Mountain Top University Journal of Applied Science and Technology

https://mujast.mtu.edu.ng/

Research Article

(2025) 5(1), 14-23 **MUJAST**

Health Risk Assessment of Potentially Toxic Elements in Selected Medicinal Plants for Treatment of Typhoid in Ijagun, Ogun State, Nigeria

Osinubi D. Adejoke[1*] Lawal O. Elizabeth[1,2] Anselm H. Oluwaseun[1] Ogundiran A. Abimbola[1] and Odusina O. Babatope[1]

[1] Chemical Sciences Department, College of Science and Information Technology, Tai Solarin University of Education, Ijebu-Ode, Ogun State, Nigeria.

[2] Comprehensive Senior High School, 40, Aje Road Sabo, Yaba Lagos

Osinubi Orcid No: 0000-0002-6719-305X
Anselm Orcid No: 0000-0003-3570-0915
Ogundiran Orcid No: 0000-0002-6249-5219
Odusina Orcid No: 0000-0002-1993-3340

Abstract

Typhoid fever is a prevalent ailment around the globe, especially in developing countries like Africa and Asia. Majority of people in this region depend on herbs for treatment. Concerns have, however, been raised regarding herbal contamination from potentially toxic elements (PTEs). This study analysed the concentration of five potentially toxic elements, Cu, Cd, Fe, Pd, and Zn in eight commonly used anti-typhoid medicinal plants in Ijagun, Ogun State. Their associated health risk was also assessed. The concentration of the metals was determined using Atomic Absorption Spectrophotometer (AAS), and their health risk was assessed using estimated daily intake (EDI), hazard quotient (HQ), and hazard index (HI) calculations. Fe was the most abundant element in the plant, with *M. indica* containing the highest concentration (81.01 mg/kg), while cadmium had the lowest concentration in all samples analysed. The health risk assessment showed that all the plant samples screened had HI values <1 (0.0111 to 0.0498), indicating no significant health risks associated with their use as alternative medicine. The varying HI values, however, suggest different safety margins among the plants. The findings of this work provide a reassurance of the general safety of the selected anti-typhoid plants, however, continuous monitoring of the PTE concentration in medicinal plants is required to prevent heath implication due to bioaccumulation from long-term exposure.

Keywords: Typhoid; Medicinal Plants; Potentially toxic elements; Health Risk, Ijagun; AAS

Citation: Osinubi A, Lawal E, Anselm O, Ogundoran A, Odusina B (2025). Health Risk Assessment of Potentially Toxic Elements in Selected Medicinal Plants for Treatment of Typhoid in Ijagun, Ogun State, Nigeria. *Mountain Top University Journal of Applied Science and Technology*, 5(1), 14-23.

Corresponding Author E-mail: adejokeadeyemii70@gmail.com

Received date: 11th March, 2025
Accepted date: 10th July, 2025

1. Introduction

Typhoid fever, an ailment brought on by the bacteria *Salmonella typhi* in spoilt foods or impure food and water is among the leading causes of sickness and death in many parts of the world, and more especially the developing nations and developed nations such as Nigeria (Oyedeji-Amusa, *et al.,* 2024). Despite the development of drugs by pharmaceutical companies (Chegaing *et al.,* 2020) and the success of eradicating the disease in most advanced nations, the disease still prevails in developing countries. The prevalence of this disease is reported to be due to poor hygiene during food preparation, the cost of acquiring modern medicines, antimicrobial resistance, and biases from the reports of side effects that synthetic drugs may cause (Luby *et al.,* 2015, Dogara, *et al.,* 2021). These among other reasons cause people in developing countries especially Nigeria to choose medicinal plant-based treatments over synthetic ones for treating different ailments, typhoid inclusive.

Medicinal plants have been a mainstay in the healthcare delivery system globally, they are natural deposit of several compounds that form the bases of numerous pharmaceuticals. These plants have been preferred by native people as their main source of medication, particularly around Africa and Asia (Oyedeji-Amusa, *et al.,* 2024). At the same time, the active principles may be extracted and made into formulations for different medical applications. Some of the plants that have been employed in the treatment of typhoid include but are not limited to *Tectona grandis, Mangifera indica, Vernonia amygdalina, Sphenocentrum jollyanum, Azadirachta indica, Morinda lucida, Psidium guajava, Senna hirsute* (Ali *et al.,* 2018, Yusuf, *et al.,* 2021). Their therapeutic ability is characterised by the presence of bioactive compounds. Nonetheless, concerns have been raised regarding the potential for toxic elements to be present in the so-named plants (Tokalıoglu, 2012). This poses a threat to the life of the consumers.

Substances in the environment that occur naturally and pose serious problems to the environment and human health are called potentially toxic elements. These elements threaten human health since they have a toxic effect when accumulated. Their presence at elevated levels in humans poses serious effects because they cannot be degraded by any known means (Anselm, *et al.,* 2024) or be excreted from the body (Dghaim *et al.,* 2015). As a result, they accumulate in different body parts, organs, and tissues, resulting in severe health effects in humans (Sigh and Kalamdhad, 2011).

There is increasing evidence of potentially toxic elements (PTEs) in various medicinal plants consumed by people in different countries (Awodele, *et al.,* 2013), predisposing consumers to severe health problems such as decreased immunity, heart problems as well as impaired neurological and psychosocial behaviour (Harris, *et al.,* 2011). Due to different activities like smelting, industrial emissions, chemical production, incineration, mining, transportation, and so on (Brenko, *et al.,* 2024) toxic heavy metals find their path into the environment, where they contaminate air, soil, and water. These toxic elements seep into and accumulate in medicinal plants from the environment, rendering the plants unsafe for human consumption and undermining their usefulness.

