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Toxic Metals Contamination and Health Risk Assessment in Spices and Herbal Teas from Abuja, Nigeria

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ABSTRACT

Herbal teas and spices, valued for their nutritional, medicinal, and cultural significance in urban and peri-urban communities, can pose health risks due to heavy metal contamination. This study evaluates heavy metal levels in 12 herbal teas randomly purchased in Abuja and 11 spices, alongside their health risks, using AOAC 2000 analytical methods. Detectable concentrations of metals were found in all samples. Among spices, ginger powder showed the highest manganese (Mn: 598.8 mg kg^{-1}) and chromium (Cr: 15.13 mg kg^{-1}), while turmeric powder had elevated Mn (403.8 mg kg^{-1}) and Cr (12.96 mg kg^{-1}). Yellow pepper contained high lead (Pb: 7.89 mg kg^{-1}) and cadmium (Cd: 2.280 mg kg^{-1}), and garlic powder had notable Cr (10.88 mg kg^{-1}). In herbal teas, Top tea exhibited high Mn (1661 mg kg^{-1}) and Pb (35.12 mg kg^{-1}), while Moringa tea showed elevated Pb (77.00 mg kg^{-1}). Compared to WHO/FAO limits (Cd: 0.100 mg kg^{-1}; Co: 0.200 mg kg^{-1}; Cr: 2.000 mg kg^{-1}; Cu: 20.00 mg kg^{-1}; Mn: 0.120 mg kg^{-1}; Ni: 1.630 mg kg^{-1}; Pb: 10.00 mg kg^{-1}), Mn, Cr, and Pb frequently exceeded safe thresholds. Health risk assessment indicated a significant manganese hazard quotient (11.26), suggesting neurotoxicity risks, and a lead (1.11) slightly above safe limits, pointing to potential nervous, renal, and hematopoietic effects. Other metals (Cd, Co, Cr, Cu, Ni) had HQ < 1, indicating lower risk. These findings highlight significant contamination in widely consumed teas and spices, necessitating stricter regulatory measures to mitigate chronic dietary exposure risks and protect public health.

KEYWORDS: *Beverages, Condiment, Metals, Toxicity, Risk*

1. INTRODUCTION

Heavy metals, characterized by high atomic weights or densities, include toxic elements such as cadmium (Cd), lead (Pb), mercury (Hg), arsenic (As), and hexavalent chromium (Cr^{6+}), which are harmful even at low levels.[1] Spices and herbal teas, derived from plant parts like bark, rhizomes, and leaves, are valued for their culinary and medicinal properties, including antimicrobial, anti-inflammatory, and antioxidant effects. [2, 3] However, these products are susceptible to contamination from natural and anthropogenic sources, including soil bioaccumulation, industrial runoff, mining, pesticide use, and improper waste disposal. [4, 5, 6] Additional contamination arises from power plant emissions, vehicular exhaust, oil spills, and poor post-harvest handling. [7,8,9,10] While metals like iron, zinc, and copper are essential, excessive exposure to non-essential metals such as Cd and Pb can lead to osteoporosis, kidney and neurological disorders, cancers, and cardiovascular complications. [11,12,13] Heavy metals may also disrupt gut microbiota and mental health.[14] Accurate measurements use techniques such as Flame Atomic Absorption Spectrometry (FAAS) and Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) (Inobeme *et al.,* 2023). International safety is guided by ADI limits set by EFSA and FAO/WHO.[15] This study investigates the levels of selected heavy metals in spices and herbal teas sold in Abuja, FCT, Nigeria, against these standards.

