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Human health risk assessment of heavy metal in common traditional herbs sold in Ibadan markets

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Abstract

Concerns about the safety and quality of African medicinal herbs are increasing due to potential heavy metal contamination, which poses significant health risks. This study aimed to assess the concentrations of heavy metals—including Ca, Mg, K, P, Na, Fe, Cu, Zn, Cr, Cd, Co, Ni, Pb, and Se in 180 traditional herbs sourced from ten local government areas in Ibadan, Nigeria. The herbs were processed using the aqua-regia wet digestion method and analyzed using Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES). Health risks associated with herb consumption were evaluated using metrics such as Chronic Daily Intake (CDI), Hazard Quotient (HQ), Hazard Index (HI), and Target Carcinogenic Risk (TCR). Descriptive and inferential statistical analyses were applied to the data.

The findings revealed that the herbs were rich in essential nutrients like Mg, Ca, P, and K, with concentrations ranging from 0.72×10^4 to 2.25×10^4 mg/kg for Mg, 0.25×10^4 to 0.78×10^4 mg/kg for Ca, 0.54×10^4 to 1.71×10^4 mg/kg for P, and 0.07×10^4 to 0.23×10^4 mg/kg for K. This suggests their potential as dietary supplements. However, some heavy metals, such as Cr, Ni, and Pb, were found at levels exceeding safe limits. The TCR values for these metals surpassed the USEPA threshold of 1×10^{-4}, indicating a potential cancer risk for both adults and children. While most metals had HQ values below 1, implying no significant non-carcinogenic risk, some herbs posed higher risks.

Keywords: Human Health Risk; Indigenous Herbs; Traditional Medicine; Heavy Metals

1. Introduction

Medicinal plant use spans millennia, with herbs serving as critical therapeutic resources across human cultures [1]. Traditional medicine, particularly in Africa, has long been a primary healthcare approach, with local healers playing a fundamental role in community health management [9].

Herbal remedies represent a sophisticated approach to treatment, rooted in generational knowledge and empirical observation [1][2]. These plant-based interventions address various health conditions through their inherent chemical compounds and biological properties.

During the early nineteenth century, the emergence of orthodox medical practices challenged traditional medicinal approaches [11]. Scientific scrutiny initially viewed traditional medicine skeptically due to limited systematic documentation and empirical validation of active botanical components [12]. This perspective stemmed from a lack of standardized research methodologies that could comprehensively analyze and authenticate the therapeutic mechanisms of herbal treatments.

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The scientific community's initial resistance highlighted the complex intersection between traditional healing practices and emerging Western medical paradigms [18]. Traditional medicine's knowledge base, accumulated through centuries of practical experience, often operated outside conventional scientific frameworks, making comprehensive assessment challenging [13].

Despite initial skepticism, contemporary research has increasingly recognized the potential of herbal medicines. Modern scientific techniques now allow for more rigorous examination of plant-based treatments, bridging traditional wisdom with evidence-based medical understanding [12].

Plant resources now make up a significant portion of the global medicine market and are employed by the pharmaceutical industry in both developed and developing nations as raw materials, over-the-counter medical products, and home remedies [3].

Because of this, the World Health Organization (WHO) has emphasized how crucial it is to protect the medicinal herbal products' quality by using modern regulatory frameworks and putting in place suitable standards [16].

Herbal medicine, a global health practice recognized by the World Health Organization, encompasses medicinal products derived from plant materials [4][7]. These botanical preparations include various forms such as fresh juices, essential oils, resins, and dry powders extracted from different plant parts like leaves, bark, roots, and rhizomes [5].

Produced using diverse regional techniques, herbal goods can be created through methods like stirring, baking, steaming, or roasting [23]. These preparations often incorporate additional ingredients such as honey or alcohol to enhance extraction and preservation.

The fundamental characteristic of herbal medicine is its use of whole plants or crude plant extracts with therapeutic potential [22]. Each preparation represents a unique combination of natural compounds believed to offer health benefits. Unlike synthetic pharmaceuticals, these medicines leverage the complex chemical composition of plants, which can contain multiple active ingredients working synergistically [23].

Different cultures worldwide have long-standing traditions of herbal medicine, developing sophisticated techniques for identifying, harvesting, and processing medicinal plants [10][21]. These practices reflect deep ecological knowledge and understanding of local botanical resources.

While herbal medicines offer potential health advantages, modern scientific research continues to investigate their efficacy, safety, and interactions with conventional medical treatments [20]. Healthcare professionals increasingly recognize the value of integrating traditional botanical knowledge with contemporary medical understanding [17].

Practitioners and consumers of herbal medicine appreciate its holistic approach, which often focuses on supporting overall wellness rather than targeting isolated symptoms [19]. This perspective emphasizes prevention, natural healing, and the interconnected nature of human health.

