Assessment of Trace Elements Concentrations and Health Risks of Medicinal Plant Leaves in Gombe Metropolis, Northeastern, Nigeria

Aminu Muhammad[1]; Seydou Hankouraou[2]*; Ishiyaku Ibrahim Babayo[3]; Ahmadu Muhammad Aliyu[4]; Hamza Abubakar Hamza[5]

Department of Pure and Applied Physics, Faculty of Science,
Gombe State University, Gombe

Publication Date: 2026/08/08

Abstract: Medicinal plants remain an important component of primary healthcare in many developing countries, including Nigeria, due to their accessibility, affordability, and long-standing therapeutic use. However, the safety of herbal materials is increasingly threatened by environmental contamination, particularly from trace and toxic elements that may accumulate in plant tissues. This study assessed the trace element concentrations and associated health risks of selected medicinal plant leaves collected from fifteen locations within Gombe Metropolis, Northeastern, Nigeria. Fifteen medicinal plant species were sampled, identified, air-dried, pulverized, and analyzed using Energy Dispersive X-Ray Fluorescence (EDXRF).

The analysis revealed the presence of twenty-two trace elements, including both essential and potentially toxic elements such as Na, Mg, P, S, Cl, K, Ca, Mn, Fe, Cu, Zn, As, Sr, Y, Zr, Mo, Si, Ti, Ni, Br, Rb, and Al. The concentrations in (ppm) of trace elements in the plant extracts were found to be as follows: Na(0.00 ppm to 19438.71 ppm), Mg (7680ppm to 17100ppm), P (14277.46 ppm to 66366.2 ppm), Ni (65.9 ppm to 199 ppm), S (12400 ppm to 111000 ppm) Cl (4780 ppm to 72600 ppm), K (102063.8 ppm to 414893.6ppm), Ca (180000 ppm to 462857.1 ppm) Mn (732 ppm to 21720 ppm) Fe (5005 ppm to 28980 ppm), Cu (241 ppm to 1830 ppm) As (0.00ppm to 20.8 ppm), Zn (408 ppm to 1950ppm) Br (54 ppm to 2480 ppm), Rb (353 ppm to 2720 ppm) Sr (220 ppm to 4490 ppm) Ti (385.345ppm to 1627.5 ppm) Zr (38.1 ppm to 482 ppm) Mo (33.1 ppm to 99.7 ppm), Si (7280 ppm to 69533.3 ppm), Y (33.5 ppm to 193 ppm) and Al (20329.41 ppm – 74464.70 ppm). Health risk assessment using Estimated Daily Intake (EDI), Health Risk Index (HRI), Target Hazard Quotient (THQ), and Estimated Cancer risk (ECR) suggested that regular consumption of some of these plants may pose potential non-carcinogenic and carcinogenic risks, especially with long-term exposure. The findings highlight the need for routine monitoring, quality control, and regulatory oversight of medicinal plants sold and consumed in Gombe Metropolis to ensure public safety.

Keywords: *Trace Elements, Medicinal Plants, Heavy Metals, Health Risk Assessment, Gombe Metropolis.*

How to Cite: Aminu Muhammad; Seydou Hankouraou; Ishiyaku Ibrahim Babayo; Ahmadu Muhammad Aliyu; Hamza Abubakar Hamza (2026) Assessment of Trace Elements Concentrations and Health Risks of Medicinal Plant Leaves in Gombe Metropolis, Northeastern, Nigeria. *International Journal of Innovative Science and Research Technology*, 11(7), 3301-3311. https://doi.org/10.38124/ijisrt/26jul1558

I. INTRODUCTION

Medicinal plants have been widely used for centuries in the prevention and treatment of various human diseases. In many developing countries, including Nigeria, herbal medicine remains an essential component of primary healthcare due to its accessibility, affordability, and cultural acceptance (World Health Organization, 2019). The therapeutic effectiveness of medicinal plants is largely attributed to the presence of bioactive compounds and essential trace elements that contribute to various physiological functions in the human body.

Trace elements are chemical elements present in very small concentrations in biological systems but play crucial roles in metabolic and biochemical processes. Essential elements

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jul1558

such as iron (Fe), zinc (Zn), copper (Cu), manganese (Mn), and magnesium (Mg) are required for enzyme activities, oxygen transport, immune function, and cellular metabolism (Alloway, 2013). However, excessive intake of these elements or exposure to toxic elements such as arsenic (As), nickel (Ni), cadmium (Cd), and lead (Pb) may lead to adverse health effects including organ damage, neurological disorders, and carcinogenic risks (Jaishankar *et al.,* 2014).

Medicinal plants have the ability to absorb and accumulate trace elements from their surrounding environment, including soil, irrigation water, fertilizers, and atmospheric deposition. Environmental pollution, agricultural practices, and industrial activities can significantly influence the levels of trace elements in plants (Kabata-Pendias, 2011). As a result, medicinal herbs may contain elevated concentrations of certain metals that can pose health risks to consumers when used continuously or in large quantities.

In recent years, the assessment of trace elements in medicinal plants has gained considerable scientific attention due to increasing concerns about food safety and environmental contamination. Studies conducted in different parts of the world have reported the presence of both essential and toxic metals in herbal plants used for traditional medicine (Sardar *et al.,* 2013). Monitoring the concentrations of these elements is therefore important to ensure the safety and quality of herbal products.

