

DETERMINATION OF THE ACTIVITY CONCENTRATIONS OF RADIONUCLIDES AND THE ASSOCIATED HAZARDS OF SAND SAMPLES USED FOR BUILDING CONSTRUCTION IN SELECTED LOCAL GOVERNMENT AREAS IN AKWA-IBOM STATE, NIGERIA

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ABSTRACT

Sand which is used as a building material often emits radiation both outdoors [to the surrounding environment] and indoors [to the building residents]—whose doses may or may not be hazardous. In this study, the Radionuclide Activity Concentrations of ^{40}K , ^{238}U and ^{232}Th in sixteen (16) Sand samples used for constructing buildings that were randomly collected from eight (8) rivers and eight (8) burrow-pits in six (6) Local Government Areas (LGAs) of Akwa-Ibom State, Nigeria; were determined by carrying-out a Gamma spectrometry using a NaI (TI) detector. Also, the Radiological Hazard Assessment of the sixteen (16) Sand samples which involves indices such as Absorbed dose Rate (D), Hazard indices (external, H_{ex} and internal, H_{in}), Radium equivalent (Ra_{eq}), Annual effective dose rate (AEDR) (outdoor and indoor), Representative level index (I_{γ}) and Total absorbed dose rate ($D_{4\pi}$) of the Sand samples were obtained through established Models (Equations) and Comparative analysis. Based on the results obtained, the following could be seen: the average activity concentration ranges of ^{40}K were $91.86 \pm 6.58 \text{ Bq.kg}^{-1}$ to $167.64 \pm 11.99 \text{ Bq.kg}^{-1}$ for Essien Udim, 61.72 ± 4.43 to $172.90 \pm 7.37 \text{ Bq.kg}^{-1}$ for Ikot Ekpene, 115.01 ± 8.25 for Ikono; the average activity concentration ranges of ^{238}U were 5.70 ± 1.27 to $61.11 \pm 12.99 \text{ Bq.kg}^{-1}$ for Essien Udim, 13.19 ± 3.09 to $14.71 \pm 3.01 \text{ Bq.kg}^{-1}$ for Ikot Ekpene, $10.80 \pm 2.46 \text{ Bq.kg}^{-1}$ for Ikono; and the average activity concentration ranges of ^{232}Th were 2.68 ± 0.26 to $6.14 \pm 0.60 \text{ Bq.kg}^{-1}$ for Essien Udim, 3.26 ± 0.32 to $4.34 \pm 0.42 \text{ Bq.kg}^{-1}$ for Ikot Ekpene, $4.36 \pm 0.43 \text{ Bq.kg}^{-1}$ for Ikono; amongst others. Also, the mean values of Absorbed dose Rate (D), Hazard indices (external, H_{ex} and internal, H_{in}), Radium equivalent (Ra_{eq}), Annual effective dose rate (AEDR) (outdoor and indoor), Representative level index (I_{γ}) and Total absorbed dose rate ($D_{4\pi}$) were: $18.799 \text{ nGy.h}^{-1}$, (0.107, 0.173) Bq.kg^{-1} , $39.508 \text{ Bq.kg}^{-1}$, (0.023, 0.092) mSv.y^{-1} , 0.283 Bq.kg^{-1} and $13.622 (10^{-8} \text{ Gy.h}^{-1})$ respectively, amongst others. The above values indicate that both Absorbed dose radiation and Radiation hazard index are considerably low, thus implying that the Sand samples are good (safe) for building construction.

Key words: Radionuclide activity concentration, Radiological hazard, Radiation, Sand, NaI (TI), Gamma spectrometry.

INTRODUCTION

Oftentimes, many building materials especially those that exist naturally or were artificially produced with mineral-containing materials, tend to exhibit some levels of natural radioactivity (Trevisi et al., 2012). Natural radioactivity in building materials is usually caused by the natural radioactive disintegration of Th-232, U-238, and radionuclide K-40. Chronic exposure to external radiation such as beta particles and gamma rays, and to internal radiation such as Rn-222 inhalations, particularly in public/institutional buildings often pose a serious hazard to man. As more and more people develop the habit of staying indoors for longer periods (an average of 80%) of their 24-hour daily time, man is increasingly exposed to more and more internal and external radiation emitted from building materials. Furthermore, the increased adoption of naturally occurring radioactivity material (NORM)-industry residuals and by-products as base materials and/or incorporated materials for the manufacture of building materials has become a major concern which threatens public safety in many developing countries like Nigeria. These therefore make it important to regulate the extraction of natural building materials and the production of artificial building materials, while ensuring strict monitoring and control of radiations from building materials of all types—to enhance public safety (Niger Delta Budget Monitoring Group, 2023).

