	0.005-1.6	0.9958	y = 0.2175x + 0.0040
Cadmium	228.8	0.004-1.8	0.9971	y = 0.1947x +0.0006
Lead	217	0.1-12	0.9992	y = 0.0253x +0.0005

Human Health Risk Assessment

Consumption of leaves or seeds of *Moringa oleifera* containing heavy metals may pose a risk to human health. This risk can be assessed based on the estimated daily intake (EDI) (equation 1) of heavy metals, the target hazard quotient (THQ) (equation 2) and the hazard index (HI) (equation 3). To estimate the daily metal burden in the body of a consumer of a given body weight, the estimated daily intake (EDI) was calculated using the following equation 1 [38,39].

$$EDI = \frac{Cn*IR*EF*ED}{BW*AT*1000} \quad \text{equation 1}$$

(*EDI* is the estimated daily intake of heavy metals ingested from an agricultural crop in mg/kg day, *Cn* is the concentration of heavy metal in agricultural crop measured in mg/kg, IR is the ingestion rate which is measured in mg/day, *EF* is the exposure frequency in days/year, *ED* is the exposure duration over years, BW is the body weight of the exposed individual in kg, AT is the time period over which the dose is averaged in days as seen in Table 2).

Table 2: Exposure parameters for health risk assessment through various exposure pathways for plants [40].

Parameter	Unit	Adult
Body weight	Kg	70
Exposure frequency (EF)	days/year	350
Exposure duration (ED)	year	30
Ingestion rate (IR)	mg/day	100
Plant adherence factor (AF)	mg/cm^2	0.07
Dermal absorption factor (ABS)	None	0.1
Dermal exposure ratio (FE)	None	0.61
Average time (AT): For carcinogens	Days	365 x 70
For Non-carcinogens	Days	365 x ED

Target Hazard Quotient (THQ)

Prolonged exposure to heavy metals from medicinal plant extracts may pose a carcinogenic risk to consumers. This risk is assessed using the target hazard quotient (THQ) method calculated, according to equation 2, as a percentage of the determined dose relative to the reference dose (RFD) [41]. If the THQ is less than 1, no risk to human health is expected; if the THQ is greater than 1, adverse health effects could occur. The THQ is calculated as the ratio of the average daily intake (EDI) to the reference dose (RFD, Table 3) (equation 2) :

$$THQ = \frac{EDI}{RFD} \qquad \text{equation 2}$$

Table 3: Reference doses (RFD) used for Fe, Ni, Cu, Zn and Pb.

Metal	Cr	Fe	Cu	Zn	Cd	Pb
RFD (mg)	0.003	3	0.04	0.3	0.001	0.004

Hazard Index

Consumption of leaves or seeds of *Moringa oleifera* containing several heavy metals can pose a significant risk to the consumer's health. Indeed, the effects of these different toxic metals can be additive. The hazard index (HI) is a tool for assessing the total non-carcinogenic risk induced by these metals on human health. The HI is calculated according to equation 3 using the sum of the individual THQ of each metal hazardous to human health. The health risk level is low if HI < 1, while the health risk is high if HI > 1.

$$HI = \sum THQ \qquad \text{equation 3}$$

Table 4: Metal levels in triplicate (mg/Kg) and Provisional Tolerable Weekly Intake (PTWI) values for metals [42].

Element (mg/Kg)	Leaves	Seeds	PTWI for a 70-kg Individual (mg/week)	LOD (mg/l)
Na	132.11 ± 0.04	29.42 ± 0.02	14000	0.030
K	1121.92 ± 0.01	1027.93 ± 0.01	24500	0.2
Mg	190.1 ± 0.027	845.3 ± 0.019	2940	0.0008
Ca	422.8 ± 0.011	211.4 ± 0.009	8400	0.0007
Cr	2.3 ± 0.001	< LOD	1.631	0.005
Fe	215.3 ± 0.001	39.30 ± 0.004	392	0.001
Cu	1.1 ± 0.001	< LOD	245	0.001
Zn	4.7 ± 0.003	29.1 ± 0.001	490	0.001
Cd	0.3 ± 0.000	0.1 ± 0.000	0.490	0.0004
Pb	3.0 ± 0.001	< LOD	1.750	0.005

PTWI: Provisional Tolerable Weekly Intake, LOD: Limit Of Detection.

III. Results And Discussion

Levels of minerals in leaves and seed of *Moringa oleifera*

Macro elements (Na, K, Mg, and Ca) which are essential for the proper functioning of the body and Micro elements (Cr, Fe, Cu, Zn, Cd and Pb) which can cause serious damage are present in leaves and seed of *Moringa oleifera*. The concentrations (mg/kg) in the leaves and seeds of *Moringa oleifera* grown in Senegal are presented in Table 4.

Sodium

Sodium is a cation involved in maintaining constant osmotic pressure, regulating membrane potentials, nerve impulse conduction, and muscle irritability [43,44]. An excess or deficiency of sodium in biological fluids can cause significant disturbances such as diarrhea, vomiting, nephrosis, or intestinal diseases [45-47]. The recommended daily minimum intake of Na is estimated as 2400 mg/day [48]. In the leaves and seeds of *Moringa oleifera* from Senegal, the sodium contents are 132.11 ± 0.04 mg/Kg and 29.42 ± 0.02 mg/Kg, respectively. The results of analyses of leaves and seeds of *Moringa oleifera* harvested in India give concentrations of 1541.7 mg/Kg and 224.8 mg/kg [49]. *Moringa oleifera* leaves harvested in Nigeria have a sodium content [132.1 ± 1.1 mg/kg] [50] almost identical to our results.

Potassium

Potassium plays a central role in the body's physiology. It is linked to sodium metabolism and plays an essential role in the functioning of the cardiac system by preventing arrhythmias [51,52]. Its presence facilitates the conduction of nerve impulses and contributes to the proper functioning of the muscular system [53,54]. Potassium deficiency can lead to kidney failure, heart failure and hypertension [55]. The recommended daily intake of potassium is 3500 mg [56]. In the leaves and seeds of *Moringa oleifera* from Senegal, the potassium contents are 1121.92 ± 0.01 mg/Kg and 1027.93 ± 0.01 mg/Kg, respectively. The potassium content of *Moringa oleifera* seeds harvested from India is twice as high [2357.71 ± 1.87 mg/Kg] as that of seeds from Senegal [57]. On the other hand, *Moringa oleifera* leaves harvested in India have lower potassium contents [603.4 mg/Kg to 665.4 mg/Kg] than those of leaves from Senegal [58].

