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Radioactivity estimation of baobab *(Adonsonia digitata)* in katsina metropolis, katsina state Nigeria

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Abstract

Radioactivity estimation of baobab plants was carried out in Katsina metropolis, Katsina State, Nigeria. Samples of soil, roots, and leaves were collected, prepared and analyzed to estimate the activity concentration of the natural radionuclides of U-238, Th-232, and K-40using NaI (TI) gamma ray spectrometry detector. The results obtained showed that the activity concentration ranged from 0.1 Bq/kg to 33.26 Bq/kg, 1.98 Bq/kg to 64.98 Bq/kg and 65.89 Bq/kg to 1009.69 Bq/kg with overall mean values of 11.35, 18.87 and 545.14 in Bq/kg for U-238, Th-232 and K-40 respectively. In order to assess the radiological parameters of the natural radioactivity; the radium equivalent activity (Raeq), an absorbed dose rate and the measured annual effective dose equivalent were calculated and lies in the ranges of 18.83 to 183.22 (Bq/kg), 9.07 to 85.90 nGy/h and 0.011 to 0.105 mSv/y respectively; mean values obtained are 87.20 Bq/kg, 40.55 nGy/h and 0.050 mSv/y respectively. However, the calculated values obtained for all the radiological parameters falls below the world acceptable limits of 370 Bq/kg for Raeq; 89 nGy/h for the absorbed dose rate and 1 mSv/y annual effective dose rate for the general public; for the annual effective dose due to ingestion or inhalation of NORMS in the soil, medicinal plants and food is 0.07 mSv/y and the value is within the acceptable limit of intake; external and internal hazard index were calculated and found to have values of 0.23 Bq/kg for H_{ex} and 0.30 Bq/kg for H_{in} and are lower than unity set by ICRP. Base on the radiological hazards evaluations, there is no any health risk due to radiation from the natural sources in using the roots and leaves parts of baobab plants for any purposes in the study area. Moreover, the measured soil around the study area was found to be safe and will not pose any radiation exposure to the population. Hence, the research will serve as the baseline for detection of any future released activities of related natural radionuclides especially around the consumable plants. However, effort should be made to ensure that the radiological parameters of the study area are kept as low as reasonably achievable.

Keywords: Katsina State; Natural Radioactivity; Baobab plant; Soil; Root; Leaves; NaI (Tl)

1. Introduction

In northern part of Nigeria, baobab plant is regarded for its multipurpose uses in different aspect of life; its fruit and leaves are believed to have high potential rich sources of nutrients including minerals, vitamins and other nutraceuticals benefits [**1**]; the mode in which the leaves and root parts of this plants are pre-prepared for food and other medicinal benefits call for concerns as there are possibility of contamination with natural radioactivity in the soil and uptakes by plants However, it is unaware that human beings are exposed to radiation from different sources such as an intakes of naturally occurring radionuclides through inhalation, ingestion in water, air, soil and plants [**2**]; the major isotopes of concern from these sources are largely potassium, uranium and thorium [**3, 4**]; In this study, radioactivity estimation of baobab plants was carried out in Katsina metropolis, Katsina State, Nigeria. Samples of soil, roots, and leaves were collected, prepared and analyzed to estimate the activity concentration of the natural radionuclides of U-238, Th-232,

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and K-40. Different methods and techniques have been used to measure the amount of natural radioactivity in plants. The use of Sodium Iodide (TL) Gamma Spectrometry detector has been adopted for this study to investigate natural radioactivity present in the baobab plant in order to ascertain the possible radiological effects associated with the use of the roots, leaves and the soil samples in the baobab plant. Additionally, the information from the literature that is currently accessible indicates that no such work has been done in the study area; therefore this research will help to contribute to the data that may be used for future research.

2. Material and Method

2.1. Geology and Location of the Study Area

The study was conducted in the 24,192 km^3 (9,341 sq m) Katsina metropolis, which is situated in the North West Zone of Nigeria between the geological coordinates of latitude 12°15'N and longitude 7°30'E [**12**]. There are two distinct seasons in Katsina State: wet and dry. While the dry season starts in November and ends in March, the rainy season starts in April and lasts until October. The dry season was when the samples were obtained and the analysis was conducted. Katsina State's average yearly temperature, relative humidity, and rainfall are 50.2%, 27.3°C, and 1,312 mm, respectively [**12**].