Trace elements enter medicinal plants mainly through soil uptake, atmospheric deposition, and irrigation water, processes that are strongly influenced by environmental conditions, anthropogenic pollution, and soil chemistry (Sadisu Girigisu *et al.,* 2024). While essential trace elements are vital for plant metabolism and have therapeutic value, excessive accumulation of heavy metals poses significant health risks to humans, including neurotoxicity, renal dysfunction, and carcinogenesis when consumed above permissible limits (Adetola *et al.,* 2023).

Studies within Nigeria have demonstrated variable concentrations of trace elements in medicinal plants. For instance, investigations in Oyo State reflected that most heavy metal contents in selected medicinal plants were below the World Health Organization (WHO) permissible limits, although this varies with species and environmental exposure (Adetola *et al.,* 2023). Furthermore, comparative analyses of plant and soil samples showed that essential elements such as iron and manganese often dominate the trace metal profile, but non-essential metals like lead and cadmium can also be present at significant levels (Sadisu Girigisu *et al.,* 2024).

In Nigeria, medicinal plants are widely used in traditional medicine for the treatment of ailments such as malaria, infections, gastrointestinal disorders, and inflammatory diseases. In Gombe metropolis, several medicinal plants are commonly harvested and consumed by the local population for therapeutic purposes. However, limited information is available regarding the levels of trace elements present in these plants and the potential health risks associated with their consumption.

Therefore, this study aims to determine the concentrations of essential and non-essential trace elements in selected medicinal plant leaves collected from Gombe metropolis using Energy Dispersive X-Ray Fluorescence (EDXRF) analysis. In addition, the study evaluates the potential health risks associated with the detected elements by comparing their concentrations with established permissible limits. The findings of this study will contribute to understanding the safety of medicinal plants used in the region and provide useful information for public health authorities, researchers, and consumers.

II. MATERIALS AND METHODS

- *Study Area*

This study was carried out in Gombe metropolis, located within Gombe Local Government Area (LGA), Gombe State, North eastern Nigeria. Gombe Metropolis lies approximately between latitude 10º15’N and 10º30’N and longitude 11º10’E and 11º20’E. The area experiences a tropical savannah climate characterized by distinct wet and dry seasons, with moderate to high temperatures throughout the year. The study area was selected because medicinal plants are widely harvested and consumed by residents for therapeutic purposes. A map of the study area.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jul1558