Human beings are often exposed to radiations that naturally occur from sources such as natural radionuclide [U-238] and cosmic radiations which take place at minute scales within the earth crust. An estimated 30nGy/h of is absorbed dose rate in air that people is exposed to at sea level, due to their exposure to cosmic radiation (UNSCEAR, 2000). Natural radioactive nuclides are contained in varying proportions in Building/construction materials. For instance, Building/construction materials which are obtained from soils and rocks mainly contain Potassium (K-40)—a radioactive isotope and Thorium (Th-232) and Uranium (U-238)—both of which are natural radionuclides. Within the uranium radioactive decay series, the radioactive decay chain segment which starts with Radium (Ra-226) is regarded as the most relevant from a radiological viewpoint (Kovler, 2005).

Building materials of all types which include blocks/bricks, limestone, gypsum, granite, cement, sand, gravel, concrete and other aggregates etc., bring about human exposure to direct radiation from them, since they contain varying proportions of radioactive potassium, thorium, and uranium. As a material with numerous applications that span beyond the general building/construction industry to the ornamental and decoration industries etc., due to its attractive colours and well-polished surface, granite is one of the most used materials in today's world (Cetin et al., 2012).

As a natural radiation-emitting mineral rock, the term 'Granite' is refers to igneous rocks of all types, and a particular construction material which is often added as a coarse aggregation during the production of concrete. Among all the plutonic rocks in the mountainous belts, granite is the most abundantly present, and occurs virtually everywhere in the earth crust. Often found to occur in near proximity with other solid mineral rocks such as granodiorite, quartz, gabbros, monzonite, and diorite etc., granite rocks naturally occurs in 'bacoliths' covering as much as several thousand square kilometers of land. Owing to the large deposits of granites that naturally occur, geological experts are of the opinion that, the vast majority rocks were formed by the partial or complete melting of sandstone and shale buried deeply in the ground (Alnour et al., 2012). When decorative granite as a household building material may exposure the entire human body of the occupants to radiation from it (Llope, 2011).

In a study carried out by Essien, et al., (2017), on Estimation of Radiological Hazard Indices Due to Radioactivity in Soils in Ibiono Ibom, Akwa Ibom State, Nigeria. The radionuclide activity concentrations in the soil samples were measured using gamma spectroscopy method. According to their report, the mean activity concentration of ^{40}K are $238.10 \pm 22.47 \text{ Bq.Kg}^{-1}$, $73.84 \pm 7.15 \text{ Bq.Kg}^{-1}$ and $106.58 \pm 8.63 \text{ Bq.Kg}^{-1}$ respectively for the three sites, for ^{238}U , the mean values for the three sites are respectively $8.26 \pm 2.06 \text{ Bq.Kg}^{-1}$, $6.11 \pm 1.58 \text{ Bq.Kg}^{-1}$ and $3.16 \pm 0.80 \text{ Bq.Kg}^{-1}$ and for ^{232}Th the mean values are $9.13 \pm 1.03 \text{ Bq.Kg}^{-1}$, $8.13 \pm 0.91 \text{ Bq.Kg}^{-1}$ and $5.91 \pm 0.66 \text{ Bq.Kg}^{-1}$ respectively. The mean radium equivalent for the three areas is $27.222 \text{ Bq.Kg}^{-1}$. The mean absorbed dose rates for the areas were $19.805 \text{ nGy.h}^{-1}$, $10.863 \text{ nGy.h}^{-1}$ and 9.787 nGy.h^{-1} . The mean total annual effective dose equivalent obtained for the areas were 0.101 mSv.y^{-1} , 0.062 mSv.y^{-1} and 0.060 mSv.y^{-1} respectively. The values for all the hazards indices obtained were found to be below the world limits. Therefore, the level of exposure at the study areas presently poses no significant health threat, hence, the soils can be used as building materials.

