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ASSESSMENT OF HEAVY METALS ACCUMULATION AND ASSOCIATED HEALTH RISKS ON *MORINGA OLEIFERA* FROM SOUTHERN KADUNA, NIGERIA

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Abstract

Minerals, proteins, vitamins and phytocompounds abound in *Moringa oleifera.* A significant species of medicinal tree belonging to the *Moringaceae* family. *Moringa oleifera* leaves obtained from Ambam (Jama'a LGA) and Maro (Kajuru LGA) in Kaduna State, Nigeria, were subjected to an AAS analysis to determine the content of specific heavy metals (Cd, Cr, Cu, Fe, Mn, Ni, Pb, and Zn) and associated health risk. Fe 7.627 mg/kg, Pb 0.598 mg/kg, Ni 0.454 mg/kg, Mn 0.451 mg/kg, Zn 0.333 mg/kg, Cu 0.286 mg/kg, and Cr 0.191 mg/kg were the metal concentrations in *Moringa oleifera* at Ambam. The concentration followed the order Fe > Pb

Introduction

Background of the Study

Native to the *Moringaceae* family, *Moringa oleifera* is a very nutrient-dense vegetable tree that is becoming more and more well-liked in Nigeria. It is widely produced and cultivated in northern Nigeria, where it is known by the Hausa name Zogale, the English name Moringa, and the Adara name Uzogale. The tree itself is slender and reaches a height of roughly 10 meters, with drooping limbs. Although *Moringa oleifera* can be grown in a variety of soil types, it is best

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> Ni > Mn > Zn > Cu, > Cr > Cd. Nonetheless, Maro metal concentration trend follows a different order: Cd has the lowest concentration at 0.035 mg/kg, followed by Fe (3.453 mg/kg), Mn (0.601 mg/kg), Pb (0.505 mg/kg), Ni (0.327 mg/kg), Zn (0.262 mg/kg), Cu (0.221 mg/kg), and Cr (0.155 mg/kg). Ambam and Maro have Cd, Ni, and Mn concentrations below the WHO recommended acceptable range. While Pb is over the WHO established permitted limit, the concentration of Cr in both Ambam and Maro was found to be within the limit. Consuming *Moringa oleifera* from this area may provide a risk of cancer because the THQ values of Cd, Cu, Fe, Ni, and Pb were found to be greater than 1. The use of *Moringa oleifera* in the study regions may have a negative impact on the health of the adult population, as indicated by the health index (HI) values of 43.7222 and 35.2028 at Ambam and Maro, respectively.

Key words: *Moringa oleifera,* Ambam, Maro, Heavy Metals Accumulation, Associated Health Risk.

Suited for sandy or loamy soil that drains well and is just slightly alkaline (Faustin *et al.,* 2015). It is a fast-growing, drought-resistant tree that thrives in dry, sandy soils. It can also withstand poor soil conditions, including those found along the shore. Africa, Central and South America, Sri Lanka, India, Mexico, Malaysia, and the Philippines are among the countries that currently farm it widely. Practically every portion of the Moringa tree may be eaten as food or has a variety of other helpful qualities, it is regarded as one of the most beneficial trees in the world (also known as a "miracle tree"); (Ajayi *et al.,* 2014).

Every part of the *Moringa oleifera* plant is good for humans and animals. The oil from the seeds is used as coolants, in soaps, cooking, and cosmetics. The leftover material from the oil extraction process, known as press cakes, is applied to the soil as fertilizer. Because they are high in vitamins, both humans and animals eat the pods and leaves. Significantly, the tree's leaf extract is used as a corrosion inhibitor in engineering (Alaneme & Olusegun, 2012).

Figure 1; *Moringa Oleifera* leaves (Ajayi *et al.,* 2014).

