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Radiological Assessment and Potential Health Risks of Tailings from Komu, Southwestern Nigeria

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ABSTRACT

There are reports that radionuclides found in mining tailings pose significant challenges to the natural environment and cause health risks to humans. The study investigated the levels of activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K radionuclides, as well as radiological hazard indices in tailings sourced from Komu, a community emblematic of mining activities in the Southwest of Nigeria. Thirty (30) tailing samples were collected and analysed by a High-purity Germanium (HpGe) detector. The results revealed high activity concentrations of these radionuclides exceeding global averages and indicating potential health risks. The activity concentration of ^{226}Ra ranged between 312.07 and 851.14 Bq/kg, with an average of 652.86 Bq/kg. Similarly, the activity concentration of ^{232}Th ranged between 33.31 and 160.10 Bq/kg, with an average of 116.26 Bq/kg. In addition, the activity concentration of ^{40}K ranged between 96.11 and 1184.65 Bq/kg, with an average of 717.53 Bq/kg. The radiological hazard indices considered in this study exceeded the internationally accepted safety limit for building construction materials. These findings indicate heightened exposure risks, emphasizing the need for regulatory measures to mitigate hazards associated with tailings sourced from Komu, particularly for building construction purposes.

Keywords:
Radiological assessment,
Tailings,
Health risks,
Komu,
Nigeria

INTRODUCTION

Mining activities often result in the accumulation of various waste materials, commonly referred to as tailings. Tailings usually contain radioactive materials, which have the potential to increase the levels of radioactivity in our environment (Christensen *et al.*, 2014). This increase in radioactivity presents an elevated risk of exposure to ionizing radiation, consequently raising the potential for various radiological health impacts such as cancer, kidney diseases, leukaemia, development of tumours, anaemia, liver complications, bone growth issues, and compromised immune systems (UNSCEAR, 2009; Hossain *et al.*, 2021).

Several studies (Sabo *et al.*, 2018; Ajetunmobi *et al.*, 2019; Usikalu *et al.*, 2019) have highlighted the potential health risks, though they have predominantly concentrated on assessing the levels of radioactivity within the soil in and around mining sites. Despite that, there remains a notable lack of research focusing on the radiological health risks linked with tailings exposure for both miners and residents living in buildings made from such materials, particularly in Southwestern Nigeria. This oversight shows a critical gap in our comprehension of the environmental consequences and possible health hazards associated with tailings.

The escalation of crude mining activities in Nigeria, particularly in communities like Komu town in the Southwest, emphasizes this concern. In Komu, the surge in mining activities and the demand for cost-effective construction materials, often lead to the utilization of tailings. This practice not only exposes miners to outdoor radiation hazards but also exposes residents living inside buildings constructed with these contaminated materials to indoor radiation risks.

This research aims to fill the knowledge gap by assessing the radioactivity levels and evaluating the associated health risks in tailings originating from pegmatite's mining site in Komu, Southwestern Nigeria. By doing so, this study will contribute to the existing pool of knowledge and provide a critical assessment of the radiological threats presented by these tailings. The results are expected to inform effective mitigation strategies and policy formulations, thereby protecting the environment and public health against the adverse impacts of radiation exposure.

MATERIALS AND METHODS

Study Area

Komu is situated within Itesiwaju Local Government Area of Oyo State, Southwestern Nigeria. Positioned approximately 170 km northwest of Ibadan, it occupies coordinates of 8°13'60" N latitude and 3°12'0" E longitude. Komu experiences a savanna climate and harbours an estimated population of around 136,772 inhabitants. Geologically, the region is dominated by Precambrian igneous and metamorphic rocks, collectively known as the basement complex. These rocks host a diverse range of mineral deposits, especially granitic pegmatites, which also consist of gemstones, tantalite, tourmaline, mica, quartzite, garnet, magnetite, feldspar, and zircon, among others. Furthermore, these pegmatites are within older rocks such as gneisses, amphibolite, and granites, formed during the Pan-African Orogeny, an event dating back approximately 550 million years ago (Adetunji and Ocan, 2010).

