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Determination of Activity Concentration and Radiological Risks from Gold Mine Tailings around Ilahun-Ijesa in Obokun Local Government, Osun State, Nigeria

BAMIDELE, L; EDUN, AO

Department of Science Laboratory Technology, Osun State College of Technology, Esa–Oke, Osun State, Nigeria

**Corresponding Author Email: bamlat15@gmail.com*
**ORCID ID: https://orcid.org/0000-0001-8007-4293*
**Tel: +2348067912315*

Co-Authors Email: edunayomide2020@gmail.com

ABSTRACT: In this study, the activity concentrations and radiological risks associated with exposure to NORMS in soils around the gold mine tailings in Ilahun – Ijesa, Obokun Local Government, Osun State, Nigeria was evaluated. A Sodium Iodide (NaI) gamma spectroscopy was used to determine the activity concentrations of the natural radio nuclides in soil samples that were collected from the gold mine tailings. The mean activity concentration for ^{238}U, ^{232}Th and ^{40}K were 14.50±2.40, 10.45±3.20 and 332.70±6.10 Bqkg^{-1} respectively. The average absorbed dose was calculated to be 26.4 nGy/h and the corresponding average annual effective dose was found to be 0.0031 mSv, which is less than the total annual effective dose of 1 mSv recommended by ICRP for public exposure control. Radiological hazard parameters were evaluated from activity concentrations and the average values were found to be lower than recommended safety limits.

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Naturally occurring radioactive materials (NORMs) such as ^{40}K, and decay series of ^{232}Th and ^{238}U are present everywhere in our environment. The radio nuclides levels vary from place to place and depend on geological formation of each location (Al-junda *et al.*, 2003; Orabi *et al*., 2006). Terrestrial and cosmic radio nuclides are the two main sources of natural radiation exposure. Also human activities such as mining produce anthropogenic radio nuclides which may increase natural radiation levels in the environment. Mining has been identified as one of the major sources of exposure to naturally occurring radioactive materials (UNSCEAR, 2000). Recently, gold mining activity is on-going in certain part of Osun State South-western Nigeria. Two types of mining process are being employed in this area, they are artisanal gold mining and semi-mechanized mining, which are marked by large amount of mining wastes that may contaminate the soil over large areas causing health risks to humans and the presence of scattered abandoned opened pit impacting the environment negatively. Studies on the environmental impact of these mining activities in this area have not been carried out. Therefore the objective of this study was to determine the activity concentration and the radiological risks from Gold mine tailings around Ilahun Ijesa in Obokun Local Government, Osun State Nigeria.

MATERIALS AND METHODS

Study Area: The study area is Ilahun Ijesa in Obokun Local Government Area, Osun State. The area covers

**Corresponding Author Email: bamlat15@gmail.com*
**ORCID ID: https://orcid.org/0000-0001-8007-4293*
**Tel: +2348067912315*

238 km2 and its geographical coordinates are 7°77' N and 4.78' E. The town is within the Precambrian Basement Complex of southwestern, Nigeria, which is predominantly composed of migmatite, granitic, gneiss, quartzite and so on.

Sample collection and sample preparation: The samples were collected at depths ranging from 5 cm to 20 cm using a soil auger from four (4) mining locations. These were then packed in cylindrical plastic containers and labeled for easy identification. The soil samples were crushed and air dried for a week and then put in an oven and set to a temperature of 105^0c to allow it to dry overnight to remove any available moisture. After drying, the samples were sieved with a 2mm diameter mesh to remove organic materials, stones, and lumps. Afterward, the homogenized samples were weighed and packed in a cylindrical plastic beaker of height 7cm by 6cm diameter which is the same as the geometry of the sodium iodide counting detector. The samples to be analyzed were kept for 30 days to allow for U^{238} and its short-lived progenies to reach radioactive equilibrium.