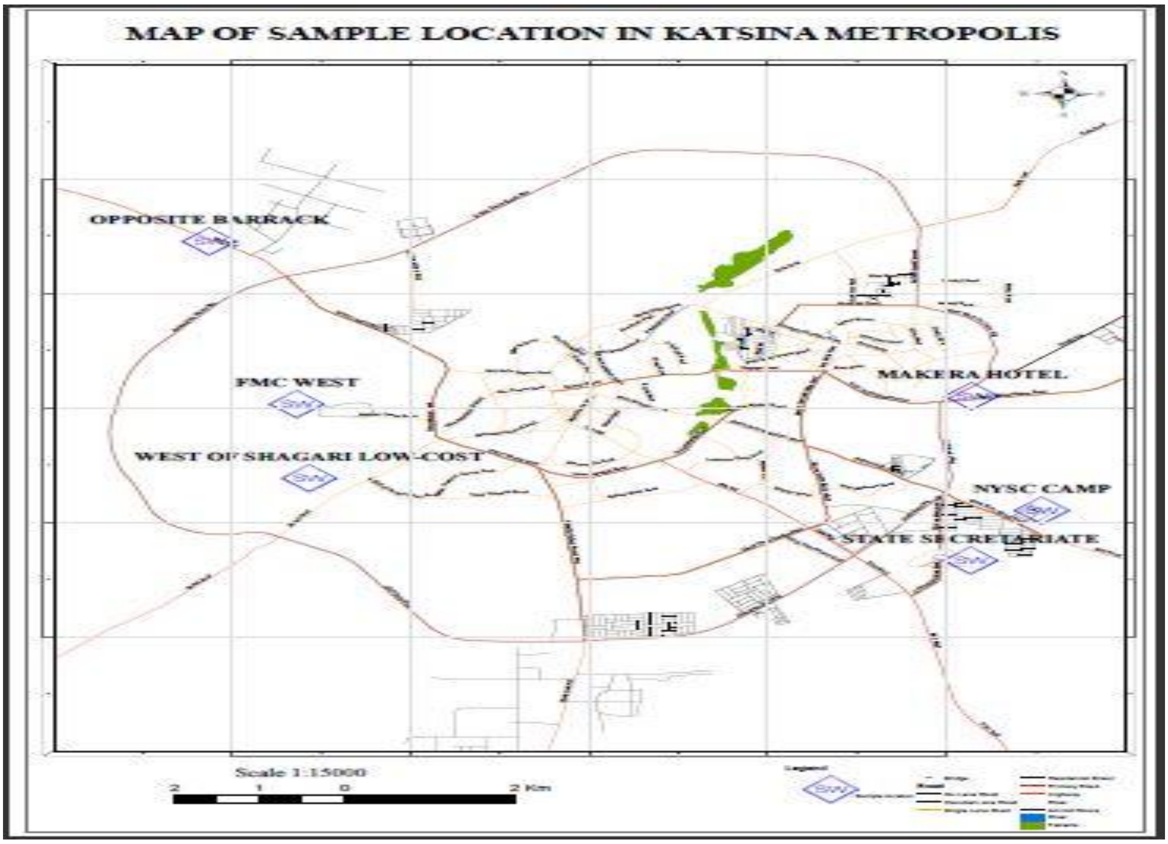

Figure 1 Katsina map, showing the sampling locations

2.2. Sample Collection and Preparations

Eighteen samples of the baobab plant's soil, roots, and leaves were collected for the radioactivity measurement, and they were kept open to dry in a clean environment to prevent contamination [**13**]. After being dried and ground into a fine powder using a table ceramic mortar, the samples were packed into radon-impermeable cylindrical plastic containers measuring 7 cm in height and 6 cm in diameter. A sample weighing about 300g could fit inside each container. To stop Ra-222 from escaping, a three-stage sealing system has been designed for every package; this entails applying vaseline to the inside rims of every container lid, using candle wax to close the space between the lid and the container, and tightening the lid of the container with masking adhesive tape [**13**]. In order to give radon and its short-lived progenies time to reach secular radioactive equilibrium, the prepared samples were kept in storage before being subjected to gamma spectroscopy measurements.

2.3. Sample Analysis

For this study, soil, root, and leaf samples were placed on the detector surface and counted for approximately 18000 seconds according to the established lab protocol at the National Institute of Radiation Protection and Research, University of Ibadan. The radioactivity of the baobab plant was estimated using a computer-based multichannel analyzer (MCA) with the ACCUSPEC computer programme for data acquisition and analysis of gamma spectra, and the assessment for the activity concentrations of U-238, Th-232, and K-40 was performed using an energy range ranging from 59.54keV to 1460.8 keV. Using the equation below, the measured samples were determined for each of the gamma energies under consideration:

$$\varepsilon = \frac{NC_i}{A_i \times y_i \times M \times T} \quad (1)$$

ε =efficiency of the NaI at the energy of the i^{th} radionuclide

NC_i= net counts of the i^{th} radionuclide (background subtracted) in the corresponding photo peak

A_i -is the activity concentration of the i^{th} radionuclide in Bq/kg

y_i= the emission probability of the i^{th} radionuclide

M=Mass of the sample (soil, root and root) in kg

T= counting time (18000 seconds).