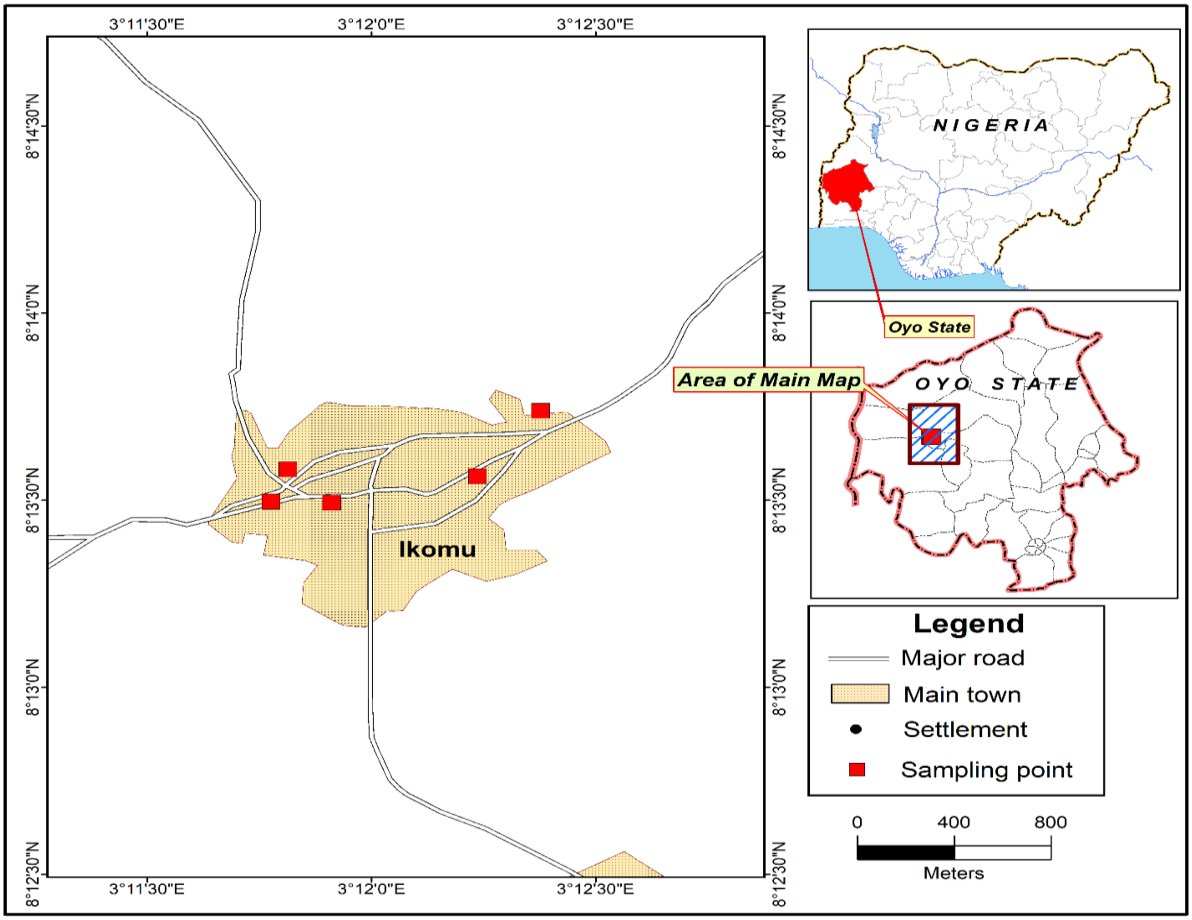

Figure 1: Map showing some sampling points in Komu area of Oyo State.

