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Assesement of The Radionuclides Activity Concentration in Some Sharp Sand Commonly Used in Benue State, Nigeria

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ABSTRACT

This study assessed radionuclides (238U, 232Th and 40K) activity originating from naturally occurring radioactivity in some selected sharp sand used in Benue State. Four different sharp sands, were selected. The samples were crush to a grain size of 1mm and weighed 5 grams at Civil Engineering Department, Joseph Saawuan Tarka University, Makurdi, and were moved to National Institute of Radiation Protection and Research (NIRPR), University of Ibadan, Nigeria, where the samples were analyzed using NaI(Tl) detector. The concentration of the selected radionuclide in each sample was obtained and the result for sharp sand shows that the activity concentration of 238U and 232Th in the selected samples ranged from 0.24±0.02-0.33±0.01 Bq/kg and 3.35±0.01- 3.96±0.04 Bq/kg respectively, which were both below the respective set standards of 50 and 30 Bq/kg by UNSCEAR, 2000. Result of the concentration of 40K in sharp sands sample shows that activity concentration of 40K was higher (946.75±12.21 Bq/kg) in OSSD sample than the recommended of 400 Bq/kg by UNSCEAR, (2000). The study concludes that, activity concentration in sampled sharp sand used in Benue State are radiologically safe except OSSD sample in which 40K was above the recommended standard of 400 Bq/kg by UNSCEAR, (2000).

1.INTRODUCTION

1.1 Background of the Study

Radioactivity is the emission of radiation or the release of energy from decayed nuclei of some certain kinds of atoms and isotopes. It originates from the emission of Naturally Occurring Radioactive Materials (NORMs) within the earth's crust. These NORMs enters into the soil, air, water, food and human body through different routes (Sombo et al., 2016).