Proteins, vitamins, minerals, folic acid and β-carotene are all abundant in *Moringa oleifera*. Indigenous medicine has utilized all parts of the plant to treat a variety of illnesses (Calderon *et al.,* 2019). Nonetheless, the plant's leaves are the most abundant source of nutrients (Agboola *et al.,* 2016). Traditional medicine, human and animal nutrition both make use of *Moringa oleifera* (Tiloke *et al.,* 2018). Additionally, the leaves are added to culinary preparations as dietary integrators. Prior research has demonstrated that *Moringa oleifera* confers a number of potential effects, such as antibacterial (Farjana *et al.,* 2003), antioxidant (Fozia *et al.,* 2012), antidiabetic (Birendra *et al.,* 2017) and anticancer activity (Charoensin, 2014). However, heavy metals like manganese (Mn), copper (Cu), iron (Fe), zinc (Zn), chromium (Cr), nickel (Ni), lead (Pb), cadmium (Cd), arsenic (As), and gallium (Ga) can contaminate medicinal plants by root uptake or direct atmospheric deposition onto plant surfaces. Consuming medicinal herbs that contain high levels of heavy metals can lead to major health issues, including disruptions in the biological function of the kidney, liver, glands, and essential organs (Vikashni *et al.,* 2012; Umeh *et al.,* 2020). Even at low concentrations, elements like lead, cadmium, mercury and arsenic are harmful to humans (Ogunfowokan *et al.,* 2019).

The earth's crust naturally contains metals, and the environmental concentrations of these metals might range geographically depending on the location. The characteristics of the metal and the effects of ambient conditions determine how metals are distributed in the environment (Ajaya *et al.,* 2014; Patel *et al.,* 2012). Numerous studies have documented how the levels of minerals and other nutrients in *Moringa oleifera* vary depending on the plant's geographic location. The results showed that the plant's levels of macro and micro elements may vary based on the topography and soil characteristics during growth. Serious health issues can arise from high concentrations of heavy metals that exceed the WHO's standard acceptable limit (Ogunfowokan *et al.,* 2019). Therefore, the significance of measuring heavy metal levels cannot be overstated. In order to determine the health risks and heavy metal buildup in *Moringa oleifera* from Ambam and Maro in Jama'a and Kajuru LGA in Southern Kaduna, Nigeria, this study's goal is to use AAS to conduct a qualitative and quantitative assessment.

Materials and Methods

Description of the Study Area

Ambam is a hamlet in southern Kaduna, Kaduna State, Nigeria, located in the Jama'a local government area. Situated between latitude 9.3827° or 9° 22' 58" north and longitude 8.2681° or 8° 16' 5" east, Jama'a occupies an area of 1,384 km^2 (NPC, 2006). It is bordered to the north by Zangon Kataf LGA, to the west by Jaba LGA, to the east by Sanga LGA, to the northeast by Kaura LGA, to the east by Riyom LGA of Plateau State, and to the south by Karu LGA of Nasarawa State. With gently sloping plains on either side, the Jama'a Local Government Area is situated on a wide, low-lying terrain. It has two rivers on either side. The Amere or Mada River lies to the northwest of the region; it is known by the locals as the "River Wonderful" because it has killed many people, including some colonial engineers who were working on the rail bridge at Aduwan (another bridge built on the same river during the British colonial era exists near Kogum River Station). The Sanga River, also known as the Kogum River, originates from the plateau and is the second river to the southeast. Near the Kogum River Station, the two rivers converge. In addition, there are several hills, valleys, and streams. Additionally, the rolling terrain offers rich soil for farming.

Kajuru, a local government area in southern Kaduna, Kaduna State, Nigeria, including the ward of Maro. Maro town serves as the Maro ward's headquarters. The Kajuru local government occupies 2,229 km^2 and is situated at latitudes 7° 34'E and 8° 13'E and longitudes 9° 59'N and 10° 55'N (NPC, 2006). The Kajuru Local Government Area (LGA) is bordered to the north by Igabi LGA, to the west by Chikun LGA, to the east by Kauru LGA, and to the southwest and south by Zangon Kataf LGA and Kachia LGA, respectively. A network of streams that primarily originate in the remote highland regions nearby drain the study area (Maro). River Iri, River Kutura, River Agom, and River Bauda drain it. According to vegetation classification, Maro is a guinea savannah zone. In the plains, Maro soils are typically sandy-loam and loamy, and they drain effectively. In the valleys, however, there are deposits of hydromorphic soils that fill the river flood plains. Because of the high mineral concentration of the soils, the region's agricultural production is excellent.