Herbal medicines, which are traditionally made from naturally existing plants and plant extracts and have been used with little to no industrial preparation to treat illnesses in indigenous or regional healing systems, are currently gaining a lot of attention in conversations about global health [6]. Herbs have been used traditionally to treat a variety of medical conditions. They have been widely accepted as medicine and as refreshing drinks, like teas, both historically and now. According to WHO estimates, over 80% of the world's population receives their primary medical treatment from these "alternative" plant-based medications [8]. Although there are cases of severe and persistent intoxication caused by their users, herbal remedies are usually recognized as medicinal [15]. Roughly 80% of Africans use traditional herbal treatments, and the annual global market for these goods is valued at approximately US ±$60 billion [9].

2. Materials and Methods

2.1. Sample collection and preparation

An oral survey was carried out among sellers and consumers of herbal medicines in 10 Local Government Areas in Ibadan, Oyo State, Nigeria, who were selected at random. To find out which medical herbs are most frequently used, participants were asked a series of questions. Participation was completely optional. Based on the survey's findings, during November and December 2020, 180 samples of six widely utilized indigenous traditional herbs (n = 3) (Table

3.1) were bought from ten significant traditional herb markets situated within ten Local Government Areas of Ibadan, Oyo State, Nigeria. After being gathered and wrapped in foil paper, the purchased herbs were put into black polyethylene bags that had been previously cleaned and marked before being brought to the lab. The University of Ibadan's Department of Botany identified and verified the plants.

Plant parts were cleaned using tap water and distilled water before being cut into little pieces and allowed to air dry for a period of two weeks. The plant components were dried, then ground into a fine powder (finer than 0.5 mm) and kept at 4 °C in sealed containers pending analysis.

2.2. Statistical analysis

The collected data were analyzed using a one-way analysis of variance (ANOVA) and descriptive statistics (mean SD) to find significant differences ($P < 0.05$) in the mean concentrations of heavy metals among the categories of medicinal plants. The element data was also subjected to Pearson's correlation matrix analysis and post-hoc analyses using Tukey's test. The Statistical Package for the Social Sciences (PASW version 24, IBM Corporation, Cornell, NY, USA) was used for all statistical analyses.

2.3. Chronic daily intake (CDI) indices

Using the heavy metal concentrations (C) in mg/kg, the daily medicinal plant consumption (DI) in g/day, and the body weight (BW) in kg (60 kg for adults and 16 kg for children as input through Eq. 1), the chronic daily intake (CDDI) of heavy metals through the consumption of the studied medicinal plants was computed.

$$CDI = (C \times DI) / (BW) \quad \text{(Eq. 1)}$$

2.4. Target Hazard quotient (THQ)

Using Eq. 2, the Target Hazard Quotient (HQ) was utilized to assess the non-carcinogenic hazard associated with the ingestion of therapeutic plants.

$$THQ = CDI / RfD \quad \text{(Eq. 2)}$$

where the oral toxicity reference dose (RD) values in (mg/kg/day) according to USEPA IRIS (2011)[8] are given as: 0.005, 0.003, 0.02, 0.04, 0.8, 0.14, 0.0035 and 0.3 mg/kg/day for Ca, Cr, Ni, Cu, Fe, Mn, Pb and Zn respectively. The exposed population is assumed to be safe when

THQ < 1, but if the value of THQ > 1, there is an unacceptable risk of adverse non-carcinogenic effects on human health.

2.5. Target carcinogenic risk (TCR)

The potential cancerous health risk via the consumption of the medicinal plants was estimated using the toxicity index known as slope factor (SF) to compute the potential cancerous health risk of an individual developing cancer over a lifetime as a result of exposure to possible carcinogen using Eq. 3.

$$TCR = SF \times CDI \quad (3)$$

Where the oral carcinogenic slope factor (SF) from USEPA (2015)'° was; 0.38, 0.5, 1.7 and 0.009 $(mg/kg/day)^{-1}$ for Cd, Cr, Ni and Pb respectively converts the CDI to the incremental risk of individual developing cancer. TCR values higher than the USEPA recommended safe limit of (1x10 ±)" for cancer risk indicate possible carcinogenic risk.