To determine the activity concentrations of U-238, Th-232, and K-40, all raw data were converted to conventional units using calibrating factors. To estimate the activity concentration in soil, root, and leaf samples, the IAEA mixed standard of Ra-226, Th-232, and K-40 of the same dimensions as the samples was subjected to the same experimental procedures after background counts were subtracted and the count per second was converted to activity concentration in Bq/kg.

2.4. NORM - Related Radiological Hazard in the Samples of Soil, Root and Leaves

2.4.1. Absorbed Dose Rate.

The dose can be calculated using absorbed dose rate conversion factors. The UNSCEAR [**3**] conversion factors were used, and the gamma absorbed dose rates were calculated using the formula below:

$$D\ (nGy/hr) = 0.0417A_K + 0.462A_{Ra} + 0.604A_{Th} \quad (2)$$

The dose coefficients in nGy/h per Bq/kg were obtained from UNSCEAR [**3, 14**].

2.4.2. Radium Equivalent Activity (Ra_{eq}).

Radium and its daughter products produce 98.5% of the uranium series' radiological effects. The ^{238}U contribution has been replaced by the decay product ^{226}Ra:

$$Ra_{eq} = A_{Ra} + 1.43A_{Th} + 0.077A_K \quad (3)$$

Radium Equivalent Activity is a new index that combines the specific activities of ^{226}Ra, ^{232}Th, and ^{40}K into a single quantity. This takes into account the radiation risks they pose. The relation can be used to calculate the first index, UNSCEAR [**3**].

2.4.3. Annual Effective Dose Equivalent (AEDE).

The annual effective dose rate (AEDE) was calculated to assess the health effect of the absorbed dose rate. The following factors must be considered when estimating annul effective doses: (a) the coefficient of conversion from absorbed dose to effective dose. (b) The occupancy variables:

$$AEDE\ (mSv/y) = D\ (nGy/\ h) \times 8760h \times 0.7\ Sv/Gy \times 0.2 \times 10^{-6} \quad (4)$$

A member of the public's annual effective dose equivalent is calculated using a conversion factor of 0.7 SvG/y, which is used to convert the absorbed dose rate to human effective dose equivalent with a 20% outdoor occupancy [**15, 3**].

2.4.4. External and Internal Hazards Indices.

External and internal radiation hazards are represented by two indices defined by Beretka and Mathew [**14**]. The given equation 5 is used to calculate the external hazard index [**14, 16**]:

External Hazard Index: $H_{ex} = \frac{Ara}{370} + \frac{Ath}{259} + \frac{Ak}{4810} \leq 1$ (5)

Internal exposure to carcinogenic radon and its short-lived progeny is measured using the internal hazard index (Hin) [**17**]. To account for this risk, the maximum permissible concentration of ^{226}Ra (value of the Raeq activity 370 Bq/kg) must be reduced to half of its normal limit (185 Bq/kg) [**14**]:

Internal Hazard Index: $H_{in} = \frac{Ara}{185} + \frac{Ath}{259} + \frac{Ak}{4810} \leq 1$ (6)

3. Results and Discussion

The specific radioactivity concentration values of ^{40}K, ^{232}Th, and ^{226}Ra measured in the collected samples are presented in Table 1 below; the data were obtained from the NaI (Ti) gamma ray spectrometry analysis performed at the National Institute of Radiation Protection and Research, University of Ibadan, Oyo State. The laboratory data were then analyzed for radiological hazard parameters (radium equivalent activity (Bq/kg), absorbed dose rate (nGy/hr), effective dose rate (mSv/yr), and external hazard index (Bq/kg).