The potassium/sodium ratio is an important factor in preventing high blood pressure and the recommended K/Na ratio should be greater than 1. The potassium-sodium ratio calculated by the recommended dietary allowances (RDA) which are 8.49:1 (leaves) and 34.96:1 (seeds), suggest that the consumption of the different parts of *Moringa oleifera* cultivated in Senegal can have a beneficial effect on high blood pressure.

Magnesium

Magnesium is a cofactor of many enzymes and is involved in protein, DNA and RNA synthesis and energy metabolism [59]. Magnesium is an important element in the control of ischemic heart disease and calcium metabolism in bones [60]. Magnesium deficiency may be associated with the development of cardiovascular problems and diabetes [61]. The recommended dose is 300 mg/day for women and 350 mg/day for men [62]. In the leaves and seeds of *Moringa oleifera* from Senegal, the magnesium contents are 190.1 ± 0.027 mg/Kg and 845.3 ± 0.019 mg/Kg, respectively. The results of analyses of magnesium in *Moringa oleifera* leaves from Mexico give values between 3255 mg/Kg and 3406 mg/Kg, which are significantly higher than our results [17,23]. Other studies have given results between 584.25 mg/Kg and 617.43 mg/Kg closer to the results of this study [63].

Calcium

Calcium helps fight the risks of osteoporosis in the elderly, high blood pressure, premenstrual syndrome and cancer [64,65]. The maximum recommended calcium intake is 2500 mg/day [66]. Doses up to 4000 mg/day are not considered dangerous, but higher doses lead to calcification of various internal organs [67]. Calcium deficiency can lead to osteoporosis, rickets or tetany [68]. In the leaves and seeds of *Moringa oleifera* from Senegal, the calcium contents are 422.8 ± 0.0011 mg/Kg and 211.4 ± 0.009 mg/Kg, respectively. In another study, the Ca concentration found in *Moringa oleifera* leaves harvested in Mexico are much higher than our results and are between 2016.5 mg/Kg and 2620.5 mg/Kg [17,23]. *Moringa oleifera* leaves from Bangladesh give Ca concentrations between 13.22 mg/Kg and 26.45 mg/Kg which are much lower than our results [69]. The disparity in these Ca concentrations is likely related to differences in soil and irrigation water quality, the environment, and the geographic harvesting area of the *Moringa oleifera* samples. The calcium-magnesium ratio values calculated for the leaves (2.22) and seeds (0.25) of *Moringa oleifera* from Senegal are outside the recommended values (between 1 and 2) and confirm that the consumption of *Moringa oleifera* leaves and seeds grown in Senegal has no positive impact on health. The amounts of sodium, potassium, magnesium, and calcium present in the different parts of the plant can contribute to ensuring the required daily intake of these macronutrients.

Chromium

The Cr concentration in *Moringa oleifera* leaves is 2.3 mg/Kg while in seeds the chromium concentration is below the detection limit. The Cr concentration found in this study is lower than those reported for Moringa cultivated in Ethiopia (4.35 to 9.0 mg/Kg) [38]. Chromium is a micronutrient necessary for the proper functioning of the body at low concentrations below 0.03 mg/kg. It is an element that can accumulate in the body and cause, in the long term, metabolic dysfunctions leading to cardiovascular problems, chronic hypoglycemia, cancers, dermatitis, lesions of the nasal mucosa, and eating disorders [70]. The permissible limit of chromium in plant raw materials is 2.0 mg/kg and that of finished products is 0.02 mg/day [71]. Our results show that the Cr level in *Moringa oleifera* grown in Senegal is higher than the reference value defined by the WHO for medicinal plants. *Moringa oleifera* grown in Senegal should be consumed with caution to avoid long-term health complications.

Iron

Iron concentrations in the leaves and seeds of *Moringa oleifera* grown in Senegal are very different and are 215.3 and 39.30 g/Kg, respectively. These values are higher than the values obtained for *Moringa oleifera* leaves (4.75 to 29.37 mg/Kg) [72]. Iron is an essential component in the formation of hemoglobin and myoglobin for oxygen transport and cellular growth and division processes [72]. Iron deficiency can lead to severe anemia (Anal, 2014). The dietary limit of iron in the diet is 10 to 60 mg per day. Excess iron in the body is associated with the development of cancer, diabetes, cardiovascular or liver diseases [73]. Moringa leaves contain a significant amount of iron to be a potential source of iron supplement for consumers. These values are lower than the limit value of 392 mg/Kg, defined by WHO/FAO [74], the iron concentration is not of concern from the point of view of toxicity of leaves or seeds of *Moringa oleifera* used for consumption.

Copper

The Cu concentration in *Moringa oleifera* leaves is 1.1 mg/Kg while in seeds the copper concentration is below the detection limit. This value is comparable to the values reported for *Moringa oleifera* leaves from Pakistan at different stages of maturity (0.595 to 2.08 mg/Kg) [75]. However, it is lower than that found in *Moringa oleifera* leaves harvested (7.1 to 8.7 mg/Kg) in Ethiopia [38]. Copper is an essential element in human metabolism and controls biological functions, energy production, neurotransmitter synthesis and iron metabolism [39]. Excessive consumption of copper can cause health conditions such as irritation of nasal mucosa, nausea, kidney or liver problems [76,77]. This study showed that the consumption of *Moringa oleifera* grown in Senegal does not present any risks in terms of the presence of copper at a dose of 1.1 mg/Kg, far from the guide dose set by the WHO at 10 mg/Kg [39].