Figure 2; Study Area. Adopted from NPC google map (2006).

Reagents and Chemicals

For ionization of atoms and purging gasses, argon and nitrogen were used. *Moringa oleifera* leaves, nitric acid (69% HNO_3, Spectrsol, England), and chloric acid (70% $HClO_4$, Aldrich,

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Germany) were utilized. Each element's standard solution (Cd, Cr, Cu, Fe, Mn, Ni, Pb, and Zn). Deionized water for solution preparation and glassware cleaning.

Apparatus and Instruments

The heavy metals (Cd, Cr, Cu, Fe, Mn, Ni, Pb, and Zn) were analyzed using an Elmer pin AAcle 900H AAS, a mortar, a pestle, a herbarium to hold plant samples, and 21OVGP cathode lamps for each element. Plant samples are digested in a Kjeldahl digester (VELPE SCIENTIFIC, Japan), ground in a blender (FW 100 high Speed Universal Disintegrator), cleaned with a brush, and sieved to achieve uniform size using a 200 μm mesh size. Filter paper no. 42 was used for filtration, and the samples were weighed using an analytical balance (JF/JTA JA 5003 series, range: 0 – 500 g).

Sample Collection and Preparation

Moringa oleifera leaf samples were randomly taken from 30 plants at each sampling site in the study sites (Ambam and Maro). The samples were labeled and placed in a paper envelope before being taken to the biology department's herbarium at Federal University Dustin-Ma in Katsina State, Nigeria. After being carefully cleaned with tap water and then deionized water, the leaves were allowed to air dry for two weeks at room temperature. For analysis, 100 g of each dry sample was extracted from each location.

Digestion

A 50 mL volumetric flask was filled with 0.5 g of samples of *Moringa oleifera* leaves that had been precisely weighed on a digital analytical balance. Three milliliters of 69% HNO_3 and 70% $HClO_4$ were added to the flask, and the combination was digested using a Kjeldhal apparatus by first raising the temperature to 333K for 30 minutes and then to 453K for the next hour. For five minutes without removing the condenser from the flask and for ten minutes after doing so, the digested solution was left to cool. Whitman filter paper number 42 was used to filter the mixture. Three different digestions were performed. The identical digestion process used for the sample was used to prepare the blank solutions.

The digested samples were refrigerated until the Atomic Absorption Spectrometer (AAS) (AOAC, 2000) with 21OVGP AAS cathode lamps measured the concentrations of each metal in the sample solution. All of the elements were identified using an air-acetylene flame.

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Health Risk Assessment Associated with *Moringa Oleifera* Consumption

The estimated daily intake (EDI) of the metal, the target hazard quotient (THQ), and the Hazard Index (HI) were used to assess the risk associated with consuming heavy metals in Moringa to human health. The average daily loading of metals into the body system of a consumer with a given body weight is estimated by the daily intake dosage (EDI). The following formula was used to determine the EDI value:

$$C_{metal} \times \frac{IR}{BW} = EDI \qquad 2.1$$

Where BW is the average body weight (Kg), IR (ingestion rate) is the average daily consumption of Moringa (gram/day per person), and C_{metal} (mg/kg) is the average weighted heavy metal concentration in Moringa (Woldetsadik *et al.,* 2017). Adults typically consume 100 g of Moringa per day per day of dry weight. Adults were thought to have an average body weight of 60 kg.

When evaluating the non-carcinogenic risk to humans of prolonged exposure to heavy metals from fruits, vegetables and medicinal plants, the target hazardous quotient (THQ) is utilized. THQ values were computed as follows:

$$\frac{EDI}{RfD} = THQ \qquad 2.2$$

Where RfD stands for reference dose values in milligrams per kilogram of day^{-1} for each metal of interest. For Cd, Cr, Cu, Fe, Mn, Ni, Pb, and Zn, the reference dose values were 0.001, 1.5, 0.040, 0.070, 0.014, 0.020, 0.0035, and 0.300 mg/kg/day. A THQ score of more than one means that eating food crops contaminated with metals will put the population's health at risk (USEPA IRIS, 2006).