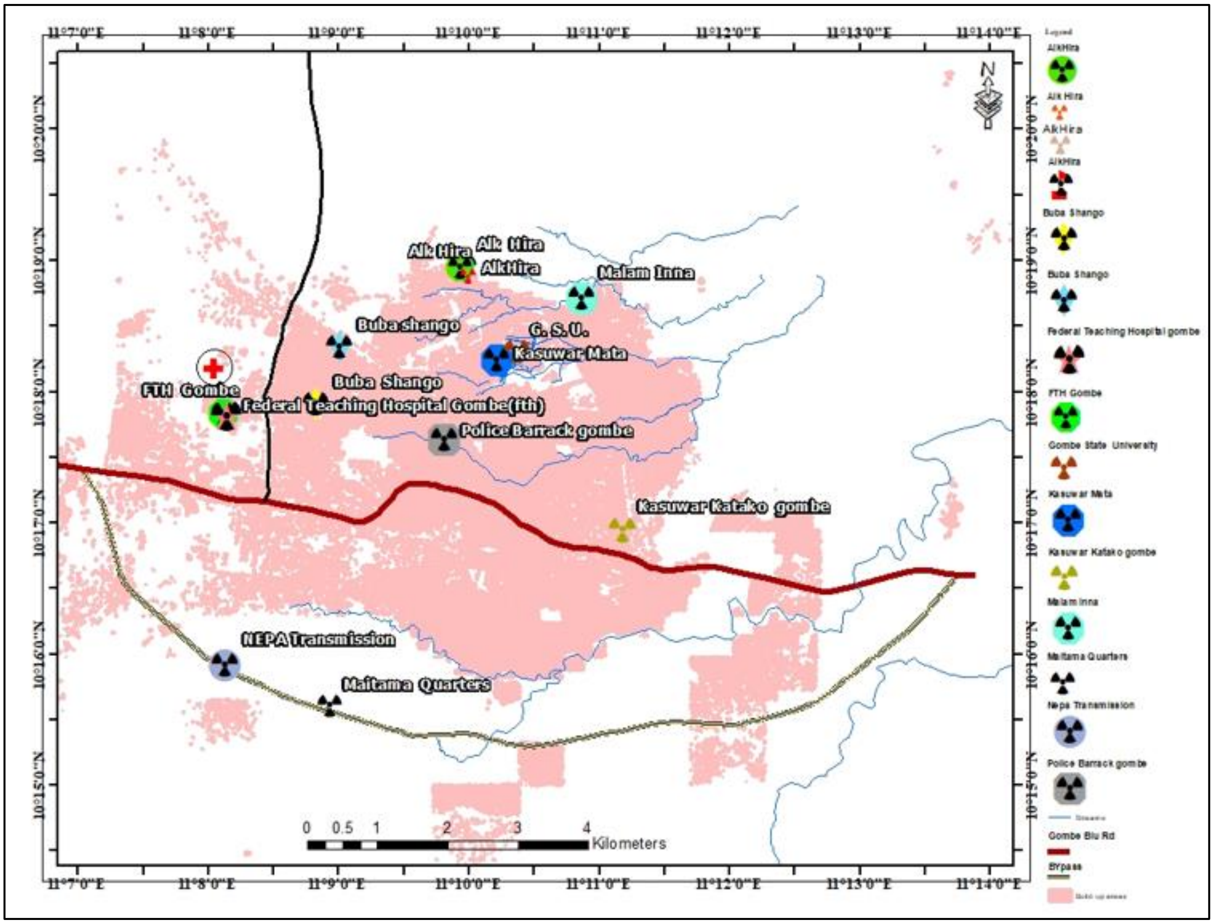

Fig 1: Sampling Location

➢ *Research Design*

This study adopted an experimental and analytical research design involving field sampling of selected medicinal plant leaves from different locations within Gombe metropolis. Laboratory preparation of collected samples under contamination controlled conditions. Elemental analysis of the prepared samples using energy dispersive X-ray fluorescence (EDXRF) technique, and health risk assessment of detected potential toxic trace elements using established exposure and risk models. This design was chosen to quantitatively determine trace element concentrations in medicinal plants and to evaluate the possible health implications associated with their long term consumption.

➢ *Sample Collection and Identification*

A total of fifteen (15) medicinal plant leaf samples commonly used in traditional medicine were collected from fifteen different sampling locations within Gombe Metropolis. The selected plants were chosen based on: their frequent use in ethnomedicine, their availability within the study area, and Their reported medicinal relevance in local communities.

Fresh, mature, and disease-free leaves were handpicked using clean gloves and stainless-steel scissors to avoid contamination. Each sample was placed in a clean labelled polyethylene bag immediately after collection. During sampling, care was taken to prevent contact with dust, soil particles, and metallic surfaces that could alter the elemental composition.

The geographical coordinates (latitude, longitude, and altitude) of each sampling point were recorded using a Global Positioning System (GPS) device. The botanical identity of all collected plant species was authenticated at the Department of Botany, Faculty of Science, Gombe State University. The local names, English names, scientific names, and sample codes of the plants are presented in Table 1.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jul1558

Table 1: Local and Botanical Names of the Collected Plants Leaves

S/N	English Name	Scientific Name	Local Name	Sample Code
1	Physics Nut	Jatropha curcas	Banida zugu/ Bitada zugu	BIU
2	Moringa	Moringa oleifera	Zogale	ZOG
3	Sacred Garlic Pear	Crateva religiosa	Gidido	GIO
4	Guava	Psidium guajava	Gwaiba	GUA
5	Ficus PlatyPhylla	Ficus platyphylla	Gamji	GAI
6	Mango	Mangifera indica	Mangworo	MAO
7	Bitter leafs	Vernonia amygdalina	Shuwaka	SHA
8	Pawpaw	Carica papaya	Gwanda	GWA
9	Desert Date	Balanites aegyptiaca	Aduwa	ADA
10	RiverRed Eucalaptus	Eucalyptus camaldulensis	Zaiti/Bishiyan turare	ZAI
11	Parkia	Parkia biglobosa	Dorawa/dorowa	DOA
12	Baobab	Adansonia digitate	Kuka	KUA
13	Neem	Azadirachta indica	Neem	NEM
14	Cassia	Cassia spp. (e.g., Cassia fistula)	Gadina	GAN
15	Bauhinia	Bauhinia spp. (e.g., Bauhinia variegata, Bauhinia purpurea)	Kalgo/Kargo	KAO

➢ *Sample Preparation*

The collected leaf samples were first rinsed gently with distilled water to remove adhering dust and surface contaminants. The samples were then air-dried at room temperature in a clean, dust-free laboratory environment for several days until a constant weight was achieved. To avoid alteration of elemental composition, no metallic drying trays were used.

After drying, the samples were crushed and ground into fine powder using a clean agate mortar and pestle (or non-metallic grinder where available). The powdered samples were sieved through a fine mesh to obtain a homogeneous particle size suitable for XRF analysis.

Approximately 5 g of each homogenized sample was weighed using a digital analytical balance and transferred into 32 mm sample cups lined with 4 µm polypropylene X-ray film. The samples were then compacted (pressed) using a hydraulic press to improve sample uniformity, reduce porosity, and enhance analytical precision. The sample cups were subsequently capped and labelled appropriately before instrumental analysis. These preparation steps align with the uploaded EDXRF method section (5 g aliquot, 32 mm cups, 4 µm polypropylene film, hydraulic pressing).

➢ *Instrumental Analysis Using EDXRF*

Elemental analysis of the prepared medicinal plant leaf samples was carried out using a Rigaku NEX DE Energy Dispersive X-ray Fluorescence (EDXRF) spectrometer. The instrument was equipped with a 15-position sample changer and operated in slow and steady spin mode to improve counting statistics and analytical reproducibility.