Zinc

The zinc concentration in *Moringa oleifera* leaves is 4.70 mg/Kg while the seeds have a much higher concentration with a value of 29.1 mg/kg. These concentrations are higher than those reported in different samples of *Moringa oleifera* (3.2 to 4.8 mg/Kg) [78]. Although zinc is an essential element for different processes such as enzymatic catalysis, excessive zinc intake can have a negative impact on the health of consumers [79]. Consumption of low doses over a long period can also cause health risks [80]. In this study, the zinc concentrations of *Moringa oleifera* leaf and seed samples are below the limit value of 50 mg/Kg, set by WHO.

Cadmium

Cadmium concentrations are three times higher in leaves than in seeds, with values of 0.3 mg/kg and 0.1 mg/kg, respectively. The highest concentration found in leaves is identical to the WHO maximum permissible limit of 0.3 mg/kg (2007). These concentration values are comparable to those found in samples of *Moringa oleifera* grown in Nigeria (0.156 to 0.312 mg/kg) [81] but are lower than the values reported for samples collected in South Africa (3.7 mg/Kg) [82] and Ghana (0.553 mg/Kg) [83]. Cadmium is very toxic at high doses. It can accumulate in the kidneys and cause serious damage leading to kidney failure, disruption of the vascular immune system, bone fragility and lung problems [84,85]. Our study showed that the cadmium concentration in the leaves and seeds of *Moringa oleifera* cultivated in Senegal are well within the WHO recommendations.

Lead

Lead concentrations in *Moringa oleifera* leaves grown in Senegal are 3.0 mg/kg, while the concentration in seeds is below the detection limit. This concentration is well below the WHO limit of 10.0 mg/kg for medicinal plant preparations [79]. This value is lower than that reported for *Moringa oleifera* samples from Mexico (0.355 mg/kg) [17] and Ghana (0.370 mg/kg) [86]. Lead is a toxic element known to cause severe anemia, kidney, brain, nerve, and liver damage, and reproductive disorders (ATSDR, 2007). The results show that lead concentrations in the leaves and seeds of *Moringa oleifera* grown in Senegal are well within WHO values.

Health Risk Assessment of Heavy Metals Analyzed

The health risks associated with the presence of metals in harvested crops are assessed by determining the estimated daily intake (EDI) of these elements in consumers. The estimated daily intake (EDI) includes the consumer's body weight, frequency, and duration of consumption. Table 5 presents the estimated daily intakes (EDI) of the different elements. The values found for the heavy metals Cr, Fe, Ni, Zn, Cd and Pb are lower than the reference doses, which suggests that the consumption of leaves and seeds extract of *Moringa oleifera* does not pose significant risk to consumer health.

Table 5: Estimated daily intake (µg/Kg/day) according to the average concentration of each metal in leaves and seeds of Moringa for adults.

Part of plant	Leaves	Seeds
Na	7.755×10^{-2}	1.726×10^{-2}
K	6.6586×10^{-1}	6.2988×10^{-1}
Mg	1.116×10^{-1}	4.4963×10^{-1}
Ca	2.2482×10^{-1}	1.2411×10^{-1}
Cr	1.35×10^{-3}	-
Fe	1.264×10^{-1}	2.3072×10^{-2}
Cu	6.458×10^{-4}	-
Zn	2.759×10^{-3}	1.7084×10^{-3}
Cd	1.761×10^{-4}	5.8708×10^{-5}
Pb	1.761×10^{-3}	-

Non-carcinogenic risk assessment

Table 6 presents the non-carcinogenic target risk quotient (THQ) and the non-carcinogenic risk index (HI). The THQ values for Cr, Fe, Ni, Cu, Zn, Cd and Pb in the leaves and seeds of *Moringa oleifera*, are all less than 1, suggesting that the consumption of extracts poses no health risks to consumers. The HI values are less than 1 for leaves and seeds of *Moringa oleifera* extracts, indicating that the combined effects of the various heavy metals pose no long-term health risks to consumers. Our results are similar to those reported by other authors who report THQ and HI values lower than 1 for numerous varieties of Moringa [81,87].

Table 6: HQ and HI (mg/kg/day) of heavy metal in leaves and seeds of *Moringa oleifera* for adults.

Element	THQ (Leaves)	THQ (Seeds)
Fe	4.2133×10^{-2}	7.6908×10^{-3}
Cu	1.6145×10^{-2}	-
Zn	9.1977×10^{-3}	5.6947×10^{-3}
Cd	1.7613×10^{-1}	5.8708×10^{-2}
Pb	4.4031×10^{-1}	-
HI	$\mathbf{6.8391 \times 10^{-1}}$	$\mathbf{7.2094 \times 10^{-2}}$

THQ: Target Hazard Quotient, HI: Hazard Index.

IV. Conclusion

This study examined the presence of macro and micronutrients in the leaves and seeds of the medicinal plant *Moringa oleifera* grown in Senegal. The results showed that the concentrations of microelements (Na, K, Mg and Ca) contribute to the daily intake and that the Na/K ratios are less than 1, which is the maximum recommended value for the consumption of leaves and seeds to be beneficial for the consumer. However, the Ca/Mg ratios, which are 0.25 for seeds and 2.22 for leaves, are outside the recommended guideline values (between 1 and 2). The results also showed that the concentrations of macro elements (Cr, Fe, Cu, Zn, Cd and Pb) are in line with the guideline values, where they exist, defined by the World Health Organization. The non-carcinogenic target hazard quotient (THQ) results indicated that the consumption of *Moringa oleifera* leaf and seed extracts grown in Senegal does not pose any health risks to consumers. The non-carcinogenic hazard index (HI) values in both samples suggest that the combined effects of these heavy metals do not cause any cumulative health problems with long-term consumption.