2. MATERIALS AND METHODS

A total of 11 spices and 12 herbal tea brands were purchased randomly from different grocery stores and supermarkets within the Federal Capital Territory, Abuja (FCT), and were labeled accordingly. 2g ± 0.01g of each pulverized sample was digested using 20 mL of aqua regia, consisting of a 3:1 ratio of concentrated hydrochloric acid and nitric acid. The mixture was digested for 10 min at 155 °C for a further 7 min at 200 °C. The digested sample was filtered into a 50 ml standard volumetric flask and made up to the mark. The residual levels of 7 heavy metals in herbal teas and spices were determined using Solaar Elemental Thermo Scientific Atomic Absorption Spectrophotometry (AAS) located at

Kembiz Scientific and Laboratories Nigeria Limited, Gwagwalada FCT, Abuja. Cadmium (Cd), Cobalt

(Co), Lead (Pb), Chromium (Cr), Copper (Cu), Manganese (Mn), and Nickel (Ni). [16,17] The concentration of each metal was calculated using the following formula:

Final concentration $n\ (mg/kg) = \frac{\text{Concentration of Metal ion} - \text{Blank}}{Weight\ of\ sample\ (g)} \times Dilution\ factor$

Quality control measure was affected using blanks and performing a recovery study with spiked samples and blanks, equilibrated for 1 hour before digestion, and verifying method accuracy and precision. [18] Recovery was calculated from 4 replicates using the following formula:

$$\text{Percentage recovery} = \frac{Concentration\ of\ spiked\ sample - Concentration\ of\ unspike\ sample}{Amount\ \ added} \text{ X } 100$$

2.1 Assessment of Human Health Risk

The Food and Agriculture Organization (FAO) previously stated that Nigeria's annual food supply is 3.650 kg/capita for spices and 0.6 kg/capita for herbal teas, equating to food ingestion rates (FIR) of 0.01 kg/capita/day and 0.0016 kg/capita/day, respectively, as further illustrated in the equation below:

$\text{EDI} = CXFIR/BW$ …….Eqn I

Where C is the dry weight concentration of the residual heavy metals in the spice and herbal tea in mg kg^{-1}, FIR accuracy rate, and BW is the reference body weight of 60 kg for an adult human.

Hazard quotient: The hazard quotient (HQ) was regarded as the probable risk of undesirable health effects from pesticide mixtures to specify the long-term assessment of risk and was computed by dividing the EDI by the pertinent ADI and multiplying by 100, as stated in the equation below. [17]

$\text{HQ} = \text{EDI}/\text{ADI} \times 100$ ……….. Eqn ii

3. RESULTS AND DISCUSSION

Heavy metal contamination in spices poses a significant public health concern due to their bioaccumulative and toxic nature. Table 1 depicts residual concentrations of seven heavy metals (Cd, Co, Cr, Cu, Mn, Ni, Pb) in eleven commonly consumed spices sold in FCT Abuja, Nigeria, with results compared against established regulatory limits.

Table 1: Residual Concentrations of Heavy Metals in Different Spices Sold in Abuja, Nigeria

	Concentration (mg kg^{-1})						
Spices	**Cd**	**Co**	**Cr**	**Cu**	**Mn**	**Ni**	**Pb**
Black pepper	1.640±0.011	0.960±0.01	BDL	58.30±0.02	157.95±0.02	6.110±0.00	6.830±0.00
Cayenne pepper	0.910±0.02	3.500±0.00	3.780±0.00	36.36±0.02	33.84±0.01	2.690±0.03	3.170±0.00
Nutmeg	0.720±0.00	BDL	3.320±0.01	55.36±0.03	54.72±0.00	4.070±0.01	3.740±0.00
Curry powder	0.930±0.01	0.660±0.00	4.650±0.01	29.78±0.01	51.59±0.00	3.070±0.00	2.520±0.01
Chicken season	0.840±0.03	BDL	6.080±0.00	22.35±0.00	52.18±0.00	4.190±0.02	2.870±0.02
Fried seasoning	0.680±0.00	BDL	9.170±0.00	4.380±0.01	15.53±0.01	3.670 ±0.01	1.750±0.03
Yellow pepper	2.280±0.01	1.310±0.01	8.100±0.00	23.51±0.01	20.06±0.00	2.460±0.00	7.890±0.02