According to Turtiainen, et al., (2008), the building, it has been pointed out that the highest concentrations of radionuclides are found in mineral-based materials such as stone, sand, bricks, cement and sediments. Though these radionuclides are known to be widely distributed in the environment, their concentrations have been found and reported by Iqba, *et al.*, (2000), Measurement of Natural Radioactivity in marble, to depend on the geological setting of a particular environment, and as such they vary from place to place.

Sand is a granular material composed of finely divided rock and mineral particles. Sand has various compositions but is defined by its grain size. Sand grains are smaller than gravel and coarser than silt. Sand can also refer to a textural class of soil or soil type; i.e., a soil containing more than 85 percent sand-sized particles by mass. The composition of sand varies, depending on the local rock sources and conditions, but the most common constituent of sand in inland continental settings and non-tropical coastal settings is silica (silicon dioxide, or SiO_2), usually in the form of quartz. Sand is a non-renewable resource over human timescales, and sand suitable for making concrete is in high demand (Wikipedia, 2019).

The Study-area is Akwa Ibom State, Nigeria. Created in the year 1987, Akwa Ibom State, is a major oil producing state in the Niger Delta region, south-south geopolitical zone of Nigeria. Akwa Ibom's 6900 sq. km land area is located between Cross River, Abia and Rivers on the sand coastal plain of the Gulf of Guinea. It is bordered on the south by Atlantic Ocean which stretches from Ikot Abasi to Oron. Akwa Ibom State lies within Latitude $4^{\circ}30'0''$ and $5^{\circ}30'0''$ N and Longitude $7^{\circ}30'0''$ and $8^{\circ}15'0''$ E. The major dialects spoken in Akwa Ibom State are Ibibio language, Eket language, Annang language, and Oron language. Akwa Ibom has six (6) major cities—Uyo (the State capital), Ikot ekpene, Abak, Ikono, Eket, Etinan, and Oron. On the state's eastern border is Cross River State, on its western border is Rivers State, and on its southern border is the Atlantic Ocean. Its population exceeds 5 million [as at May 2023]. Uyo is the capital city of Akwa-Ibom State, with an estimated population of about half a million persons. Presently, Akwa Ibom has two seaports and one airport—Akwa Ibom International Airport, a 30,000-seater stadium, and a world-class E-library and information center. The sampling locations are shown in the highlighted Local Government Areas (Niger Delta Budget Monitoring Group, 2023).

Despite the numerous dangers of human exposure to internal and external radiation from building materials, there seems to be a relative unavailability of data on the radioactive concentration of the and radiological impact assessments of sand collected from the study-area, which poses a serious threat to the general health conditions and well-being of the

building occupants in the study-area. Also, presently in Nigeria, there is virtually no regulation currently controlling the use of materials in relation to their radioactivity levels.

During the last four decades, there has been increased interest in the study of the radioactivity levels of diverse building materials. Several national and regional surveys have been conducted to establish the radioactivity concentrations and radiological impact of various building materials such as sand, bricks, concrete, granite, cement, ceramic tiles, clay, etc.

Therefore, the aim of this study is to determine the activity concentrations of ^{238}U , ^{232}Th and ^{40}K and the associated hazards of Sand samples [used for building construction], which were obtained from rivers and borrow pits in selected Local Government Areas (LGAs) in Akwa Ibom State, Nigeria.

METHODOLOGY

Eight (8) sand samples were randomly obtained from at four rivers within four local government areas (LGAs) in Akwa-Ibom State, Nigeria, as follows:

- a) From Essien Udim local government area:
 - i. One river Sand sample was obtained at Ukana Onuk, named as RS.UO
 - ii. One river Sand sample was obtained at Atan Ikot Okoro, named as RS.AT
 - iii. One river sand sample was obtained at Afaha Ikot Ebak, named as RS.AIE
 - iv. One river sand sample was obtained at Ekpoyoun, named as RS.EK
- b) From Ikot Ekpene local government area:
 - i. One river sand sample was obtained at Mbiaso, named as RS.MB
 - ii. One river sand sample was obtained at Ikot Asudua, named as RS.IA
- c) From Ini local government area:
 - i. One river sand sample was obtained at Ikpe Ikot Nkon, named as RS.IN
- d) From Abak local government area:
 - i. One river sand sample was obtained at Ibagwa, named as RS.IB

Similarly, eight (8) Sand samples were randomly obtained from at eight burrow pits dug at five local government areas (LGAs) in Akwa-Ibom State, Nigeria, as follows:

- a) From Essien Udim local government area:
 - i. One burrow pit sand sample was obtained at Ukana Onuk, named as BPS.UO
 - ii. One burrow pit sand sample was obtained at Atan Ikot Okoro, named as BPS.AT
 - iii. Two burrow pit sand samples were obtained at Afaha Ikot Ebak, named as BPS.AIE₁ and BPS.AIE₂ respectively.
- b) From Ikono local government area:
 - i. One burrow pit sand sample was obtained at Uyo Afaha, named as BPS.UA
- c) From Ini local government area:
 - i. One burrow pit sand sample was obtained at Naenin, named as BPS.NE
- d) From Ibiono local government area:
 - i. One burrow pit sand sample was obtained at Mbiaobong Edem Edet, named as BPS.MEE
- e) From Abak local government area:
 - i. One burrow pit sand sample was obtained at Afaha Obong, named as BPS.AO

Immediately after the sand samples were obtained from their natural sources—rivers or burrow pits, they were cleaned to remove both organic and inorganic dirt (matter), drained to remove

water (where necessary), packed in polythene bags and carefully labeled. Then, each sand sample was oven-dried at a temperature of 105°C in order to get rid of moisture. Later each sample was sealed in washed a marinelli beaker for period 28 days until it attains a state of secular equilibrium [giving enough room for a radionuclide to be formed within the marinelli beaker], after which they were transported to the 'National Institute of Radiation Protection and Research (NIRPR)' at the University of Ibadan in Nigeria, for radiological analysis.

With the aid of a Gamma ray spectrometric system and a model 802 NaI (TI) detector, spectrometric measurements of gamma radiation were performed on the Sand samples. After mounting the NaI (TI) detector vertically, it was coupled with an 8k PC based multi-channel Analyzer (MCA), and then enclosed in a massive lead shield for the purpose of reducing background radiations from the system. Using point sources ^{241}Am , ^{60}Co , ^{22}Na ^{137}Cs for energy (IAEA – 385), the NaI (TI) detector was calibrated with the aid of Gemie 2000 software template (which calculates the following: efficiency, percentage error, uncertainty in activity, energy, activity concentration, uncertainty efficiency, gamma probability, county uncertainty, uncertainty in Gamma probability etc.). Its operational software—the 'Gemie 2000' is capable of analyzing the different energy levels of ^{232}Th , ^{238}U , and ^{40}K .

For the purpose of ensuring a reduction of statistical uncertainty, every one of the collected samples was subjected to a 36,000-second counting. After washing the marinelli beaker, it was placed within the NaI (TI) detector and subjected to a similar 36,000-second counting for the purpose of ascertaining the level of background radiation of the laboratory environment, which was later deducted from each Sand sample's gamma ray spectra. Then, a reporting template was developed to obtain each Sand sample's radionuclide concentration. This reporting template was used to collate and report certain important data such as efficiency, percentage error, uncertainty in activity, energy, activity concentration, uncertainty efficiency, gamma probability, county uncertainty, uncertainty in Gamma probability etc. Before ending the measurement, the different regions of interest were subtracted from the values of the background radiation, and then included in the developed reporting template.

Then, amongst other things, some of the parameters of interest were obtained through equations (1) to (9) as shown below:

a) Activity Concentration:

$$A = \frac{N}{\xi t \gamma M} \quad (1)$$

Where,

'A' is Absorbed dose rate, measured in BqKg^{-1}

'N' is the Net peak-area of the radionuclide

' ξ ' is the detector energy-dependent efficiency

't' is the Counting live time, measured in s

' γ ' is the gamma-ray yield per disintegration of the nuclide

'M' is the mass of the Sand sample, measured in Kg (Faanu, et al., 2011)

b) Absorbed Dose Rate:

$$D = 0.462A_U + 0.621A_{Th} + 0.0417A_K \quad (2)$$

Where,

'D' is Absorbed dose rate, measured in $\text{nGy} \cdot \text{h}^{-1}$

' A_U ' is the Specific Activity concentration of Uranium, measured in $BqKg^{-1}$

' A_{Th} ' is the Specific Activity concentration of Thorium, measured in $BqKg^{-1}$

' A_K ' is the Specific Activity concentration of Potassium, measured in $BqKg^{-1}$