References

[1] Akabari, A. H., Shah, D. P., Patel, S. P., & Patel, S. K. (2022). Ethanopharmacology, Phytochemistry, Pharmacology And Toxicology Of Moringaceae Family : A Review. Systematic Reviews In Pharmacy, 13(9), 909-929. Https://Doi.Org/10.31858/0975-8453.13.9.909-929

[2] Boopathi, N.M., Abubakar, B.Y. (2021). Botanical Descriptions Of Moringa Spp., (P. 11-20). In: Boopathi, N.M., Raveendran, M., Kole, C. (Eds) The Moringa Genome. Compendium Of Plant Genomes. Springer, Cham. Https://Doi.Org/10.1007/978-3-030-80956-0_2

[3] Ayerza (H), R. (2012). Seed And Oil Yields Of Moringa Oleifera Variety Periyakalum-1 Introduced For Oil Production In Four Ecosystems Of South America. Industrial Crops And Products, 36(1), 70-73. Https://Doi.Org/10.1016/J.Indcrop.2011.08.008

[4] Bania, J. K., Nath, A. J., Das, A. K., Sileshi, G. W. (2023). Integrating Moringa Oleifera And Moringa Stenopetala In Agroforestry For Adaptation And Mitigation Of Climate Change In Asia And Africa. In: Dagar, J.C., Gupta, S.R., Sileshi, G.W. (Eds) Agroforestry For Sustainable Intensification Of Agriculture In Asia And Africa. Sustainability Sciences In Asia And Africa (P. 719-737). Springer, Singapore. Https://Doi.Org/10.1007/978-981-19-4602-8_22

[5] El Bilali, H., Dan Guimbo, I., Nanema, R. K., Falalou, H., Kiebre, Z., Rokka, V.-M., Tietiambou, S. R. F., Nanema, J., Dambo, L., Grazioli, F., Naino Jika, A. K., Gonnella, M., & Acasto, F. (2024). Research On Moringa (Moringa Oleifera Lam.) In Africa. Plants, 13(12), 1613. Https://Doi.Org/10.3390/Plants13121613

[6] Bibi, N., Rahman, N., Ali, M. Q., Ahmad, N., & Sarwar, F. (2024). Nutritional Value And Therapeutic Potential Of Moringa Oleifera : A Short Overview Of Current Research. Natural Product Research, 38(23), 4261-4279. Https://Doi.Org/10.1080/14786419.2023.2284862

[7] Hossain, M. F., Numan, S. M., Khan, S. S., Mahbub, S., & Akhtar, S. (2022). Human Consumption, Nutritional Value And Health Benefits Of Moringa (Moringa Oleifera Lam.) : A Review. International Journal Of Community Medicine And Public Health, 9(9), 3599-3604. Https://Doi.Org/10.18203/2394-6040.Ijcmph20222229

[8] Gomes, S. M., Leitão, A., Alves, A., & Santos, L. (2023). Incorporation Of Moringa Oleifera Leaf Extract In Yoghurts To Mitigate Children's Malnutrition In Developing Countries. Molecules, 28(6), 2526. Https://Doi.Org/10.3390/Molecules28062526

[9] Sokhela, H., Govender, L., & Siwela, M. (2023). Complementary Feeding Practices And Childhood Malnutrition In South Africa : The Potential Of Moringa Oleifera Leaf Powder As A Fortificant : A Narrative Review. Nutrients, 15(8), 2011. Https://Doi.Org/10.3390/Nu15082011

[10] Zongo, U., Zoungrana, S. L., Savadogo, A., & Traoré, A. S. (2013). Nutritional And Clinical Rehabilitation Of Severely Malnourished Children With Moringa Oleifera Lam. Leaf Powder In Ouagadougou (Burkina Faso). Food And Nutrition Sciences, 4(9), 991-997. Https://Doi.Org/10.4236/Fns.2013.49128

[11] Barhoi, D., Upadhaya, P., Barbhuiya, S. N., Giri, A., & Giri, S. (2021). Aqueous Extract Of Moringa Oleifera Exhibit Potential Anticancer Activity And Can Be Used As A Possible Cancer Therapeutic Agent : A Study Involving In Vitro And In Vivo Approach. Journal Of The American College Of Nutrition, 40(1), 70-85. Https://Doi.Org/10.1080/07315724.2020.1735572

[12] El-Gendi, H., Albrahim, J. S., Alenezi, H., El-Fakharany, E. M., El-Maradny, Y. A., & Saleh, A. K. (2025). Bioactive Bacterial Cellulose/Chitosan/Sodium Alginate Composite Film Functionalized With Moringa Oleifera Seed Extract : Antimicrobial, Anticancer, And Molecular Docking Studies. International Journal Of Biological Macromolecules, 307, 141958. Https://Doi.Org/10.1016/J.Ijbiomac.2025.141958

[13] Panova, N., Gerasimova, A., Tumbarski, Y., Ivanov, I., Todorova, M., Dincheva, I., Gentscheva, G., Gledacheva, V., Slavchev, V., Stefanova, I., Petkova, N., Nikolova, S., & Nikolova, K. (2025). Metabolic Profile, Antioxidant, Antimicrobial, Contractile, And Anti-Inflammatory Potential Of Moringa Oleifera Leaves (India). Life, 15(4), 583. Https://Doi.Org/10.3390/Life15040583

[14] Sankhalkar, S., & Vernekar, V. (2016). Quantitative And Qualitative Analysis Of Phenolic And Flavonoid Content In Moringa Oleifera Lam And Ocimum Tenuiflorum L. Pharmacognosy Research, 8(1), 16-21. Https://Doi.Org/10.4103/0974-8490.171095

[15] Abbas, R. K., Elsharbasy, F. S., & Fadlelmula, A. A. (2025). Analysing The Nutritional Values Of Moringa Oleifera, Under The Semi-Arid Conditions Of Sudan. Contemporary Research And Perspectives In Biological Science 9, 51-58. Https://Doi.Org/10.9734/Bpi/Crpbs/V9/4068

[16] Chibuye, B., Singh, I. S., Chimuka, L., & Monyai, M. (2025). Nutrients And Toxic Heavy Metals In Strychnos Cocculoides (Loranthaceae) : Implications For Traditional Medicine. Toxicology Reports, 14, 102050. Https://Doi.Org/10.1016/J.Toxrep.2025.102050

[17] Valdez-Solana, M. A., Mejía-García, V. Y., Téllez-Valencia, A., García-Arenas, G., Salas-Pacheco, J., Alba-Romero, J. J., & Sierra-Campos, E. (2015). Nutritional Content And Elemental And Phytochemical Analyses Of Moringa Oleifera Grown In Mexico. Journal Of Chemistry, 2015(1), 860381. Https://Doi.Org/10.1155/2015/860381