Radionuclides activity concentration refers to the amount of radioactivity per unit volume and unit mass in materials that include radionuclides. The background radiation in a given area is a function of the amount of NORMs available in such an area. (Oladapo, 2012). Natural radioactivity is widespread in human immediate environment. It can originate from terrestrial radiation, cosmic radiation or indoor radiation from building materials. Research have shown that the presence of natural radioactive sources such as Radium-226 (226Ra), Thorium-232 (232Th), with their progenies, and Potassium-40 (40K) in Building materials results in harmful external and internal effects to occupants. The external effect is caused by direct gamma radiation from the NORMs affecting external organs like skin. The internal effect which normally affects internal organs mainly the respiratory tract, is due to radon and its daughters which are released from building materials. Several studies have revealed the risks of human exposure and impact of ionizing radiation from NORMs in some building materials. Some harmful effects caused by radionuclide from building materials enumerated include pre-matured death, others are; leukemia, bone neurosis, chromosome aberrations, bone and lung cancer, hematological depression and cataract of the eye. There is no available literature, on radioactivity levels of sharp sand used for building in Benue State. Adequate data on radioactivity level of building materials (such as sand) is important for regulatory and advisory purposes for the protection of the public from unnecessary exposure to radiation. Therefore, measuring the radioactivity concentration of sharp sand in Makurdi will breach the knowledge gap. The aim of this research is to determine the radionuclide activity in sharp sand for building in Benue State. The work assessed the concentration of Thorium (232Th), Uranium (238U) and Potassium (40K) present in sharp sand used for building, it also estimates activity concentration index I, absorbed dose rate, hazard indices and annual effective dose equivalent (AEDE) of radionuclides in some sharp sand samples used for building in Benue State. The result obtained was compare with UNSCEAR Safety standard for radionuclides. The result of this work will help building technologists to make informed choice of sharp sand to be use for building in Benue State. Furthermore, the research will build on the sparsely available data for Radioactivity of sharp sand. A lot of works has been done on the assessment of radioactivity levels in various materials from different areas around the world. A study carried out by Vanasundari et al. (2012) to assess radioactivity concentration in building materials used in chengam and Tiruvannamali districts in India using detector based gamma ray spectrometer. They observed that the specific activity concentration of 226Ra, 232Th and 40K were 4.57, 119.42 and 388.78 in Bq/kg respectively. From the analysis, it was found that these materials do not pose significant radiation hazards when used for construction of buildings. Fasae (2013) worked on Natural Radioactivity in Locally Produced Building Materials in Ekiti State using gamma-ray spectrometry (7.62 cm × 7.62 cm) NaI(Tl) detector. He determined activity concentration in 160 samples of brick block and 160 samples of concrete block and found the mean activity concentration values of 572.6 ± 175.9 Bq kg-1, 47.9 ± 9.8 Bq kg-1 and 63.8 ± 9.4 Bq kg-1 for 40K, 226Ra and 232Th respectively in concrete blocks were higher compared to the mean activity concentration values 351.1 ± 3.1 Bq kg-118.7 ± 6.2 Bq kg-1 and 39.8 ± 3.5 Bq kg-1obtained in brick blocks. He concluded that, the use of brick block and cement block materials for constructing buildings for human habitation in the study area may pose a health risk to the population if there is no remediation by the regulatory body in the state. Joel et al. (2018) assessed natural radioactivity in various commercial tiles used for building purposes in Nigeria. They evaluated the activity concentration of natural radionuclides (226Ra, 232Th and 40K) for fifteen (15) different brands of tile samples used for building purposes in Nigeria. They analyzed tile samples using High purity Germanium gamma detector. Their result on mean activity concentrations of 226Ra, 232Th, and 40K were found to be 61.1±5.5 Bq/kg, 70.2 ±6.08 Bq/kg and 514.7 ± 59.8 Bq/kg respectively. Their results on mean radium equivalent activity (Raeq), the absorbed dose rate (D), external and internal hazard index, the annual effective dose (AEDR) equivalent, Gamma activity Index (Iγ) and Alpha Index (Iα) were: 204.42 Bq/kg, 177.61 nGyh-1, 0.55, 0.77, 0.96 mSvyr1, 0.74 and 0.32 respectively. Their average value of radium equivalent obtained is less than that of the recommended value of 370 Bq/kg but their average values of the other radiological hazards for some samples were found to be slightly above international recommended values except Hex, Hin and AEDE which are within the international reference value of unity. Khatun et al. (2018) worked on Measurement and Assessment of Natural Radioactivity and Radiological Hazards in Some Building Materials Used in Bangladesh using HPGe gamma ray spectrometer and found that the radium equivalent activity, the absorbed dose rate, annual effective dose, external and internal hazard indices, gamma index, alpha index, annual gonadal dose equivalent and excess lifetime cancer risk were also evaluated to assess the potential radiation hazards associated with these building materials. All samples under investigation were found to be within the recommended safety limit and do not pose any significant radiation hazards. Sombo et al. (2016) worked on the assessment of radioactivity and health implications of some surface soils in Guma local government area of Benue State, North Central Nigeria. Their results showed that the soil activity for urban areas ranged from 38.12–58.10 Bq/kg, 3.53–4.41 Bq/kg, and 3.35 –7.11 Bq/kg for 40K, 238U and 232Th respectively for urban areas while in the rural areas the concentrations ranged from 54.06 –76.17 Bq/kg, 3.66 – 5.27 Bq/kg and 4.74 – 7.18 Bq/kg for 40K, 238U and 232Th respectively. The absorbed dose and annual effective dose range from 5.89 – 7.70 nGy/h and 0.01 mSv/yr in the urban areas with mean of 6.48 nGy/h and 0.01 mSv/yr while in the rural area, the values ranges from 7.48 – 8.52 nGy/h and 0.01 – 0.02 mSv/yr with mean values of 8.00 nGy/h and 0.01 mSv/yr. All the computed values are much lower than permissible value recommended by the United Nation’s Scientific Committee on Effect of Atomic Radiation (UNSCEAR, 2008).

2.MATERIALS AND METHODS

2.1 Materials

Materials used in this research include,

Four samples of sharp sand used for building construction across Benue State, a mesh, plastic containers, Thallium-activated Sodium Iodide detector [NaI(TI)] and a computer system.