It should be noted that maximum permissible dose rate is $51 \text{ nGy} \cdot h^{-1}$ (UNSCEAR, 1993).

c) Outdoor Annual Effective Dose Rate:

$$AEDR_{outdoor} = 1.2D \times 10^{-3} \text{ mSv} \cdot y^{-1} \quad (3)$$

Where,

' $AEDR_{outdoor}$ ' is Outdoor annual effective dose rate, in $\text{mSv} \cdot yr^{-1}$ (UNSCEAR, 1993)

d) Indoor Annual Effective Dose Rate:

$$AEDR_{indoor} = 4.91D \times 10^{-3} \text{ mSv} \cdot y^{-1} \quad (4)$$

Where,

' $AEDR_{indoor}$ ' is Indoor annual effective dose rate, in $\text{mSv} \cdot yr^{-1}$ (UNSCEAR, 2000)

e) External Hazard Index:

$$H_{ex} = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (5)$$

Where,

' H_{ex} ' is External hazard index (UNSCEAR, 2000)

f) Internal Hazard Index:

$$H_{in} = \frac{A_U}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (6)$$

Where,

' H_{in} ' is Internal hazard index (Raad and Hayder, 2011)

For radiation hazard to be considered negligible, H_{ex} and H_{in} should be less than 1.

g) Representative Level Index:

$$I_\gamma = \frac{A_U}{150} + \frac{A_{Th}}{100} + \frac{A_K}{1500} \leq 1 \quad (7)$$

Where,

' I_γ ' is External hazard index (Turhan, et al., 2008)

When

$I_\gamma \leq 1$, then, the annual effective dose of less than or equal to 1mSv

$I_\gamma \leq 0.5$, then, the annual effective dose of less than or equal to 0.3mSv

h) Radium Equivalent:

$$Ra_{eq} = A_U + 1.43A_{Th} + 0.077A_K \quad (8)$$

Where,

Ra_{eq} is Radium Equivalent (UNSCEAR, 2000)

RESULTS AND DISCUSSION

Below is a discussion of the results and data obtained from six (6) selected local government areas of the Study-area that were obtained during the course of this study, and are carefully reported in five (5) tables.

Table 1: Surface Dose Rates of Sand Samples Collected from 16 Sources at the Study-area

S/n	Local Government Area	Location of Sand source (River/Burrow-pit)	Sand source	Sand sample code	Surface Dose Rate (mR.h ⁻¹)
1	Essien Udim	Ukana Onuk	River	RS.UO	0.011
2	Essien Udim	Atan Ikot Okoro	River	RS.AT	0.021
3	Essien Udim	Afaha Ikot Ebak	River	RS.AIE	0.019
4	Essien Udim	Ekpoyoun	River	RS.EK	0.019
5	Ikot Ekpene	Mbiaso	River	RS.MB	0.016
6	Ikot Ekpene	Ikot Asudua	River	RS.IA	0.011
7	Ini	Ikpe Ikot Nkon	River	RS.IN	0.007
8	Abak	Ibagwa	River	RS.IB	0.016
9	Essien Udim	Ukana Onuk	Burrow pit	BPS.UO	0.007
10	Essien Udim	Atan Ikot Okoro	Burrow pit	BPS.AT	0.015
11	Essien Udim	Afaha Ikot Ebak	Burrow pit	BPS.AIE1	0.006
12	Essien Udim	Afaha Ikot Ebak	Burrow pit	BPS.AIE ₂	0.005
13	Ikono	Uyo Afaha	Burrow pit	BPS.UA	0.007
14	Ini	Naenin	Burrow pit	BPS.NE	0.013
15	Ibiono	Mbiaobong Edem Edet	Burrow pit	BPS.ME E	0.016
16	Abak	Afaha Obong	Burrow pit	BPS.AO	0.014

Surface Dose Rate

Table 1 which shows the ‘Sand Sample code’ and ‘Surface dose rate’ of each of sixteen (16) Sand samples, i.e. eight (8) collected from rivers and eight (8) collected from burrow pits at the Study-area. From Table 1, it can be seen that the Surface dose rate ranged from 0.005 to 0.021 mR.hr⁻¹, with an average of 0.013 mR.hr⁻¹.