➢ *Operating Conditions*

The EDXRF measurements were performed under the following conditions:

- Atmosphere: Helium (He)
- X-ray tube target: Palladium (Pd)
- Tube voltage: 60 kV
- Tube current: 10 µA
- Beam spot size: 10 mm
- Detector: Silicon Drift Detector (SDD) with Peltier electronic cooling system

➢ *Calibration and Quantification*

The instrument was operated using standardless Fundamental Parameters (FP) calibration through Rigaku RPF-SQX software, which allows simultaneous multi-element quantification of unknown samples. The software automatically applies matrix corrections and spectral deconvolution to estimate elemental concentrations accurately.

The EDXRF system is capable of detecting elements from sodium (Na, Z = 11) to uranium (U, Z = 92), with detection limits ranging from low parts per million (ppm) to weight percent (%wt) depending on the element and sample matrix. Analytical precision was maintained within an estimated relative standard deviation (RSD) of 0.1–1%. These instrumental settings and performance characteristics are drawn directly from the uploaded methods draft.

➢ *Quality Assurance and Quality Control (QA/QC)*

To ensure the reliability and accuracy of analytical results, strict quality control procedures were adopted throughout sample collection, preparation, and analysis:

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jul1558

- Use of clean sampling materials: All sample containers, tools, and preparation surfaces were thoroughly cleaned before use.
- Avoidance of metallic contamination: Non-metallic materials were used wherever possible during grinding and handling.
- Replicate preparation and measurement: Selected samples were prepared and analysed in duplicate to verify reproducibility.
- Instrument stability checks: Instrument background and energy calibration were checked before analysis.
- Blank/control checks: Empty sample cups fitted with polypropylene film were used to verify background contributions.
- Homogenization: All samples were finely ground and thoroughly mixed to ensure representative analysis.
- Consistent sample mass and geometry: Approximately equal sample mass and identical sample cup geometry was maintained for all analyses to minimize matrix effects.

These QA/QC steps improve confidence in the generated concentration data and reduce analytical bias.

➢ *Determination of Trace Element Concentrations*

The concentrations of trace elements detected in the medicinal plant leaves were expressed in parts per million (ppm), which is equivalent to mg/kg for solid samples. The study focused on both:

- Essential trace elements (e.g., K, Ca, Mg, Mn, Fe, Cu, Zn), and
- Potentially toxic/non-essential elements (e.g., As, Ni, and other detectable elements of concern).

For health risk evaluation, only the elements with recognized toxicological significance and measurable concentrations were considered.

➢ *Health Risk Assessment*

The following variables constitute the health risk calculation for this study: estimated daily intake of heavy metal (EDI), health risk index (HRI), target hazard quotient (THQ) for non- carcinogenic risk, and estimation of cancer risk (ECR).

The EDI of a heavy metal through ingestion is given by Equation 1

$$EDI = \frac{CxEF\ X\ EDxIR}{BW\ X\ AT} \tag{1}$$

Where EDI is the estimated daily intake of heavy metal in the herbal plant (mg/kg/ day), EF is the exposure frequency (350 days/year), ED is the exposure duration (average age of 7 years for children and 30 years for adults in Nigeria), IR is the ingestion rate of herbal drug (IR is assumed to be 0.25 L/day and 0.75 L/ day for children and adults) (Katuura *et al.*, 2016) C is the concentration of heavy metals in herbal plants (mg/kg), BW is body weight which is assumed to be 30 kg and 60 kg for an average child and adult in Nigeria, and AT is the averaging time based on life expectancy.

Average life expectancy (AT) is equal to exposure duration (ED) and the average life expectancy of a typical Nigerian was considered to be 55 years according to World Health Organization (2019).

The HRI was calculated using Equation 2

$$HRI = \frac{EDI}{Rfd} \tag{2}$$

Where EDI is estimated daily intake of heavy metals from herbal plants, and Rfd is the oral reference dose for non-carcinogenic risk (Pb, Cd, Cu, Mn, Cr and Ni values are 0.0035, 0.001, 0.040, 0.14, 1.5 and 0.020 mg/kg/day respectively, According to United States Environmental Protection Agency (2006).

The THQ can be generated from the hazard index (HI) and is given by Equation 3

$$HI = \sum_{i=1}^{n} THQn \tag{3}$$

The ECR was calculated using Equation 4

$$ECR = EDI * CSf \tag{4}$$

Where EDI is the estimated daily intake of a heavy metal; CSf is the ingestion slope factor (Pb = 0.0085 and Ni = 0.84), Fengying (2008). A cancer risk index ranging between 10^{-6} (1 in 1 000 000) and 10^{-4} (1 in 10 000) shows the predicted lifetime risks for cancer- causing agents. Chemicals with risk factors lower than 10^{-5} (1 in 10 000) are not considered to be chemicals of further concern (Nkpaa *et al.,* 2016).

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jul1558

III. RESULTS AND DISCUSSION

➢ *Trace Element Profile of Medicinal Plant Leaves*

Table 2 presents the concentrations of twenty-two trace elements detected in the medicinal plant leaves collected from different locations in Gombe metropolis. The results show wide variability in elemental composition across plant species, which strongly suggests species-dependent uptake mechanisms and environmental influence.

The dominance of potassium (K), calcium (Ca), phosphorus (P), sulfur (S), and magnesium (Mg) across most samples indicates that these plants are rich in essential macronutrients. The exceptionally high potassium values (up to 414,893.6 ppm in ZAI) and calcium concentrations (up to 462,857.1 ppm in GAN) confirm that medicinal plants can significantly contribute to dietary mineral intake. This aligns with earlier studies that reported high mineral accumulation in leafy medicinal plants due to their active metabolic processes and soil interactions.