Garlic powder	0.760±0.012	0.690±0.00	10.88±0.012	11.53±0.00	13.12±0.00	3.420±0.01	4.270±0.00
Turmeric powder	1.030±0.01	0.930±0.02	12.96±0.00	18.63±0.01	403.8±0.02	2.740±0.01	0.270±0.01
Ginger powder	1.270±0.00	0.000±0.00	15.13±0.00	27.53±0.00	598.8±0.03	3.710±0.00	3.120±0.00
Thyme leaves	1.230±0.011	0.000±0.01	18.40±0.00	31.84±0.02	69.89±0.02	4.140±0.00	3.370±0.01
Limit (mg kg^{-1})	0.100	0.200	2.000	20.00	0.120	1.630	10.00

BDL: Below detection limit (of 0.001), mg kg^{-1}: milligram per kilogram

Heavy metal contamination in packaged herbal teas raises public health concerns due to their potential bioaccumulation and toxicity. Table 2 displayed the residual levels of seven heavy metals (Cd, Co, Cr, Cu, Mn, Ni, Pb) in twelve commercial herbal tea varieties from Abuja markets, Nigeria, benchmarked against regulatory limits.

Table 2: Heavy Metal Concentrations (mg kg^{-1}) in Packaged Herbal Tea in Abuja Markets

Herbal tea	Concentration (mg kg^{-1})						
	Cd	Co	Cr	Cu	Mn	Ni	Pb
Green tea	0.790±0.03	BDL	21.52±0.00	55.94 ±0.00	505.2±0.11	6.48±0.00	5.090±0.01
Guava tea	0.390±0.02	0.850±0.01	22.76±0.01	23.06±0.01	31.19±0.02	3.59±0.02	6.16±0.01
Eyes bright	0.320±0.02	0.000±0.01	25.94±0.02	29.38±0.01	527.5±0.03	5.530±0.01	6.240±0.01
Moringa tea	0.600±0.01	BDL	5.930±0.01	15.63±0.00	50.05±0.02	2.940±0.01	77.00±0.01
Tummy and fatreducing tea	1.450±0.00	BDL	BDL	12.65±0.01	58.64±0.00	4.220±0.01	5.340±0.01
Lipton tea	0.270±0.00	1.310±0.01	BDL	31.65±0.01	1369.±0.01	8.340±0.00	1.370±0.00
Nals pure natural mint I	0.620±0.01	BDL	10.41±0.01	33.74±0.02	110.9±0.02	5.940±0.00	1.680±0.00
Lemon-ginger tea	0.940±0.00	BDL	9.480±0.00	11.73±0.11	198.6±0.01	3.060±0.00	1.620±0.00
Top tea	0.690±0.00	BDL	11.23±0.01	42.87±0.01	1661±0.03	10.22±0.02	35.12±0.01
Mango tea	0.600±0.11	BDL	9.130±0.03	66.97±0.00	355.44±0.01	5.710±0.01	2.560±0.00
Highland tea	0.750±0.01	BDL	12.41±0.00	28.68±0.01	419.14±0.11	7.970±0.00	BDL
Beetroot tea	0.430±0.02	BDL	10.25±0.00	17.27±0.00	63.83±0.02	3.090±0.00	30.90±0.03
Limit (mg kg^{-1})	0.100	0.200	2.000	20.00	0.120	1.630	10.00

