Assessment of Natural Radioactivity in Sediments and Groundwater from Selected Areas in Funtua Town, Katsina State, Nigeria

TYONGIGA, S; ATSUE, T; *JOSEPH, E

Department of Physics, Faculty of Physical Sciences, Federal University Dutsin-Ma, Katsina State, Nigeria

*Corresponding Author Email: ejoseph@fudutsinma.edu.ng
*ORCID: https://orcid.org/0000-0002-6916-1641
*Tel: +234 803 625 1745

Co-Authors Email: sundaytyongiga@gmail.com; tatsueter@gmail.com

ABSTRACT: Natural radionuclides, particularly 238U, 232Th, and 40K are the main sources of radiation exposure. Therefore, their detection is key to radiation safety measurement, among others. Therefore, this study is aimed at assessing the natural radioactivity concentrations of 238U, 232Th, and 40K of 15 sediment and water samples from selected locations in Funtua town, Katsina state, Nigeria using gamma spectroscopy NaI (TI) and CR-39 Cn detectors respectively. Data obtained show that, the activity concentrations in the sediment samples were found to range between 11.50 - 61.89, 7.15 – 49.46, and 646.01 – 1368.33 Bq/kg with average activity concentrations of 37.15, 35.66, and 914.73 Bq/kg for 238U, 232Th, and 40K, respectively. These average values exceeded the worldwide values of 25, 25, and 37 Gbq/kg respectively. In water samples, the values of 238U ranged from 0.20 to 36.78 Bq/L (x̄ = 16.12 Bq/L); activity concentration values for 232Th radionuclide ranged from 2.75 Bq/L to 76.90 Bq/L (x̄ = 11.71 Bq/L) and that of 40K radionuclide ranged from 42.28 Bq/L to 179.95 Bq/L (x̄ = 111.81 Bq/L) respectively. These values are higher than the recommended value of 30000 g/L as reported by the EPA. The average activity concentrations of 238U, 232Th, and 40K were found to be higher in the sediment samples than in the water samples. The estimated total annual effective dose AED in the water sample was found to be less than the worldwide values of 0.1mSv/y or 0.2 to 0.8. The excess life cancer risk ELCR of radon in the water ranged from 0.098×10⁻⁸ to 1.808×10⁻⁸ with a mean value of 0.794×10⁻⁸. This value is less than the worldwide limit of 1.0×10⁻⁷. Therefore, the groundwater (wells) in Funtua town is said to be safe based on the effects of the activity concentrations of these natural primordial radionuclides and radon on the environment. However, the need for continuous monitoring should be a priority.

DOI: https://dx.doi.org/10.4314/jasem.v28i6.19

Open Access Policy: All articles published by JASEM are open-access articles and are free for anyone to download, copy, redistribute, repost, translate and read.

Copyright Policy: © 2024. Authors retain the copyright and grant JASEM the right of first publication with the work simultaneously licensed under the Creative Commons Attribution 4.0 International (CC-BY-4.0) License. Any part of the article may be reused without permission provided that the original article is cited.

Cite this Article as: TYONGIGA, S; ATSUE, T; JOSEPH, E. (2024). Assessment of Natural Radioactivity in Sediments and Groundwater from Selected Areas in Funtua Town, Katsina State, Nigeria. J. Appl. Sci. Environ. Manage. 28 (6) 1799-1806

Dates: Received: 21 February 2024; Revised: 22 March 2024; Accepted: 20 April 2024 Published: 09 June 2024

Keywords: Average radium equivalent; Excess life cancer risk; Hazard index; Gamma spectroscopy