However, the presence of aluminum (Al), nickel (Ni), arsenic (As), and copper (Cu) in several samples raises toxicological concerns. For instance: Nickel (Ni) reached up to 199 ppm (GIO), indicating possible contamination from soil or anthropogenic activities. Arsenic (As), although mostly non-detectable, was present in KUA (20.8 ppm), this is significant due to its carcinogenic nature. Aluminum (Al) showed consistently high concentrations across many samples, suggesting geogenic origin or soil acidity influence.

The non-detection of cadmium (Cd), lead (Pb), and mercury (Hg) is a positive finding, indicating relatively low contamination from industrial heavy metals in the study area.

Additionally, elements such as silicon (Si), strontium (Sr), zirconium (Zr), and rubidium (Rb), though not directly toxic at low levels, indicate complex geochemical interactions between soil and plant systems.

Table 2: Elemental Concentration Results in PPM

	SAMPLE CODE	ADA	BIZ	DRA	GAN	GAI	GUA	GWA	KAO
S/N	Elements								
1	Na	ND	ND	ND	19438.71	ND	ND	ND	ND
2	Mg	128	7680.00	13800.00	ND	ND	ND	17100.00	ND
3	Al	9952.94	8047.05	20329.41	9794.11	ND	10641.18	10429.41	11541.18
4	Si	25200.00	560	69533.33	14560.00	43213.33	55066.67	28466.67	18620.00
5	P	14277.46	27288.73	43661.97	35191.55	30214.08	23359.15	25673.24	66366.2
6	K	129446.80	102063.80	180063.80	110361.70	394148.9	152680.90	189191.50	321957.40
7	Ca	434285.70	427142.90	234285.70	462857.10	215000.00	392857.10	386428.60	231428.60
8	Ti	1554.69	ND	1627.28	ND	ND	ND	ND	ND
9	Mn	8520.00	3216.00	15660.00	3294.00	7080.00	3270.00	732.00	5034.00
10	Fe	7140.00	6755.00	28980.00	10920.00	9240.00	10570.00	12040.00	9590.00
11	S	37200.00	15100.00	38800.00	25800.00	12400.00	30600.00	24700.00	37000.00
12	Cl	33600.00	33500.00	27200.00	8730.00	21000.00	17200.00	13800.00	4780.00
13	Ni	85.2.00	65.90	ND	164.00	105.00	ND	87.90	ND
14	Cu	241.00	308.00	547.00	682.00	491.00	616.00	338.00	1830.00
15	Zn	514.00	799.00	1350.00	1020.00	626.00	583.00	854.00	1950.00
16	As	ND	ND	ND	ND	ND	ND	ND	ND
17	Br	2480.00	366.00	1220.00	109.00	55.9.00	ND	ND	ND
18	Rb	711.00	353.00	1250.00	519.00	1460.00	923.00	740.00	2720.00
19	Sr	3810.00	1970.00	1710.00	3690.00	965.00	2520.00	2320.00	1980.00
20	Y	193.00	96.90	175.00	ND	ND	ND	ND	131.00
21	Zr	362.00	272.00	301.00	323.00	159.00	356.00	322.00	286.00
22	Mo	ND	ND	33.10	42.30	ND	ND	ND	ND

S/N		KUA	MAO	ZOE	NIM	GIO	SHA	ZAI
1	Na	ND	ND	ND	ND	ND	ND	ND
2	Mg	ND	ND	ND	ND	ND	ND	ND
3	Al	9582.35	13076.47	7464.71	12282.35	ND	7835.29	11435.29
4	Si	14980.00	23753.33	7280.00	23380.00	7233.33	29260.00	10406.67

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jul1558

5	P	29646.48	21481.69	44535.21	21438.03	21612.68	20084.51	28292.96
6	K	158489.40	161808.50	234000.00	151851.10	279638.30	257234.00	414893.60
7	Ca	439285.70	436428.60	317142.90	445714.30	328571.40	330714.30	180000.00
8	Ti	ND	ND	ND	ND	ND	385.35	ND
9	Mn	996.00	912.00	3420.00	1278.00	4350.00	1416.00	21720.00
10	Fe	6209.00	14210.00	6993.00	14700.00	6405.00	6762.00	5005.00
11	S	14400.00	20100.00	111000.00	20100.00	94600.00	14100.00	13600.00
12	Cl	41100.00	20900.00	9360.00	21200.00	22800.00	64400.00	72600.00
13	Ni	ND	ND	179.00	57.70	199.00	94.40	146.00
14	Cu	424.00	378.00	418.00	372.00	260.00	465.00	563.00
15	Zn	850.00	744.00	1030.00	732.00	408.00	1720.00	1120.00
16	As	20.8.00	ND	ND	ND	ND	ND	ND
17	Br	1080.00	146.00	ND	155.00	54.00	232.00	330.00
18	Rb	479.00	682.00	1250.00	629.00	1190.00	659.00	1520.00
19	Sr	4490.00	3420.00	2400.00	3590.00	1070.00	1070.00	220.00
20	Y	139.00	50.00	33.50	ND	ND	ND	ND
21	Zr	482.00	374.00	238.00	394.00	141.00	187.00	38.10
22	Mo	ND	ND	ND	ND	99.70	ND	ND

➢ *Health Risk Assessment*

The health risk assessment component of the study adds substantial value because it moves beyond simple concentration reporting and evaluates the possible consequences of human exposure. The study employed Estimated Daily Intake (EDI), Health Risk Index (HRI), Target Hazard Quotient (THQ), and Estimated Cancer Risk (ECR) for adults and children. The exposure assumptions included different body weights and ingestion rates for children and adults, which is appropriate because children are often more vulnerable to toxic exposures due to lower body mass and developing physiological systems.

