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# ASSESSMENT OF NATURAL RADIONUCLIDE CONCENTRATIONS AND RADIOLOGICAL HEALTH RISKS IN TRADITIONAL HERBAL MEDICINES COMMONLY CONSUMED WITHIN ZARIA METROPOLIS, NIGERIA

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## ABSTRACT

Traditional herbal medicines play a vital role in primary healthcare across developing countries, including Nigeria. However, concerns persist over their safety due to possible contamination with toxic natural radionuclides. This study assessed the level of activity concentrations of three radionuclides $^{40}$K, $^{226}$Ra, and $^{232}$Th presence in 20 commonly consumed traditional herbal medicines sold within Zaria metropolis. Samples were analyzed using a NaI (Tl) gamma-ray spectrometry. The evaluated mean activity concentrations were 182.65 ± 6.47 Bq/kg for $^{40}$K, 26.36 ± 2.94 Bq/kg for $^{226}$Ra, and 23.65 ± 2.46 Bq/kg for $^{232}$Th. The highest activity concentration of $^{40}$K (282.10 ± 8.54 Bq/kg) was measured in *Bauhinia thonningii (Camel foot tree)*, while *Cyambopogam citrates (Lemon grass)* and *Khaya senegalensis (African mahogany)* exhibited the highest concentrations of $^{226}$Ra (56.57 ± 5.09 Bq/kg) and $^{232}$Th (46.64 ± 3.84 Bq/kg) respectively. The calculated radiological parameters Radium Equivalent Activity (Raeq), External Hazard Index (Hex), Internal Hazard Index (Hin), and Annual Effective Dose (AED) were all within international safety limits, but the Excess Lifetime Cancer Risk (ELCR) exceeded the ICRP permissible value of $1.0 \times 10^{-4}$ in all samples, indicating potential long-term cancer risks. Although the radiological dose through ingestion was below 1 mSv/year limit, the elevated ELCR values call for regulatory attention.

**Keywords**: Traditional herbal medicines, NaI(Tl) gamma spectrometry, radionuclides, radiological risk, Excess Life time Cancer Risk (ELCR), herbal safety.

## INTRODUCTION

Herbal medicines, defined as naturally occurring plant-derived substances used with minimal processing for therapeutic purposes, remain an integral component of healthcare systems in many developing nations (Tilburt *et al*., 2008). The use of traditional herbal medicines has become increasingly widespread in recent years. Various parts of plants including roots, stems, bark, leaves, fruits, and flowers are utilized in the formulation of herbal preparations. Because of their natural origin, herbal remedies are often perceived by individuals to be safer than conventional pharmaceutical products. The increasing reliance on these remedies is largely driven by factors such as affordability, accessibility, and the belief in their safety relative to synthetic drugs. According to the World Health Organization (WHO, 2002), more than 80% of people in Africa and other developing regions depend on herbal medicines to meet their primary healthcare needs. In Zaria metropolitan of Nigeria, traditional herbal preparations are widely consumed owing to their perceived safety, accessibility, and affordability compared to modern pharmaceuticals.

However, natural radionuclides such as Uranium-238 ($^{238}U$), Thorium-232 ($^{232}Th$), and Potassium-40 ($^{40}K$) are present in the earth's crust and can be absorbed by plants through the soil-water system (Ademola and Ethiedu, 2010: Merrill and Tom, 1990). These elements ($^{238}U$), ($^{232}Th$) and ($^{40}K$) and their decay products occurred at trace levels in all ground formation as reported by Garba et al. (2024). Their presences in high concentration elevated background radiation and pose serious radiological health risks (Kessaratikoon and Awaekeshi, 2008). The human exposure to high radionuclide exposures in food, soil and water can adversely affect the human's health which may leads to genetic mutation and either living things potentially cause cancer (Sathyapriva *et al*., 2017; Hernandez *et al*., 2004; USEPA, 2009).

Several studies have evaluated the contamination of herbal medicines and environmental matrices with heavy metals and radionuclides (Okunola et al., 2020; Garba *et al*., 2021; Shuaibu *et al*., 2025). However, there are limited studies that focused on the combined assessment of natural radionuclides in medicinal herbs consumed in northern Nigeria. The present research therefore investigates the activity concentrations of $^{40}K$, $^{226}Ra$, and $^{232}Th$ in traditional herbal medicines commonly consumed in Zaria metropolis. The presence of natural radionuclides may raise concern about their potential radiological risks, as these elements contribute to background radiation levels. Although radionuclides occur naturally, their accumulation in herbal preparations may increase the toxic burden on both humans and environment through ingestion and disposal pathways. The study aims to evaluate the radiological health risks associated with consuming traditional herbal medicine and establish a baseline database to ensure the safe consumption and regulation of traditional herbal medicines in Nigeria.

## MATERIALS AND METHODS

### Sample collection

Twenty (20) traditional herbal medicine samples were randomly collected from markets within Zaria metropolis, Kaduna State, Nigeria. The sample was based on the popularity and frequency of used as determined through preliminary survey with local herbalists and consumers.