Lead and cadmium for example are potential carcinogens, just like mercury, and are associated with neurological and cardiovascular diseases. They are metals of interest with serious public health concerns because of their level of toxicity (Mafulul *et al.,* 2023). Other metals like Cu, Ni, Mn, Cr, V, Mo, Fe, and Zn, though required by humans for some metabolic processes at low concentrations pose toxicity potentials at elevated concentrations (Ahmed-Lascar and Younus, 2019).

The people who rely on medicinal plants as their biggest source of medication may be exposed to fatal impacts of these elements if they continuously use plants containing higher levels of these elements, therefore, there is a need to analyse some of the anti-typhoid medicinal plants to ensure their safety to the consumers. In light of the above, this study aims to evaluate the health risks posed by selected potentially toxic elements in commonly consumed medicinal plants used for treating typhoid in Ijagun, Ogun State, Nigeria.

2. Materials and Methods

2.1. Study area

Ijagun is one of the towns in Odogbolu, situated along the Sagamu-Benin express road in Ogun state, in the Southwest region of Nigeria. It is about 110 km northeast of Lagos by road. Ijagun a town close to Ijebu-Ode happens to be the host community for the premier University of Education, Tai Solarin University of Education which is also the third in Africa and eighth in the world, it is majorly dominated by university students and native inhabitants whose major economic activity include trade, craftsmanship and farming (of maize, cassava and vegetables).

2.2. Sampling

Eight samples representing medicinal plants were harvested from their natural habitats around Ijagun town. The plants were collected from pollution-free sites, cleaned under running water, and air-dried under shade. The medicinal plants were identified at the herbarium of the Botany Department of the University of Lagos, Nigeria. Botanical names, Families, local names, parts used, and the voucher number of the plants are listed in Table 1

Table 1: Botanical names, family names, local names, and parts used for the treatment of typhoid fever.

S/N	Botanical names	Family	Local names	Part used	LUH No
1	*Tectona grandis*	Verbenacea	Ewe tiiki	Leaves	7049
2	*Mangifera indica*	Anarcadiaceae	Ewe mongoro	Leaves	7044
3	*Vernonia amygdalina*	Poaceae	Ewuro	Whole plant	7045
4	*Sphenocentrum jollyanum*	Menispermaceae	Akerejunpon	Leaves	7046
5	*Azadirachta indica*	Meliaceae	Dongoyaro	Leaves	7048
6	*Morinda lucida*	Rubiaceae	Oruwo	Leaves	7043
7	*Psidium guajava*	Mytraceae	Guafa	Leaves	7050
8	*Senna hirsute*	Caesalpinaceae	Ifo	Leaves	7047

*LUH: Lagos University herbarium

2.3. Sample preparation and analysis

The plant samples were air-dried on a clean tray by exposing them to the atmosphere to get rid of moisture. Once dried, they were pulverised using a stainless-steel blender (Kenwood electric blender: BL330 Series). The pulverised samples (5 g) were digested with nitric acid (HNO3) (20 mL) and placed in a digestion tube at a temperature of 135 ºC for 90 min. This was followed by filtration of the digest into a volumetric flask (100 mL) and made up to mark with distilled water and then stored in the refrigerator at 4ºC for further analysis.

2.4. Analysis of samples

Once the digests had thawed they were analysed in duplicates for Cu, Cd, Fe, Pd, and Zn using Atomic Absorption Spectrophotometer (BUCK AAS975.23, 2003).

2.5. Human health risk assessment

Hazard identification through estimated daily intake (EDI), hazard quotient (HQ) and hazard index (HI) were used to evaluate the potential health risk of intake of heavy metals from medicinal plants to human health. The EDI was calculated to determine the amount of metals that would impact the body system of a consumer with a particular weight per day. The following formula was used to calculate the value of EDI

$$\mathrm{EDI} = \frac{(\mathrm{C}_m \times \mathrm{IR})}{BW} \qquad (1)$$

In this case, C_m (mg/kg) stands for the mean concentration of heavy metal in the medicinal plant, IR for the average ingestion rate of the medicinal plant which in this case is herb per day per person and BW for the average body weight in kilograms. For an adult, the intake of the medicinal plant per day was estimated to be 20 g/person/day (Meseret *et al.,* 2020) and the average weight of an adult was considered to be 65 kg based on the estimated average weight of an adult in Nigeria (Adedokun *et al.,* 2016). Hazard Quotient was adopted in assessing the non- carcinogenic health risk in humans which was posed by the long-term consumption of vegetables, medicinal plants and fruits with respect to toxic heavy metals connected to them. When HI ≤ 1, it indicates no appreciable health risk, while if HI > 1, then it indicates a reason for health concern and there are tendencies to have health risks because of exposure (Anselm *et al.,* 2022). The HQ is calculated as a portion of the established dose to the reference dose as indicated by the formula below (Equation 2)

$$HQ = \frac{EDI}{R_f\mathrm{D}} \quad (2)$$

where EDI is evaluated as the average of the herbal preparations consumption per day (mg/kg/day) and the R_fD is an oral reference dose of the metal (mg/kg/day). R_fD is an estimate of daily oral reference doses to which a person can reasonably be exposed without suffering adverse health effects throughout the life span (Barnes *et al.,* 1988). The R_fD of Fe is 0.7 mg/kg/day while that of Pb, Cu, Cd, and Cr is 0.004 mg/kg/day, 0.04 mg/kg/day, 0.001 mg/kg/day and 0.003 mg/kg/day respectively (Ebrahimzadeh *et al.,* 2024).

The HI is used to measure the total or overall risk that is posed to human health from one or more heavy metals. If exposure is greater than one pollutant the result is additive. The HI is the addition of the hazardous quotient (HQ) of all heavy metals, as represented in the equation 3:

$$HI = \Sigma\, HQ_{Cu} + HQ_{Zn} + HQ_{Fe} + HQ_{Cd} + HQ_{Pb}. \quad (3)$$

If HI > 1, it may cause adverse effects on human health.