Table 1 Value of Radionuclides activity Concentrations at each sample point for ^{40}K, ^{226}Ra and ^{232}Th in (Bq/kg)

SAMPLE CODE	K-40	Ra-226	Th-232
A L01	1009.69	16.88	3.150
A L02	872.310	6.830	1.980
A L03	344.810	1.990	3.450
A L04	736.440	9.680	31.74
A L05	758.160	4.970	25.11
AL06	619.810	0.220	8.420
BR01	740.780	21.85	29.37
BR02	750.650	33.26	64.98
BR03	616.160	10.98	48.84
BR04	486.160	20.33	25.16
BR05	398.550	12.87	9.090
BR06	332.29	11.69	61.83
CS01	762.320	17.24	16.09
CS02	986.980	15.90	26.23
CS03	65.8900	1.870	10.45
CS04	136.960	7.570	2.130
CS05	122.320	0.100	6.500
CS06	82.3100	10.19	14.07
Range	1009.69-65.89	33.26-0.100	64.98-1.980

Mean	545.14	11.35	18.87

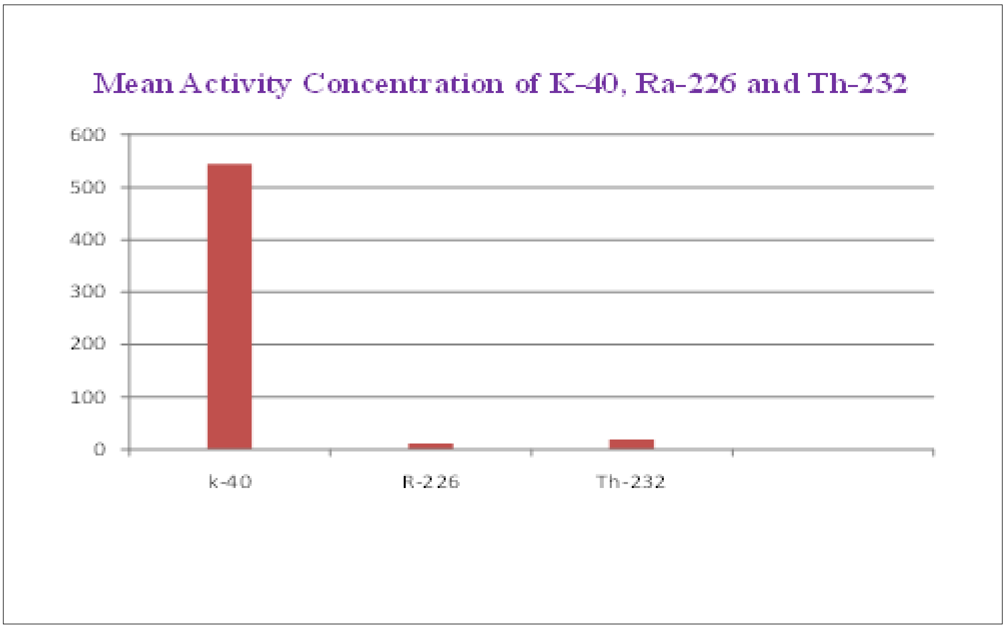

Figure 2 Chart of the mean activity concentration of K-40, Ra-226 and Th-232

An estimated mean activity concentration value contributed by the three primordial radionuclides in soil roots and leaves samples of baobab plant**.** Table 1 shows the activity concentrations of Ra-226,Th-232 and ^{40}K in the eighteen (18) different samples of leaves, roots, and soil used in this study. The maximum activity concentrations of Ra-226, Th-232, and K-40 are 33.26 Bq/kg, 64.98 Bq/kg, and 1009.69 Bq/kg, respectively, while the minimum values are 0.1 Bq/kg, 1.98 Bq/kg, and 65.89 Bq/kg; their mean values are 11.35 Bq/kg, 18.87 Bq/kg, and 545.14 Bq/kg. These mean values were lower than the world recommended standard of 35 Bq/kg and 30 Bq/kg for Ra-226 and Th-232, as defined by UNSCEAR [**3**] and that recently reported [21,22]. The potassium activity concentration (K-40) was found to be higher than the UNSCEAR recommendation of 400 Bq/kg; high activity level of K-40 could be due to continual deposition of the organic manure and public waste generated by the locals in the study area which might lead to radiation health effects.

Table 2 Estimated values of the radiological parameters

Sample Code	D (nGy/h)	R_{eq} (Bq/kg)	H_{ex} (Bq/kg)	H_{in} (Bq/kg)	AEDR (mSv/y)
AL01	51.79	99.14	0.26	0.31	0.063
AL02	40.72	76.83	0.20	0.22	0.049
AL03	17.37	33.47	0.09	0.10	0.021
AL04	54.35	111.77	0.30	0.34	0.067
AL05	49.07	99.26	0.26	0.27	0.060
AL06	31.03	59.99	0.22	0.16	0.038
BR01	58.72	120.88	0.31	0.39	0.072
BR02	85.90	183.22	0.49	0.56	0.105
BR03	60.264	128.26	0.34	0.38	0.073
BR04	44.71	93.73	0.25	1.18	0.054
BR05	28.05	110.4	0.15	0.19	0.034
BR06	56.60	125.70	0.33	0.37	0.069