Each plant used in the traditional herbal medicine was identified by its botanical name, common name, local name and the family to which it belongs to. These plants were commonly consumed markets within Zaria metropolis and are widely used by local herbalist and consumers for the treatment and management of various alignment such as malaria, fever, typhoid, digestive issues, ulcer, Malaria, wound infection and skin infections. The plant parts used (such as leaves, roots, bark or stem), its traditional and therapeutic uses are tabulated presented in Table 2.1

**Table 2.1:** Medicinal plants used for treating viral diseases

| | Botanical Name | Common Name | Local Name | Family Name | Plant Parts Used | Source | Method of Preparation | Method of Application | Medicinal Use |
|---|---|---|---|---|---|---|---|---|---|
| 1 | *Mangifera Indica* | Mango | Mangoro | Anacardiaceae | Leaves | Wild | Decoction | Oral | Diabetes, Diarrhea, asthma, Malaria, Typoid |
| 2 | *Psidium Guajava* | Guava | Goba | Mystaceae | Leaves | Wild | Decoction | Oral | Digestive health, Typoid, Yellow Fever, dysentery, Cough and fever, menstrual cramps, Diabetes, cancer etc |
| 3 | *Citrus aurantifolia* | Lemon | Lemun Tsami | Rutaceae | Leaves | Wild | Decoction | Oral | Kidney stone, Weight Loss, Skin, Blood pressure |
| 4 | *Moringa Oleifera* | Drumstick | Zogale | Moringacea | Leaves | Wild | Decoction | Oral | Malaria treatment, Immune system, Hypertension, |
| 5 | *Bauhinia Thonningii* | Camel foot tree | Kalgo | Fabaceae | Stem Bark | Wild | Decoction | Oral | Hypertitis |
| 6 | *Khaya Senegalensis* | AfricanMahogany | Madaci | Meliaceae | Stem Bark | Wild | Decoction | Oral | Stomach ache |
| 7 | *Ficus Sycomorus* | Fig | Baure | Moraceae | Bark | Wild | Mixed with pap or water mixed with pap or Nono | Oral | Ulcer |
| 8 | *Anogeisus Leocarpus* | Axlewood tree | Marke | Combrataceae | Barks | Wild | Hot or cold water, Tom tom | Oral | Cough |
| 9 | *Boswellia Dalzielii* | Frankincense tree | Ararrabi | Burseraceae | Powder | Wild | Infusion | Oral | Pile |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 10 | *Artemisia Annua L.* | Sweet annie | Tazargade | Arteraceae | Leaves | Wild | Boiling | Oral | Malaria, Typoid |
| 11 | *Ziziphus Mucronata* | Buffalo thorn | Magarya | Rhamnaceae | Leaves | Wild | Infusion | Oral | |
| 12 | *Cochlospermum Tinctorium* | African butter tree | Rawaya | Cochlospermaceae | | | Decoction | Oral | Fever, Hepatitis, abdominal pain |
| 13 | *Calotropis Procera (Aiton) Dryand* | Sodom Apple | Tunfafiya | Apocynaceae | Leaves | Wild | Concoction/also mixed powdered stem bark of hannu | Oral for one week and a portion of it is used in bathing. | Small box, Monkey pox, treating a hole in teeth |
| 14 | *Annona Ssenegalinsis* | Wild custard apple | Gwanda Daji | Annonaceae | Leaves | Wild | Concoction | Oral | Poliomyelitis, Sore throats |
| 15 | *Acarcia Nilotica (L) delile* | Scented thorn | Bagaruwa | Mimosaceae | Leaves | Wild | Decoction/ Prepared with Pap | Oral | Hepatitis, Monkey Pox, Meningitis, Small pox, Poliomyelitis, COVID-19 |
| 16 | *Guiera Senegalensis J.F. Gmel.* | Moshi Medicine | Sabara | Combretaceae | Leaves | Wild | Decoction/ Prepared with Pap | Oral | Yellow fever, Poliomyelitis, Small pox, COVID -19, |

**Sample Preparation**

All the plant sample collected were thoroughly washed with distilled water to remove any accumulated impurities from handing and distribution. Each of the traditional herbal medicine sample collected was dried at ambient temperature, and crushed to fine powder using agate mortar and pestle at low background counting laboratory at the Centre for energy research and training, Ahmadu Bello University, Zaria. The obtained powder was further dried to remove moisture before being sieved to obtain a uniform grain size (Jimoh *et al*., 2023). For analysis, a portion of the fine powder was then prepared for gamma spectrometric analysis.

**Sample Analysis**

First, the empty container's mass was measured and recorded. About 7.135 to 21.688g of the fine powder was placed inside the container and measured. The weighing balance was used to confirm a precise reading (Barba-lobo *et al*., 2022). The samples were then Packaged in radon-impermeable cylindrical plastic containers, selected based on the space allocation of the detector vessel which measures 7.6cm by 7.6cm in dimension (geometry). To prevent radon-222 escape, the packaging in each container was triple-sealed (Seo et al., 2025).

The sealing process included smearing of the inner rim of each container lid with Vaseline jelly, filling the lid assembly gap with candle wax to block any opening (gaps between lid and container), and tightly-sealing the lid-container with masking adhesive tape. To allow $^{226}$Ra, $^{222}$Radon and its short-lived progenies to reach secular equilibrium, the sealed samples were stored for 28-30 days prior to gamma spectrometry measurements (Khandakar *et al.,* 2012; UNSCEAR, 2000).