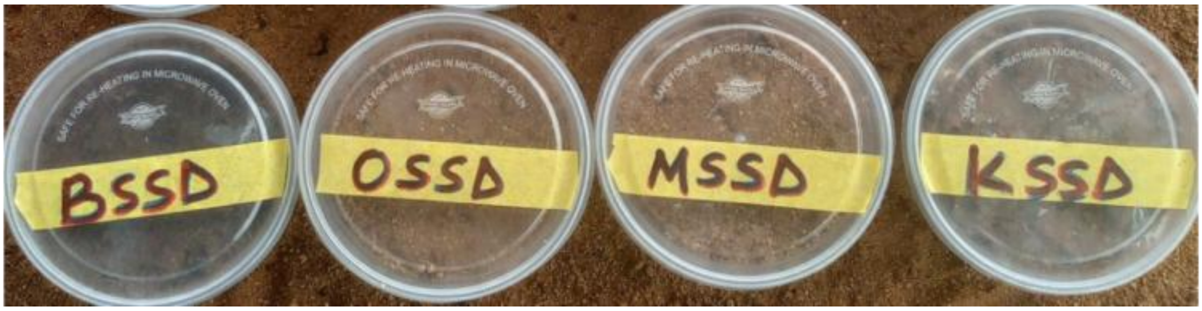

Figure 1: Sample of sharp sand used for the study

2.2 Study Area

The study area is Benue State Nigeria, Benue state is one of the largest states in north central Nigeria with a population of about 4,253,641 people in 2006 census, with a projected growth rate of 3.05% per annum (NPC, 2007). The State lies in the Southern Guinea Savanna between latitudes 6◦25'N and 8◦8'N and longitudes 7◦47'E and 10◦E' (Onlinenigeria, 2003). The state has a land mass estimated to be 5.09 million hectares. It has 23 local government areas which are embraced in three major geopolitical zones of the state, which are zone A, B, and C. The state two major Rivers (River Benue and River Katsina Ala along which samples were obtained).

2.2.1 Map of the Study Area

Map of the study area showing the study locations is presented in Figure 2

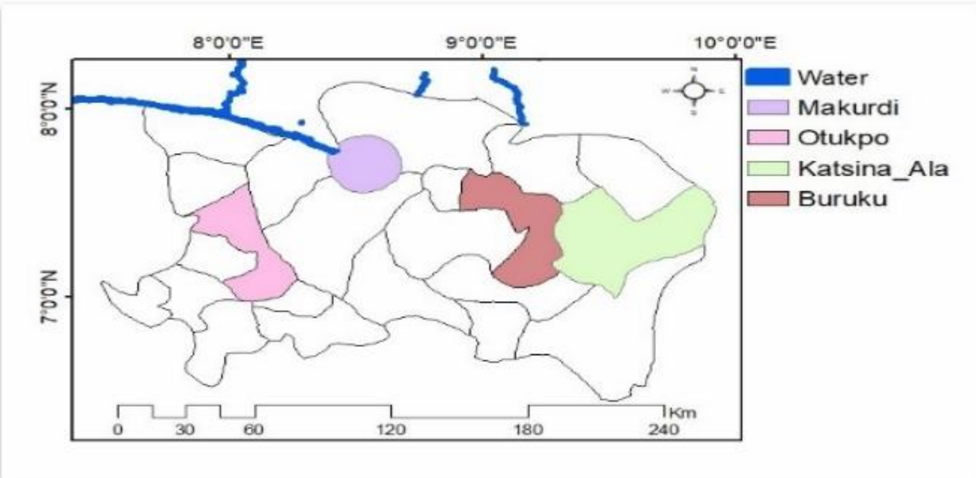

Figure 2: Map of Benue State showing the sampling sites

2.3 Sampling Sites and Sample Preparation

Samples of sharp sand used in this study were collected in the major towns of Benue State consisting of large water bodies (Makurdi, Buruku, Katsina-Ala, and Otukpo). Four different kinds of sharp sand were obtained, catalogued and marked according to the origin/location site. These samples were analyzed in natural form, after crushing, powdering, coning and quartering them to a maximum grain size of 1mm; they were dried in an oven at a temperature of about 110ºC until sample weight became constant. The powdered samples were then stored in tight plastic containers (fit to well volume of the detector) for 30 days to allow for radioactive equilibrium to be reached (secular equilibrium where the rate of decay of the daughters becomes equal to that of the parent). This step was necessary to ensure that radon gas confined within the volume and the decay products also remain in the sample.