Materials from the Earth such as bedrock, sand, and gravel can naturally contain radioactive elements. These materials can dissolve in or absorb water from a variety of sources used for domestic and irrigation purposes (Ahmad et al., 2015). Conversely, other human activities resulting from industrial waste (mining and chemical waste) and agricultural activities (irrigation with polluted water, use of mineral fertilizers, pesticides containing heavy metals and radionuclides, etc) may be discharged into the aquatic environment and eventually, into human bodies through food and drinking water (Flynn and MacGregor, 2002). Such radioactive elements (40K, 232Th, and 238U) from the Earth which are known to have existed in such form for ages before the formation of the Earth are known as primordial radionuclides. They are distinct from other radionuclides owing to the length of their half-lives compared to the lifetime of the Earth. For instance, 40K has a half-life of approximately 1.2 billion years, 232Th...
has a half-life of ≈ 1.5 billion years, and $^{238}\text{U}$ has a half-life of ≈ 4.5 billion years. Cosmic radiation results from the interaction of space radiation with the surface of the Earth and the atmosphere (Aldahan and Possnert, 2003). The cosmogenic radionuclides are useful in the agewise chronological arrangement of the primordial radionuclides. For example, $^{228}\text{Th}$ and $^{238}\text{U}$ are primordial radioactive isotopes that continuously decay to produce radionuclides in the natural decay series. Different kinds of subatomic particles are released together with nuclear change in the decay processes (Faure and Mensing, 2005). Environmental exposure occurs to radionuclides and the nuclide decay of these daughters is a substantial source of radiation dangers, contributing about 80% of the total effective radiation exposure to the environment. This exposure occurs through human activities like the testing of nuclear weapons, unintentional releases from nuclear power plants, reprocessing of nuclear fuel, and numerous other industrial and medical applications. Both naturally occurring and man-made radioactive substances can enter the human body through ingestion and inhalation (WHO, 2011). Thus, it is critical to assess the risk to human health and conduct research on these radionuclides. The most commonly occurring Natural uranium is found in the lithosphere of various rock minerals that are mined to extract uranium known as uranium ores (World Nuclear Association, 2014). Natural leaching of uranium, thorium, and their decay products from rocks can occur as weathered rock particles in soil, sediments, and dust, and can transfer the elements into water systems. Because plants and animals can absorb these elements into their bodies, when isotope levels rise above certain thresholds, they can pose a threat to the environment. Although the amount of nuclear research and applications being conducted in Nigeria, along with the worldwide interest in measuring natural background radiation, have not yet led to the determination of the natural radioactivity level for the majority of her environments. Arogunjo et al., (2009) reported that certain earlier studies on environmental radioactivity in Bakori, a border community to Funtua town, focused on measuring naturally occurring radionuclides in soil and rock samples for particular locations had comparatively higher radioactivity levels (Jibril et al., 2014; Jibril et al., 2016; Bashir et al., 2013). A report of Rn-222 assessment for selected sources of water in Dutsin-ma was given in 2018 (Joseph, et al., 2018).

The outcomes of this study would establish a baseline of scientific data regarding the naturally occurring radioactivity levels in Funtua town which can be used for subsequent environmental monitoring and assessment in the event of accidental local or global releases of radioactive materials. Such information may also be utilized to evaluate the health effects of natural radiation in the surroundings and to confirm and plan for potential radiation-related issues in the local community. Therefore, this study is aimed at assessing the natural radioactivity concentrations of $^{238}\text{U}$, $^{232}\text{Th}$, and $^{40}\text{K}$ of 15 sediment and water samples from selected locations in Funtua town, Katsina state, Nigeria.

**MATERIALS AND METHODS**

**Samples Preparation:** The research area covered Funtua town, a total length of 2 km radius from which samples were randomly collected. Fifteen sediments and groundwater samples were collected at a depth of between 10 – 20 cm each from October to November of 2022. The reason for the random sampling application was to enhance the statistical sensitivity of the sampling (IAEA, 2004). The samples were collected in polythene bags and placed in 1 liter acidified (HNO$_3$) plastic containers, then labeled. The sediment samples were dried at a temperature of 150 °C for 7 days, ground into fine powdered and sieved, then packed into polythene bags, weighed at 750 g each, and sealed. The water samples were also sieved and stored in separate plastic containers, and both were taken to the laboratory. The research sampling sites were mapped using the coordinates of the sample points taken with GPS coordinate app as shown in Figure 1.

**Spectroscopic Analysis of Gamma-Rays:** The Gamma-ray spectrometer utilized in this study is a NaI(TI) scintillation detector system manufactured by CANBERRA. Due to the low natural activity of radionuclides in water, counting was done for ten hours. The MCA algorithm was used to measure the spectrum and compute the area under the photo peaks. The radionuclides in the natural decay series of $^{238}\text{U}$ and $^{232}\text{Th}$, as well as the non-series $^{222}\text{Rn}$, were identified as the source of the prominent photo peak seen in the sample’s spectrum. The concentration of the end-series nuclides $^{226}\text{Ra}$ (a decay series of naturally occurring radionuclides headed by $^{238}\text{U}$) and $^{222}\text{Rn}$ (a decay series of naturally occurring radionuclides headed by $^{232}\text{Th}$) were then ascertained using the transition lines of 1764.5 KeV of 214Bi and 2614.7 KeV of $^{303}\text{TI}$, separately. A library of potential radionuclides was matched to different gamma energy peaks using the spectrum analysis program, SAMPO 90 (Ahmed, 2004; Nwankwo, 2012; Nasirian et al., 2008).