**Gamma Spectrometric Analysis Using NaI (Tl) Detector**

The analyses were carried out using a 76 mm x 76 mm NaI (Tl) detector crystal optically coupled to a photomultiplier tube (PMT) (Gilmore, 2011). The assembly has a preamplifier incorporated into it and a 1kilovolt external source. The detector was enclosed in a 6cm thick lead shield with cadmium and copper sheets. This arrangement was aimed at minimizing the effects of background and scattered radiation (Itodo *et al*., 2020).

The data acquisition was performed using Maestro software (Canberra Nuclear Products). Each sample was counted for 28,800 seconds. The net peak areas corresponding to known gamma-ray energies were used to calculate activity concentrations in each sample using equation (1) (Kolo *et al.,* 2015).

$$C\ (Bq.kg^{-1}) = \frac{Cn}{Cfk} \tag{1}$$

Where,

C = activity concentration of the radionuclide $Bqkg^{-1}$, Cn = Count rate (counts per second, cps)

$C_{fk}$= Calibration factor of the detecting system.

Count Per Second (CPS) were calculated using equation (2)

$$\text{Count Per second (cps)} = \frac{\text{Net Count}}{\text{Live Time}} \tag{2}$$

$$\text{Hence;}\quad \frac{\text{CPS}}{\text{Conversion factor}}\ (Bq/kg) \tag{3}$$

Equations (1), (2) and (3) were used to calculate activity concentration and measurement uncertainty (Table 2). CPS (Counts per second) was used to represent the rate at which radioactive decays were detected. These values were then converted to Bq/kg, the standard unit for measuring activity concentration in environmental samples; using defined conversion factors, specifically: $^{226}$Ra = 0.000643 CPS/Bq.kg$^{-1}$, $^{232}$Th = 0.000863 CPS/Bq.kg$^{-1}$ and $^{40}$K = 0.000877 CPS/Bq.kg$^{-1}$(IAEA, 1989). The analysis employed a calibration factor of $\times 10^{-4}$ to adjust for instrument sensitivity, ensuring accurate conversion of detected gamma emissions into concentration values (Gilmore, 2011). Additionally, each radionuclide in Table 2 had a minimum detection limit below which results may not be reliably quantified, set at 14.54Bq /kg for $^{40}$K, 3.84Bq/kg for $^{226}$Ra, and 9.08Bq/kg for $^{232}$Th. These parameters are critical in ensuring the accuracy, sensitivity, and reliability of the radiological assessment carried out on the medicinal plant samples.

International Atomic Energy Agency IAEA (1989) standard reference ($^{238}U$, $^{232}Th$ and $^{40}K$) were used for calibration involved using standard point sources of $^{137}Cs$ and $^{60}Co$, each counted for 100seconds. These were done with the amplifier gain that gives 72% energy resolution at the 66.16 keV peaks of $^{137}Cs$, or 1173.2 keV and 1332.5 keV for $^{60}Co$ followed by a 30minutes counting period (Ademola et al., 2010). Energy Calibration was established based on the known photo peaks of the standard sources. After calibration, the system was validated and then used for sample analysis under identical conditions, saving each sample spectrum under unique identifiers. Calibration of the spectrometric system was validating using the IAEA gamma spectrometric reference materials: RGK-1 for $^{40}K$, RGU-1 for $^{226}Ra$ (using the $^{214}Bi$ peak) and RTG-1 for $^{232}Th$ (using the $^{208}Ti$ peak) (Jodlowski *et al.*, 2025).

## Radiological Risk Assessment

### Annual Effective Dose

The annual effective dose (E) due to ingestion of radionuclides in herbal medicines was calculated using equation (4) as reported by (UNSCEAR, 2000).

$$E = \sum (Ai \times DCFi \times M) \tag{4}$$

where E is the annual effective dose (Sv/year), Ai is the activity concentration of radionuclide (Bq/kg), DCFi is the dose conversion factor for ingestion of radionuclide i (Sv/Bq), M is the annual consumption rate of herbal medicine (kg/year).

The dose conversion factors used were 6.2 × $10^{-9}$ Sv/Bq for $^{40}K$, 2.8 × $10^{-7}$ Sv/Bq for $^{226}Ra$, and 2.3 × $10^{7}$ Sv/Bq for $^{232}Th$ in equation (4) (ICRP, 2012). The annual consumption rate was estimated at 2.5 kg/year based on surveys of local consumption patterns.

### Radium Equivalent Activity

The radium equivale nt activity ($Ra_{eq}$) was calculated to compare the specific activities of samples containing different concentrations of $^{40}K$, $^{226}Ra$, and $^{232}Th$ using equation (5) as reported by (USEPA, 1989).

$$Ra_{eq} = A_{Ra} + 1.43A_{Th} + 0.077A_{K} \tag{5}$$

where $A_{Ra}$, $A_{Th}$, and $A_K$ are the activity concentrations of $^{226}Ra$, $^{232}Th$, and $^{40}K$, respectively.

### External and internal hazard indices

The external hazard index (Hex) was calculated using (6) as reported by (USEPA, 1989).

$$Hex = \frac{ARA}{370} + \frac{ATH}{259} + \frac{AK}{4810} \tag{6}$$

$$Hin = \frac{ARA}{185} + \frac{ATH}{259} + \frac{AK}{4810} \tag{7}$$

For radiation safety, the values of both indices should be less than unity.