The Hazard Index (HI) aids in assessing the total non-carcinogenic risk that many heavy metals pose to human health. According to the following formula, it is the total hazardous quotient (THQ) of all heavy metals:

The formula is

$$\sum THQ; i = 1,2,3 \ldots\ldots n = HI \qquad 2.3$$

If the HI value is less than 1, the population will not be at danger; if it is equal to or more than 1, the population will suffer from negative health effects (Kamunda *et al.,* 2016).

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Statistical Analysis

Measurements were made in triplicate, and the mean $\pm$ S.D (standard deviation) for triplicate results was used. The IBM SPSS Statistics 20.0 program was used to statistically analyze the data using the t test in order to investigate the variations in the means of metal concentration in Moringa samples at a 95% confidence level.

Results and Discussion

Concentration of Metals Assessment

AAS was used to measure the content of eight metals in *Moringa oleifera* leaves from Maro and Ambam. The findings demonstrated that there were differences in the levels of metal in *Moringa oleifera* leaves between the two research locations. All eight of the identified heavy metals were detected in samples from both study locations within the detection limit. As a result, hazardous metals are present in the Moringa samples from the two research regions. Table 1 provides a summary of the metal concentrations in Moringa oleifera leaves from the research locations.

Table 1: Concentration (mg/kg) of trace metals in *Moringa oleifera* samples (Mean±SD)

Heavy Metals	Maro	Ambam
Cd	0.035 ± 0.001 0.036 ± 0.001 $0.034 \pm ,0.001$	0.047 ± 0.001 0.045 ± 0.001 0.046 ± 0.001
Cr	0.155 ± 0.002 0.156 ± 0.002 0.154 ± 0.002	0.191 ± 0.002 0.191 ± 0.002 0.190 ± 0.002
Cu	0.220 ± 0.001 0.222 ± 0.001 0.220 ± 0.001	0.287 ± 0.001 0.285 ± 0.001 0.286 ± 0.001
Fe	3.458 ± 0.010 3.456 ± 0.010 3.445 ± 0.010	7.626 ± 0.020 7.625 ± 0.020 7.620 ± 0.020
Mn	0.602 ± 0.001 0.600 ± 0.001 0.604 ± 0.001	0.451 ± 0.001 0.450 ± 0.001 0.451 ± 0.001

Ni	0.327 ± 0.001 0.324 ± 0.001 0.330 ± 0.001	0.454 ± 0.001 0.452 ± 0.001 0.455 ± 0.001
Pb	0.502 ± 0.002 0.504 ± 0.002 0.510 ± 0.002	0.599 ± 0.002 0.597 ± 0.002 0.598 ± 0.002
Zn	0.262 ± 0.001 0.260 ± 0.001 0.264 ± 0.001	0.333 ± 0.001 0.335 ± 0.001 0.332 ± 0.001

Source; AAS analysis BUK central laboratory 2024.

Table 2; Average Concentration (mg/kg) of trace metals in *Moringa oleifera* samples (Mean $\pm$ SD)

Heavy Metals	Maro	Ambam
Cd	0.035 ± 0.001	0.046 ± 0.001
Cr	0.155 ± 0.002	0.191 ± 0.002
Cu	0.221 ± 0.001	0.286 ± 0.001
Fe	3.453 ± 0.010	7.627 ± 0.020
Mn	0.601 ± 0.001	0.451 ± 0.001
Ni	0.327 ± 0.001	0.454 ± 0.001
Pb	0.505 ± 0.002	0.598 ± 0.002
Zn	0.262 ± 0.001	0.333 ± 0.001

Source; AAS analysis BUK central laboratory 2024.