BDL: Below detection limit (of 0.001), mg kg^{-1}: milligram per kilogram

Table 1 revealed that manganese levels were notably high in spices, with ginger powder at 598.75 mg kg^{-1}, 4,989-fold exceedance of the 0.120 mg kg^{-1} MPL, and turmeric powder at 403.77 mg kg^{-1}. Some of the values reported in this current study far exceed those reported elsewhere, such as 45.8 mg kg^{-1} in turmeric,[18], and 93.70 mg kg^{-1} in ginger.[19] Herbal teas also showed extreme manganese contamination, with Top tea at 1,661 mg kg^{-1} (13,842-fold exceedance of the limit), Lipton tea at 1,369.04 mg kg^{-1}, and green tea at 505.2 mg kg^{-1}, surpassing ranges previously reported elsewhere (0–200 mg kg^{-1}) [20] and 62.1 mg kg^{-1} in green tea. [21] Elevated manganese levels, linked to neurotoxicity and manganism among other diseases [22,23], suggest localized contamination from soil, water, or industrial emissions. [24,25] Cadmium exceeded the 0.100 mg kg^{-1} maximum permissible limit (MPL) in all spice samples, notably yellow pepper (2.28 mg kg^{-1}) and fried seasoning (0.680 mg kg^{-1}), higher than values reported elsewhere. [26] In herbal teas, cadmium reached 1.45 mg kg^{-1} in Tummy and Body FatReducing

teas and 0.79 mg kg⁻¹ in green tea. These levels, associated with renal dysfunction, bone demineralization, and carcinogenesis [27,28], indicate severe environmental or industrial contamination relative to previous findings [29].[30]. Copper levels exceeded the 20.00 mg kg⁻¹ MPL in spices, with black pepper at 58.30 mg kg⁻¹, nutmeg at 55.36 mg kg⁻¹, and cayenne at 36.36 mg kg⁻¹, compared to 13.6–21.3 mg kg⁻¹ obtained by [31]. Teas also showed elevated copper: Mango tea (66.97 mg kg⁻¹), green tea (55.94 mg kg⁻¹), and Top tea (42.87 mg kg⁻¹), surpassing 0.06–15.08 mg kg⁻¹ [32], and 11.02–24.12 mg kg⁻¹ earlier reported .[33] High copper levels, linked to oxidative stress, hepatotoxicity, and nephrotoxicity [34], may originate from processing or environmental sources. Nickel exceeded the 1.63 mg kg⁻¹ MPL in spices: black pepper (6.11 mg kg⁻¹), ginger (3.71 mg kg⁻¹), and turmeric (2.74 mg kg⁻¹), higher than 1.2 mg kg⁻¹ [35] In teas, nickel reached 10.22 mg kg⁻¹ in Top tea and 8.34 mg kg⁻¹ in Lipton tea, exceeding 1.2–3.0 mg kg⁻¹ obtained previously [36]. These concentrations, linked to allergic dermatitis, respiratory complications, and renal damage. [37] align with Nigerian reports from Awka spices 0.34–2.89 mg kg⁻¹ [38] and Ibadan teas 3.50–8.00 mg kg⁻¹. [39] Lead contamination was particularly severe in teas, with Moringa tea (77.00 mg kg⁻¹), Top tea (35.12 mg kg⁻¹), and Beetroot tea (30.90 mg kg⁻¹), exceeding the 10.00 mg kg⁻¹ MPL, compared to 5.0–10.0 mg kg⁻¹.[40] Spices, such as yellow pepper (7.89 mg kg⁻¹) and black pepper (6.83 mg kg⁻¹), approached the limit, surpassing 5.0 mg kg⁻¹. [41] Lead, associated with neurotoxicity and developmental effects. [42, 43] were higher than Port Harcourt values (0.76–3.56 mg kg⁻¹). [44] Chromium exceeded the 2.00 mg kg⁻¹ MPL in most spices (thyme leaves, 18.40 mg kg⁻¹; ginger, 15.13 mg kg⁻¹) and teas (Eyes Bright tea, 25.94 mg kg⁻¹; Guava tea, 22.76 mg kg⁻¹, far above 0.200 mg kg⁻¹ [45]. These may include carcinogenic hexavalent chromium, exceeding Awka (0.001–3.81 mg kg⁻¹), [39] and Kano (0.6–6.5 mg kg⁻¹). [31] Cobalt, surpassing the 0.200 mg kg⁻¹ MPL, was observed in cayenne pepper (3.50 mg kg⁻¹), Guava tea (0.850 mg kg⁻¹), and Lipton tea (1.310 mg kg⁻¹), higher than typical Nigerian levels 0.28–3.07 mg kg⁻¹, [39], raising concerns for cardiotoxicity and thyroid dysfunction [29] These findings, consistent with previous Nigerian studies [33,46], highlight the FCT as a contamination hotspot,
particularly in teas, likely due to unique environmental, soil, and industrial factors. [25, 26]