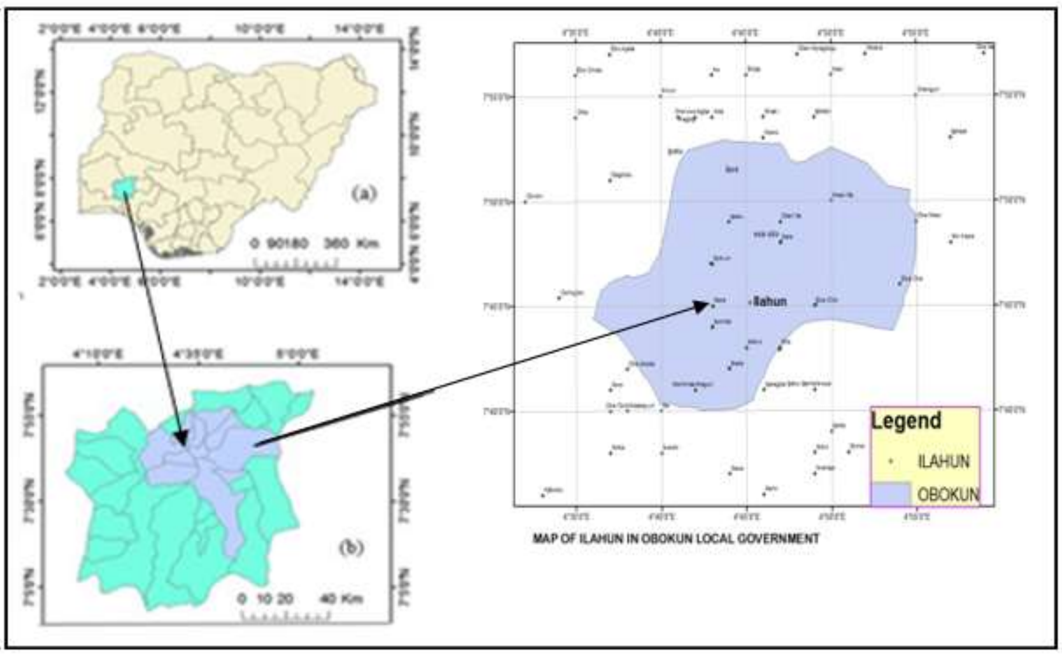

Fig 1: Map showing (a) Nigeria (b) Osun State and (c) the location of the study area

Experimental setup and procedure for Radioactivity Measurement: The samples were counted for a period of 36000 s, using a gamma spectrometry system with NaI (TI) as the detector. The scintillation detector, a 3x3 inch NaI(TI), product of Princeton Gamma Tech., USA was placed in a lead shield to reduce the effect of background radiation. Before the sample measurement, an empty container of the same geometry of the detector was counted for the same duration of time in order to determine the background gamma ray distribution. The gamma energies used for the estimation of radionuclide concentrations were ^{40}K at 1460.8 keV, ^{214}Bi at 1764.5 keV for ^{238}U, and 208Tl at 2614.7 keV for ^{232}Th. The sample activity concentration A_c (Bqkg-1) was determined using the Equation

$$A_c = C_n P_y M_e \qquad (1)$$

Where Cn is the net count rate under the corresponding peak, Pγ is the absolute transition probability of specific gamma ray, ε is the full energy peak efficiency of the detector, and m is the sample mass (kg).

Air Absorbed Dose Rates: The external gamma dose rate (D_y) at 1.0m above ground for the soil was calculated from the activity concentration using Eq. (2) (Uosif, 2007).

$$D_y(nGyh^{-1}) = 0.0417A_k + 0.462A_u + 0.604 \quad (2)$$

Where A_K, A_U, and A_{Th} are the activity concentration for K^{40}, U^{238}, and Th^{232} respectively.