### Excess Lifetime Cancer Risk

The excess lifetime cancer risk (ELCR) was estimated using equation (8) as reported by (Azhdarpoor *et al.*, 2021).

$$ELCR = E \times DL \times RF \tag{8}$$

where E is the annual effective dose (Sv/year), DL is the average duration of life (63.4 years) for Nigeria (WHO, 2021). RF is the risk factor ($Sv^{-1}$), which is 0.05 according to ICRP recommendation for stochastic effects.

## RESULTS AND DISCUSSION

### Activity Concentrations of Natural Radionuclides ($^{40}K$, $^{226}Ra$, and $^{232}Th$)

The activity concentrations of the natural radionuclides $^{40}K$, $^{226}Ra$, and $^{232}Th$, together with their associated measurement uncertainties, in the analyzed traditional herbal medicine samples are presented in Table 3.1. The results revealed notable variations in the concentrations of these radionuclides among the different herbal species. Such variations may be attributed to differences in plant species, root depth, soil composition, and environmental conditions at the collection sites (Dyakova *et al.*, 2025).

Radionuclides present in the environment can enter plants through several transfer pathways; one of the major environmental pathways that lead to the ingestion of radionuclides by human beings is the soil-plant-man pathway (Ibikunle *et al.*, 2019). The primary mode of transfer is root uptake from the soil solution, where radionuclides such as $^{226}Ra$ and $^{232}Th$ adsorbed onto soil particles and subsequently become available for absorption by plant roots (Asaduzzaman *et al.*, 2015). The efficiency of this uptake is influenced by several factors such as soil pH, organic matter content, cation exchange capacity, and the chemical form of the radionuclide. In contrast, $^{40}$K, being an essential nutrient element, is readily absorbed by plants through potassium transport mechanisms, often leading to higher activity concentrations compared to other radionuclides (Khanal *et al*., 2024).

From table 3.1, it is observed that *Khaya senegalensis* has lower values of $^{40}$K (50.87 ± 4.99 Bq/kg) and $^{226}$Ra (21.12 ± 1.16 Bq/kg) but highest value in $^{232}$Th (46.64 ± 3.84 Bq/kg). The elevated level of $^{232}$Th could be attributed to soil-to-plant transfer processes or the plant's specific uptake mechanism for Thorium-bearing minerals. Therefore, it is important to monitor its consumption to ensured radiological safety, especially concerning Thorium exposure.

**Table 3.1:** Activity concentrations (Bq/kg) of natural radionuclides in commonly consumed samples within Zaria metropolis.

| Samples Name | $^{40}$K (Bq/kg) | $^{226}$Ra (Bq/kg) | $^{232}$Th (Bq/kg) |
|---|---|---|---|
| *Calitrospis procera* | 155.49 ± 5.89 | 47.31 ± 4.18 | 24.61 ± 1.64 |
| *Cyambopogam citrates* | 186.41 ± 6.44 | 56.57 ± 5.09 | 27.26 ± 1.10 |
| *Conchlospermum tinctorium* | 132.16 ± 5.57 | 23.21 ± 3.89 | 22.96 ± 2.34 |
| *Bauhinia thonningii* | 282.10 ± 8.54 | 35.88 ± 5.56 | 27.00± 2.78 |
| *Anogeisus Leocarpus* | 178.69 ± 7.67 | 14.00 ± 1.87 | 19.83 ± 1.67 |
| *Chrozophora senegalensis* | 196.73 ± 5.96 | 21.35 ± 2.46 | 22.01 ± 3.14 |
| *Anacardium occidentale l.* | 169.13 ± 6.77 | 13.52 ± 1.52 | 13.78 ± 1.86 |
| *Citrus aurantifolia* | 127.49 ± 5.46 | 18.38 ± 2.39 | 29.06 ± 2.80 |
| *Moringa oleifera* | 157.03 ± 7.36 | 27.05 ± 2.11 | 15.40 ± 3.13 |
| *Psidium guajava.i* | 155.36 ± 5.95 | 44.50 ± 4.53 | 13.07 ± 1.50 |
| *Mangifera indica* | 189.91 ± 6.49 | 30.17 ± 2.80 | 14.81 ± 3.12 |
| *Ficus sycomorus* | 194.13 ± 7.03 | 26.06 ± 2.47 | 20.59 ± 1.90 |
| *Boswellia dalzielii* | 199.32 ± 8.86 | 21.64 ± 3.16 | 15.37 ± 1.00 |
| *Ziziphus Mauritania* | 141.98 ± 4.43 | 13.24 ± 1.32 | 21.31 ± 2.10 |
| *Annona senegalensis* | 134.47 ± 3.62 | 11.30 ± 1.66 | 29.90 ± 3.04 |
| *Guiera senegalensis* | 161.74 ± 5.60 | 22.97 ± 3.04 | 27.01 ± 4.48 |
| *Carica papaya* | 187.84 ± 5.33 | 21.36 ± 2.50 | 23.41 ± 3.13 |
| *Acarcia nilotica* | 219.41 ± 4.99 | 19.35 ± 2.56 | 38.08 ± 3.02 |
| *Artemisia maciverae linn* | 201.68 ± 6.47 | 38.14 ± 2.76 | 20.94 ± 1.70 |
| *Khaya senegalensis* | 50.87 ± 4.99 | 21.12 ± 1.16 | 46.64 ± 3.84 |