From Table 2, all metals assessed in Ambam, Fe stayed the uppermost concentration of 7.627 mg/kg, and the uppermost concentration of Fe is likely influenced by the region's geology, presence of iron ore deposits, geological processes, mining activities, and environmental factors such as weathering and erosion that have contributed to the accumulation of iron minerals in the area. Pb was the second most hoarded heavy metal next to Fe with 0.598mg/kg, this may arise from mining and smelting activities in the area which could have released lead into the environment. Pb is often found in association with other metals like Zn and mining activities, targeting these metals may inadvertently release Pb as well. The third abundant metal is Ni with 0.454 mg/kg, Mn with 0.451 mg/kg, Zn with 0.333 mg/kg, Cu with 0.286 mg/kg, Cr with 0.191mg/kg, the least is Cd with 0.046mg/kg.

In Maro Fe was the uppermost metal with 3.453 mg/kg, Mn was the second most hoarded heavy metal following to Fe with 0.601 mg/kg, this may be due to naturally occurring element in the Earth's crust that can be found in various types of rocks and minerals in the area. Geological processes such as weathering and erosion can also lead to the high concentration of Mn. The third abundant metal is Pb with 0.505 mg/kg, Ni with 0.327 mg/kg, Zn with 0.262mg/kg, Cu with 0.221 mg/kg, Cr with 0.155mg/kg, the least is Cd with 0.035mg/L this may result from lack of anthropogenic activities like mining, industrial activities and the use of fertilizers or pesticides containing cadmium in the area.
In comparison to the amounts of other metals, Fe was found to be the highest, while Cd was found to be the lowest. The command of the metal concentrations in the Ambam *Moringa oleifera* leaf samples was Fe > Pb > Ni > Mn > Zn > Cu > Cr > Cd. The metal concentration trend in Maro, however, is in a different command: Fe > Mn > Pb > Ni > Zn > Cu > Cr > Cd. These discrepancies might result from the regions' seasonal fluctuations and botanical origins.

Assessment of Risk Associated with Heavy Metals

Table 3: EDI, THQ and HI values associated with consumption of *Moringa oleifera.*

Location	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn	HI
Maro EDI	0.0058	0.0258	0.0368	0.5755	0.1002	0.0545	0.0842	0.0437	35.2028
THQ	5.8000	0.0172	0.9200	0.8221	0.7157	2.7250	24.0571	0.1457	
Ambam EDI	0.0077	0.0318	0.0477	1.2710	0.0752	0.0757	0.0997	0.0555	
THQ	7.7000	0.0212	1.1925	1.8157	0.5371	3.7850	28.4857	0.1850	43.7222

The EDI, THQ, and HI values of the mental constituents in the *Moringa oleifera* samples are shown in Table 3. The EDI values for Ambam were 0.0077, 0.0318, 0.0477, 1.2710, 0.0752, 0.0757, 0.0997, and 0.0555 for Cd, Cr, Cu, Fe, Mn, Ni, Pb, and Zn, respectively, whereas the EDI values for Maro were 0.0058, 0.0258, 0.0368, 0.5755, 0.1002, 0.0545, 0.0842, and 0.0437. Ambam had THQ values of 7.700, 0.02120, 1.1925, 1.8157, 0.5371, 3.7850, 28.4857, and 0.1850 for Cd, Cr, Cu, Fe, Mn, Ni, Pb, and Zn, while Maro had THQ values of 5.8000, 0.0172, 0.9200, 0.8221, 0.7157, 2.7250, 24.0571, and 0.1457.
It was discovered that the THQs for Cd, Cu, Fe, Ni, and Pb in Ambam were higher than 1. Signifying that the toxicity of consuming *Moringa oleifera* may expose people to a possible carcinogenic health risk. Nonetheless, the THQ values for Cr, Mn, and Zn were less than 1, signifying that users are not at risk for cancer from

toxicity brought on by consuming *Moringa oleifera*. The THQs for Pb, Ni, and Cd in Maro were found to be higher than 1. Signifying that the toxicity of consuming *Moringa oleifera* may expose people to a possible carcinogenic health risk. Nonetheless, the THQ values for Cr, Cu, Fe, Mn, and Zn were less than 1, signifying that users are not at danger for cancer from toxicity brought on by consuming *Moringa oleifera*.

With HI values of 43.7222 and 35.2028 at Ambam and Maro, respectively, the HI (the total of individual metals THQ) was discovered to be marginally higher than unity. When HI is greater than 10, significant long-term health effects have been noted (Khan *et al.,* 2009).