2.4 Data Collection and Analysis

Four (4) samples of sharp sand were collected at four different locations and were prepared according to the IAEA standards for preparation of sample for spectrometric analysis which were analyzed using NaI(Tl) detector connected to a personal computer-based data acquisition system, at National Institute of Radiation Protection and Research (NIRPR), University of Ibadan, Nigeria. The samples were placed on the NaI(Tl) detector and each sample was set to counting time of 28,800 s. The background count was estimated by empting the container and counting it in a closed detector using the same container lid geometry as in the previous count. This procedure was maintained throughout the analysis. The count rate in count per second (CPS) was obtained for each radionuclide in every sample analyzed and the background count was subtracted for every count. The activity concentration of each of the radionuclide was calculated using equation 1.

$$D = 0.462C_U + 0.604C_{Th} + 0.0417C_k \qquad (1)$$

2.4.1 Activity Concentration Index

Activity concentration index is calculated using equation 2.

$$D = 0.462C_U + 0.604C_{Th} + 0.0417C_k \qquad (2)$$

where x represents the nuclide of interest, n is the number of different kinds of buildings materials, Cxi(Bq kg–1) is the measured activity of each nuclide in the building material, wi is the weight fractional usage of the building material, i, and Ax (Bq kg–1) are the parameter values representing the activity concentration of each nuclide of interest.

2.4.2 External hazard index

The external hazard index of the activity concentration of Ra-226, Th-232 and K-40 will be analyzed using equation 3.

$$(H_{Ex}) = \frac{C_U}{370} + \frac{C_{Th}}{259} + \frac{C_k}{4810} \qquad (3)$$

2.4.3 Internal hazard index

The internal hazard index of the activity concentration of Ra-226, Th-232 and K-40 was analyzed using equation (4).

$$H_{In} = \frac{C_U}{185} + \frac{C_{Th}}{259} + \frac{C_k}{4810} \qquad (4)$$

2.4.4 Absorbed dose rate

The absorbed dose rate (D) is calculated using equation 5.

$$D = 0.462C_U + 0.604C_{Th} + 0.0417C_k \qquad (5)$$

2.4.5 Annual effective dose equivalent (AEDE)

The annual effective dose equivalent received by a person is calculated from the absorbed dose rate by applying dose conversion factor of 0.7Sv/Gy. Taking into consideration that, people on average, spent 20% of their time outdoors, occupancy factor for outdoor and indoor are 0.2 and 0.8 respectively (Avwiri et al., 2014; Bashir et al., 2013). The AEDE equivalent for sharp sand used for construction in Benue state was calculated using equation 6.

AEDE (outdoor) (μSv/y) = Absorbed dose (D) (nGy/h) × 8760h × 0.7Sv/Gy × 0.2 ×10-3 (6)

2.4.6 Annual Effective Indoor Dose Equivalent (AEIDE)

AEDE (indoor) occurs within a house where radiation risk due to building materials only are taken into consideration while AEDE (outdoor) involves a consideration of the absorbed dose emitted from radionuclides in the environment such as226Ra (238U), 232Th and 40K.

The standard AEDE (outdoor) value is 70μSv/y and that for AEDE (indoor) is 450μSv/y. These indices measure the risk of stochastic and deterministic effect in the irradiated individual (Avwiri et al., 2014). Annual effective dose equivalent (indoor) for soil, rocks and cement used for building construction in Benue state is calculated using equation 7.