The procedure to measure the activity concentrations of the radon in the samples in this work is the Can

**TYONGIGA, S; ATSUE, T; JOSEPH, E.**
plastic detector which was also obtained at the National Institute of Radiation Protection and Research laboratory, Ibadan. The plastic Can distribution technique was used to determine the concentrations of radon in sediments and water. A measured amount of sample was added to the Can's base, and it was sealed for thirty days to achieve equilibrium between the decay series of radium and radon. Subsequently, the UK-issued CR-39 nuclear track detector, measuring 500 µm in thickness and 1.36g/cm², was divided into a two-dimensional area measuring 1 by 1 cm and affixed within the Can's cover (refer to Figure 3). Following a sixty-day exposure period, the detector was cleaned with sodium hydroxide and dried in the air after being heated to a temperature of roughly 60 °C for 3300 seconds using distilled water. A model 400Y microscope was employed to record the track density. The following formulae were used to determine the density of the track (D) in the samples (Klement, 1982).

\[
\text{Track Density (D)} = \frac{\text{Average number of total track (Nave)}}{\text{area of field view (A)}} \quad (1)
\]

Radon concentration was measured using the relationship shown in equation 2.1 (Jebur et al., 2014).

\[
C_x = \frac{C_s}{\rho_s} \quad (2)
\]

Where \( C_x, C_s \) are radon exposure (Bq/m³) for standard and sample respectively, \( \rho_x, \rho_s \) are track density, for standard and sample respectively, and

\[
C_x = C_s \frac{\rho_x}{\rho_s} \quad (3)
\]

**Parameters in Sediments:** Radium equivalent activity \( Ra_{eq} \): The radium equivalent activity is defined by UNSCEAR (2000) as the following equation:

\[
Ra_{eq} (Bq/Kg) = A_U + 1.42A_{Th} + 0.077A_K \quad (4)
\]

Where the conversion rates are 1, 1.42, and 0.077. \(^{238}U, ^{232}Th,\) and \(^{40}K\), which results in the same gamma dose rate at the maximum allowable \( Ra_{eq} \) of 370 Bq/kg.

\( Ra_{eq} \) is measured in Bq/kg, and its definition assumes that 370 Bq/kg for \(^{226}Ra\) uniformly distributed in any environmental sample can perform in the annual effective dose of 1 mSv at 1 m above ground level, and \( A_U, A_{Th}, \) and \( A_K \) are activity concentrations of Uranium, thorium, and potassium, respectively.

**Hazard index (H):** The following equation can be used to calculate the Hazard index: (UNSCEAR, 2000)

\[
H_{ex} = \frac{Ra_{eq}}{370} (Bq/Kg) \quad (5)
\]

TYONGIGA, S; ATSUE, T; JOSEPH, E.
H_{ex} = \frac{A_R}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \ (Bq/Kg) \ \ (6)

Where \( H_{ex} \) and \( H_{in} \) are external and internal hazards, respectively.

Annual effective dose equivalent (AED): The annual effective dose equivalent (AED_{out}) and (AED_{in}) are calculated from the following equations according to UNSCEAR (2000).

\[
\text{AED}_{\text{out}} (\mu Sv/y) = D_{\text{out}}(\text{nGy/h}) \times 8760(\text{h/y}) \\
\times 0.20 \times 0.7(\text{SvG/y}) \\
\times 10^{-3} \ \ (7)
\]

\[
\text{AED}_{\text{in}} (\mu Sv/y) = D_{\text{in}}(\text{nGy/h}) \times 8760(\text{h/y}) \times 0.80 \\
\times 0.7(\text{SvG/y}) \times 10^{-3} \ \ (8)
\]

Excess lifetime cancer risk (ELCR): Using Eq. (9), the excess lifetime cancer risk (ELCR) was calculated from the annual effective dose equivalent, (Binesh et al., 2010).

\[
\text{ELCR} = \text{AED}_{\text{out}} \times DL \times RF \ \ (9)
\]

Where DL and RF are the public’s lifetime (70 years) and risk factor (0.05 Sv⁻¹) for radon effects from low-level radiations, respectively. The risk factor was defined by ICRP (2012) as a fatal cancer risk per Sievert and was assigned a value of 0.05. (Taskin et al., 2009).