The values surface dose rate in the study locations were below the recommended safety limit (1.0 mR.hr⁻¹). This implies that the obtained values did not indicate any radiological health

threat on the citizens of the area. The average value obtained in this research are found to be below the average values obtained at different locations in the study area by other researchers (Etuk *et al.*, 2015; Essien and Essiett, 2016; Essien *et al.*, 2017; Etuk *et al.*, 2017).

Table 2: Radionuclide (^{40}K , ^{238}U and ^{232}Th) Activity Concentration in the Study Area

S/n	Local Government Area	Sand sample Code	Activity Concentration (Bq.kg^{-1})		
			^{40}K	^{238}U	^{232}Th
1	Essien-Udim	BPS.UO	101.81 ± 7.30	7.10 ± 1.61	4.01 ± 0.39
2		RS.UO	167.64 ± 11.99	35.36 ± 7.81	6.14 ± 0.60
3		BPS.AT	137.50 ± 9.87	5.70 ± 1.27	4.19 ± 0.41
4		RS.AT	119.79 ± 8.63	37.73 ± 8.23	2.68 ± 0.26
5		BPS.AIE ₁	116.83 ± 8.36	32.48 ± 7.14	3.22 ± 0.31
6		BPS.AIE ₂	109.65 ± 7.87	20.42 ± 4.60	3.80 ± 0.37
7		RS.AIE	146.08 ± 10.26	15.19 ± 3.10	4.38 ± 0.42
8		RS.EK	91.86 ± 6.58	61.11 ± 12.99	3.40 ± 0.33
		Mean	123.90 ± 8.86	22.00 ± 5.84	3.98 ± 0.39
9	Ikot-Ekpene	RS.MB	172.90 ± 12.15	14.71 ± 3.01	4.34 ± 0.42
10		RS.IA	61.72 ± 4.43	13.19 ± 3.09	3.26 ± 0.32
		Mean	117.31 ± 8.29	13.95 ± 3.05	3.80 ± 0.37
11	Ikono	BPS.UA	115.01 ± 8.25	10.80 ± 2.46	4.36 ± 0.43
		Mean	115.01 ± 8.25	10.80 ± 2.46	4.36 ± 0.43
12	Ini	RS.IN	167.08 ± 12.04	22.87 ± 5.07	5.23 ± 0.51
13		BPS.NE	140.08 ± 10.00	44.69 ± 9.82	8.19 ± 0.80
		Mean	153.58 ± 11.02	33.78 ± 7.45	6.71 ± 0.66
14	Ibiono	BPS.MEE	46.60 ± 3.35	33.44 ± 7.37	3.19 ± 0.38
		Mean	46.60 ± 3.35	33.44 ± 7.37	3.19 ± 0.38
15	Abak	BPS.AO	22.45 ± 1.58	26.04 ± 5.33	3.68 ± 0.35
16		RS.IB	155.10 ± 11.12	9.03 ± 2.00	4.54 ± 0.51
		Mean	88.78 ± 6.35	17.54 ± 3.67	4.11 ± 0.43

Adsorption Radionuclides Activity Concentration in Sand Samples

Table 2, Table 3, and Table 4 shows the Radionuclide (^{40}K , ^{238}U and ^{232}Th) Activity Concentrations of the sixteen (16) Sand samples collected from various locations

[rivers and burrow pits] in the study-area.

Table 3: Radionuclide Activity Concentration of River Sand Samples in the Study Area

S/n	Sand sample Code	Activity Concentration (Bq.kg ⁻¹)		
		⁴⁰ K	²³⁸ U	²³² Th
1	RS.UO	167.64 ± 11.99	35.36 ± 7.81	6.14 ± 0.60
2	RS.AT	119.79 ± 8.63	37.73 ± 8.23	2.68 ± 0.26
3	RS.AIE	146.08 ± 10.26	15.19 ± 3.10	4.38 ± 0.42
4	RS.EK	91.86 ± 6.58	61.11 ± 12.99	3.40 ± 0.33
5	RS.MB	172.90 ± 12.15	14.71 ± 3.01	4.34 ± 0.42
6	RS.IA	61.72 ± 4.43	13.19 ± 3.09	3.26 ± 0.32
7	RS.IN	167.08±12.04	22.87±5.07	5.23±0.51
8	RS.IB	155.10±11.12	9.03±2.00	4.54±0.51
	Mean	135.10±9.65	26.15±6.53	4.25±0.42

The mean activity concentrations of ⁴⁰K range from 91.86 ± 6.58 Bq.kg⁻¹ to 167.64±11.99 Bq.kg⁻¹ for Essien Udim, 61.72 ± 4.43 to 172.90 ± 7.37 Bq.kg⁻¹ for Ikot Ekpene, 115.01 ± 8.25 for Ikono, 140.08 ±10.00 to 167.08±12.04 Bq.kg⁻¹ with mean 169.27 ± 12.14 for Ini, 46.60 ± 3.35 for Ibiono Ibom and 22.45 ± 1.58 to 155.10 ± 11.12 Bq.kg⁻¹ for Abak.