AEDE (indoor) (μSv/y) = Absorbed dose (D) (nGy/h) × 8760h × 0.7Sv/Gy × 0.8 × 10-3 (7)

2.4.7 Radium equivalent activity (Ra_{eq})

According to Avwiri *et al.* (2014), Radium equivalent activity (Bq/Kg) is estimated using the equation below;

$$Ra_{eq} = C_U + 1.43C_{Th} + 0.077C_k) \quad (8)$$

where,

Ra_{eq} is a single parameter used to represent the radionuclide concentration of ^{238}U. ^{232}Th and ^{40}K, taking into account their respective radiation hazards. The maximum permissible standard value for Ra_{eq} is 370Bq/Kg (Hasan *et al.*, 2014; Bashir *et al.*, 2013).

2.4.8 External hazard index (H_{ex})

The external hazard index (H_{ex}) is defined by Avwiri*et al*. (2014)

$$(H_{Ex}) = \frac{C_U}{370} + \frac{C_{Th}}{259} + \frac{C_k}{4810} \quad (9)$$

Where, $C_U, C_{Th} and C_K$ are the radioactivity concentration in Bq/Kg of ^{238}U, ^{232}Th and ^{40}K. The value of this index must be less than unity for the radiation hazards to be insignificant.

2.4.9 Internal hazard index (H_{in})

The internal hazard index is given as in equation 10

$$H_{In} = \frac{C_U}{185} + \frac{C_{Th}}{259} + \frac{C_k}{4810} \quad (10)$$

Where, $C_U, C_{Th} and C_K$ are the radioactivity concentration in Bq/Kg of ^{238}U, ^{232}Th and ^{40}K.

H_{In}, should be less than unity for the radiation hazard to be insignificant.

3. RESULTS

The samples were analyzed at National Institute of Radiation Protection and Research (NIRPR), University of Ibadan Nigeria, and the results are presented in Figure 2-4.

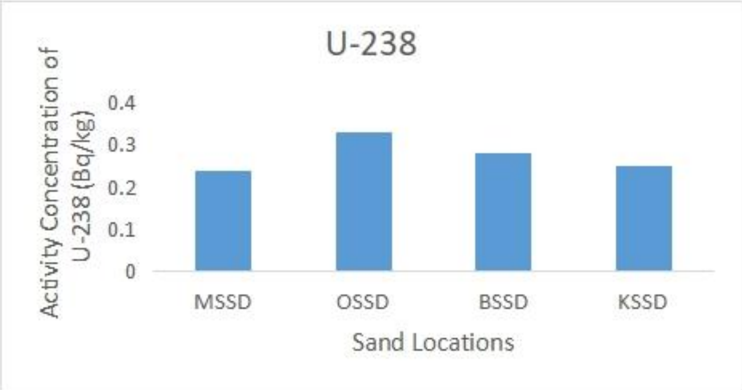

Figure 2: U-238 Activity Concentration in Sharp Sand obtained at different locations in Benue State

Key

MSSD is Makurdi Sharp Sand

OSSD is Otukpo Sharp Sand

BSSD is Buruku Sharp Sand

KSSD is Katsina Ala Sharp

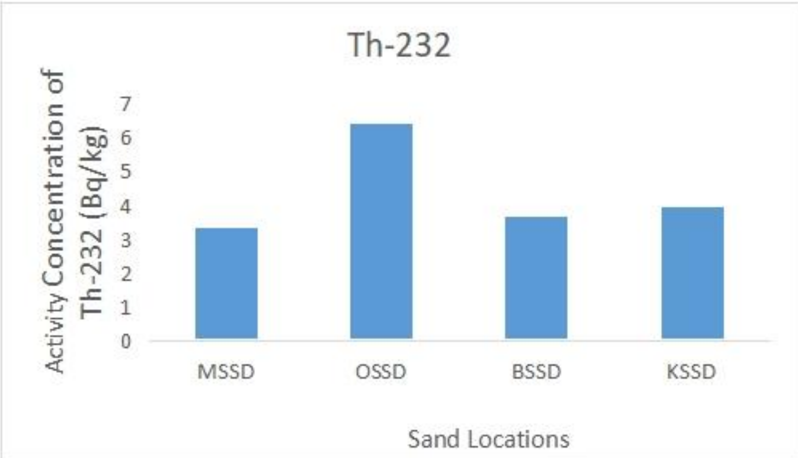

Figure 3: Th-232 Activity Concentration in Sharp Sand obtained at different locations in Benue State