[18] Gul, P., Khan, J., Li, Q., & Liu, K. (2025). Moringa Oleifera In A Modern Time : A Comprehensive Review Of Its Nutritional And Bioactive Composition As A Natural Solution For Managing Diabetes Mellitus By Reducing Oxidative Stress And Inflammation. Food Research International, 201, 115671. Https://Doi.Org/10.1016/J.Foodres.2025.115671

[19] Jamil, S., Turabi, T. H., Ahmad, S., Riaz, M., Wariss, H. M., & Akter, Q. S. (2025). Comparative Investigation Of The Nutritional Profiling And Antipyretic Activity Of Moringa Oleifera Leaves, Bark, And Root From Different Sites Of Punjab, Pakistan. Food Science & Nutrition, 13(1), E4706. Https://Doi.Org/10.1002/Fsn3.4706

[20] Menichetti, F., Berteotti, C., Schirinzi, V., Poli, C., Arrighi, R., & Leone, A. (2025). Moringa Oleifera And Blood Pressure : Evidence And Potential Mechanisms. Nutrients, 17(7), 1258.

Https://Doi.Org/10.3390/Nu17071258
[21] Sidharta, B. R. A., Purwanto, B., Wasita, B., Widyaningsih, V., Soetrisno, S., Cilmiaty, R., & Ardyanto, T. D. (2025). The Effect Of Moringa Oleifera Ethanol Extract On Improving Cisplatin Induced Liver Cells Damages. Asian Pacific Journal Of Cancer Prevention, 26(6), 2175-2183.
Https://Doi.Org/10.31557/APJCP.2025.26.6.2175
[22] Uwaya, D. O., & Effiong, O. N. (2024). Quantification Of Phytochemical Constituents, And Non-Enzymatic Antioxidants Of Polyherbal-Formulated Tea On Antitussive, Expectorant, And Analgesic Activity In Rodent. Research In Biotechnology And Environmental Science, 3(1), 9-17.
Https://Doi.Org/10.58803/Rbes.V3i1.29
[23] Villegas-Vazquez, E. Y., Gómez-Cansino, R., Marcelino-Pérez, G., Jiménez-López, D., & Quintas-Granados, L. I. (2025). Unveiling The Miracle Tree : Therapeutic Potential Of Moringa Oleifera In Chronic Disease Management And Beyond. Biomedicines, 13(3), 634.
Https://Doi.Org/10.3390/Biomedicines13030634
[24] Abubakar, U. S., Bashir, L. U., Garba, A. I., Abdullahi, M. S., & Musa, B. (2021). Evaluation Of Heavy Metals, Phytochemical Constituents And Median Lethal Dose Of Two Anti-Diabetic Plants (Moringa Oleifera And Carica Papaya). Journal Of Current Biomedical Research, 1(4), 70-79.
Https://Journals.Unizik.Edu.Ng/Jcbr/Article/View/865
[25] Agboola, O. O., Orji, D. I., Olatunji, O. A., & Olowoyo, J. O. (2016). Bioaccumulation Of Heavy Metals By Moringa Oleifera In Automobile Workshops From Three Selected Local Governments Area, Ibadan, Nigeria. West African Journal Of Applied Ecology, 24(1), 9-18.
Https://Www.Ajol.Info/Index.Php/Wajae/Article/View/143459
[26] Fakankun, O. A., Babayemi, J. O., & Utiaruk, J. J. (2013). Variations In The Mineral Composition And Heavy Metals Content Of Moringa Oleifera. African Journal Of Environmental Science And Technology, 7(6), 372-379.
Https://Doi.Org/10.5897/AJEST12.228
[27] Amadi, N., & Tanee, F. B. G. (2014). Efficacy Of Moringa Oleifera As A Phytoextraction Plant In The Remediation Of Heavy Metals Polluted Soil. African Journal Of Plant Science, 8(12), 546-553.
Https://Doi.Org/10.5897/AJPS2014.1226
[28] Vega, F. A., Covelo, E. F., Andrade, M. L., & Marcet, P. (2004). Relationships Between Heavy Metals Content And Soil Properties In Minesoils. Analytica Chimica Acta, 524(1), 141-150.
Https://Doi.Org/10.1016/J.Aca.2004.06.073
[29] Gad, N., Sekara, A., & Abdelhamid, M. T. (2019). The Potential Role Of Cobalt And/Or Organic Fertilizers In Improving The Growth, Yield, And Nutritional Composition Of Moringa Oleifera. Agronomy, 9(12), 862.
Https://Doi.Org/10.3390/Agronomy9120862
[30] Merwad, AE.M.A. (2018). Influence Of Natural Plant Extracts In Reducing Soil And Water Contaminants. In: Negm, A.M., Abu-Hashim, M. (Eds) Sustainability Of Agricultural Environment In Egypt: Part I. The Handbook Of Environmental Chemistry, Vol 76. Springer, Cham.
Https://Doi.Org/10.1007/698_2018_260
[31] Pawaskar, S. M., & Khan, S. (2023). Heavy Metal Analysis Of The Leaf Extracts Of Some Indian Medicinal Plants From Western Maharashtra. Research Journal Of Pharmacy And Technology, 16(6), 2801-2807.
Https://Doi.Org/10.52711/0974-360X.2023.00461
[32] Aissi, A. K., Pazou, E. Y., Ahoyo, T. A., Fah, L., Fanou, B., Koumolou, L., Koudokpon, H., Agbangla, C., Gnandi, K., Loko, F., & Edorh, P. A. (2014). Evaluation Of Toxicological Risk Related To Presence Of Lead And Cadmium In Moringa Oleifera Lam. Leaves Powders Marketed In Cotonou (Benin). Food And Nutrition Sciences, 5, 770-778.
Https://Doi.Org/10.4236/Fns.2014.59087
[33] Alhassan, U. S., & Dajal, J. S. (2023). Health Risk Assessment From The Consumption Of Moringa Oleifera Leaves Cultivated Along River Ginzo, Katsina. Fudma Journal Of Sciences, 7(6), 66-74.
Https://Doi.Org/10.33003/Fjs-2023-0706-2173
[34] Mahapatra, H. S., Bhattacharyya, S., & Batra, V. V. (2021). A Rare Report Of Heavy-Metal-Associated Hemodialysis-Dependent Chronic Kidney Disease Secondary To Ayurvedic Medication. Indian Journal Of Clinical Medicine, 11(1-2), 51-54.
Https://Doi.Org/10.1177/26339447221099991
[35] Parida, L., & Patel, T. N. (2023). Systemic Impact Of Heavy Metals And Their Role In Cancer Development : A Review. Environmental Monitoring And Assessment, 195(6), 766.
Https://Doi.Org/10.1007/S10661-023-11399-Z
[36] Perera, R. A., Perera, R. T., Liyanage, U. P., Premaratne, J., & Liyanage, J. A. (2024). Chemometric Assessment Of Bioaccumulation And Contamination Pathways For Toxic Metals In Diet And Environment : Implications For Chronic Kidney Disease Of Unknown Etiology (Ckdu) In Sri Lankan Agricultural Regions. Environmental Monitoring And Assessment, 196(12), 1179.
Https://Doi.Org/10.1007/S10661-024-13316-4
[37] Manrique, S., Gómez, J., Piñeiro, M., Sampietro, B. A., Peschiutta, M. L., Tapia, A., Simirgiotis, M. J., & Lima, B. (2023). Zuccagnia Punctata Cav., A Potential Environmentally Friendly And Sustainable Bionematicide For The Control Of Argentinean Horticultural Crops. Plants, 12(24), 4104.
Https://Doi.Org/10.3390/Plants12244104
[38] Adefa, T., & Tefera, M. (2020). Heavy Metal Accumulation And Health Risk Assessment In Moringa Oleifera From Awi Zone, Ethiopia. Chemistry Africa, 3(4), 1073-1079.
Https://Doi.Org/10.1007/S42250-020-00181-0
[39] Oladeji, O. M., Kopaopa, B. G., Mugivhisa, L. L., & Olowoyo, J. O. (2024). Investigation Of Heavy Metal Analysis On Medicinal Plants Used For The Treatment Of Skin Cancer By Traditional Practitioners In Pretoria. Biological Trace Element Research, 202(2), 778-786.
Https://Doi.Org/10.1007/S12011-023-03701-4
[40] US Environmental Protection Agency. (2004). United States Environmental Protection Agency (USEPA). Guidelines For Water Reuse.
Https://Www.Epa.Gov/Sites/Default/Files/2019-08/Documents/2004-Guidelines-Water-Reuse.Pdf. Accessed July 10, 2025
[41] USEPA. (2013). USEPA (2013) Regional Screening Level (RSL) Summary Table (TR=1E− 6, HQ= 1). United States Environmental Protection Agency. Regional Screening Levels (Rsls).