Samples collection, preparation, and analysis

Thirty (30) tailing samples were randomly collected by digging to a depth of at least 3 cm and carefully packed into labelled polyethene bags. The samples were then taken to the laboratory and subjected to drying to reduce their moisture levels. Afterwards, the samples were crushed and sieved. Following this, spectrometry analysis of the samples was carried out with the aid of a High-purity Germanium (HpGe) detector at the National Institute of Radiation Protection and Research (NIRPR) under the Nigerian Nuclear Regulatory Authority (NNRA), University of Ibadan, Nigeria (Odoh *et al.*, 2019).

Measurement of Activity Concentrations

The activity concentrations of ^{226}Ra,^{232}Th and ^{40}K in the tailing samples were estimated using the formula (Ridha and Hasan, 2016; Alausa *et al.*, 2020):

$$A = \frac{N}{(\mathrm{E})(y)(m)(t)} \tag{1}$$

Where A is the activity concentration of a specific radionuclide (in Bq/kg), N is the net counts of the radionuclide, E is the efficiency of the detector at the energy of the radionuclide, y is the emission probability of the radionuclide, m stands for the mass of the soil sample (kg), and t is the counting time (18,000 s).

Radiological Hazard Indices

Radium Equivalent Activity

The radium equivalent activity is determined using the model (Jibiri *et al.*, 2009 and Shaheen *et al.*, 2023):

$$Ra_{eq} = 0.077A_K + A_{Ra} + 1.43A_{Th} \qquad (2)$$

Where Ra_{eq} is the radium equivalent activity, A_{Ra} is ^{226}Ra activity concentration, A_{Th} is ^{232}Th activity concentration, and A_K is ^{40}K activity concentration.

External Hazard Index

The radiological suitability of the tailing samples for building construction purposes was determined by the external hazard index (Hex) which was evaluated using the model by Yang *et al.*, 2005:

$$H_{ex} = \frac{A_K}{4810} + \frac{A_R}{370} + \frac{A_{Th}}{259} \leq 1 \qquad (3)$$

Where A_{Ra} is ^{226}Ra activity concentration, A_{Th} is ^{232}Th activity concentration, and A_K is ^{40}K activity concentration.

Internal Hazard Index

The internal exposure to radon and its daughter products was determined by the internal hazard index (Hin), as given by (Tufail *et al.*, 2007):

$$H_{in} = \frac{A_K}{4810} + \frac{A_R}{185} + \frac{A_{Th}}{259} \leq 1 \qquad (4)$$

Where A_{Ra} is ^{226}Ra activity concentration, A_{Th} is ^{232}Th activity concentration, and A_K is ^{40}K activity concentration.

Alpha Representative Index

The Alpha Representative Index (Iα) assesses excess alpha radiation dosage due to radon inhalation by using tailings as building materials. This index was determined using Righi and Bruzzi (2006).

$$I_\alpha = \frac{A_{Ra}}{200} \qquad (5)$$

where A_{Ra} is the ^{226}Ra activity concentration.

Gamma Index

The Gamma Index (Iγ) identifies building materials that may cause health problems due to high quantities of gamma radiation. This assures the safety and well-being of residents in structures built using tailings. The index was estimated using the European Commission's (1999) proposal:

$$I_\gamma = \frac{A_K}{3000} + \frac{A_{Ra}}{300} + \frac{A_{Th}}{200} \qquad (6)$$

where A_K, A_{Ra}, and A_{Th}, represent ^{40}K, ^{226}Ra, and ^{232}Th activity concentrations, respectively.