Table 3 shows the estimated daily intake (EDI) of trace elements for both adults and children, reflecting exposure levels through consumption of medicinal plants.

The results indicate that: Adults consistently show higher EDI values than children, due to higher ingestion rates. However, children remain more vulnerable because exposure is higher relative to body weight. Extremely high EDI values were recorded for: Calcium (Ca) (up to 1,104,377 mg/kg/day in GAN), Potassium (K) (up to 940,439 mg/kg/day in GAI), Silicon (Si) and phosphorus (P) also showed elevated intake levels. While these elements are essential, such excessive intake may lead to physiological imbalance, including: Hypercalcemia (excess calcium), Electrolyte imbalance (high potassium), metabolic stress. More importantly, EDI values for toxic elements such as: Nickel (Ni) (up to 390 mg/kg/day in GAN), Copper (Cu) (up to 1625 mg/kg/day in GAN), Aluminum (Al) (very high across samples) suggest potential health risks, especially with chronic exposure. The detection of arsenic intake (in KUA) is particularly concerning because even low doses of arsenic over time can lead to cancer and organ damage.

Table 3: Daily Intake of Trace Element for all Medicinal Plants Leaves for Adults and Children for Each Trace Element with Respect to their Sampling Points in this Study.

S/N	SAMPLE CODE		ADA	BIZ	DRA	GAN	GAI	GUA	GWA
	Elements	**Daily Intake**							
1	Na	Adult	ND	ND	ND	46380.76	ND	ND	ND
		Child	ND	ND	ND	7211.76	ND	ND	ND
2	Mg	Adult	30493	18324	32926	ND	ND	ND	40800
		Child	4741	2849	5119	ND	ND	ND	6344

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jul1558

3	Al	Adult	23747	19200	48505	23368.77	ND	25389.86	24884
		Child	3692	2985	7542	3633.62	ND	3947.89	3869
4	Si	Adult	60127	133616	165906	34740.16	103107	131389.07	67921
		Child	9349	20776	25796.85	5401.76	16032	20429.75	10561
5	P	Adult	34066	65110	104177.46	83967.04	72090	55734.93	61256
		Child	5296	10124	16198.6	13056.08	11209	8666.26	9524
6	K	Adult	308860.06	243524	429632.23	263323.02	940439	364296	451410
		Child	48024.84	37865	66803.74	40944.3	146229	56644.65	70190
7	Ca	Adult	1036205.7	1019162	559005.68	1104377	512990	937357.04	922018
		Child	161120.11	158470	86920.11	171719.95	7976	145749.95	143365
8	Ti	Adult	3709.49	ND	3882.7	ND	ND	ND	ND
		Child	576.79	ND	603.72	ND	ND	ND	ND
9	Mn	Adult	20328.72	7673.38	37364.76	7859.48	16892.88	7802.22	1746.55
		Child	3160.92	1193.14	5809.86	1222.07	2626.68	1213.17	271.57
10	Fe	Adult	17036.04	16117.43	69146	26055	22046.64	25220.02	28727.44
		Child	2648.94	2506.11	10751	4051	3428.04	3921.47	4466.84
11	S	Adult	88647.6	35983.3	92460	61481	29549.2	72919	58860.1
		Child	13801.2	5602.1	14394	9571	4600.4	11352	9163.7
12	Cl	Adult	80068	79830	64817	20803	50043	40987	32885
		Child	12465	12428	10091	3238	7791	6381	5119
13	Ni	Adult	203	157	ND	390	250	ND	209
		Child	31	24	ND	60	38	ND	32
14	Cu	Adult	574	733	1303.5	1625	1170	1467	805
		Child	89.41	114.27	202	253.02	182	228	125
15	Zn	Adult	1224.86	1904.02	3217	2430	149	1389	2035
		Child	190.69	296.43	500	378	232	216	316
16	As	Adult	ND	ND	ND	ND	ND	ND	ND
		Child	ND	ND	ND	ND	ND	ND	ND
17	Br	Adult	5917.28	873.28	2910.92	260.07	133.38	ND	ND
		Child	920.08	135.79	452.62	40.44	20.74	ND	ND
18	Rb	Adult	1696.45	842.26	2982.5	1238.33	3483.56	2202.28	1765.64
		Child	263.78	130.96	463.75	192.55	541.66	342.43	274.54
19	Sr	Adult	9090.66	4700.42	4080.06	8804.34	2302.49	6012.72	5535.52
		Child	1413.51	730.87	634.41	1368.99	358.02	934.92	860.72
20	Y	Adult	460.5	231.2	417.55	ND	ND	ND	ND
		Child	71.6	35.95	64.93	ND	ND	ND	ND
21	Zr	Adult	863.73	648.99	718.19	770.68	379.37	849.42	768.29
		Child	134.3	100.91	111.67	119.83	58.99	132.08	119.46
22	Mo	Adult	ND	ND	78.98	100.93	ND	ND	ND
		Child	ND	ND	12.28	15.69	ND	ND	ND

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jul1558

The below Table 4 presents the Health Risk Index (HRI), which evaluates non-carcinogenic risk. An HRI > 1 indicates potential health risk, and in this study, all values far exceed 1, indicating serious safety concerns. Extremely high HRI values for: Manganese (Mn) (up to 370,170 in ZAI for adults), Iron (Fe) (up to 98,780 in DRA), Copper (Cu) (up to 109,022 in KAO), Nickel (Ni) (up to 23,740 in GIO), Aluminum (Al) also shows very high HRI values across most samples.