Https://Www.Epa.Gov/Risk/Regional-Screening-Levels-Rsls-Generic-Tables. Accessed 10 July 2025.

[42] ATSDR. (2007). Toxicological Profile For Lead. Agency For Toxic Substances And Disease Registry : US Department Of Health And Human Services, Public Health Service, Atlanta, GA, United States.

[43] Luo, Y., & Roux, B. (2010). Simulation Of Osmotic Pressure In Concentrated Aqueous Salt Solutions. The Journal Of Physical Chemistry Letters, 1(1), 183-189.
Https://Doi.Org/10.1021/Jz900079w

[44] Mohamed, E. T., Mahmood, F. N., Mohammed, G., Merie, G. M. S., & Saadi, A. M. (2025). The Medical Importance Of Sodium And Potassium. International Journal Of Pharma Growth Research Review, 2(2), 01-10.
Https://Doi.Org/10.54660/IJPGRR.2025.2.2.01-10

[45] Harbord, M., & Pomfret, S. (2013). Nausea And Vomiting. Medicine, 41(2), 87-91.
Https://Doi.Org/10.1016/J.Mpmed.2012.11.008

[46] Sheikh, I. A., Ammoury, R., & Ghishan, F. K. (2018). Chapter 68—Pathophysiology Of Diarrhea And Its Clinical Implications. In H. M. Said (Éd.), Physiology Of The Gastrointestinal Tract (Sixth Edition) (Sixth Edition, P. 1669-1687). Academic Press.
Https://Doi.Org/10.1016/B978-0-12-809954-4.00068-2

[47] Soi, V., & Yee, J. (2017). Sodium Homeostasis In Chronic Kidney Disease. Advances In Chronic Kidney Disease, 24(5), 325-331.
Https://Doi.Org/10.1053/J.Ackd.2017.08.00

[48] Brouillard A. M., Deych E., Canter C., & Rich M.W. (2020). Trends In Sodium Intake In Children And Adolescents In The US And The Impact Of US Department Of Agriculture Guidelines: NHANES 2003-2016. The Journal Of Pediatrics, 225, 117-123.
Https://Doi.Org/10.1016/J.Jpeds.2020.04.048

49] Goordeen, A., & Mohammed, M. (2021). Growth, Development, Maturation Indices, Proximate And Mineral Composition Of Moringa (Moringa Oleifera). Journal Of Horticulture And Postharvest Research, 4(4), 427-438.
Https://Doi.Org/10.22077/Jhpr.2021.4296.1205

[50] Iyaka, Y. A., Idris, S., Alawode, R. A., & Bagudo, B. U. (2014). Nutrient Content Of Selected Edible Leafy Vegetables. American Journal Of Applied Chemistry, 2(3), 42-45.
Https://Doi.Org/10.11648/J.Ajac.20140203.12

[51] Gao, C., Xu, T., Ye, L. L., & Duan, D. D. (2025). Traditional Chinese Medicine For Anti-Arrhythmias : Mechanisms Via Potassium Channels. Basic & Clinical Pharmacology & Toxicology, 137(1), E70059.
Https://Doi.Org/10.1111/Bcpt.70059

[52] Picard, K., Mager, D. R., Senior, P. A., & Richard, C. (2025). Potassium-Based Sodium Substitutes Impact The Sodium And Potassium Content Of Foods. Journal Of Renal Nutrition, 35(1), 64-71.
Https://Doi.Org/10.1053/J.Jrn.2024.05.010