RESULTS AND DISCUSSION

Activity Concentrations of Radionuclides

The activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K radionuclides in the tailing samples from the study area are presented in Table 1. The activity concentration of ^{226}Ra ranged from 312.07 ± 8.61 to 851.14 ± 49.40 Bq/kg, with a mean value of 652.86 ± 33.75 Bq/kg. This mean activity concentration exceeds the global average of 35 Bq/kg for ^{226}Ra, and values reported by Ademola and Obed (2012) of 39.8 Bq/kg, Suleiman *et al.* (2018) of 49.43 Bq/kg, Osimobi *et al.* (2018) of 33.2 Bq/kg, Focus *et al.* (2021) of 42.59 Bq/kg, and Muhammad *et al.* (2022) of 72.47 Bq/kg.

Similarly, the activity concentration of ^{232}Th ranged from 33.31 ± 5.64 to 160.10 ± 15.48 Bq/kg, with a mean value of 116.26 ± 7.70 Bq/kg, exceeding the world average of 30 Bq/kg. This mean value surpasses reported values by Ademola and Obed (2012) of 17.7 Bq/kg, Ademola *et al.* (2014) of 26.4 Bq/kg, Osimobi *et al.* (2018) of 77.7 Bq/kg, Focus *et al.* (2021) of 35.48 Bq/kg, Muhammad *et al.* (2022) of 86.91 Bq/kg, and Babatunde *et al.* (2023) of 2.85 Bq/kg.

Furthermore, the activity concentration of ^{40}K ranged from 96.11 ± 1.75 to 1184.65 ± 68.04 Bq/kg, with an average value of 717.53 ± 38.29 Bq/kg. This average value is above the world average of 400 Bq/kg and reported values by Ademola and Obed (2012) of 384.2 Bq/kg, Ademola *et al.* (2014) of 505.1 Bq/kg, Osimobi *et al.* (2018) of 100.7 Bq/kg, Focus *et al.* (2021) of 652.36 Bq/kg, Ma *et al.* (2022) of 533.9 Bq/kg, and Babatunde *et al.* (2023) of 440.45 Bq/kg.

Table 1: The activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in tailings from the pegmatite mining site in Komu

SAMPLE	^{226}Ra (Bq/kg)	^{232}Th (Bq/kg)	^{40}K (Bq/kg)
1	847.51 ± 45.77	155.16 ± 11.85	106.09 ± 8.23
2	843.41 ± 41.67	151.06 ± 7.75	101.99 ± 4.13
3	842.70 ± 40.96	150.35 ± 7.04	101.28 ± 3.42
4	844.72 ± 42.98	152.37 ± 9.06	103.30 ± 5.44
5	848.22 ± 46.48	155.87 ± 12.56	106.80 ± 8.94
6	845.31 ± 43.57	152.96 ± 9.65	103.89 ± 6.03
7	844.58 ± 42.84	152.23 ± 8.92	103.16 ± 5.30
8	851.14 ± 49.40	158.79 ± 15.48	109.72 ± 11.86

9	849.48 ± 47.74	157.13 ± 13.82	108.06 ± 10.20
10	837.53 ± 35.79	145.18 ± 1.87	96.11 ± 1.75
11	322.05 ± 18.59	43.29 ± 4.34	871.62 ± 48.04
12	317.95 ± 14.49	39.19 ± 0.24	867.52 ± 43.94
13	317.24 ± 13.78	38.48 ± 0.47	866.81 ± 43.23
14	319.26 ± 15.80	40.50 ± 1.55	868.83 ± 45.25
15	322.76 ± 19.30	44.00 ± 5.05	872.33 ± 48.75
16	319.85 ± 16.39	41.09 ± 2.14	869.42 ± 45.84
17	319.12 ± 15.66	40.36 ± 1.41	868.69 ± 45.11
18	325.68 ± 22.22	46.92 ± 7.97	875.25 ± 51.67
19	324.02 ± 20.56	45.26 ± 6.31	873.59 ± 50.01
20	312.07 ± 8.61	33.31 ± 5.64	861.64 ± 38.06
21	795.18 ± 43.05	156.47 ± 11.85	1181.02 ± 64.41
22	791.08 ± 38.95	152.37 ± 7.75	1176.92 ± 60.31
23	790.37 ± 38.24	151.66 ± 7.04	1176.21 ± 59.60
24	792.39 ± 40.26	153.68 ± 9.06	1178.23 ± 61.62
25	795.89 ± 43.76	157.18 ± 12.56	1181.73 ± 65.12
26	792.98 ± 40.85	154.27 ± 9.65	1178.82 ± 62.21
27	792.25 ± 40.12	153.54 ± 8.92	1178.09 ± 61.48
28	798.81 ± 46.68	160.10 ± 15.48	1184.65 ± 68.04
29	797.15 ± 45.02	158.44 ± 13.82	1182.99 ± 66.38
30	785.20 ± 33.07	146.49 ± 1.87	1171.04 ± 54.43
Mean ± σ	**652.86 ± 33.75**	**116.26 ± 7.70**	**717.53 ± 38.29**
Minimum	312.07 ± 8.61	33.31 ± 5.64	96.11 ± 1.75
Maximum	851.14 ± 49.40	160.10 ± 15.48	1184.65 ± 68.04