Annual Effective Dose Equivalent (AEDE): The annual effective dose equivalent (AEDE) was estimated from the absorbed dose rate by applying a dose conversion factor of 0.7Sv/Gy and the occupancy factor for indoor and outdoor are 0.2 and 0.8 respectively (UNSCEAR 2000, Veiga *et al.*, 2006)

$$AEDE(outdoor)\left(\mu Sv/_{yr}\right) = (Absorbed\ dose)\ ^{nGy}/_{h} \times 0.2 \times 10^{-3} \times 8760h \times 0.7\ ^{Sv}/_{Gy} \quad (3)$$

$$AEDE(indoor)\left(\mu Sv/_{yr}\right) = (Absorbed\ dose)\ ^{nGy}/_{h} \times 0.8 \times 10^{-3} \times 8760h \times 0.7\ ^{Sv}/_{Gy} \quad (4)$$

Radiological Parameters: The radiological risk of NORM in soils in the study area was assessed by calculating the radium equivalent activity (Ra_{eq}) and the external hazard and internal hazard indices.

Radium Equivalent (Ra_{eq}) is a widely used hazard index and it was determined using Eq.(5) (Berekta and Mathew, 1985).

$$Ra_{eq} = C_u + 1.43C_{Th} + 0.077C_k \quad (5)$$

External Hazard Index (H_e) : This is an assessment of the hazard of the natural gamma radiation and it is given by Eq.(6) (Berekta and Mathew, 1985; Aborisade *et al.*, 2018)

$$H_{ex} = {}^{C_u}/_{370} + {}^{C_{Th}}/_{259} + {}^{C_k}/_{4810} \quad (6)$$

Where C_u, C_{Th} and C_k are the activity concentration of ^{238}U, ^{232}Th and ^{40}K respectively.

Internal Hazard index: Internal exposure to radon and its short lived products is quantified by an internal hazard index and expressed mathematically by Berekta& Mathew (1985).

$$H_{ex} = {}^{C_u}/_{185} + {}^{C_{Th}}/_{259} + {}^{C_k}/_{4810} \quad (7)$$

Where C_U, C_{Th} and C_k are the activity concentration of ^{238}U, ^{232}Th and ^{40}K respectively.

The value of the external hazard index must be less than unity for the external gamma radiation hazard to be considered negligible.

RESULTS AND DISCUSSION

Activity concentrations of ^{238}U, ^{232}Th and ^{40}K for soil samples from the mine tailings are summarized in Table 1. The absorbed dose rate, annual effective dose, radium equivalent and hazard indices in the soil samples are summarized in Table 2. The result from the Table 1 above, shows that activity concentration of ^{238}U ranged from 10.43±3.19 - 18.16±2.21 Bq/kg with mean value of 13.65±3.36 Bq/kg .^{232} Th also ranged from 10.03±3.24 - 14. 54±3.16) Bq/kg with the mean value of 10.73±3.15 Bq/kg and K^{40} also ranged from 301.04 ±15.07 – 391.18 ± 15.15Bq/kg with mean value of 332.03 ± 20.89 Bq/kg. The activity concentrations ^{238}U, ^{232}Th and ^{40}K obtained in this study were lower than values in normal continental soils (UNSCEAR, 2000). The absorbed dose rate ranged from 18.15 – 29.06 nGy/h with an average mean of 25.95 nGy/h.

Table 1: Activity concentrations of ^{238}U, ^{232}Th and ^{40}K for soil samples from the mine tailings

Location	No of Sample	Parameter	Activity concentration (Bq kg^{-1})		
			^{238}U	^{232}Th	^{40}K
Tailing one	15	Average	11.54±2.69	10.76±2.79	331.09±22.42
		Min	10.19±1.01	10.03±3.24	301.04±20.16
		Max	12.35±1.20	11.31±2.10	372.38±25.07
Tailing two	15	Average	13.65±3.36	10.73±3.15	332.03±20.89
		Min	10.43±3.19	10.03±3.24	312.38±15.60
		Max	17.43±3.20	12.08±2.65	391.18±15.15
Tailing three	15	Average	14.25±2.12	12.25±1.54	376.21±20.15
		Min	11.65±3.25	11.45±2.65	324.61±25.12
		Max	18.16 ±2.21	14.54 ±3.16	385.42 ±18.41
Tailing four	15	Average	14.17±3.57	11.48±2.45	320.09±20.16
		Min	11.25±3.12	10.03±5.16	312.16±30.01
		Max	17.43±2.19	12.05±2.10	358.37±20.10