3. Results

3.1 Concentration of heavy metal in anti-typhoid medicinal plants samples

The concentration of PTEs in medicinal plants, especially those used in treating typhoid in Ijagun, is a matter of concern. Their presence in plants with limits surpassing the permissible poses a great risk to public safety globally. The risk of accumulation of these elements with potential toxicity, especially in Ijagun, a small town in Ogun state, Nigeria, is a serious matter of concern because the plants form the primary medical resource of the people and their use is neither passed through any quality control agency nor regulatory body

The concentrations of Cu, Zn, Fe, Cd, and Pd in the selected anti-typhoid medicinal plants employed in Ijagun town are represented in Table 2. Among the elements screened as observed in the table, Fe was the most abundant element found in the plants, followed by Zn, Cu was more abundant than Pb in all plants screened except *A.indica* and *S. hirsute* while Cd was the least abundant. Across the plants screened, *S.jollyanum* was observed to have the highest concentration of Cu (0.23 mg/kg). In contrast, the highest concentration of Zn was observed in *V. amygdalina* (5.49 mg/kg) followed by *M.lucida* (2.16 mg/kg). *M.indica* accumulated the most abundant Fe concentration (81.01 mg/kg). Accumulation of these three elements (Cu, Fe, and Zn) in other plants was negligible. At the same time, Cd and Pb were only found in trace quantity.

Table 2: Mean concentrations (mg/kg) of PTEs in the medicinal plants

S/N	Botanical names	(Cu)	(Zn)	(Fe)	(Cd)	(Pb)
1	*T. grandis*	0.19 ± 0.01	0.37 ± 0.01	3.63 ± 0.03	0.04 ± 0.00	0.19 ± 0.00
2	*M. indica*	0.21 ± 0.01	0.53 ± 0.00	81.01 ± 0.01	0.02 ± 0.00	0.02 ± 0.00
3	*V. amygdalina*	0.08 ± 0.002	5.49 ± 0.01	20.00 ± 0.00	0.03 ± 0.00	0.05 ± 0.00
4	*S. jollyanum*	0.23 ± 0.01	0.33 ± 0.00	29.45 ± 0.05	0.02 ± 0.00	0.15 ± 0.00
5	*A. indica*	0.20 ± 0.00	0.20 ± 0.01	9.65 ± 0.05	0.01 ± 0.00	0.53 ± 0.00
6	*M. lucida*	0.18 ± 0.004	2.16 ± 0.00	2.91 ± 0.01	0.03 ± 0.00	0.11 ± 0.01
7	*P. guajava*	0.05 ±0.002	0.53 ± 0.01	9.11 ± 0.01	0.01 ± 0.00	0.04 ± 0.00

8	*S. hirsute*	0.13 ± 0.01	0.70 ± 0.01	6.21 ± 0.01	0.01 ± 0.01	0.17 ± 0.00

3.2. Health Risk Assessment of PTEs in the anti-typhoid medicinal plants

The PTEs in the anti-typhoid medicinal plants were extensively assessed through the Estimated Daily Intake (EDI) as presented in the table below (Table 3). This assessment provides crucial insights into the potential health implications associated with consuming these traditional medicinal plants.

Table 3: EDI of PTEs in the medicinal plants

	EDI (mg/kg bw/day)				
	Cu	Zn	Fe	Cd	Pb
T. grandis	5.85×10^{-5}	1.14×10^{-5}	1.12×10^{-3}	1.23×10^{-5}	5.85×10^{-5}
M. indica	6.46×10^{-5}	1.63×10^{-4}	2.49×10^{-2}	6.15×10^{-6}	6.15×10^{-5}
V. amygdalina	2.46×10^{-5}	1.69×10^{-3}	6.15×10^{-3}	9.23×10^{-6}	1.54×10^{-5}
S. jollyanum	7.08×10^{-5}	7.08×10^{-5}	9.06×10^{-3}	6.15×10^{-6}	4.62×10^{-5}
A. indica	6.15×10^{-5}	6.15×10^{-5}	2.97×10^{-3}	3.08×10^{-6}	1.631×10^{4}
M. lucida	5.54×10^{-5}	6.65×10^{-4}	8.954×10^{-4}	9.23×10^{-6}	3.38×10^{-5}
P. guajava	1.54×10^{-5}	1.63×10^{-4}	2.80×10^{-3}	3.08×10^{-6}	1.23×10^{-5}
S. hirsute	4×10^{-5}	2.15×10^{-4}	1.91×10^{-3}	3.08×10^{-6}	$5. 23 \times 10^{-5}$

Table 4 represents the result obtained from Hazard quotient (HQ), and Hazard Index (HI) estimation of the studied medicinal plants

Table 4: **HQ and HI of PTEs in the medicinal plants**

	HQ_{Cd}	HQ_{Cu}	HQ_{Fe}	HQ_{Pb}	HQ_{Zn}	HI
T. grandis	1.23×10^{-2}	1.46×10^{-3}	1.60×10^{-3}	1.462×10^{-2}	3.8×10^{-4}	3.04×10^{-2}
M. indica	6.15×10^{-3}	1.62×10^{-3}	3.561×10^{-2}	1.54×10^{-3}	5×10^{-4}	4.55×10^{-2}
V. amygdalina	9.23×10^{-3}	6.2×10^{-4}	8.79×10^{-3}	3.85×10^{-3}	5.63×10^{-3}	2.81×10^{-2}
S. jollyanum	6.15×10^{-3}	1.77×10^{-3}	1.295×10^{-2}	1.154×10^{-2}	2.40×10^{-4}	3.26×10^{-2}
A. indica	3.08×10^{-3}	1.54×10^{-3}	4.24×10^{-3}	4.077×10^{-2}	2.10×10^{-4}	4.98×10^{-2}
M. lucida	9.23×10^{-3}	1.38×10^{-3}	1.28×10^{-3}	8.46×10^{-3}	2.22×10^{-3}	2.26×10^{-2}
P. guajava	3.08×10^{-3}	3.8×10^{-4}	4.00×10^{-3}	3.08×10^{-3}	5.40×10^{-4}	1.11×10^{-2}
S. hirsute	3.08×10^{-3}	$1.00\ 10^{-3}$	2.73×10^{-3}	1.308×10^{-2}	7.20×10^{-4}	2.06×10^{-2}