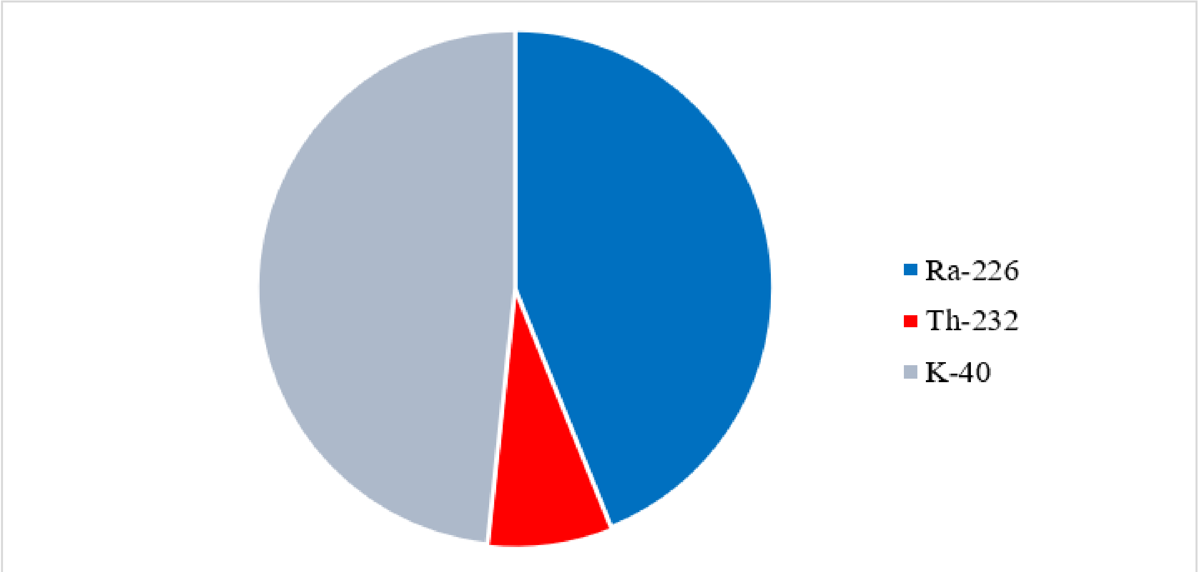

Figure 1: Pie chart depicting the average activity levels of ^{226}Ra, ^{232}Th and ^{40}K radionuclides found in the tailings

Radium Equivalent

Table 2 presents the mean, minimum and maximum radium equivalent (Ra$_{eq}$) and hazard indices. The radium equivalent ranged from 426.04 to 1118.38 Bq/kg, with a mean value of 874.36 Bq/kg which is above the ICRP recommended safe threshold of 370 Bq/kg.