Tables 3 and 4 present the health risk assessment (HRA) of heavy metals detected in spices and herbal teas sold across Abuja, FCT, Nigeria.

Table 3: Health Risk Assessment of Spices Sold in Abuja, Nigeria

Heavy Metal	Cd	Co	Cr	Cu	Mn	Ni	Pb
Avg	0.654	0.180	7.86375	30.80	445.9	5.590	14.42
Max	1.450	1.310	12.41	66.97	1660.79	10.22	77.00
Min	0.270	0	0	11.73	31.19	2.940	0
Sum	7.850	3.650	83.18	479.07	7488.1	85.84	264.5
ADI (mg/60day)	0.06	0.008	0.035	0.900	0.660	0.78	0.216
EDI	0.00010903	0.00003	0.001311	0.005133	0.07431	0.000932	0.002404
HQ	0.18171306	0.001667	0.007281	0.122212	11.25905	0.119462	1.112911

ADI: Acceptable daily intake, EDI: Estimated daily intake, HQ: Hazard quotient **Table 4: Health Risk Assessment of Herbal Tea Sold in Abuja, Nigeria**

Heavy metals	Cd	Co	Cr	Cu	Mn	Ni	Pb
Max	2.280	3.500	18.40	58.30	598.75	6.110	7.890
Min	0.680	0	0	4.38	13.12	2.48	0.270
Avg.	1.1127	0.7665	8.406	29.05	133.76	3.661	3.618
ADI (mg/60 days)	0.060	0.008	0.035	0.900	0.660	0.780	0.216
EDI	2.9672E-05	2.04E-05	0.000224	0.000775	0.003567	9.76E-05	9.65E-05

HQ	0.04945333	0.001136	0.001245	0.018444	0.540444	0.012516	0.044667

ADI: Acceptable daily intake, EDI: Estimated daily intake, HQ: Hazard quotient

The Estimated Daily Intakes (EDIs) for all metals were considerably below their respective Acceptable Daily Intakes (ADIs), indicating minimal immediate exposure concerns. However, the hazard quotient (HQ) analysis revealed significant findings. Manganese recorded an exceptionally high HQ value of 11.26 above the allowable limit of less than 1, indicating a potential neurotoxic threat associated with long-term consumption. Lead also exhibited an HQ of 1.11, slightly exceeding the safe threshold, thereby suggesting possible nervous, renal, and hematopoietic complications on long-term consumption. In contrast, other metals, including cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), and nickel (Ni), recorded HQ values were well below 1, reflecting minimal non-carcinogenic risk. The overall hazard index was well within the safety margin, except for manganese in spices (11.2590), where prolonged exposure may pose notable health hazards. These findings align with the observations made previously [47], who similarly reported hazard quotients below 1 in several Nigerian herbal beverages.

4. CONCLUSION

This study reveals significant public health risks from heavy metal contamination in Abuja's spices and herbal teas. Spices like ginger, turmeric, black pepper, and yellow pepper showed high manganese and lead levels, exceeding safe limits and posing risks of neurotoxicity and renal damage. Herbal teas had lower contamination, but cadmium, manganese, and lead were still detected. These findings underscore the need for stricter food safety regulations, continuous monitoring, and public awareness to reduce health risks from dietary exposure.

CONFLICT OF INTERESTS

The authors declare no conflict of interest.

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