Key

MSSD is Makurdi Sharp Sand

OSSD is Otukpo Sharp Sand

BSSD is Buruku Sharp Sand

KSSD is Katsina Ala Sharp

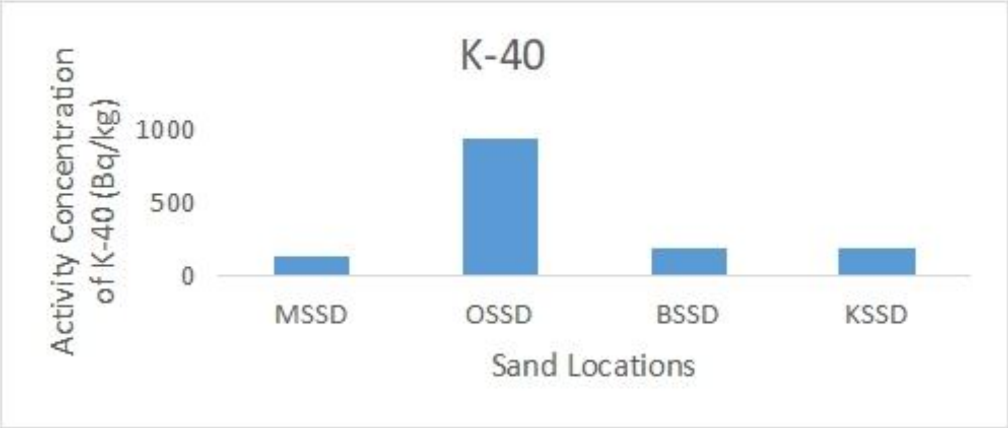

Figure 4: K-40 Activity Concentration in Sharp Sand obtained at different locations in Benue State

Key

MSSD is Makurdi Sharp Sand

OSSD is Otukpo Sharp Sand

BSSD is Buruku Sharp Sand

KSSD is Katsina Ala Sharp

3.1 Comparison of Mean Activity Concentration of Radionuclides in sampled building materials with UNSCEAR Standard.

Mean activity concentration of some radionuclides in selected sharp sand was computed

and the result compared with set standard by UNSCEAR 2000 and is presented in Figure 5

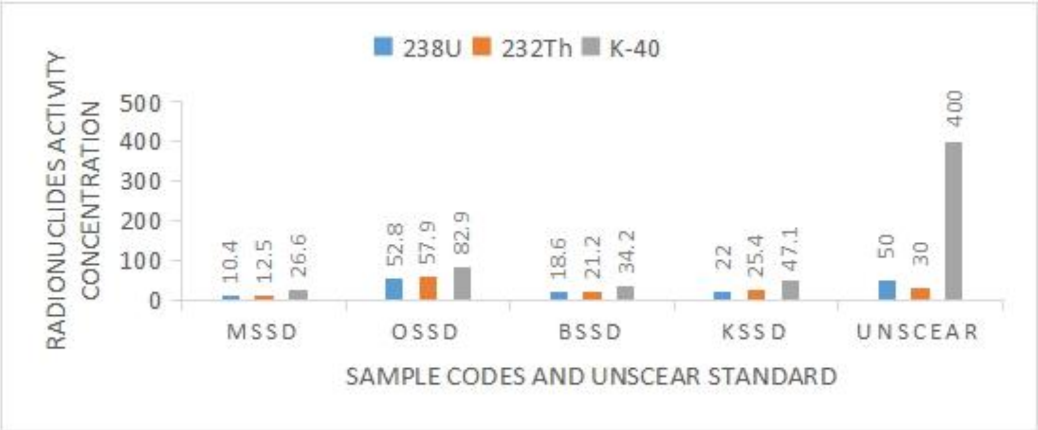

Figure 5: Comparison of mean Activity Concentration of Radionuclides in Sharp Sand with UNSCEAR standard

3.2 Radionuclides Activity Concentration in Sharp Sands in Benue State

The result of the selected radionuclides in sharp sand from four selected locations in Benue State are presented on Table 1