CS01	49.47	98.95	0.26	0.31	0.061
CS02	64.33	129.40	0.35	0.39	0.078
CS03	9.420	21.88	0.10	0.06	0.012
CS04	10.49	21.16	0.13	0.07	0.013
CS05	9.07	18.83	0.05	0.05	0.011
CS06	16.64	36.65	0.09	0.13	0.020
Range	85.90-9.07	183.22-18.83	0.49-0.05	1.18-0.05	0.105-0.011
Mean	40.99	87.20	0.23	0.30	0.050

Radiological parameters in table 2 had the mean values of 87.20 Bq/Kg for the radium equivalent activity; 40.99 nGy/hr for the absorbed dose rate; 0.23 Bq/Kg for the external hazard index; 0.30 Bq/Kg for the internal hazard index and 0.050 mSv/yr for the annual effective dose equivalent respectively.

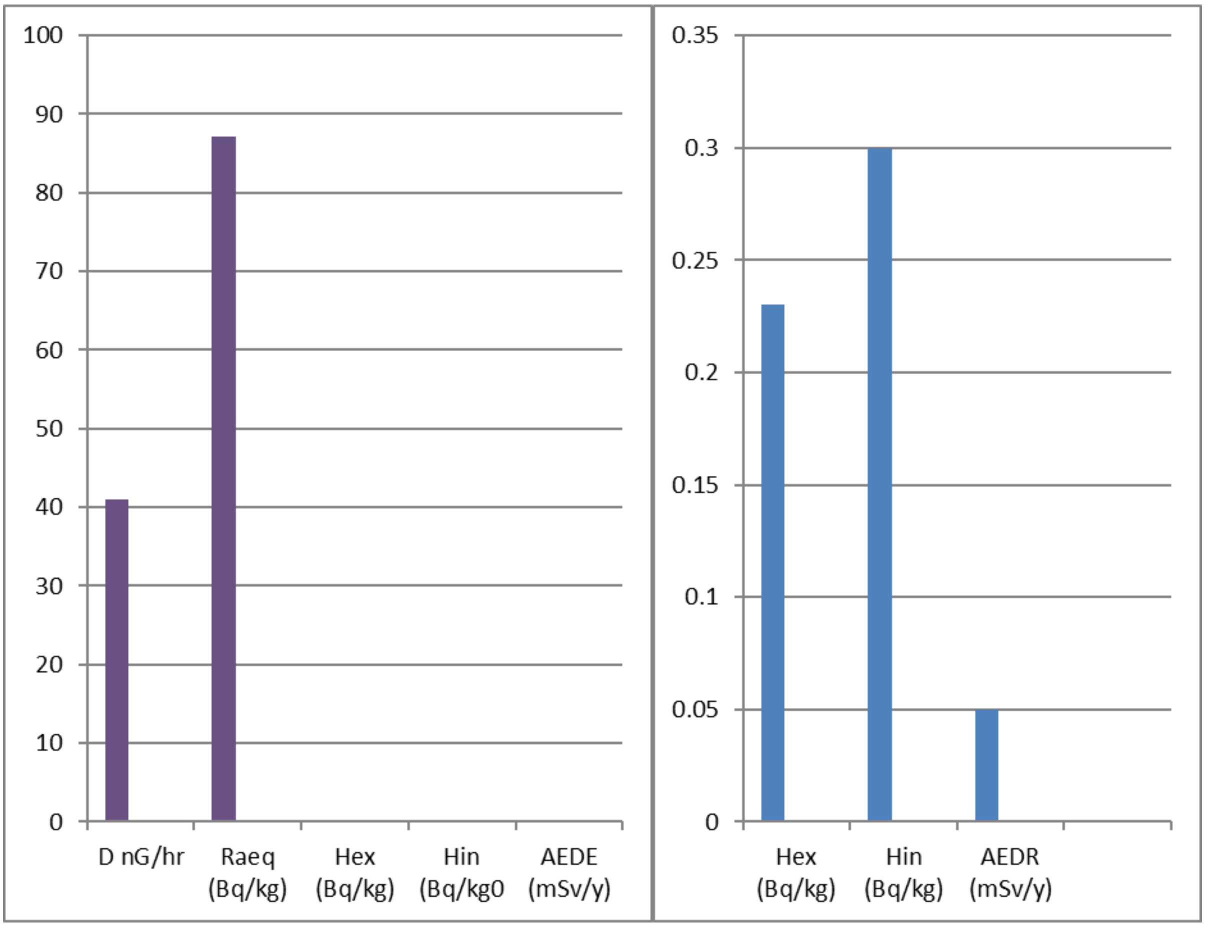

Figure 3 Charts of radiological parameters

Radiological parameters due to consumption of the roots, leaves sample and soil inhalation of naturally occurring radioactive materials in the samples are presented in Table 2 as well as figure 3.