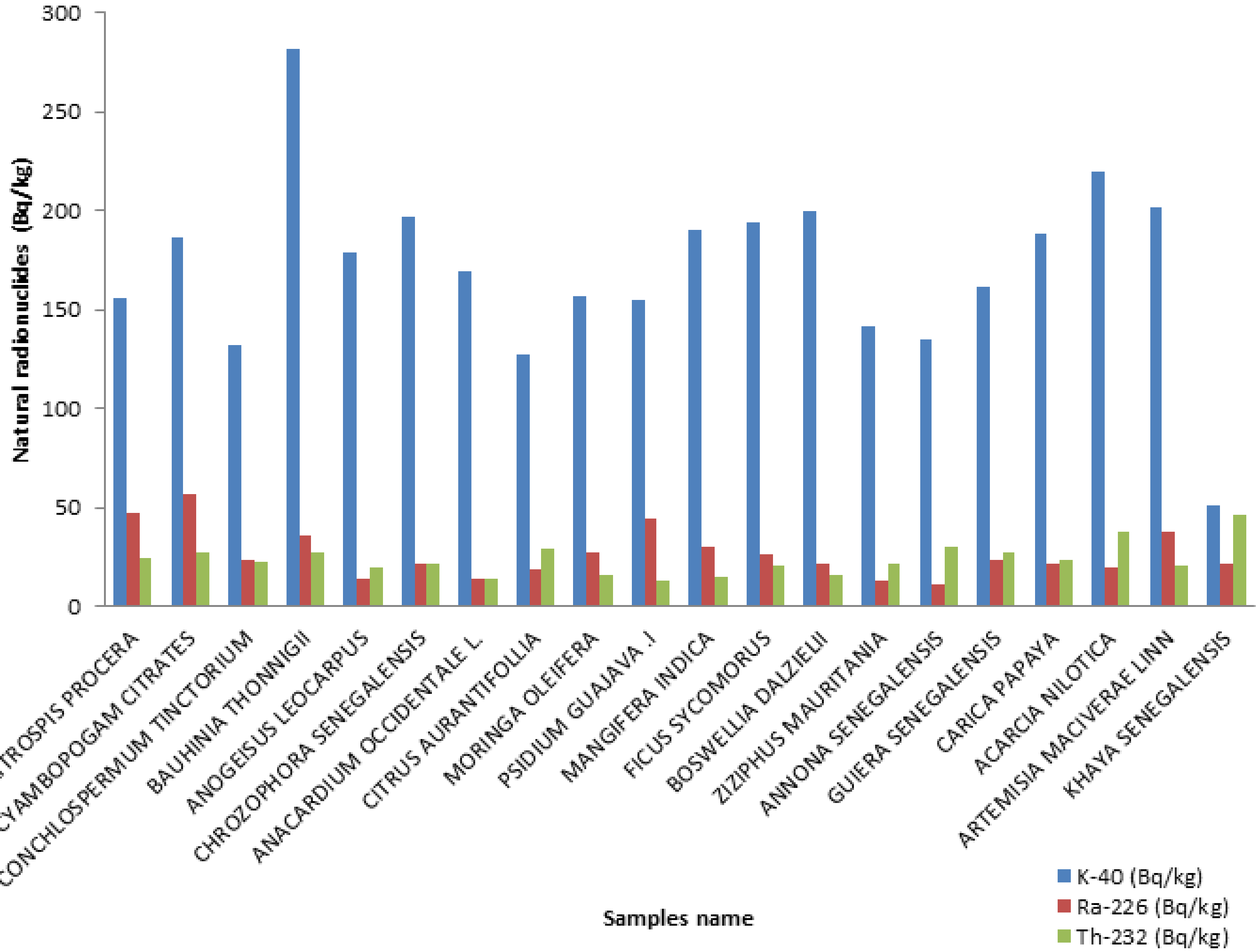


**Fig. 1:** Activity concentration of natural radionuclides in commonly consumed traditional herbal medicines

From Fig 1, it's observed that, the activity concentration of $^{40}$K ranged from 50.87 ± 5.00 Bq/kg in Khaya *senegalensis* to 282.10 ± 8.54 Bq/kg in *Bauhinia thonnigii,* with a mean value of 182.65 ± 6.47 Bq/kg. For $^{226}$Ra, the concentration ranged from 11.30 Bq/kg in *Annona senegalensis* to 56.57 Bq/kg in *Cyambopogam citrates*, with a mean value of 26.36 ± 2.94 Bq/kg. The activity concentration of $^{232}$Th varied from 13.07Bq/kg in *Psidium guajava* to 46.64 ± 3.84 Bq/kg in *Khaya senegalensis*, with a mean value of 23.65 ± 2.46 Bq/kg. The variation in activity concentrations among different plant species suggests different uptake of radionuclides from the soil composition, radionuclides mobility and availability, root structure and absorption ability of each plant (Shuaibu *et al*., 2024). For instance, *Bauhinia thonnigii* accumulate more $^{40}$K due to the higher availability of Potassium in its growing environment. While higher levels of $^{226}$Ra and $^{232}$Th, such as the 56.57 ±5.09 Bq/kg of $^{226}$Ra in *Cyambopogam citrates*, are significant because the higher the concentration, the greater the internal dose and can pose a radiological health risk when ingested regularly (Kolo *et al*., 2015).