[53] Huang, W., Wu, Y., Ding, Q., & Jia, Y. (2025). Effects Of Potassium Channel Blockage On Chimera-Like States In The Excitatory–Inhibitory Neuronal Network. The European Physical Journal Special Topics, 1-13.
Https://Doi.Org/10.1140/Epjs/S11734-025-01529-8

[54] Lindinger, M. I., & Cairns, S. P. (2021). Regulation Of Muscle Potassium : Exercise Performance, Fatigue And Health Implications. European Journal Of Applied Physiology, 121(3), 721-748.
Https://Doi.Org/10.1007/S00421-020-04546-8

[55] Steffensen, I.-L., Frølich, W., Dahl, K. H., Iversen, P. O., Lyche, J. L., Lillegaard, I. T. L., & Alexander, J. (2018). Benefit And Risk Assessment Of Increasing Potassium Intake By Replacement Of Sodium Chloride With Potassium Chloride In Industrial Food Products In Norway. Food And Chemical Toxicology, 111, 329-340.
Https://Doi.Org/10.1016/J.Fct.2017.11.044

[56] EFSA Panel On Dietetic Products, N. And A. (NDA), Turck, D., Bresson, J., Burlingame, B., Dean, T., Fairweather-Tait, S., Heinonen, M., Hirsch-Ernst, K. I., Mangelsdorf, I., & Mcardle, H. (2016). Dietary Reference Values For Potassium. EFSA Journal, 14(10), 4592.
Https://Doi.Org/10.2903/J.Efsa.2016.4592

[57] Liang, L., Wang, C., Li, S., Chu, X., & Sun, K. (2019). Nutritional Compositions Of Indian Moringa Oleifera Seed And Antioxidant Activity Of Its Polypeptides. Food Science & Nutrition, 7(5), 1754-1760.
Https://Doi.Org/10.1002/Fsn3.1015

[58] Divyabharathi, V., Swaminathan, V., Paramaguru, P., Venkatesan, K., Anitha, T., & Arumugam, T. (2020). Impact Of Heading Back And Pinching On Mineral Status Of Moringa Leaves (Moringa Oleifera Lam. Cv. PKM-1). International Journal Of Current Microbiology And Applied Sciences, 9(11), 3496-3501.
Https://Doi.Org/10.20546/Ijcmas.2020.911.417

[59] Ma, J., Folsom, A. R., Melnick, S. L., Eckfeldt, J. H., Sharrett, A. R., Nabulsi, A. A., Hutchinson, R. G., & Metcalf, P. A. (1995). Associations Of Serum And Dietary Magnesium With Cardiovascular Disease, Hypertension, Diabetes, Insulin, And Carotid Arterial Wall Thickness : The ARIC Study. Journal Of Clinical Epidemiology, 48(7), 927-940.
Https://Doi.Org/10.1016/0895-4356(94)00200-A

[60] Ishida, H., Suzuno, H., Sugiyama, N., Innami, S., Tadokoro, T., & Maekawa, A. (2000). Nutritive Evaluation On Chemical Components Of Leaves, Stalks And Stems Of Sweet Potatoes (Ipomoea Batatas Poir). Food Chemistry, 68(3), 359-367.
Https://Doi.Org/10.1016/S0308-8146(99)00206-X

[61] Shuhratovna, Q. S. (2023). Trace Elements Analysis In Some Medicinal Plants Using Graphite Furnace-Atomic Absorption Spectroscopy. International Journal Of Pedagogics, 3(11), 209-213.
Https://Doi.Org/10.37547/Ijp/Volume03Issue11-41

[62] Duruibe, J. O., Ogwuegbu, M. O. C., & Egwurugwu, J. N. (2007). Heavy Metal Pollution And Human Biotoxic Effects. International Journal Of Physical Sciences, 2(5), 112-118.
Https://Doi.Org/10.5897/IJPS.9000289

[63] Setiaboma, W., Kristanti, D., & Herminiati, A. (2019). The Effect Of Drying Methods On Chemical And Physical Properties Of Leaves And Stems Moringa Oleifera Lam. AIP Conference Proceedings, 2175(1), 020030.
Https://Doi.Org/10.1063/1.5134594

[64] Barger-Lux, M. J., & Heaney, R. P. (1994). The Role Of Calcium Intake In Preventing Bone Fragility, Hypertension, And Certain Cancers1, 2. The Journal Of Nutrition, 124, 1406S-1411S.
Https://Doi.Org/10.1093/Jn/124.Suppl_8.1406S

65] Heaney, R.P. (2001). Calcium Intake And The Prevention Of Chronic Disease. In: Wilson, T., Temple, N.J. (Eds) Nutritional Health. Nutrition And Health. Humana Press, Totowa, NJ.
Https://Doi.Org/10.1007/978-1-59259-226-5_3

[66] Leśniewicz, A., Jaworska, K., & Żyrnicki, W. (2006). Macro- And Micro-Nutrients And Their Bioavailability In Polish Herbal Medicaments. Food Chemistry, 99(4), 670-679.
Https://Doi.Org/10.1016/J.Foodchem.2005.08.042

[67] Gupta, J., Gupta, A., & Gupta, A. K. (2014). Determination Of Trace Metals In The Stem Bark Of Moringa Oleifera Lam. International Journal Of Chemical Studies, 2(4), 39-42.