In order to ascertain the safeguard for the members of public in the study area annual effective dose rate was calculated using equation (4) and the results was presented in table (2), all the values obtained from the 18 samples were below ICRP [**11**] recommended value of 1mSv for the general public. An annual effective dose due to ingestion or inhalation of naturally occurring radioactive materials in soil, medicinal plants and food should not exceed 0.07mSv/y as defined by UNSCEAR [**3**]. Meanwhile; the values obtained in this work were within the acceptable limits (0.05) mSv/yr.

Figure 4 below is the comparisons of annual effective dose rate in (mSv/yr) with United Nations Scientific Committee on the Effect of Atomic Radiation [20]:

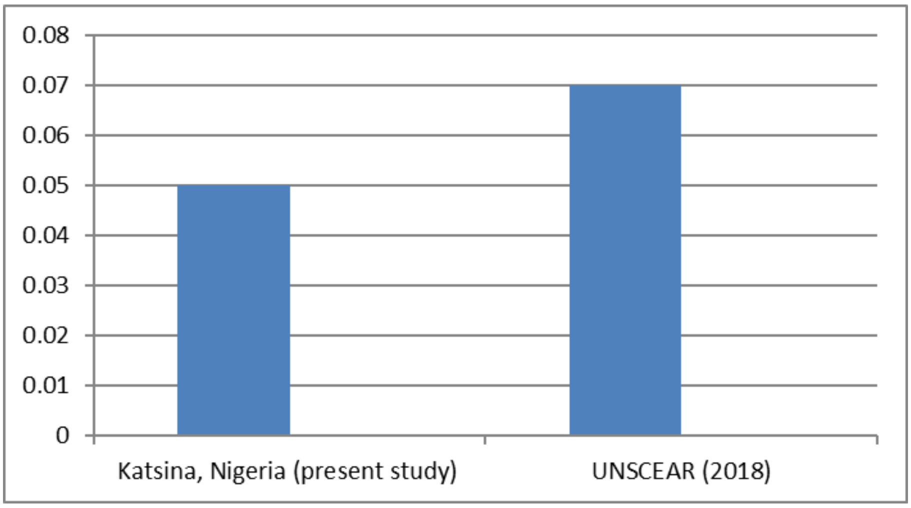

Figure 4 Comparison of Annual Effective Dose Rate (mSv/yr) with UNSCEAR

Figure 5 below is the graph of annual effective dose equivalent in (Bq/kg). The graph of AEDE is plotted against samples consumption.

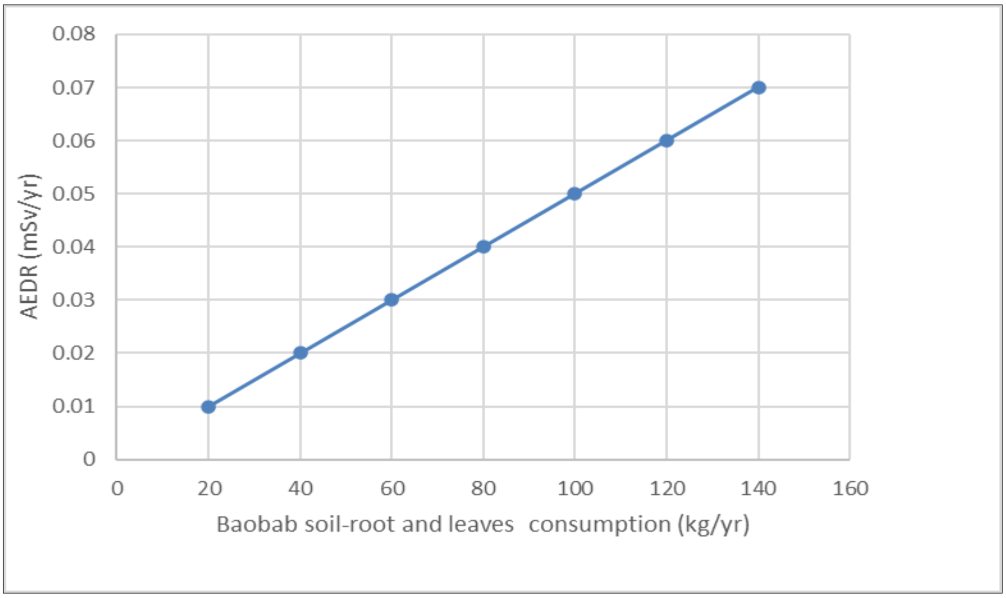

Figure 5 Graph of AEDE against samples of soil, root and leave due to consumption of natural radionuclides in (kg/yr)