4. Discussion

4.1. Concentration of heavy metal in anti-typhoid medicinal plants samples

4.1.1. Copper

The Cu content in the medicinal plants varied from 0.23 mg/kg in *S. jollyanum* up to 0.05 mg/kg in *P. guajava*. This showed that *S. jollyanum* contained the highest amount of Cu at 0.23mg/kg while the *M. indica* contained the second highest amount of Cu at 0.21 mg/kg**.** 0.20 mg/kg of Cu was found present in *A. indica* and *T. grandis* contained 0.19 mg/kg. *M. lucida, S. hirsute, V. amygdalina* and *P. guajava* had concentrations of 0.18, 0.13, 0.08, and 0.05 mg/kg respectively. Cu is an essential element that plays a principal role in reproduction, and glucose metabolism (Nardi *et al.,* 2009). It serves as a vital enzymatic element for normal plant growth and development (Khan *et al.*, 2008), however, it could be toxic at concentrations higher than the recommended daily allowance of 0.2 mg - 0.9 mg (NIH dietary supplement factsheet, accessed 11-2024) inducing processes that are detrimental to human health, for example, oxidative stress, reduced cell proliferation, and DNA damage (Royer and Sharman, 2023). The concentration of Cu in this study do not exceed the recommended daily allowance. This finding is in consonance with that of Bala and Sahal (2023) who screened typhoid medicinal plants used in Kaduna state, Nigeria and found that the concentration of Cu (0.007 – 0.003 μg/g) among other elements they screened was within permissible limits set by WHO.

4.1.2. Zinc

Zinc is the second most common element in the plants analysed in the study. *V. amygdalina* had the highest concentration (5.49 mg/kg) followed by *M.lucida* (2.16 mg/kg) and the least concentration was observed in *A.indica* (0.20 mg/kg). It is an important trace element responsible for physiological and metabolic processes. In the synthesis of proteins, Zn plays a vital role (Nazir *et al.,* 2015). Its presence in medicinal plants can therefore be said to be vital for the biological activity of such plant. As observed from the result, none of the plants had concentrations exceeding the WHO permissible limits (100 mg/kg) for plants (WHO 2007, Bala and Sahal, 2023). This low concentration may be attributed to Zn's mobility which is determined by the soil pH, which when neutral or alkaline causes clay fractions, phosphorus, and soil organic matter to bind to it and as a result reduce its mobility (Borah *et al.,* 2020) and translocation to the various plant parts. The low concentration observed in this study qualifies the plant as safe for disease treatment, albeit caution must be taken in their consumption as accumulation may be toxic to humans.

4.1.3. Iron

The highest concentration of Fe was found in the leaves of *M. indica* (81.01 mg/kg) followed by *S. jollyanum* (29.45 mg/kg), *V. amygdalina* (20.00 mg/kg), *A.indica* (9.65 mg/kg), *P. guajava* (9.11 mg/kg), *S. hirsute* (6.21 mg/kg), *T.grandis* (3.63 mg/kg) and *M.lucida* (2.91 mg/kg). Fe is an essential element present in haemoglobin and needed by all mammals. As a component of many tissue enzymes, iron plays vital roles in different metabolic activities, including, energy production and immune system function as well as blood production in humans where it serves as the integral component of haemoglobin and other enzymes responsible for the transfer of oxygen in the blood from the lungs to the tissues (Yiannikourides and Latunde-Dada, 2019, Garba *et al.,* 2023). This potential and its predominant presence in the selected plants could indicate the use of the selected medicinal plants in treating typhoid. Its deficiency, however, cannot be underplayed as it could lead to anaemia. Fe's predominant presence was also observed in the work of Bala and Sahal (2023). Although within permissible limit, it was the second abundant metal found in the herbal medicines they screened, this showcases its predominance in the plants employed in the treatment of typhoid fever. A similar trend on Fe was also observed by Sulaiman *et al.,* 2022 where it was found to have the maximum concentration.

Elevated concentrations can be detrimental to human health as high amounts of iron beyond the recommended limit; 0.27 mg – 27 mg (NIH dietary supplement fact sheet) could lead to severe health issues such as cancer, fibrosis, diabetes, and even endocrine disruption when present in excess in the tissues (Gujja *et al.,* 2010, Fisher and Babitt, 2022). The study conducted by Liehr and Jones (2001) revealed that a rise in body stores of iron poses an increased risk of estrogen-induced cancer (Liehr and Jones (2001). In the data obtained in this study, *M. indica* and *S. jollyanum* leaves appear to be the plant with an elevated amount of iron, hence caution is required in their use, otherwise an alternative plant with a similar therapeutic effect and lower Fe concentration is recommended. The high concentration of Fe in all the plants screened relative to other metals suggests its absorption from the surrounding atmosphere. This can be attributed to the predominant use of Fe-based roofing sheets, burglary gates/doors, and even perimeter fences in the study area. Consequently, as these materials wither away due to aging/corrosion it is suggested that the disintegrated Fe is released into the atmosphere. These tiny particles could then be absorbed by surrounding plant materials and accumulate therein.