Table 4: Radionuclide Activity Concentration of Burrow-pit Sand Samples in the Study Area

S/n	Sand sample Code	Activity Concentration (Bq.kg ⁻¹)		
		⁴⁰ K	²³⁸ U	²³² Th
1	BPS.UO	101.81 ± 7.30	7.10 ± 1.61	4.01 ± 0.39
2	BPS.AT	137.50 ± 9.87	5.70 ± 1.27	4.19 ± 0.41
3	BPS.AIE ₁	116.83 ± 8.36	32.48 ± 7.14	3.22 ± 0.31
4	BPS.AIE ₂	109.65 ± 7.87	20.42 ± 4.60	3.80 ± 0.37
5	BPS.UA	115.01 ± 8.25	10.80 ± 2.46	4.36 ± 0.43
6	BPS.NE	140.08±10.00	44.69±9.82	8.19±0.80
7	BPS.MEE	46.60±3.35	33.44±7.37	3.19±0.38
8	BPS.AO	22.45±1.58	26.04±5.33	3.68±0.35
	Mean	98.74±6.68	22.58±4.98	4.33±0.40

For ^{238}U , the mean concentration ranges for Essien Udim, Ikot Ekpene, Ikono, Ini, Ibiono Ibom and Abak Local Government Areas of Akwa Ibom State are 5.70 ± 1.27 to $61.11 \pm 12.99 \text{ Bq.kg}^{-1}$, 13.19 ± 3.09 to $14.71 \pm 3.01 \text{ Bq.kg}^{-1}$, $10.80 \pm 2.46 \text{ Bq.kg}^{-1}$, 22.87 ± 5.07 to $44.69 \pm 9.82 \text{ Bq.kg}^{-1}$, $33.44 \pm 7.37 \text{ Bq.kg}^{-1}$ and 9.03 ± 2.00 to $26.04 \pm 5.33 \text{ Bq.kg}^{-1}$ respectively.

Health Risk Assessment of ^{238}U , ^{232}Th and ^{40}K in Sand and Gravel Samples

The Radium equivalent (R_{eq}), Absorbed dose Rate (D), Annual effective dose rate (AEDR), Hazard index (external, H_{ex} and internal, H_{in}) (Bq.l^{-1}), Total absorbed dose rate ($D_{4\pi}$), and Radioactivity level index (I_{γ}) for Sand samples in the study locations are presented in Table 5. The average value of radium equivalent was $39.508 \text{ Bq.kg}^{-1}$. The values of absorbed dose rate ranged from $10.016 - 34.175 \text{ nGy.h}^{-1}$ with an average of $18.799 \text{ nGy.h}^{-1}$.

Table 5: Radiological Impact Assessments for Sand Samples in the Study-area

Sand Sample code	D (nGy.h^{-1})	R_{eq} (Bq.kg^{-1})	Hazard Index (Bq.kg^{-1})		AEDR (mSv.y^{-1})		I_{γ} (Bq.kg^{-1})	$D_{4\pi}$ ($10^{-8} \text{ Gy.h}^{-1}$)
			External	Internal	Outdoor	Indoor		
BPS.UO	10.016	20.674	0.056	0.075	0.012	0.049	0.155	10.42
RS.UO	27.14	57.048	0.154	0.25	0.033	0.133	0.409	19.56
BPS.AT	10.969	22.279	0.06	0.076	0.013	0.054	0.172	13.51
RS.AT	24.091	50.786	0.137	0.239	0.029	0.118	0.358	15.05
BPS.AIE ₁	21.877	46.081	0.125	0.212	0.026	0.107	0.327	14.31
BPS.AIE ₂	16.366	34.297	0.093	0.148	0.02	0.08	0.247	12.49
RS.AIE	15.829	32.702	0.088	0.129	0.019	0.078	0.242	15.3
RS.EK	34.175	73.045	0.197	0.363	0.041	0.168	0.503	15.06
RS.MB	16.701	34.23	0.092	0.132	0.02	0.082	0.257	17.66
RS.IA	10.692	22.604	0.061	0.097	0.013	0.052	0.162	7.35
BPS.UA	12.493	25.891	0.07	0.099	0.015	0.061	0.192	12.04
RS.IN	20.781	43.214	0.117	0.179	0.025	0.102	0.316	18.1
BPS.NE	31.574	67.188	0.182	0.302	0.038	0.155	0.473	18.32
BPS.MEE	19.373	41.59	0.112	0.203	0.023	0.095	0.286	8.086
BPS.AO	15.252	33.031	0.089	0.16	0.018	0.075	0.225	5.207
RS.IB	13.459	27.465	0.074	0.099	0.016	0.066	0.209	15.49
Average	18.799	39.508	0.107	0.173	0.023	0.092	0.283	13.622