These results indicate that regular consumption of these plants may lead to toxic accumulation, affecting: Nervous system (Mn toxicity), Liver and kidney function (Cu toxicity), Blood and metabolic processes (Fe overload). The KUA sample shows extremely high arsenic HRI, confirming it as a high-risk plant for carcinogenic exposure. Children show lower absolute HRI values but still far exceed safe limits, meaning they are at greater relative risk due to lower body mass.

Table 4: Health Risk Index of Adults and Children for Each Toxic Trace Element

SAMPLE CODE		Al	Mn	Fe	Ni	Cu	Zn	As
ADA	Adult	23747.7	145205	24337	10151	14357	4082	ND
	Child	3692.54	22578	3784	1580	2235	635	ND
BIZ	Adult	19200.3	54809	23024	7851	18349	6346	ND
	Child	2985.46	8522	3580	1222	2856	988	ND
DRA	Adult	48506	266891	98780	ND	32587	10723	ND
	Child	7542.21	41498	15359	ND	5073	1669	ND
GAN	Adult	23368.8	56139	37221	19540	40630	8102	ND
	Child	3633.62	8729	5787	3042	6325	1261	ND
GAI	Adult	ND	120663	31495	12511	29251	4972	ND
	Child	ND	18761	4897	1948	4554	774	ND
GUA	Adult	25389.9	55730	36028	ND	36698	4630	ND
	Child	3947.89	8665	5602	ND	5713	720	ND
GWA	Adult	24884.6	12475	41039	10473	20136	6783	ND
	Child	3869.31	1939	6381	1630	3135	1056	ND
KAO	Adult	27537.3	85793	32688	ND	109022	15489	ND
	Child	4281.79	13340	5082	ND	16973	2411	ND
KUA	Adult	22863.5	16974	21163	ND	25291	6760	165429
	Child	3555.05	2639	3290	ND	3932	1051	25722
MAO	Adult	31200.5	15543	48435	ND	22547	5917	ND
	Child	4851.38	2416	7531	ND	3505	920	ND
MOA	Adult	17810.8	58286	23836	21354	24933	8191	ND
	Child	2769.41	9062	3706	3320	3876	1273	ND
NIM	Adult	29305.7	21780	50106	6883	22189	5821	ND
	Child	4556.77	3386	7791	977	3450	905	ND
GIO	Adult	ND	74136	21831	23740	15509	3244	ND
	Child	ND	11527	3394	3691	2411	504	ND
SHA	Adult	18695	24132	23048	11261	27737	13679	ND
	Child	2906.89	3752	3583	1751	4312	2127	ND
ZAI	Adult	27284.6	370170	17059	17417	33583	8907	ND
	Child	4242.5	57557	2652	2708	5221	1385	ND

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jul1558

Table 5 below presents the Hazard Index (HI), which represents the combined effect of multiple toxic elements. An HI > 1 indicates potential health risk, and all samples in this study show extremely high HI values, confirming serious cumulative toxicity risks.

ZAI (HI = 474,421) and DRA (HI = 457,487) recorded the highest risk levels, KAO (HI = 270,529) and KUA (HI = 258,481) also show significant risk, Even the lowest HI values (e.g., GWA = 115,791) are far above safe limits

These elevated HI values are mainly driven by: High manganese (Mn) and iron (Fe) concentrations, Significant contributions from copper (Cu), nickel (Ni), and aluminum (Al), Presence of arsenic (As) in KUA, increasing carcinogenic risk.

The results indicate that: Combined exposure to multiple elements is more dangerous than individual exposure. There is a synergistic toxic effect, increasing the likelihood of adverse health outcomes. The high HI values suggest potential risks such as: Organ damage (liver, kidney), Neurological disorders, Increased cancer risk (especially where arsenic is present)

Table 5: Hazard Index of Adults for Each of the Sampled Plants Leaves

SAMPLE CODE		Al	Mn	Fe	Ni	Cu	Zn	As	(HI)
ADA	Adult	23747.7	145205	24337	10151	14357	4082	ND	221880
BIZ	Adult	19200.3	54809	23024	7851	18349	6346	ND	129579
DRA	Adult	48506	266891	98780	ND	32587	10723	ND	457487
GAN	Adult	23368.8	56139	37221	19540	40630	8102	ND	185001
GAI	Adult	ND	120663	31495	12511	29251	4972	ND	198892
GUA	Adult	25389.9	55730	36028	ND	36698	4630	ND	158476
GWA	Adult	24884.6	12475	41039	10473	20136	6783	ND	115791
KAO	Adult	27537.3	85793	32688	ND	109022	15489	ND	270529
KUA	Adult	22863.5	16974	21163	ND	25291	6760	165429	258481
MAO	Adult	31200.5	15543	48435	ND	22547	5917	ND	123643
MOA	Adult	17810.8	58286	23836	21354	24933	8191	ND	154411
NIM	Adult	29305.7	21780	50106	6883	22189	5821	ND	136085
GIO	Adult	ND	74136	21831	23740	15509	3244	ND	138460
SHA	Adult	18695	24132	23048	11261	27737	13679	ND	118552
ZAI	Adult	27284.6	370170	17059	17417	33583	8907	ND	474421