Relationship of Current Study with Outcomes from Other Countries

Table 4 Relationship of concentration of metals (mg/kg) in *Moringa oleifera* with that of testified in the rest of the world.

Country	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn	Reference
Poland	NS	6.6	3.63	NS	NS	NS	2.6	17.45	Wioletta *et al.,* (2017)
Nigeria (Kashere)	NS	NS	0.14 - 0.34	NS	NS	NS	0.164-0.947	2.39 - 3.40	Abdukadir *et al.,* (2016)
Mexico (Lombardia)	NS	NS	4.1	NS	NS	NS	NS	16	Valdez-solaana *et al.,* (2015)
Mexico (San Pedro)	NS	NS	10.3	NS	NS	NS	NS	10	
Algeria	NS	NS	12.2	NS	NS	NS	NS	30.9	Leone *et al.,* (2015)
India	NS	18.9	20 8	NS	NS	NS	NS	7.7	Gowrishankar *et al.,* (2010)
Thialand	<0.182	0.09 - 2.63	6.45 - 28.29	NS	NS	NS	0.001-3.28	33.36-139.68	Limmatvapirat *et al.,* (2015)
Ethiopia (Hawassa)	NS	NS	9.44	NS	NS	NS	NS	24.7	Melesse *et al.,* (2012
Ethiopia (Arbaminch)	NS	NS	9.58	NS	NS	NS	NS	25.2	
Kenya	NS	NS	6.92	NS	NS	NS	NS	35.6	Kumssa *et al.,* (2017)
Ethiopia (Awi zone)	ND	4.35 - 9.0	7.1 - 8.7	NS	NS	NS	ND	28.7 - 56.7	Tewodros & Molla (2020)
Nigeria (Ambam and Maro)	0.035 - 0.046	0.155 - 0.191	0.221 - 0.286	3.453-7.627	0.451 - 0.601	0.32-0.454	0.505-0.598	0.262-0.333	Current study
WHO	0.1	0.2-2.0	NG	NG	3 - 5	1-5	0.3	NS	WHO (2005)

ND = Not detected, NS= Not specified

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Cu concentrations in this study were 0.286 and 0.221 mg/kg, which were within 0.14 to 0.34 mg/kg of those testified from Poland (Wioletta *et al.,* 2017), Algeria (Leone *et al.,* 2015), Mexico (Valdez-solana *et al.,* 2015), India (Gowrishankar *et al.,* 2010), Thialand (Limmatvapirat *et al.,* 2015), Ethiopia (Melesse *et al.,* 2012), and Kenya (Kumssa *et al.,* 2017). According to the table, the zinc concentrations in this study (0.262 and 0.333 mg/kg) were lower than those reported from Poland (Wioletta *et al.,* 2017), Kashere (Nigeria) (Abdukadir *et al.,* 2016), Lombardia, San Pedro in Mexico (Valdez-solana *et al.,* 2015), and India (Gowrishankar *et al.,* 2010), Thailand 33.36 – 139.68 mg/kg (Limmatvapirat *et al.,* 2015), Algeria 30.9 mg/kg (Leone *et al.,* 2015), Hawassa (Ethiopia) (24.7 mg/kg) and Arbaminch in Ethiopia (25.2 mg/kg) (Melesse *et al.,* 2012), and Kenya 35.6 mg/kg (Kumssa *et al.,* 2017).

The obtained concentration in *Moringa oleifera* was found to be comparable with the results from Thailand, ranging from 0.09 to 2.63 mg/kg, when compared to the published amounts of Cr (Limmatvapirat *et al.,* 2015). In contrast to studies from Poland (Wioletta *et al.,* 2017), India (Gowrishankar *et al.,* 2010), and Ethiopia (Melesse *et al.,* 2012), this study identified a low level of Cr. The study's Cd concentrations of 0.035 and 0.046 mg/kg were similar to Thailand's < 0.182 mg/kg (Limmatvapirat *et al.,* 2015). There was no Cd concentration established in Ethiopia (Kumssa *et al.,* 2017). No Cd concentration was testified by any of the comparator countries. The study's Pb concentrations of 0.505 and 0.598 mg/kg were similar to those in Thialand (0.001–3.28 mg/kg; Limmatvapirat *et al.,* 2015) and Kashere in Nigeria (0.164–0.947 mg/kg; Abdukadir *et al.,* 2016). The study's Pb concentration was lower than the 2.6 mg/kg levels stated from Poland (Wioletta *et al.,* 2017). There was no Pb content established in Ethiopia (Kumssa *et al.,* 2017). No Cd content was stated in any of the countries under study. Similarly, the majority of research conducted in other nations either reported or did not provide Fe, Mn, and Ni concentration.