## Radiological health hazard parameters

The calculated radiological hazard parameters for the herbal medicine samples are presented in Table 3.2 Using equation (2) and the activity concentrations of the radionuclides presented in Table 3.1, the Radium equivalent Activity concentrations were calculated and the results are presented in Table 3.2, the Radium equivalent activity (Raeq) ranged from 46.25 to 110.9 Bq/kg, with a mean value of 73.3465Bq/kg. These values are below the internationally acceptable limit of 370 Bq/kg recommended by (UNSCEAR, 2000).

**Table 3.2:** Radiological Hazard parameters for traditional herbal medicine samples

| SAMPLES NAME | Raeq (Bq/kg) | Hex | Hin | AED (mSv/y) | ELCR ($\times 10^4$) |
|---|---|---|---|---|---|
| *Calitrospis procera* | 94.475 | 0.255 | 0.383 | 0.061 | 2.15 |
| *Cyambopogam citrates* | 110.9 | 0.297 | 0.45 | 0.0582 | 2.04 |
| *Conchlospermum tinctorium* | 66.22 | 0.179 | 0.241 | 0.0315 | 1.10 |
| *Bauhinia thonnigii* | 96.21 | 0.260 | 0.357 | 0.045 | 1.58 |
| *Anogeisus Leocarpus* | 56.12 | 0.151 | 0.189 | 0.024 | 8.40 |
| *Chrozophora senegalensis* | 67.96 | 0.184 | 0.241 | 0.030 | 1.07 |
| *Anacardium occidentale l* | 46.25 | 0.125 | 0.161 | 0.020 | 7.00 |
| *Citrus aurantifollia* | 69.75 | 0.188 | 0.238 | 0.031 | 1.11 |
| *Moringa oleifera* | 61.16 | 0.165 | 0.238 | 0.030 | 106 |
| *Psidium guajava.i* | 75.15 | 0.203 | 0.323 | 0.038 | 1.33 |
| *Mangifera indica* | 65.97 | 0.178 | 0.260 | 0.032 | 1.14 |
| *Ficus sycomorus* | 70.45 | 0.190 | 0.261 | 0.033 | 1.16 |
| *Boswellia dalzielii* | 58.95 | 0.159 | 0.218 | 0.027 | 9.49 |
| *Ziziphus mauritania* | 54.65 | 0.148 | 0.183 | 0.023 | 8.29 |
| *Annona senegalensis* | 64.41 | 0.174 | 0.205 | 0.027 | 9.52 |
| *Guiera senegalensis* | 74.05 | 0.200 | 0.262 | 0.034 | 1.19 |
| *Carica papaya* | 69.30 | 0.187 | 0.245 | 0.031 | 1.10 |
| *Acarcia nilotica* | 90.69 | 0.245 | 0.297 | 0.038 | 1.36 |
| *Artemisia maciverae linn* | 82.53 | 0.223 | 0.326 | 0.041 | 1.45 |
| *Khaya senegalensis* | 91.73 | 0.248 | 0.305 | 0.029 | 1.05 |
| Mean | 73.3465 | 0.198 | 0.269 | 0.034 | 8.376 |