The range of annual effective dose rate (outdoor, indoor) was (0.012 – 0.041, 0.049- 0.168)

mSv.y⁻¹ with average of (0.023, 0.092) mSv.y⁻¹. The range of hazard index (external, internal) was (0.056 – 0.197, 0.075 – 0.363) Bq.kg⁻¹ with averages of (0.107, 0.173) Bq.kg⁻¹. The range of total absorbed dose rate was from 5.207 to 19.56 (10⁻⁸ Gy.h⁻¹) with an average of 13.622 (10⁻⁸ Gy.h⁻¹). Radioactivity level index ranged from 0.155 to 0.503 Bq.kg⁻¹ with an average of 0.283 Bq.kg⁻¹.

CONCLUSION

Sand used as a Building Material in some local government areas of Akwa Ibom State in Nigeria contains ⁴⁰K radionuclide with mean activity concentrations of 123.90 ± 8.86 Bq.kg⁻¹ for Essien Udim, 117.31 ± 8.29 Bq.kg⁻¹ for Ikot Ekpene, 115.01 ± 8.25 Bq.kg⁻¹ for Ikono, 153.58 ± 11.02 Bq.kg⁻¹ for Ini, 46.60 ± 3.35 Bq.kg⁻¹ for Ibiono Ibom and 88.78 ± 6.35 Bq.kg⁻¹ for Abak; ²³⁸U with mean concentration for Essien Udim, Ikot Ekpene, Ikono, Ini, Ibiono Ibom and Abak Local Government Areas of Akwa Ibom State as 22.00 ± 5.84 Bq.kg⁻¹, 13.95 ± 3.05 Bq.kg⁻¹, 10.80 ± 2.46 Bq.kg⁻¹, 33.78 ± 7.45 Bq.kg⁻¹, 33.44 ± 7.37 Bq.kg⁻¹ and 17.54 ± 3.67 Bq.kg⁻¹ respectively; and ²³²Th with the mean concentration as 3.98 ± 0.39 Bq.kg⁻¹, 3.80 ± 0.37 Bq.kg⁻¹, 4.36 ± 0.43 Bq.kg⁻¹, 6.71 ± 0.66 Bq.kg⁻¹, 3.19 ± 0.38 Bq.kg⁻¹ and 4.11 ± 0.43 Bq.kg⁻¹ for Essien Udim, Ikot Ekpene, Ikono, Ini, Ibiono Ibom and Abak Local Government Areas of Akwa Ibom State respectively. These activity concentration values are lower than the permissible maximum values of 33, 45 and 420 Bq.kg⁻¹ respectively for ²³⁸U, ²³²Th and ⁴⁰K.

Absorbed dose rate (D), Hazard indices (external, H_{ex} and internal, H_{in}), Radium equivalent (Ra_{eq}), Annual effective dose rate (AEDR) (outdoor and indoor), Representative level index (I_y) and Total absorbed dose rate (D4π) were calculated. The radium equivalent activity is less than the world limit of 370 Bq.l⁻¹; the hazard indices, absorbed dose rate, annual effective dose rate and radioactivity level index are respectively less than the permissible maximum value of 1, 57nGy.h⁻¹, 1 mSv.y⁻¹ and 1 Bq.kg⁻¹. Hence, sand and gravel in the study locations used as structural building materials are safe for both construction workers and the inhabitant of the building constructed.

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