With a few notable exceptions, however, the metal levels in *Moringa oleifera* were often almost identical to findings published in the literature. Variations in the composition of soil types, sample sites, and sample treatment can be credited to the difference in metal content; the existence of these factors either raises or lowers the metal concentration. The standard level and the mean concentration of metals discovered in this analysis were also contrasted. The study's mean values of Cd, Ni, and Mn were below the WHO's allowable limit, which is 0.1 mg/kg, 1–5 mg/kg, and 3–5 mg/kg, respectively (2005). The mean Pb content was higher than the 0.3 mg/kg WHO limit. The study's mean Cr values fell between 0.2 and 2.0 mg/kg, which is the WHO's acceptable limit. Since Cu, Fe, and Zn are important nutrients, the WHO did not provide a permitted limit for them. At a 95% confidence level, the average of the heavy metal concentrations in the two *Moringa oleifera* samples do not differ significantly ($p<0.05$).

Conclusion

In this work, AAS scrutinized the levels of heavy metals (Cd, Cr, Cu, Fe, Mn, Ni, Pb, and Zn) in *Moringa oleifera* plants grown in Ambam and Maro. The analysis's findings confirmed that *Moringa oleifera* had the right amounts of Cr, Cu, Fe, and Zn. The heavy metal concentrations in Ambam were found to be Fe> Pb> Ni> Mn> Zn> Cu> Cr> Cd, while in Maro, they were found to be Fe> Mn> Pb > Ni> Zn> Cu> Cr> Cd.

This study's Cd, Ni, and Mn values were determined to be below the WHO commended allowable level. In a similar vein, the Cr concentration was within the WHO suggested range. However, Ambam's (0.598 mg/kg) and Maro's (0.505 mg/kg) Pb levels were greater above the WHO commended acceptable range. Since Cu, Fe, and Zn are important nutrients, the WHO permitted limit was not provided despite their detection. The mean concentrations of all the metals did not differ significantly at the 95% confidence level. Because of anthropogenic activities such mining, industrial operations, and the use of fertilizers or pesticides in the area, the concentrations of Cd, Cr, Cu, Fe, Ni, Pb, and Zn in Ambam *Moringa oleifera* samples were superior to those in Maro samples. The Maro *Moringa oleifera* sample has a greater Mn concentration than the Ambam sample; this could be as a result of the element naturally present in the Earth's crust and is present in a variety of local rocks and minerals. The high concentration of Mn can also result from geological processes like weathering and erosion.

The THQs for Cd, Cu, Fe, Ni, and Pb were found to be larger than 1 in Ambam from a health perspective. Signifying that consuming *Moringa oleifera* may expose people to a possible carcinogenic health risk through toxication. Nonetheless, the THQ values for Cr, Mn, and Zn were less than 1, signifying that users are not at risk for cancer from toxication brought on by consuming *Moringa oleifera*. The THQs for Pb, Ni, and Cd in Maro were found to be higher than 1. Signifying that the toxicity of consuming *Moringa oleifera* may expose people to a possible carcinogenic health risk. Nonetheless, the THQ values for Cr, Cu, Fe, Mn, and Zn were less than 1, signifying that users are not at risk for cancer from toxicity brought on by consuming *Moringa oleifera*. With HI values of 43.7222 and 35.2028 at Ambam and Maro, respectively, the HI (the total of individual metals THQ) was revealed to be marginally higher than unity. When HI is greater than 10, significant long-term health effects have been noted (Khan *et al.,* 2009).

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