Also, annual effective dose equivalent ranges from 29.77 – 35.07µsv/yr and an average mean of 31.89µsv/yr. The calculated average absorbed dose is lower than the worldwide average of 60nGy/h (UNSCEAR1993, UNSCEAR 2000). Radiological hazard assessment was determined from activity concentrations of ^{238}U, ^{232}Th and ^{40}K of the soil samples. The value of the average radium equivalent in this study is 52.30Bq/kg in a range of 48.21 – 59.95 Bq/kg which is below the recommended limit of

370Bq/kg. The average value of external (H_{ex}) and internal (H_{in}) hazard indices are 0.15 and 0.18 which are less than unity. The excess life time cancer risks were below the world average of 2.9 x 10^{-4} (UNSCEAR, 2000). The comparison between the activity concentrations found in this study with those similar studies undertaken in Nigeria and other African countries as shown in Table 4. The results show that the average activity concentrations of ^{238}U, ^{232}Th and ^{40}K for soil samples in the mine tailings are lower than the results obtained in previous studies in Nigeria and other countries except the study carried out in Sudan.

Table 2: Radiation hazard indices in the soil samples per mining site

Location	Parameter	D (nGy/h)	AEDE (µSv/yr)	Raeq (Bq/kg)	Hin	Hex	ELCR (10^{-3})
Tailing one	Average	25.57	29.74	53.43	0.17	0.14	0.85
	Min	23.54	28.69	48.21	0.15	0.13	0.79
	Max	27.58	33.27	56.07	0.18	0.15	0.92
Tailing two	Average	25.95	31.89	52.14	0.19	0.15	0.83
	Min	18.15	29.76	51.08	0.14	0.13	0.82
	Max	29.06	35.07	55.05	0.21	0.18	0.88
Tailing three	Average	26.14	30.74	53.40	0.16	0.13	0.86
	Min	24 .76	29.61	49.52	0.15	0.12	0.61
	Max	27.58	32.92	59.95	0.17	0.16	0.98
Tailing four	Average	25.50	32.49	53.84	0.17	0.14	0. 82
	Min	23.64	29.77	52.30	0.16	0.12	0.77
	Max	28.39	34.82	58.47	0.20	0.18	0.96

Table 3: Comparison of average concentrations with those of similar studies carried out in Nigeria and other African countries

Activity concentrations (Bqkg^{-1})			Country	References
^{238}U	^{232}Th	^{40}K		
40.1	29.4	216,9	Cameroon	Dallou *et al.*, 2017
13.6	24.2	162.1	Ghana	Faanu *et al.*, 2011
26.0	36.0	685.0	Sudan	Hajo *et al*., 2018
8.37	11.4	232.7	Sudan	Sam et el., 2000
60.1	71.8	1168.3	Ghana	Faanu *et al.*, 2016
78.0	33.0	337.0	Egypt	El Afifi *et al.*, 2006
785.3	43.9	427.0	South Africa	Kamunda *et al*., 2016
62.7	90.6	411.2	Nigeria	Bello *et al*., 2019
21.8	11.7	6271.2	Nigeria	Aborisade 2018
13.6	10.7	332.0	Nigeria	This study

Conclusion: This study considered the public exposure to natural activity levels around Ilahun – Ijesa mining tailings. The average activity concentrations of the radionuclides in all gold mine tailings were below the world average according UNSCEAR (2000) report. The average value of external and internal hazard indices obtained were lower than unity and the annual effective dose estimated were below the annual effective dose limit of 1 mSv recommended for the public. Hence, there is no significant radiological hazard due mining activities.

REFERENCES

Aborisade, MA; Gbadebo, AM; Adedeji, OH; Okeyode, IC; and Ajayi, OA (2018): Excess life time risk and radiation pollution hazard indices in rocks and soils of some selected mining sites in Nasarawa State, Nigeria. *EAgean J. Environ. Sci.* 3(1):1 – 18.