Figure 5 present a graph of annual effective dose equivalent (AEDE) against samples of soil, roots and leaves consumption in kg/yr; the graph in the figure indicated that the higher the consumption of the samples the higher the increase in the annual effective dose due to radiation; from the graph, the consumption rates is between 0 and 100 kg/yr, therefore the threshold consumption rate in this study might not exceeded 100 kg/yr and the value is within the acceptable limit.

Based on the results from the radiological parameters presented, it was found that baobab plants in the study area and its environs (control areas) has no any significant health implications due to consumption of its roots and leaves; natural radioactivity present in the samples of soil inhaled from the study area has no any implications due to radiation exposure; hence, results in the study area and its environs showed that the radiation level are below the international standard limit of intake as defined by ICRP [**19]** and UNSCEAR **[3, 20**]

4. Conclusions

This work aims at assessing the radioactivity estimation of baobab plant in Katsina metropolis, Katsina state. Samples were collected in different locations of West Shagari low-cost, State Secretariat, Makera Daura road, NYSC Camp, Opposite Barrack and FMC West. All these samples were prepared and analyzed to estimate the extent of annual effective dose rates and the risk associated with the exposure due to natural radionuclides in baobab plants using Sodium Iodide (Tl) Gamma Spectrometry device. It is possible to see from the findings, the activity concentration of Uranium-238, Thorium-232 and Potassium-40 in the soils leaves and roots samples were found to be in the range of (33.26-0.10) Bq/kg, (64.98-1.98) Bq/kg and (1009.69-65.89) Bq/kg respectively. The mean activity of ^{238}U, ^{232}Th and ^{40}K in the soil leaves and roots samples were found to be 11.35 Bqkg^{-1}, 18.87 Bqkg^{-1} and 545.14 Bq/kg respectively. The concentrations of ^{238}U and ^{232}Th are lower than the world average value, while concentration of ^{40}K was found to be higher compared to world average established by UNSCEAR. This might be possible when there is much continuous application of potassium fertilizers and much deposition of natural organic manure generated from waste by the local communities in the study area. The average radium equivalent activity (Raeq) in the study area was 87.20 Bq/kg this is far less than the recommended safe value of 370 Bq/kg. Average absorbed dose rates delivered to the general public of the study area was 40.99 nGyh^{-1}, annual effective dose had a mean value of 0.50 mSv/yr; radiation hazard indices were calculated from the measured activity concentrations of ^{238}U, ^{232}Th and ^{40}K in the study area. The internal and external radiation hazard indices (H_{in} and H_{ex}) had mean values of 0.30 Bqkg^{-1} and 0.25 Bqkg^{-1} respectively. These values are less than the critical value of unity. This indicates that the samples in the study area are free from the radiation hazards and it was also confirmed that the sample of leaves and root used as sources of food and medicinal purposes has no effects of radiation hazards associated with the radionuclides present in the environment.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Habte, K. (2018). Metaphysical analysis of nutritional and therapeutic value of baobab(adasonia digitata), a research submitted to the department of international nutrition, institute of human nutrition, Justus LiebigUniversity Giessen, Germany.

[2] Elijah, K. (2016). Radioactivity concentrations and dose assessment for soil samples from wheat plantation areas of Narok country, Kenya.A thesis submitted in partial fulfillment of the requirement for the award of the degree of Master of Science (environmental physics) in the school of pure and applied sciences of Kenyatta University.

[3] UNSCEAR (2000). Exposures from Natural Sources, 2000 Report to General Assembly, Annex B, New York.

[4] Augustine, F. (2011). Assessment of public exposure to naturally occurring radioactive materials from mining and mineral processing activities of tarkwa goldmine in Ghana. A thesis submitted to the Department of Chemistry, College of Science, Kwame Nkrumah University of Science and Technology, Kumasi.