4.1.4. Cadmium

Cadmium unlike Cu, Fe, and Zn is not an essential element to humans due to its toxicity even in trace amounts (Genchi *et al.,* 2020). Cd is mainly sourced from soils, rocks, and industrial and agricultural activities. It is well established to cause cancer and individuals directly exposed to environmental effects have a higher likelihood of suffering from various cancers and death. Kidney disorders and respiratory system disorders and the depletion of bone density are some of the problems seen in the long term, even with trace doses (Opuni *et al.,* 2023). Potential sources of exposure with special concern to children are plastics containing cadmium, jewelry, toys, and electronic waste disposal and recycling. Other forms of human exposure include active and passive inhalation of tobacco smoke and consumption of contaminated food

(Bhattacharyya *et al.*, 2023). The Cd level in the present findings varied from 0.01 to 0.04 mg/kg with *T.grandis* sample exhibiting the highest concentration of Cd (0.04 mg/kg). As established by WHO, China and Thailand, a permissible limit of 0.3 mg/kg is the recommended limit of Cd in herbs (USEPA, 1997, WHO, 2007) (Food, 2007). In this study, however, none of the plants exhibited values above this limit, as the concentration of Cd was below the set limit in all the plants screened. For example, the concentration of Cd in *T.grandis* was 0.04 mg/kg, and 0.03 mg/kg in *V. amygdalina and M.lucida.* While its concentration in the five other plants (*M. indica* and *S. jollyanum* (0.02 mg/kg) and *S. hirsute, A.indica,* and *P.guajava* (0.01 mg/kg) were all below the permissible limit. The concentration of Cd in this study was, however, lower compared to that reported in a previous study, which had Cd concentration ranging from 0.10 to 0.51 ppm (Sulaiman *et al.*, 2022), nonetheless, another study reported lower Cd concentrations in selected plant based medicines (Nwachukwu *et al.*, 2018). This difference could be attributed to the difference in geographical location as well as economic activity in the respective locations.

4.1.5. Lead

Similar to cadmium, lead is also a non-essential element with toxic effects. Pb causes damage to the hematopoietic, renal, and reproductive functions. The central nervous system is also affected by the toxicity effect of Pd (Assi *et al.*, 2016, Collin *et al.*, 2022). Results obtained from this study showed that the highest concentration of Pd was found in *A.indica* 0.53 mg/kg followed by *T.grandis* 0.19 mg/kg, *S. hirsute* 0.17 mg/kg, *S. jollyanum* 0.15 mg/kg, *M. lucida,* 0.11 mg/kg, *V. amygdalina* 0.05 mg/kg, *P. guajava* 0.04 mg/kg and *M. indica* 0.02 mg/kg. The permissible limit as set by World Health Organization (1998) for Pd in herbal medicines is 10 mg/kg. By comparison, all the plants screened in this study had concentrations below the permissible limit as the plant with the highest concentration of Pd was not up to 1 mg/kg.

Bello *et al.*, (2004) studied the concentration of some heavy metals (Fe, Mn, Cu, Pd, and Zn) in herbal plants (*Anacardium occidentale, Azadirachta indica, Butyrospermum paradoxum, Mangifera indica, Morinda lucida, Ocimum canum, Solanum erianthum, Solanum torvum, Zingiber officinale and Hyptis suaveolens*) commonly used in Ogbomoso. The result showed Pd to be present in *A.indica* (0.49 ± 0.03 mg/kg) (ppm) while the range of Fe, Mn, Cu, and Zn were 35.6 to 241 mg/kg, 31.4 ± 685 mg/kg, 1.12 ± 24.4 mg/kg and 3.31 ± 35.1 respectively (Bello *et al.*, 2004). However, the concentrations of the elements screened in this present study were considerably lower than those reported by Bello et al. (2004), except for those of Fe. Although the different anthropogenic activities in a region can influence the concentrations of these elements in a plant, various factors may also affect their uptake, for instance, plant type, nature of the soil, climate, and agricultural practices (Tokalioglu, 2012). The elements accumulate in different parts of the soil at various concentrations. The low concentration of the elements in this study may be because the area of study has not been affected by anthropogenic activities as the common economic activities of the dwellers encompass trade, craftsmanship, and farming.

4.2 Health Risk Assessment of PTEs in the anti-typhoid medicinal plants

Analysis of the EDI values revealed varying levels of metal intake across the studied plants. For cadmium, *T. grandis* had the highest EDI (1.23×10^{-5} mg/kg/day), while *A. indica*, *P. guajava*, and *S. hirsute* had the lowest values (3.08×10^{-6} mg/kg/day). These values fall significantly below the tolerable daily intake of 0.001 mg/kg/day established by JECFA (Dghaim *et al.*, 2015). In terms of Cu intake, *S. jollyanum* had the highest EDI (7.08×10^{-5} mg/kg/day), which remains well within safe limits when compared to the recommended daily allowance of 0.9 mg/day (Alhusban *et al.*, 2019). Iron intake, as indicated by EDI values, ranged from 8.954×10^{-4} to 2.49×10^{-1} mg/kg/day, with M. indica showing the highest value. These levels align with acceptable ranges, considering the recommended dietary allowance of 8-18 mg/day for adults (Fisher and Babitt, 2022).

The hazard quotient results provide critical information regarding potential non-carcinogenic risks associated with individual metals. Notably, all analysed plants showed HQ values below 1 for individual metals, suggesting minimal risk from single-metal exposure (Ebrahimzadeh *et al.*, 2024). However, certain patterns emerged that warrant attention. *A. indica* demonstrated the highest HQ value for lead (4.077×10^{-2}), followed by *T. grandis* (1.462×10^{-2}) and S. *hirsute* (1.308×10^{-2}). While these values remain below the threshold of concern, they merit consideration given lead's established neurotoxic effects and potential for bioaccumulation (Collin *et al.*, 2022). For cadmium, *T. grandis* and *V. amygdalina* showed the highest HQ values (1.23×10^{-2} and 9.23×10^{-3}, respectively). Though these values fall below the threshold, they are particularly noteworthy given cadmium's cumulative nature and extended biological half-life in human tissues (Genchi *et al.*, 2020). The iron HQ values showed that *M. indica* had the highest value (0.03561), followed by *S. jollyanum* (0.01295). While iron plays essential roles in biological functions, elevated levels can trigger oxidative stress and tissue damage, making these values worthy of attention despite falling below harmful thresholds (Yiannikourides and Latunde-Dada, 2019).