3. Results

Table 1 Sampling point designation

	Herbal market	Local government	Longitude and Latitude
1	Ijaye-orile	Akinyele	E 003° 50' and N 07º 37'
2	Baku-jago	Egbeda	E 004° 4' and N 07° 21'
3	Oje	Ibadan North East	E 003° 54' and N 07º 23'

4	Oniyanrin	Ibadan North West	E 003° 53' and N 07º 23'
5	Bode	Ibadan North East	E 003° 53' and N 07º 21
6	Oranyan	Ibadan North West	E 003° 54' and N 07º 22'
7	Apata	Ido	E 003° 49' and N 07º 23'
8	Olodo	Lagelu	E 004° 0' and N 07º 26'
9	Amuloko	Ona-Ara	E 004° 3' and N 07º 17
10	Idi-ayunre	Oluyole	E 003° 51' and N 07º 14'

Source: Author Analysis, 2021

Table 2 Elemental concentration of Traditional Herbs from ten Local Government Areas

Element	LW	AR	AI	ML	CS	MC	WHO LIMIT 2007
±Ca	2.25 ± 0.52	1.06 ± 0.13	0.72 ± 0.12	1.19±0.15	1.94 ± 0.57	1.04 ± 0.13	800
±Mg	0.78± 0.19	0.37 ± 0.05	0.25 ± 0.04	0.41 ±0.05	0.67 ± 0.21	0.36 ± 0.05	-
±K	1.71 ± 0.42	0.81 ± 0.10	0.54 ± 0.09	0.91 ± 0.12	1.47 ± 0.46	0.79 ± 0.10	-
±P	0.23 ±0.06	0.11 ± 0.01	0.07 ± 0.01	0.12 ±0.02	0.20 ± 0.06	0.10 ± 0.01	-
Na	33.8 ± 8.22	15.9 ± 2.06	10.8 ± 1.85	17.9 ± 2.35	29.2 ± 9.10	15.6± 2.02	-
Mn	137 ± 31.6	64.6 ±7.92	43.7 ± 7.10	72.7 ± 9.03	118 ± 34.1	63.2 ± 7.77	-
Fe	274± 63.2	129 ± 15.8	87.3 ± 14.2	145 ± 18.1	236 ± 70	126 ± 15.5	20
Cu	71.3± 16.5	33.7 ± 4.12	22.7 ± 3.70	37.8 ± 4.70	61.5 ± 18.2	32.9 ± 4.05	15
Zn	151±36.8	71.3 ±9.21	48.2 ± 8.26	80.2 ± 10.5	130 ± 40.7	69.8 ± 9.04	50
Cr	22.7+5.51	10.7 ± 1.38	7.23 ± 1.24	12.0 ±1.58	19.6 ± 6.10	10.5±1.36	2
Cd	0.004 ± 0.001	0.002 ± 0.000	0.001 ± 0.000	0.002 ± 0.000	0.004 ± 0.001	0.002 ± 0.000	0.3
Co	2.83 ± 0.69	1.34 ± 0.17	0.90 ± 0.15	1.50 ± 0.20	2.44 ± 0.76	1.31 ± 0.17	-
Ni	5.69 ± 1.31	2.69 ± 0.33	1.82 ± 0.30	3.02 ± 0.38	4.91 1.45	2.63 ± 0.32	10
Pb	0.01 ± 0.00	0.01 ± 0.00	0.005 ± 0.001	0.01 ± 0.00	0.01 ± 0.00	0.01 ± 0.00	5
Se	0.12 ± 0.03	0.06 ± 0.01	0.04 ± 0.01	0.06 ± 0.01	0.10 ± 0.03	0.05 ± 0.01	800

Values are in mg kg^{-1} (Mean + SD). ± (Value ×10^{4}) (N=30). LW: Lannea welwitschii, AR: Aristolachia ringens, Al: *Azadirachta indica*, ML: *Morinda lucida*, CS: *Cassia senna*, MC: *Momordica charantia*. World Health Organization (2007) WHO guidelines for assessing the quality of herbal medicines with reference to contaminants and residues. [24]