[5] Abubakar, I., & **Joseph, E. (2023)**. Instrumental Neutron Activation Technique in Characterization of Elements in Organs of Some Fish Species Harvested from Zobe Dam, Katsina State. *European Journal of Science, Innovation and Technology*, *3*(3), 381-397. Retrieved from https://ejsit-journal.com/index.php/ejsit/article/view/225

[6] **Joseph,** E.,Atsue, T., Adams, S. (2018). Assessment of Radon-222 in Selected Water Sources at Dutsin-Ma Town, Dutsin-Ma Local Government Area, Katsina State, *Journal of Scientific and Engineering Research*, 2018, 5(5):49-59.

[7] **Joseph**, E., Nasiru, R. Sadiq, U., Ahmed, Y. A. (2015). Energy and Efficiency Calibrations for High Purity Germanium GEM30195 Coaxial Detector USING k_0-IAEA Software. *International Journal of Science and Research, Vol. 4, No. 8: 1055 – 1061, India*

[8] **Joseph**, E., Nasiru, R. (2013). Geometry Correction in Efficiency of a Sodium Iodide (Thallium Activated), NaI(Tl) Detector. *Advances in Applied Science Research. 4(1):400-406.* Pelagia Research Library/USA

[9] **Joseph**, E., Nasiru, R. Sadiq, U., Ahmed, Y. A. (2015). The use of k_0 – NAA Standardization Technique in evaluating elements of significance for plant growth in the cultivated areas of Dutsin-Ma Local Government, Katsina State-Nigeria, *IOSR Journal of Applied Physics (IOSR-JAP) e-ISSN: 2278-4861.Volume 7, Issue 5 Ver. I (Sep. - Oct. 2015), PP 49-59,* DOI: 10.9790/4861-07514959, *www.iosrjournals*

[10] **Joseph,** E., Kamal, G. & Bello, O. M. (2023a). Natural radionuclide distribution and analysis of associated radiological concerns in rock samples from a rocky town (Dutsin-Ma) in the North-Western region of Nigeria. (2023). African Scientific Reports, 2(3), 125. https://doi.org/10.46481/asr.2023.2.3.125

[11] Adams, S., **Joseph, E.,**& Kamal, G. (2022). Validation of Tritium Calibration Curve in CIEMAT/NIST Activity Measurement Using Non-Linear Least Squared Fittings and Calculations of the Half-Life and Decay Constant of Potassium-40. Journal of the Nigerian Society of Physical Sciences, 4(3). https://doi.org/10.46481/jnsps.2022.621

[12] Katsina investors guide (2016). Katsina State Investors handbook. www.katsinastate.gov.ng.

[13] Najib, M. (2015). Radiological assessment of water and sediments of zobe dam dutsinma in katsina state for natural radionuclides. A project submitted to the department of physics, Ahmadu Bello University, Zaria.

[14] Xinwei, L. (2004). Natural radioactivity in some building materials of Shaanxi, China. Journal of Radio analytical and Nuclear Chemistry, 262: 775-777.

[15] UNSCEAR (1977). Sources and Effect of ionizing Radiation. United Nation Scientific Committee on the Effect of Atomic Radiation. UNCEAR Report 44-89.

[16] Mujahid, S., Rahim, A., Hussain, S., & Farooq, M. (2008). Measurements of natural radioactivity and radon exhalation rates from different brands of cement used in Pakistan. *Radiation Protection Dosimetry*, 130: 206-212.

[17] Ramasamy, V., Suresh, G., Meenakshisundaram, V., & Ponnusamy, V. (2011). Horizontal and Vertical Characterization of Radionuclides and Minerals in River Sediments. Applied Radiation and Isotopes, 69: 184-195.

[18] ICRP (2000). Limits for intakes of Radionuclides by workers. International Commission on Radiological protection Committee II. Pergamon Press New York. Pp277.

[19] ICRP (2008). ICRP Publication 103. Recommendation of the International Commission of Radiological Protection, Annals of the ICRP, Vol. 32, 2-4.

[20] UNSCEAR (2018). Effect and risk of ionizing radiation, United Nations, New York.

[21] **Joseph, E.,** Lawal, A. U., Ubaidullah, A. & Kado, S. (2023b). Uranium and Thorium contaminations ofBaobab leave powder consumed in selected locations of Katsina State, North West Nigeria. Journal of Basics and Applied SciencesResearch (JOBASR), 1(1), 1-8.https://doi.org/10.33003/jobasr-2023-v1i1-5

[22] **Joseph, E.,** Lawal, A. U., Ubaidullah, A. & Kado, S. (2024). Health Implication and Nutritional Value of Baobab Leaves in Katsina State, Nigeria using Instrumental Neutron Activation Analysis. International Journal of Applied Science and Research, Vol. 7 Issue 1: 98 – 114. https://doi.org/10.56293/IJASR.2024.5712.