The HI, representing the cumulative potential for adverse health effects, revealed a range of values across the studied plants. *A. indica* showed the highest HI (4.98×10^{-2}), followed by *M. indica* (4.55×10^{-2}) and *S. jollyanum* (3.26×10^{-2}). The remaining plants showed progressively lower HI values: *T. grandis* (3.04×10^{-1}), *V. amygdalina* (2.81×10^{-2}), *M. lucida* (2.26×10^{-2}), *S. hirsute* (2.06×10^{-2}), and *P. guajava* with the lowest value (1.11×10^{-2}). Significantly, all HI values remained below 1, indicating that these medicinal plants, when used as recommended, pose no significant non-carcinogenic health risk. This finding aligns with similar research conducted on medicinal plants in other geographical contexts (Kohzadi *et al.*, 2019, Mafulul *et al.*, 2023). Similar to findings by Dghaim *et al.*, (2015) and Alhusban *et al.*, (2019), this study demonstrates that while PTEs are present in medicinal plants, their concentrations generally pose minimal health risks when consumed as prescribed. However, several important considerations emerge from this analysis. The potential for cumulative exposure risk must be considered, particularly in cases where multiple medicinal plants might be used concurrently or where additional dietary sources of PTEs exist (Ebrahimzadeh *et al.*, 2024). The varying HI values among different plants suggest differential safety margins, with some plants like *P. guajava* offering wider safety margins compared to others like *A. indica.* Furthermore, while acute risks appear minimal, the potential for bioaccumulation of certain metals, particularly cadmium and lead, warrants careful consideration in cases of long-term therapeutic use (Genchi *et al.*, 2020). This aspect becomes especially relevant given the traditional practice of extended use of medicinal plants in treating chronic conditions.

The results underscore the importance of continued monitoring and risk assessment of medicinal plants, even when individual metal concentrations appear to be within safe limits. While the current findings provide reassurance regarding the safety of these plants for typhoid treatment, there is still need for ongoing vigilance in quality control and safety assessment of traditional medicinal preparations. This becomes particularly relevant in regions where traditional medicine serves as a primary healthcare resource and where regulatory frameworks for traditional medicine may be less stringent.

5. Conclusions

This study examined the concentration of PTEs and evaluated their associated health risks in eight medicinal plants commonly used for treating typhoid in Ijagun, Ogun State. The concentrations of Cu, Zn, Fe, Cd, and Pb were determined, and their health risks were assessed using EDI, HQ, and HI calculations. Fe was found to be the most abundant element, with *M. indica* showing the highest concentration (81.01 mg/kg), while Cd had the lowest concentrations across all samples. The health risk assessment revealed that all plants had HI values below 1, ranging from 0.111 (*P. guajava*) to 0.498 (*A. indica*), indicating no significant non-carcinogenic health risks associated with their consumption at recommended doses. However, the varying HI values suggest different safety margins among the plants. While these findings provide reassurance regarding the general safety of these medicinal plants for typhoid treatment, there is need for regular monitoring of PTEs concentrations, especially considering potential bioaccumulation effects during long-term use.

Conflict of interest: The authors declare that they do not have any conflict of interest.

REFERENCES

Adedokun, A. H., Njoku, K. L., Akinola, M. O., Adesuyi, A. A., & Jolaoso, A. O. (2016). Potential human health risk assessment of heavy metals intake via consumption of some leafy vegetables obtained from four market in Lagos Metropolis, Nigeria. *Journal of Applied Sciences and Environmental Management, 20*(3), 530-539. https://doi.org/10.4314/jasem.v20i3.6

Ahmed Laskar, A. & Younus H. (2019). Aldehyde Toxicity And Metabolism: The Role of Aldehyde Dehydrogenases in Detoxification, Drug Resistance and Carcinogenesis. *Drug Metabolism Reviews,* 51 42-64. https://doi.org/10.1080/03602532.2018.1555587

Alhusban, A. A., Ata, S. A., & Shraim, S. A. (2019). The safety assessment of toxic metals in commonly used pharmaceutical herbal products and traditional herbs for infants in Jordanian market. *Biological trace element research, 187*, 307-315. https://doi.org/10.1007/s12011-018-1367-1

Ali, M., Diso, S., Minjibir, A., Sani, J., Nas, F., & Yahaya, A. (2018). Assessments of medicinal plants used in treatment of various ailments in Kano city, Nigeria. *Asian Journal of Biotechnology and Bioresource Technology*, *2*(4), 1-11. https://doi.org/10.9734/AJB2T/2017/38844

Anselm, O. H., Badeji, A. A., Olagbuyiro, I. M., & Osinubi, A. D. (2024). Bioaccessibility studies and human health risk assessment of potentially toxic elements in soils from Mechanic Workshops in Ogun State. *Journal of Science and Information Technology*, *18*(1), 68-77..