[68] Hassan, W., Rehman, S., Noreen, H., Gui, S., Jan, M., Zaman, B., Rehman, A. U., Shah, Z., Riaz, A., Mohammadzai, I., & Kazmi, N. (2015). Metallic Content Of One Hundred (100) Medicinal Plants Ethnobotanical Uses Of 100 Medicinal Plants Metallic Content Of 100 Medicinal Plants. Journal Of Nutritional Disorders & Therapy, 5(4), 1000177.
Https://Doi.Org/10.4172/2161-0509.1000177

[69] Sultana, S. (2020). Nutritional And Functional Properties Of Moringa Oleifera. Metabolism Open, 8, 100061.
Https://Doi.Org/10.1016/J.Metop.2020.100061

[70] Kohzadi, S., Shahmoradi, B., Ghaderi, E., Loqmani, H., & Maleki, A. (2019). Concentration, Source, And Potential Human Health Risk Of Heavy Metals In The Commonly Consumed Medicinal Plants. Biological Trace Element Research, 187(1), 41-50.
Https://Doi.Org/10.1007/S12011-018-1357-3

[71] Nkansah, M. A., Hayford, S. T., Borquaye, L. S., & And, J. H. E. (2016). Heavy Metal Contents Of Some Medicinal Herbs From Kumasi, Ghana. Cogent Environmental Science, 2(1), 1234660.
Https://Doi.Org/10.1080/23311843.2016.1234660

[72] Mawouma, S., Hamidou Yaya, S., Mbyeya, J., Doudou Walko, F., Awoudamkine, E., & Mbofung Funtong, C. M. (2024). Bioaccessibility And Speciation Of Iron From Aqueous Extracts Of Moringa Oleifera Leaves. Journal Of Food Biochemistry, 2024(1), 9312118.
Https://Doi.Org/10.1155/2024/9312118

[73] Fraga, C. G., & Oteiza, P. I. (2002). Iron Toxicity And Antioxidant Nutrients. Toxicology, 180(1), 23-32.
Https://Doi.Org/10.1016/S0300-483X(02)00379-7

[74] WHO/FAO (2011). Codex Alimentarius Commission. Food Additives And Contaminants. Joint FAO. WHO Food Standards Program. 2001;1:1–289.

[75] Qadir, R., Anwar, F., Bashir, K., Tahir, M. H., Alhumade, H., & Mehmood, T. (2022). Variation In Nutritional And Antioxidant Attributes Of Moringa Oleifera L. Leaves At Different Maturity Stages. Frontiers In Energy Research, 10, 888355.
Https://Doi.Org/10.3389/Fenrg.2022.888355

[76] Doguer, C., Ha, J.-H., & Collins, J. F. (2018). Intersection Of Iron And Copper Metabolism In The Mammalian Intestine And Liver. In Comprehensive Physiology (P. 1433-1461). John Wiley & Sons, Ltd.
Https://Doi.Org/10.1002/Cphy.C170045

[77] Festa, R. A., & Thiele, D. J. (2011). Copper : An Essential Metal In Biology. Current Biology, 21(21), R877-R883.
Https://Doi.Org/10.1016/J.Cub.2011.09.040

[78] Mallillin, A. C., Trinidad, T. P., Sagum, R. S., Leon, M. De, Borlagdan, M. P., Baquiran, A. F. P., Alcantara, J. S., & Aviles, T. F. (2014). Mineral Availability And Dietary Fiber Characteristics Of Moringa Oleifera. Food And Public Health, 4(5), 242-246.
Https://Doi.Org/10.5923/J.Fph.20140405.05

79] Price, S., & Que, E. L. (2024). Probing Metalloenzyme Dynamics In Living Systems : Contemporary Advances In Fluorescence Imaging Tools And Applications. Current Opinion In Chemical Biology, 81, 102475.
Https://Doi.Org/10.1016/J.Cbpa.2024.102475

[80] Nriagu, J. (2011). Zinc Toxicity In Humans. In J. O. Nriagu (Éd.), Encyclopedia Of Environmental Health (P. 801-807). Elsevier.
Https://Doi.Org/10.1016/B978-0-444-52272-6.00675-9

[81] Muhammad, M. A., Abdullahi, S. R., Sulaiman, M., Abba, A., Olaleye, A., Siraj, I. T., & Mustapha, I. T. (2024). Carcinogenic And Noncarcinogenic Health Risk Assessment Of Heavy Metals On Some Selected Traditional Herbal Drugs. Research Journal Of Food Science And Quality Control, 10(3), 66-79.
Https://Doi.Org/10.56201/Rjfsqc.V10.No3.2024.Pg66.79

[82] Ananias, N. K., Kandawa-Schulz, M., Hedimbi, M., Kwaambwa, H. M., Tutu, H., Makita, C., & Chimuka, L. (2016). Comparison Of Metal Content In Seeds Of Moringa Ovalifolia And Moringa Oleifera. African Journal Of Food Science, 10(9), 172-177.
Https://Doi.Org/10.5897/AJFS2016.1421

[83] Amerley Amarh, F., Selorm Agorku, E., Bright Voegborlo, R., Winfred Ashong, G., Nii Klu Nortey, E., & Jackson Mensah, N. (2023). Heavy Metal Content And Health Risk Assessment Of Some Selected Medicinal Plants From Obuasi, A Mining Town In Ghana. Journal Of Chemistry, 2023(1), 9928577.
Https://Doi.Org/10.1155/2023/9928577

[84] Mahajan, P., & Kaushal, J. (2018). Role Of Phytoremediation In Reducing Cadmium Toxicity In Soil And Water. Journal Of Toxicology, 2018(1), 4864365.
Https://Doi.Org/10.1155/2018/4864365

[85] Mahurpawar, M. (2015). Effects Of Heavy Metals On Human Health. International Journal Of Research -Granthaalayah, 3(9SE), 1-7.
Https://Doi.Org/10.29121/Granthaalayah.V3.I9se.2015.3282

[86] Lartey, M., Frimpong-Manso, S., Banahene, P. O., Addo-Lartey, A., Okine, N. N.-A., Boamah, D., & Mohammed, A. A. (2021). Heavy Metal Constituent Of Medicinal Plants : A Case Study Of Moringa Oleifera Lam. From Selected Areas S Compromise The Quality Of Medicinal Plants ? A Case Study Of Moringa Oleifera Lam. From Some Selected Areas In The Accra, Ghana. Health Sciences Investigations Journal, 2(1), 181-188.
Https://Doi.Org/10.46829/Hsijournal.2021.6.2.1.181-188

[87] Ngwenya, N., Nuapia, Y., Risenga, I., & Chimuka, L. (2024). Influence Of Different Rates Of Plant-Based Compost On Clay Soil Metal Behavior And Human Health Risk Assessment In Moringa Oleifera Leaf Biomass. Bulletin Of Environmental Contamination And Toxicology, 112(5), 68.
Https://Doi.Org/10.1007/S00128-024-03894-X