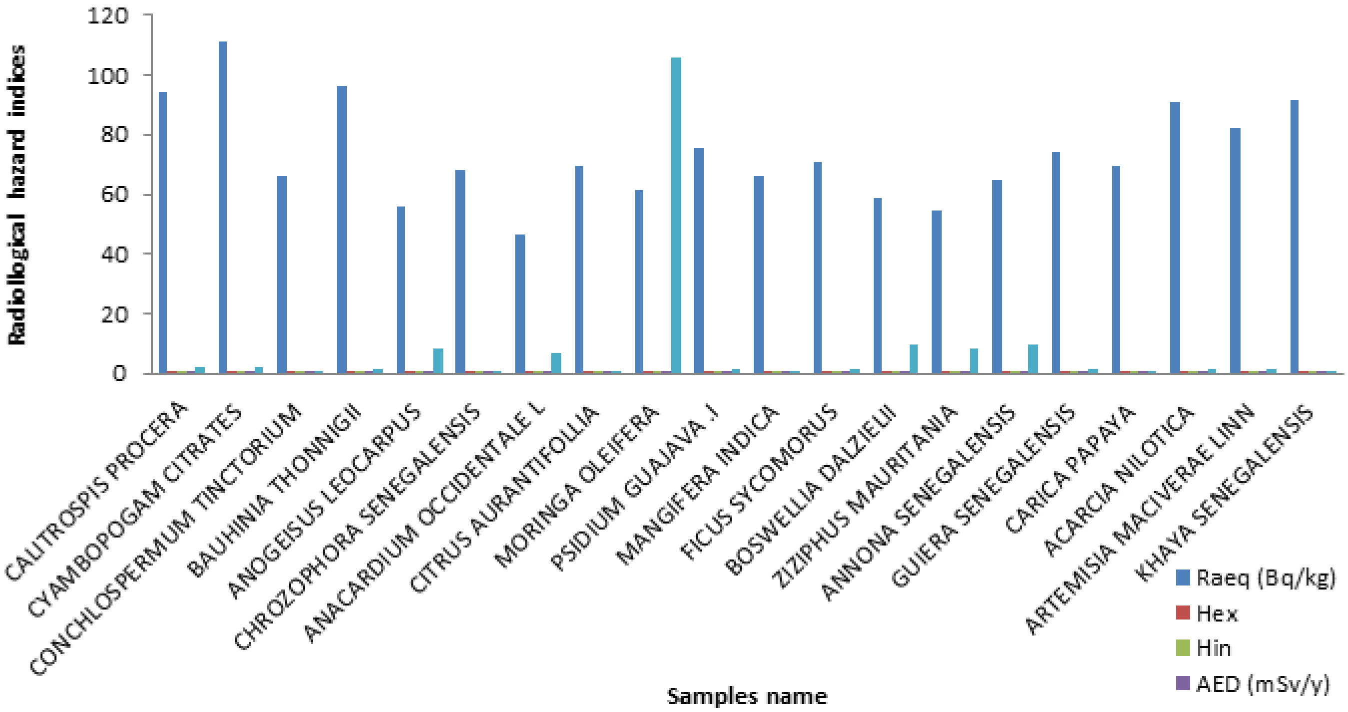


**Fig. 2:** Radiological Hazard indices across Traditional herbal medicines

(Note that 370 Bq/kg for $Ra_{eq}$, Hex ≤ 1, Hin ≤ 1, AED ≤ 1 $mSvy^{-1}$ are the permissible dose (UNSCEAR, 2000)).

From Table 3, the calculated external hazard index (Hex) ranged from 0.125 to 0.297, using equation (3) and the activity concentrations of the radionuclides presented in Table 2. The corresponding results are shown in Table 3. Similarly, the internal hazard index (Hin) values, obtained using equation (4) and the activity concentrations in Table 2, ranged from 0.161 to 0.450 (Table 3). All calculated Hex and Hin values were below unity (≤ 1), indicating that the radiological hazards associated with these herbal medicines are within acceptable limits for external and internal exposure.

The Annual Effective Doses (AED) resulting from the consumption of these herbal medicines ranged from 0.02 to 0.61mSv/year, as calculated using equation (1) and the activity concentrations of the radionuclides in Table 2. The Annual Effective Dose (AED) results are summarized in Table 3, with a mean value 0.034465 mSv/year. These values are significantly lower than the (ICRP, 2012) recommended limit of 1mSv/year for public exposure, suggesting minimal radiological risk from normal consumption patterns. However, the calculated excess lifetime cancer risk (ELCR) values ranged from $1.05 \times 10^{-4}$ to $106 \times 10^{-4}$, with a mean value of $8.3765 \times 10^{-4}$. These values were obtained using equation (5), by substituting the AED from equation (1) into equation (5). The calculated excess lifetime cancer risk (ELCR) results are presented in Table 3. Notably, 20 out of 20 samples (100%) exhibited ELCR values exceeding the ICRP acceptable risk level of $1.0 \times 10^{-4}$, suggesting potential long-term health concerns from prolonged consumption of these herbal medicines.

**Table 4 shows which Samples exceed the IRCP acceptable ELCR of $1.0×10^{-4}$ (ICRP, 2012)**

| Sample ID | ELCR ($×10^{-4}$) | Exceeds ICRP Limit ($1.0 × 10^{-4}$) |
|---|---|---|
| *Calitrospis procera* | 2.15 | Yes |
| *Cyambopogam citrates* | 2.04 | Yes |
| *Conchlospermum tinctorium* | 1.1 | Yes |
| *Bauhinia thonnigii* | 1.58 | Yes |
| *Anogeisus leocarpus* | 8.4 | Yes |
| *Chrozophora senegalensis* | 1.07 | Yes |
| *Anacardium occidentale l* | 7 | Yes |
| *Citrus aurantifollia* | 1.11 | Yes |
| *Moringa oleifera* | 106 | Yes |
| *Psidium guajava. i* | 1.33 | Yes |
| *Mangifera indica* | 1.14 | Yes |
| *Ficus sycomorus* | 1.16 | Yes |
| *Boswellia dalzielii* | 9.49 | Yes |
| *Ziziphus mauritania* | 8.29 | Yes |
| *Annona senegalensis* | 9.52 | Yes |
| *Guiera senegalensis* | 1.19 | Yes |
| *Carica papaya* | 1.1 | Yes |
| *Acarcia nilotica* | 1.36 | Yes |
| *Artemisia maciverae linn* | 1.45 | Yes |
| *Khaya senegalensis* | 1.05 | Yes |

ICRP ELCR Threshold: $1.0×10^{-4}$(ICRP, 2012).
Check for samples exceeding the threshold:
If ELCR $\geq 1.0×10^{-4}$, Mark "YES".
Otherwise, Mark "NO".

## Comparison with previous studies

Mean $^{40}K$(182.65Bq/kg) in this study is lower than values reported by Shuaibu *et al*. (2025) (5883 ± 23Bq/kg) and Azeez *et al*. (2019) (68.07-1355.36Bq/kg) while, mean $^{226}Ra$(26.36Bq/kg) is similar to Njinga *et al*. (2015) but higher than values in Azeez *et al*. (2015) (6.6-8.4Bq/kg) meanwhile $^{232}Th$ (23.65Bq/kg) is lower than values in Shuaibu et al. (2025) and Njinga *et al*. (2015) but higher than levels reported by Ademola *et al*. (2020).