Anselm, O. H., Oyeyiola, A. O., Oluseyi, T. O., & Talabi, A. J. (2022). Plants and chicken organs: Important pathways of human exposure to potentially toxic elements from e-waste recycling site in Lagos, Nigeria. *Journal of Scientific Research and Development, 21*(1), 163-175. https://jsrd.unilag.edu.ng/article/view/2453

Assi, M. A., Hezmee, M. N. M., Sabri, M. Y. M., & Rajion, M. A. (2016). The detrimental effects of lead on human and animal health. *Veterinary world*, *9*(6), 660.doi: 10.14202/vetworld.2016.660-671

Awodele, O., Popoola, T. D., Amadi, K. C., Coker, H. A. B., & Akintonwa, A. (2013). Traditional medicinal plants in Nigeria—Remedies or risks. *Journal of ethnopharmacology*, *150*(2), 614-618. https://doi.org/10.1016/j.jep.2013.09.015

Bala, A. R., & Sahal, A. (2023). Assessment of Heavy Metals Concentrations in Herbal Medicine Used For Treatment of Typhoid and Bacterial Infections in Kaduna State, Nigeria. *Nuhu Bamalli Polytechnic Journal of Science and Technology* 1: (3)

Barnes, D. G., Dourson, M., Preuss, P., Bellin, J., Derosa, C., Engler, R., . . . Francis, E. (1988). Reference dose (RfD): description and use in health risk assessments. *Regulatory Toxicology and Pharmacology, 8*(4), 471-486 https://www.tera.org/Publications/RFD%20and%20Use%20Article.pdf

Bello, M. O., Ibrahim, A. O., Ogunwande, I. A., & Olawore, N. O. (2004). Heavy trace metals and macronutrients status in herbal plants of Nigeria. *Food Chemistry*, *85*(1), 67-71. https://doi.org/10.1016/j.foodchem.2003.06.004

Bhattacharyya, K., Sen, D., Laskar, P., Saha, T., Kundu, G., Ghosh Chaudhuri, A., & Ganguly, S. (2023). Pathophysiological effects of cadmium (II) on human health-a critical review. *Journal of Basic and Clinical Physiology and Pharmacology*, *34*(3), 249-261. https://doi.org/10.1515/jbcpp-2021-0173

Borah, P., Gujre, N., Rene, E. R., Rangan, L., Paul, R. K., Karak, T., & Mitra, S. (2020). Assessment of mobility and environmental risks associated with copper, manganese and zinc in soils of a dumping site around a Ramsar site. *Chemosphere*, *254*, 126852. https://doi.org/10.1016/j.chemosphere. 2020.126852

Brenko, T., Ružičić, S., Radonić, N., Puljko, M., & Cvetković, M. (2024). Geochemical factors as a tool for distinguishing geogenic from anthropogenic sources of potentially toxic elements in the soil. *Land*, *13*(4), 434. https://doi.org/10.3390/land13040434

Chegaing S. P. F. , Mefokou, D. Y., Tangue, B. T. , Sokoudjou, J. B., Menoudji S. T. G., Gabriel Kamsu T. & Gatsing, D. (2000). Contribution to the ethnobotanical inventory of medicinal plants used for the treatment of typhoid fever in Adamaoua region, Cameroon *Int. J. Biol. Chem. Sci.* 14(9): 3078-3096, https://dx.doi.org/10.4314/ijbcs.v14i9.9

Collin, M. S., Venkatraman, S. K., Vijayakumar, N., Kanimozhi, V., Arbaaz, S. M., Stacey, R. S., ... & Swamiappan, S. (2022). Bioaccumulation of lead (Pb) and its effects on human: A review. *Journal of Hazardous Materials Advances*, *7*, 100094. https://doi.org/10.1016/j.hazadv.2022,100094

Dghaim, R., Al Khatib, S., Rasool, H., & Ali Khan, M. (2015). Determination of heavy metals concentration in traditional herbs commonly consumed in the United Arab Emirates. *Journal of environmental and public health*, *2015*(1), 973878. https://doi.org/10.1155/2015/973878

Dogara, A., Hamad, S. W., Usman, M., Tahir, S. M., Sunusi, N., & Yunusa, A. (2021). Therapeutic plants used for Typhoid Fever treatment in Kaduna State Nigeria. *Al-Qadisiyah Journal of Pure Science*, *26*(3), 9-21. https://doi.org/10.29350/qjps.2021.26.4.1432

Ebrahimzadeh, G., Omer, A. K., Naderi, M., & Sharafi, K. (2024). Human health risk assessment of potentially toxic and essential elements in medicinal plants consumed in Zabol, Iran, using the Monte Carlo simulation method. *Scientific Reports*, *14*(1), 23756. https://doi.org/10.1038/s41598-024-75159-w

FAO/WHO 2011. Safety Evaluation of Certain Food Additives and Contaminants WHO FOOD ADDITIVES SERIES:64. .

Fisher, A. L., & Babitt, J. L. (2022). Coordination of iron homeostasis by bone morphogenetic proteins: Current understanding and unanswered questions. *Developmental Dynamics*, *251*(1), 26-46. https://doi.org/10.1002/dvdy.372

Food, W.H.O. (2007). Safety evaluation of certain food additives and contaminants. https://iris.who.int/bitstream/handle/10665/44813/?sequence=1

Garba, M., Dandago, M., Igwe, E., & Zubairu, I. (2023). Assessment of Heavy Metals in Ready-To-Eat (Rte) Vegetables Salads Sold Within Kano Metropolis, Nigeria. *Fudma Journal of Agriculture and Agricultural Technology*, *9*(2), 79-86.

Genchi, G., Sinicropi, M. S., Lauria, G., Carocci, A., & Catalano, A. (2020). The effects of cadmium toxicity. *International journal of environmental research and public health*, *17*(11), 3782. https://doi.org/10.3390/ijerph17113782

Gujja, P., Rosing, D. R., Tripodi, D. J., & Shizukuda, Y. (2010). Iron overload cardiomyopathy: better understanding of an increasing disorder. *Journal of the American College of Cardiology*, *56*(13), 1001-1012. https://www.jacc.org/doi/abs/10.1016/j.jacc.2010.03.083

Harris, E. S., Cao, S., Littlefield, B. A., Craycroft, J. A., Scholten, R., Kaptchuk, T., ... & Eisenberg, D. M. (2011). Heavy metal and pesticide content in commonly prescribed individual raw Chinese Herbal Medicines. *Science of the Total Environment*, *409*(20), 4297-4305. https://doi.org/10.1016/j.scitotenv.2011.07.032

Khan, S. A., Khan, L., qbal Hussain, I., Marwat, K. B., & Akhtar, N. (2008). Profile of Heavy Metals in Selected Medicinal Plants. *Pak. J. Weed Sci. Res*, *14*(1-2), 101-110.