IV. CONCLUSION

This study demonstrated that medicinal plant leaves collected from Gombe Metropolis contain a wide range of trace elements, including both essential nutrients and potentially toxic elements. A total of twenty-two elements were detected using EDXRF, with potassium, calcium, phosphorus, sulfur, iron, and magnesium occurring at relatively high concentrations in many samples. These findings support the nutritional and therapeutic relevance of the studied medicinal plants. However, the study also revealed the presence of potentially harmful elements such as arsenic and nickel in some samples, while certain elements occurred at concentrations above permissible or desirable safety limits for medicinal plant consumption. The uploaded manuscript similarly concludes that several trace elements exceeded acceptable ranges, indicating a need for caution in their medicinal use.

The non-detection of cadmium, lead, and mercury is a positive outcome, but it does not eliminate the overall toxicological concern because arsenic, nickel, aluminum, copper, zinc, and manganese showed elevated levels or risk indicators in some plant species. The health risk assessment results suggest that regular or prolonged consumption of some of the medicinal plants may pose non-carcinogenic health risks to both adults and children, with children being potentially more vulnerable due to lower body weight and higher relative exposure. In addition, arsenic- and nickel-related exposure may contribute to carcinogenic risk where estimated values exceed acceptable thresholds.

Overall, the study highlights that medicinal plants in Gombe Metropolis cannot be assumed to be completely safe solely because of their natural origin. While they remain valuable therapeutic resources, their safety must be scientifically verified through regular elemental screening,

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26jul1558

quality assurance, and health risk evaluation. There is therefore a strong need for regulatory monitoring, public awareness, and the establishment of acceptable quality standards for medicinal plant materials in local markets. Future studies should also investigate soil-to-plant transfer patterns, seasonal variation, and the effect of processing methods on elemental concentrations in herbal preparations.

REFERENCES

[1]. Adetola, O. O., Akinyemi, G. O., Oyediji, O. T., Onafurume, O. M., & Adekoya, O. O. (2023). *Heavy metals contamination in some medicinal plants from Onigambari forest reserve*. Discovery, 59, e29d1033. pISSN 2278–5469; eISSN 2278–5450

[2]. Alloway, B. J. (2013). *Heavy metals in soils: Trace metals and metalloids in soils and their bioavailability* (3rd ed.). Springer. Dordrecht. https://doi.org/10.1007/978-94-007-4470-7 SBN **:** 978-94-007-4469-1 (print), 978-94-007-4470-7 (eBook)

[3]. Jaishankar, M., Tseten, T., Anbalagan, N., Mathew, B., & Beeregowda, K. (2014). Toxicity, mechanism and health effects of some heavy metals. *Interdisciplinary Toxicology, Volume 7* Issue 2, Pp 60–72. https://doi.org/10.2478/intox-2014-0009.

[4]. Kabata-Pendias, A. (2011). *Trace elements in soils and plants* (4th ed.). CRC Press. CRC Press. https://doi.org/10.1201/b10158

[5]. Katuura, E., Waako, P., Ogwal-Okeng, J., & Bukenya-Ziraba, R. (2016). Assessment of heavy metal contamination in herbal medicines used in Uganda. *Journal of Environmental and Public Health*, Article ID 8961504. https://doi.org/10.1155/2016/8961504

[6]. Nkpaa, K. W., Wegwu, M. O., Essien, E. B., & Ogamba, E. N. (2016). Bioaccumulation of heavy metals and human health risk assessment in three fish species from Iwofe Coastal Waters, Niger Delta, Nigeria. *Journal of Health and Pollution*, Volume 6, Issue 10, Pp1-10. https://doi.org/10.5696/2156-9614-6-10.1

[7]. Sadisu G., Aduloju, E. I., Abubakar, A., & Olanrewaju, M. O. (2024). Comparative study of heavy metals in plant and soil of some selected medicinal plants. *FUDMA Journal of Sciences, Volume 4*, Issue 1, Pp714–721

[8]. Sardar, K., Ali, S., Hameed, S., Afzal, S., Fatima, S., Shakoor, M., Bharwana, S. A., & Tauqeer, H. M. (2013). Heavy metals contamination and what are the impacts on living organisms. *Greener Journal of Environmental Management and Public Safety*, *Volume 2*, Issue 4, Pp172–179.

[9]. United States Environmental Protection Agency (EPA). (2006). Integrated Risk Information System (IRIS) – Reference Dose (RfD) for Non-Carcinogenic Risk Assessment. U.S. Environmental Protection Agency.

[10]. World Health Organization. (2019). *WHO global report on traditional and complementary medicine 2019*. WHO Press.