Variations are attributed to: Geological differences, soil mineral content, climatic factors, soil to plant transfer factors and plant physiology. Northern Nigeria's geology, with Thorium and Uranium-rich deposits, likely contributes to observed radionuclide levels (Garba *et al*., 2024).

## CONCLUSION

This study assessed the activity concentrations and radiological health risks associated with naturally occurring radionuclides in traditional herbal medicines commonly consumed within Zaria Metropolis, Nigeria. The mean activity concentrations of $^{40}K$, $^{226}Ra$, and $^{232}Th$ were found to be within global safety limits; however, the Excess Lifetime Cancer Risk (ELCR) values exceeded the threshold recommended by the International Commission on Radiological Protection (ICRP) in all analyzed samples. Although the calculated radiological doses remained within permissible levels, prolonged ingestion may elevate the probability of stochastic health effects. Regular monitoring, standardization of herbal products and public enlightenment are therefore strongly recommended to ensure consumer safety and environmental health protection. Further research should broaden the scope to incorporate seasonal variations and soil-to-plant transfer factors influencing radionuclide accumulation.

The widespread use of traditional herbal medicines in Zaria stems from their perceived safety, accessibility, and therapeutic potential in the management of various ailments. Nevertheless, these herbal formulations may become contaminated with naturally occurring radionuclides derived from the surrounding soil, water, and atmosphere. Such contamination poses public health concerns due to the potential accumulation of radioactive elements in plant tissues, leading to internal exposure upon ingestion.

The principal problem identified in this study is the lack of systematic monitoring and regulatory control over the radionuclide content of herbal preparations in Nigeria, despite their increasing consumption. Many individuals rely on these herbal remedies as a primary form of healthcare without sufficient awareness of possible radiological risks. Consequently, this study was justified by the need to establish baseline data on natural radionuclide concentrations in herbal medicines sold within Zaria, assess the associated radiological hazards, and provide scientific evidence to inform safety regulations and public health policies.

Among the investigated samples, Bauhinia thonningii, Acacia nilotica, Cymbopogon citratus, Khaya senegalensis, and Calotropis procera exhibited relatively elevated radionuclide concentrations compared to other species. Radiological hazard indices including Radium Equivalent Activity (Raeq), External Hazard Index ($H_{ex}$), Internal Hazard Index (Hin), and Annual Effective Dose (AED) were computed to estimate potential radiation exposure levels. All indices were within the internationally accepted safety limits established by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). Nevertheless, the ELCR values in all samples exceeded the ICRP reference threshold of $1.0 \times 10^{-4}$, indicating the possibility of long-term carcinogenic effects from chronic consumption.

A comparative evaluation with similar studies conducted in Nigeria and other countries revealed that the mean activity concentration of $^{40}K$ (182.65 Bq/kg) in this study was lower than values reported by Shuaibu et al. (2025) (5883 ± 23 Bq/kg) and Azeez et al. (2019) (68.07–1355.36 Bq/kg). Conversely, the mean $^{226}Ra$ concentration (26.36 Bq/kg) obtained in this study was comparable to that of Njinga *et al*. (2015) (25.02 Bq/kg) but higher than those reported by Azeez et al. (2015) and Ademola et al. (2020) for herbal nuts and seeds (6.6–8.4 Bq/kg). The mean $^{232}Th$ concentration (23.65 Bq/kg) was lower than values reported by Shuaibu *et al*. (2025) and Njinga *et al*. (2015) but higher than those observed by Ademola *et al*. (2020). These variations in radionuclide concentrations across regions are attributed to differences in geological formations, soil composition, agricultural practices, climatic conditions, and plant species' uptake capacities. The geological terrain of Northern Nigeria, characterized by uranium- and thorium-rich deposits, likely contribute to the relatively elevated $^{226}$Ra and $^{232}$Th levels observed in this study.

The findings indicate that although the analyzed herbal medicines may not pose an immediate external radiological hazard, the internal exposure risks through ingestion are non-negligible. The elevated ELCR values suggest a latent risk of radiation-induced carcinogenesis, particularly among habitual consumers of these herbal products.

In conclusion, this study provides the first comprehensive radiological baseline data for traditional herbal medicines consumed within Zaria Metropolis. The results reveal that although the overall radiological hazard indices (Raeq, Hex, Hin and AED) remain within global safety limits (UNSCEAR, 2000; ICRP, 2012). However, Excess Lifetime Cancer Risk (ELCR) values surpass recommended thresholds, indicating a potential long-term radiological health concern. Herbal species such as Bauhinia thonningii, Acacia nilotica, Cyambopogam citratus, Khaya senegalensis, and Calotropis procera demonstrated a notable capacity for radionuclide accumulation, suggesting the influence of soil-to-plant transfer mechanisms. While traditional herbal medicines continue to play a vital role in healthcare delivery within Zaria and beyond, the findings underscore the urgent need for regulatory frameworks, continuous surveillance, and consumer education to minimize potential radiological health risks and ensure sustainable use.

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