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*, 41-50. https://doi.org/10.1007/s12011-018-1357-3

Liehr, J. G., & Jones, J. (2001). Role of iron in estrogen-induced cancer. *Current medicinal chemistry*, *8*(7), 839-849. https://doi.org/10.2174/0929867013372931

Luby S. P., Saha S., Andrews J. R., Towards sustainable public health surveillance for enteric fever. Vaccine. 2015; 33: 3-7 https://doi.org/10.1016/j.vaccine.2015.02.054

Mafulul, S. G., Joel, E. B., & Gushit, J. (2023). Health risk assessment of potentially toxic elements (PTEs) concentrations in soil and fruits of selected perennial economic trees growing naturally in the vicinity of the abandoned mining ponds in Kuba, Bokkos Local Government Area (LGA) Plateau State, Nigeria. *Environmental Geochemistry and Health*, *45*(8), 5893-5914. https://link.springer.com/article/10.1007/s10653-023-01600-0

Meseret, M., Ketema, G., & Kassahun, H. (2020). Health risk assessment and determination of some heavy metals in commonly consumed traditional herbal preparations in Northeast Ethiopia. *Journal of Chemistry, 2020*(1), 8883837. https://doi.org/10.1155/2020/8883837

Nardi, S., Carletti, P., Pizzeghello, D., & Muscolo, A. (2009). Biological activities of humic substances. *Biophysico-chemical processes involving natural nonliving organic matter in environmental systems*, *2*(part 1), 305-339. http://dx.doi.org/10.1002/9780470494950.ch8

Nazir, R., Khan, M., Masab, M., Rehman, H. U., Rauf, N. U., Shahab, S., ... & Shaheen, Z. (2015). Accumulation of heavy metals (Ni, Cu, Cd, Cr, Pb, Zn, Fe) in the soil, water and plants and analysis of physico-chemical parameters of soil and water collected from Tanda Dam Kohat. *Journal of pharmaceutical sciences and research*, *7*(3), 89. https://www.jpsr.pharmainfo.in/Documents/Volumes/vol7issue03/jpsr07031501.pdf

NIH Dietary Supplement FactSheet https://ods.od.nih.gov/factsheets/Copper-HealthProfessional/#h2 (Accessed 11 Nov, 2024)

NIH Dietary Supplement FactSheet https://ods.od.nih.gov/factsheets/Iron-HealthProfessional/ (Accessed 11 Nov, 2024)

Nwachukwu, R. E., Janefrances, N. I., Jude, I. A., Fausta, I. O. C., Simon, U. O., & Ogechi, L. A. (2018). Assessment of heavy metals content of some plant-based medicines in parts of southern Nigeria, West Africa. *International Journal of Pharmaceutical Sciences and Research*, *9*(2), 775-783. http://dx.doi.org/10.13040/IJPSR.0975-8232.9(2).775-83

Opuni, K. F., Kretchy, J. P., Agbyabeng, K., Baodu, J. A., Adanu, T., Ankamh, S., Appiah, A., Amoah, G. B., BaidooM. & Kretchy I. A. (2023). Contamination of Herbal medicinal Products in Low-and Middle-Income Countries: A systematic Review. *Heliyon. 9* https://doi.org/10.1016/j.heliyon.2023.e19370

Royer, A. & Sharman, T. (2023). Copper Toxicity. 2023 Mar 27. In: StatPearls [Internet]. Treasure Island (FL): StatPearls publishing https://www.ncbi.nlm.nih.gov/books/NBK557456/

Singh, J. & Kalamdhad, A. S. (2011). Effects of Heavy Metals on Soil, Plants, Human Health, and Aquatic Life. *Int. J Res. Chem Environ*. 1, 15 – 21

Sulaiman, M. B., Santuraki, A. H., Adamu, A. M. Ezenobi, U. V., Gimba, A. M. & Akinlotan, O. O. (2022). Concentrations and Health Risk Assessment of Potentially Toxic Elements in Medicinal Herbs from Northern Nigeria. *French-Ukrainian Journal of Chemistry,* 10(2), 1 -13 http://dx.doi.org/10.17721/fujcV10I2P9-21

Tokalioğlu, Ş. (2012) Determination of Trace Elements in Commonly Consumed Medicinal Herbs by ICP-MS and Multivariate Analysis. *Food chemistry,* **134** 2504-2508. https://doi.org/10.1016/j.foodchem.2012.04.093

U.S. EPA. Exposure Factors Handbook (1997, Final Report). U.S. Environmental Protection Agency, Washington, DC, EPA/600/P-95/002F a-c, 1997. https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=12464

WHO, 2007. World Health Organization. Guidelines for Assessing Quality of Herbal Medicines With Reference to Contaminants and Residues. Geneva, Switzerland. https://iris.who.int/bitstream/handle/10665/43510/?sequence=1

World Health Organization, W. H. O (1998). *Quality control methods for medicinal plant materials*: https://www.who.int/docs/default-source/medicines/norms-and-standards/guidelines/quality-control/quality-control-methods-for-medicinal-plant-materials.pdf?sfvrsn=b451e7c6_0

Yiannikourides A. & Latunde-Dada, G. O. (2019) A Short Review of Iron Metabolism and Pathophysiology of Iron Disorders. *Medicines,* 6 85. https://doi.org/10.3390/medicines6030085

Yusuf, C., Zakawa, N., Tizhe, T., Timon, D., Andrew A. & Musa, I. (2021) Ethnobotanical Survey And Phytochemical Analysis Of Guava (*Psidium Guajava* L.) Leaves in Some Communities of Mubi North, Adamawa State, Nigeria. *Asian Journal of Research in Botany,* 5 26-33