Al-jundia, J; Al-Bataina, BA; Abu-Rukah, Y and Shehadeh, HM. (2003): Natural radioactivity concentrations in soil samples along the Amman Aqaba Highway, *Jordan. Radiat. Measure.* 36: 555 – 560.

Bello S; Nasiru R; Garba NN; Adeyemo DJ (2018): Evaluation of the activity concentration of ^{40}K, ^{226}Ra and ^{232}Th in soil and associated radiological parameters of Shanono and Bagwai artisanal gold mining areas, Kano State, *Nigeria. J. Appl. Sci. Environ. Manage.* 23 (9): 1655-1659. DOI: https://dx.doi.org/10.4314/jasem.v23i9.8

Berekta, J; Mathew, PJ (1985): Natural radioactivity of Australian building materials, industrial waste and by-products. *Health Physics*, 48: 87 – 96. DOI: https://doi.org/10.1097/00004032-198501000000007

Dallou, GB; Ngoa, EL; Ndjana, NJE et al., (2017): NORM Measurements and radiological hazard assessment in the gold mining areas of Eastern Cameroon. *Radiat Environ and Med* 6(1): 22 – 28.

El Afifi, EM; Hilal, MA; Khalifa, SM and Aly, HF (2006): Evaluation of U, Th, K and emanated radon in some NORM AND TENORM samples. J. *Rad Meas*. 41: 627 – 633. DOI: *https://doi.org/10.1016/j.radmeas.2005.09.014*

Faanu, A; Darko, EO; Ephraim, JH (2011) Determination of natural radioactivity and hazard in soils and rock samples in a mining area in Ghana. *West Afr. J. Appl. Ecol.* 19: 77 – 92.

Faanu, A; Adukpo, OK; Tettey Larbin L et al., (2016): Natural radioactivity levels in soils, rocks and water at a mining concession of Perseus gold mine and surrounding towns in Central Region of Ghana. *SpringerPlus* 5, 98 DOI: https//doi.org/101186/s40064-016 – 016 – 1716-5.

Kamunda, C; Manny, M; Morgan, M (2016): An assessment of radiological hazards from gold mine tailings in the Province of Gauteng in South Africa. *Int. J. Environ Res. Public Health.* 13 (1):138 – 156. DOI:doi.10.3390/ijerph13010138

Hajo, I; Isam, S; Abdulaziz, S; Alaamer, N; Ibrahim, A (2018): Health risk profile for terrestrial radionuclides in soil around artisanal gold mining area at Alsopag, Sudan. *Acta Geophysics* 66(20):1 – 9. DOI: https://doi.org/10.1007/s11600-018-0166-6

Orabi, H; Al-Shareaif, A; and El Galefi, M (2006): Gamma-ray measurements of naturally occurring radioactive samples from Alkharje city. *J. Radiological Nuclear Chem. 269: 99 – 102.* DOI: https://doi.org/10.1007/s10967-006-0237-z

UNSCEAR, (1993): Sources and effects of ionizing radiation. United Nation Committee on the Effect of Atomic Radiation. Exposures from natural sources of radiation1993 report to the General Assembly with scientific Annex A, United Nations, New York. DOI: https://doi.org/10.18356/2c4203dc.en

UNSCEAR (2000): Sources and effects of ionizing radiation United Nation Committee on the Effect of Atomic Radiation Exposures from natural sources of radiation. 2000 report to the General Assembly with scientific Annex B, United Nations, New York. DOI: https//doi.org/10.18356/49c437f9-en

Uosif,, AM (2007): Gamma – ray spectroscopic analysis of selected samples from the Nile river sediments in Upper Egypt. *Radiat. Prot. Dosim.* 123(2): 21`5 -220. DOI: 10.1093/rpd/ncl103

Veiga R; Sanches N; Anjos R.M; Macario K; Bastos J and Iguateny M (2006) Measurement of natural radioactivity in Brazilian Beach sands. *J. Rad Meas*, 41 (2):189 – 196. DOI: https://doi.org/10.1016/jradmeas.2005.05.001