4. Discussion

Table 3.1 shows the concentrations of dangerous, non-toxic, and important metals in six (6) different medicinal herb samples from ten (10) Local Government Areas in Ibadan, Oyo State. For every medicinal herb under study, the concentration of heavy metals (mg kg-1) in the herbal samples was in the following decreasing order: Ca > K > Mg > P > Fe > Zn > Mn > Cu > Na > Cr > Ni > Co > Se > Pb > Cd. The concentrations in mg kg of the major nutrients ranged from 0.72×10^{-4} ± 0.12 to 2.25x10^{-4} ± 0.52, 0.25x10^{-4} ± 0.04 to 0.78x10^{-4} ± 0.19, 0.54 ×10^{-4} ± 0.09 to 1.71×10^{-4} ± 0.42 and 0.07x10^{-4} ± 0.01 to 0.23x10^{-4} ± 0.06 for Ca, Mg, K, and P respectively (Table 3.2). All of the investigated medicinal plants are rich in Mg, Ca, P, and K, according to elemental data, with LW having the highest content. Moreover, the elemental result indicated that, of all the tested indigenous medicinal herbs, Ca was the most significantly plentiful. Out of all the 10 Local Government Areas where this investigation was conducted, LW has the greatest concentration of Ca. This demonstrates that the researched native medicinal herbs can function as a natural supplement for these important elements in the human diet, greatly assisting in meeting the daily necessary intake. According to previous research, K, P, Mg, and Ca are the three metal elements that are most prevalent in many plants. The results of this analysis support this theory. Also, the concentrations in mg kg' of the minor nutrients ranged from 10.8 1.85 to 33.8 \$ 8.22, 87.3 14.2 to 274 \$ 63.2, 43.7 ± 7.10 to 137 ± 31.6, 22.7 3.70 to 71.3 ± 16.5, 48.2 8.26 to 151 ± 36.8, 7.23 ± 1.24 to 22.7 ± 5.51 and 0.04 \$ 0.01 to 0.12 ÷ 0.03 for Na, Fe, Mn, Cu, Zn, Cr and Se respectively. The WHO permitted limit of 20, 15, 50, and 2 mg kg-1, respectively, was surpassed by the average concentrations of Fe, Cu, Zn, and Cr in all the medicinal herbs investigated across all ten Local Government Areas (Table 3.2). This finding implies that all of the investigated medicinal plants have a tendency to bioaccumulate Fe, Cu, Zn, and Cr, and that consuming excessive amounts of them could cause a slow build-up in people. The findings also imply that the plants under study are an excellent source of Fe, Cu, Zn, and Cr. For numerous biological processes, including the synthesis of connective tissue, the activity of enzymes, and the coloring of hair, copper is a necessary mineral. On the other hand, a high consumption of copper in the diet can lead to serious health issues such methemoglobinemia, liver and kidney damage, and hemolytic anaemia. Zinc is a necessary metal for many different enzyme systems to operate normally. Its absence, especially in young children, can cause weakness, growth retardation, appetite loss, and even a halt to sexual development. Excessive zinc consumption has detrimental impacts on blood lipoprotein levels, copper levels, and the immunological system. In a similar vein, Cr is crucial for the metabolism of glucose. For example, it raises insulin activity and activates the phosphor-glucomutase enzyme. The physiological activities of humans require it at a dosage of around 0.03 mg kg-1. Consequently, a decrease in glucose tolerance and an increased risk of cardiovascular disease result from Cr buildup and deficiency. Furthermore, the elemental result indicated that, among the minor nutrients examined, Fe was the most plentiful (Figure 4.2).This result showed that these indigenous medicinal herbs are rich source of Fe and can contribute significantly towards the daily recommended value Likewise, the potentially toxic heavy metals mean concentrations in mg kg' ranged from 0.001 # 0.000 to 0.004 ± 0.001, 0.90 ± 0.15 to 2.83 ± 0.69, 1.82 ± 0.30 to 5.69 ≤ 1.31 and 0.005 ± 0.001 to 0.01 ± 0.00 for Cd, Co, Ni and Pb respectively (Table 4.1). All mean concentrations were below the WHO maximum permissible limit for medicinal herbs. This result suggests that the studied herbs do not accumulate these potentially toxic heavy metals. The relatively higher concentrations of Co and Ni to the other trace elements might be due to the metabolic needs of the herb plants.

4.1. Summary of findings

In summary, the elemental results from this study were found to be in decreasing order of Ca > K > Mg > P > Fe > Zn > Mn > Cu > Na > Cr > Ni > Co > Se > Pb > Cd. The results also indicated that all studied medicinal herbs are rich in Mg, Ca, P and K with concentrations ranging from 0.72x10^4 to 2.25x10^4, 0.25x10^4 to 0.78x10^4, 0.54 x10^4 to 1.71x10^4 and 0.07x10^4 to 0.23x10^4 mg kg respectively. Furthermore, all ten Local Government Areas examined medicinal herb concentrations of Fe, Cu, Zn, and Cr were higher than the WHO's allowable level for traditional herbs. On the other hand, the levels of Pb, Ni, Co, and Cd in traditional herbs were all below the WHO's allowable range.

5. Conclusion

The results of this study indicate that the medicinal herbs under investigation are rich sources of biologically significant components, which may contribute to the plants' reported medical qualities. Additionally, this investigation revealed that some of the physiologically significant elements were beyond the WHO-permissible level, indicating that all of the medicinal herbs under examination have a tendency to bioaccumulate Fe, Cu, Zn, and Cr and that consuming too much of them could cause a progressive build-up in people. Thus, all of the investigated medicinal plants are not recommended for long-term human intake, according to health risk assessments that distinguish between carcinogenic and non-carcinogenic risks.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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