Table 2: Radium equivalent (Ra_{eq}), external hazard index (H_{ex}), internal hazard index (H_{in}), gamma index (I_γ), and alpha index (I_α) of the tailing samples

	Ra_{eq} (Bq/kg)	Hex	Hin	Iγ	Iα
Mean	874.36	2.39	4.15	5.99	3.26
Minimum	426.04	1.18	2.02	2.99	1.56
Maximum	1118.98	3.06	5.24	7.72	4.26

Hazard indices

Figure 2 illustrates the levels of hazard indices considered in this study alongside the permissible limit. The results indicate elevated levels of radiation hazards, as evidenced by the mean external hazard index (Hex) of 2.39, mean internal hazard index (Hin) of 4.15, mean gamma index (Iγ) of 5.99, and mean alpha index (Iα) of 3.26. The observation of these values exceeding the threshold of unity (1) raises significant concerns regarding potential radiation hazards.

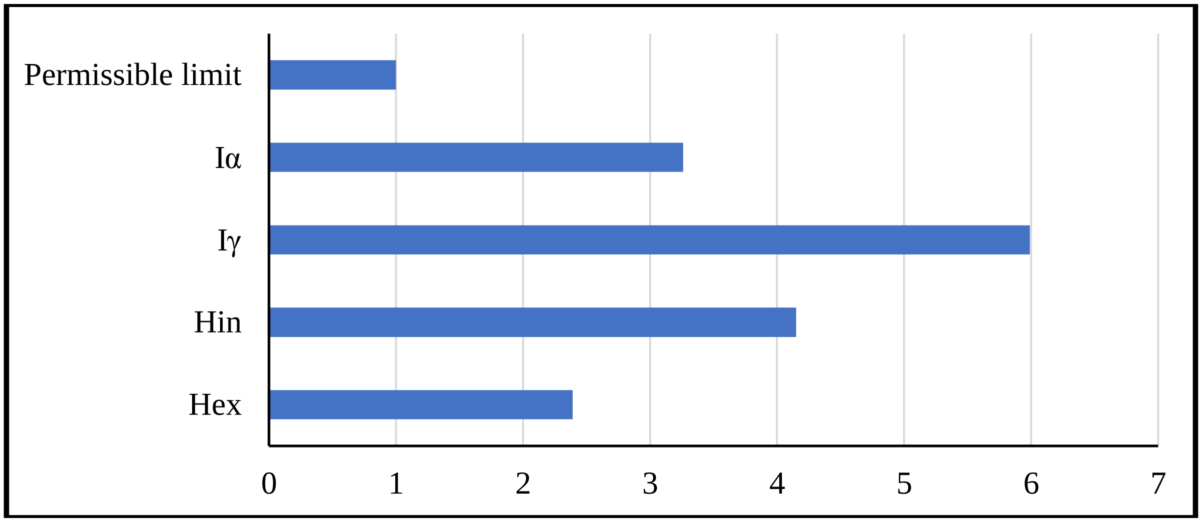

Figure 2: Comparison of hazard indices of the tailing samples with the permissible limit

CONCLUSION

The concentrations of ^{226}Ra, ^{232}Th and ^{40}K radionuclides in the tailing samples from the study area exceeded the recommended global averages. The heightened levels are likely attributed to geological factors, particularly the presence of Precambrian igneous and metamorphic rocks like granitic pegmatites, as well as intensive mining activities. These activities may disturb the natural equilibrium of radionuclides in the soil, resulting in increased concentrations in the tailings. All the hazard indices considered in the study exceeded the world permissible limit for building materials, indicating increased external and internal exposure risks. This suggests that miners at this site may face an increased risk of radiation exposure and potential health hazards. Based on these findings, the radiological hazards associated with the tailings from Komu's pegmatite mining site are deemed unacceptable, particularly for building purposes. It is therefore recommended that access to this high background radiation area should be restricted with clearly marked signs and physical barriers, and exposure time for workers and the public in this area should be limited.

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