Table 1:Radionuclide Indices of different Sharp Sand used in Benue State

S/no	Sample Code	Absorbed dose $D(\mu Gy/h^{-1})$	Activity con. Index (I)	AEDE (mSv/yr)	H_{ex}	H_{in}	Ra_{eq} (Bq/kg)
1	MSSD	0.12	0.56	0.66	0.82	0.69	146.81
2	OSSD	0.14	1.56	1.89	0.78	0.64	289.37
3	BSSD	0.12	0.92	0.71	0.98	0.78	163.80
4	KSSD	0.13	0.82	0.85	0.98	0.74	174.73
	Average	0.13	0.97	1.03	0.89	0.71	193.68

where;

MSSD is Makurdi Sharp Sand

OSSD is Otukpo Sharp Sand

BSSD is Buruku Sharp Sand and

KSSD is Katsina Ala Sharp Sand.

4. DISCUSSION

4.1 Radionuclides Concentration of Study Samples

The result presented in Figure 2 shows the concentration of 238U in sharp sand samples obtained from four locations in Benue State. A good observation of the figure indicates that 238U concentration is higher (0.33±0.09 Bq/kg) in OSSD sample followed by BSSD (0.28±0.01 Bq/kg), KSSD (0.25±0.03 Bq/Kg) and the lowest concentration (0.24±0.07 Bq/kg) was observed in MSSD sample. These results were far below the set standard of 50 Bq/kg by UNSCEAR, 2000. This result is in line with the findings of Khatun, et al. (2018) who measured and assessed natural radioactivity and radiological hazards in some building materials used in Bangladesh and found that all samples under investigation were within the recommended safety limit of 50 Bq/kg by UNSCEAR, 2000.

The result on Figure 3 shows the concentration of 232Th in samples of sharp sand obtained from four locations in Benue State. The Figure depicts that 232Th concentration was higher (6.43±0.60 Bq/kg) in OSSD sample and (3.96±0.04 Bq/kg), (3.69±0.11 Bq/kg) and (3.35±0.01 Bq/kg) for KSSD, BSSD, and MSSD respectively. These results were below the recommended standard of 30 Bq/kg set by UNSCEAR, 2000. This result agreed with findings of Khatun, et al. (2018) who assessed 232Th concentration in some building materials used in Bangladesh and founds that, all samples under investigation were within the recommended safety limit 30 Bq/kg by UNSCEAR, 2000.

Figure 4 shows the concentration of 40K in sampled sharp sands, the result shows that 40K concentration is higher (946.75±12.21 Bq/kg) in OSSD sample followed by KSSD, BSSD and MSSD with concentrations of 192.44±2.45 Bq/kg, 188.33±2.53 Bq/kg and 137.89±1.38Bq/kg respectively. The result indicates that 40K in OSSD sample is higher than the recommended of 400 Bq/kg by UNSCER, (2000) while that of KSSD, BSSD and MSSD were lower than the set standard.

4.2 Radionuclide Indices of sharp sand used in Benue State

Radionuclide indices of different sharp sand was computed; absorbed dose for each of the sample was within unity and the average result of absorbed dose was obtained to be 0.13 (μGy/h^{-1}). Result of activity concentration index (I) 1.89 (μGy/h^{-1}) for activity concentration index (I) and AEDE respectively. The result of H_{ex}, H_{in} and Ra_{eq} were below permissible limit of 1(Bq/yr) and 370 (Bq/yr) by USEPA (2000).

5. Conclusion

The work assessed the radionuclides activity concentration in some selected building materials used in Benue State. The result obtained for activity concentration in sharp sand sampled indicates that all samples were radiologically safe except OSSD sample in which 40K was above the recommended standard of 400 Bq/kg by UNSCEAR, (2000). Radionuclide indices of selected sharp sand was computed, the result obtained shows that all indices (D, Hex, Hin and Raeq) were below permissible limit of 1 (Bq/yr) by USEPA (2000) which depicts that the selected sharp sand used in Benue State are radiologically safe.

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