Parameters in Water Samples

Annual effective dose (AED): The annual effective dose (AED_{in} and AED_{inh}) as radon ingestion and inhalation were calculated for the individual consumer due to radon intake from drinking water consumption in units (Sv/y) using the following Eqs. (10 and 11) (ICRP, 1989, 1994):

\[
\text{AED}_{\text{ing}} (\mu Sv/y) = CR_{n} \times CR_{w} \times DC_{w} \ \ (10)
\]

Where \( CR_{n} \) is the radon concentration in water in (Bq/L), \( CR_{w} \) is the annual drinking water intake for adults, which is 730 L/y, and \( DC_{w} \) is the ingested dose conversion factor, which is 5 \text{ \times 10^{-9}} Sv/BL (UNSCEAR, 2000) and

\[
\text{AED}_{\text{inh}} (\mu Sv/y) = CR_{a-w} \times R_{a-w} \times EqF \\
\times ExT 9n \text{ Sv [KBqh/L]} \ \ (11)
\]

Where \( CR_{n-w} \) denotes the average radon concentration in water in kBq/L. The air-water concentration ratio (10⁻⁴) is represented by Ra-w. EqF (0.4) represents the equilibrium factor between indoor radon and its short-lived offspring. ExT denotes the exposure time to this concentration in hours (assumed to be 7000 hours per year), and 9n Sv denotes the dose conversion factor (kBq/L).

Excess cancer risk in water samples: Radiological risk based on uranium activity concentration per unit weight of radiation, Ac is uranium activity concentration calculated using equation (4.13) by Virk, (2016):\[
\text{ECR} = Ac \times R \ \ (12)
\]

Where R is a risk (per Bq/L), and ECR is the excess of cancer risk. The risk factor R associated with uranium ingestion from water is calculated by multiplying the risk coefficient of Uranium (1.19 10⁻⁹) Bq-L for mortality by the risk coefficient of per capital activity intake (I). Where I is calculated as a product of a life expectancy of 63.7 years, i.e. 3250 days, and daily water consumption of 4.05 L days (EPA, 2000). The risk factor value will be R = r I = 1.17 10⁻⁹ Bq 94162.5 L =1.12 10⁻⁴ LBq-1 because 4.05 L days -1 2325 days =94162.5 L.

RESULTS AND DISCUSSION

Activity Concentrations of ²³⁸U, ²³²Th, and ⁴⁰K Radionuclides in Sediments and Water Samples: The activity concentrations of ²³⁸U, ²³²Th, and ⁴⁰K radionuclides in the sediments and water samples have been identified and measured with results shown in Table 1. In this study, the activity concentrations in the sediment samples were found to range between 11.50 - 61.89, 7.15 - 69.46, and 646.01 - 1368.33 Bq/kg with average activity concentrations of 37.15, 35.66, and 914.73 Bq/kg for ²³⁸U, ²³²Th, and ⁴⁰K, respectively. These average values exceeded the worldwide values of 25, 25, and 370 Bq/kg respectively as reported by (UNSCEAR, 2000). Such results posed a threat to the sediment samples. In water samples, the values of ²³⁸U ranged from 0.20 to 36.78 Bq/L, with an average concentration of 16.12 Bq/L. The maximum value of 36.76 Bq/L was recorded in sample W₁₀, which is higher compared to the worldwide value of 10.0 Bq/L as reported by WHO (2011). The activity concentration values for ²³²Th radionuclide ranged from 2.75 Bq/L to 76.90 Bq/L, with an average value of 11.71 Bq/L. These values are higher than the recommended value of 1.00 Bq/L as defined by WHO and the values for ⁴⁰K radionuclide ranged from 42.28 Bq/L to 179.95 Bq/L, with an average value of 111.81 Bq/L respectively. These values are higher than the recommended value of 30000 g/L as reported by the EPA, (2012).
In both water and sediment samples, K-40 had the highest activity concentration owing to its abundance in the earth’s crust as a naturally occurring radionuclide (Ugbede and Akpolile, 2019). It was also noticed that the activity concentrations of the radionuclides in water samples on average were less than those in the sediment samples consistent with the results obtained by Ibukunle et al., (2018) for water and sediment samples in Ikogosi Spring. The activity concentrations of the radionuclides were observed to vary from sample to sample.

This variation may be attributed to the differences in the physical, chemical, and geochemical properties of the different sample locations as asserted by Ugbede and Akpolile, (2019). The average activity concentrations in the sediment samples were found to be lower for $^{238}$U and $^{232}$Th radionuclides when compared with the results of Ugbede and Akpolile, (2019) from the South-South region of Nigeria. However, the K-40 radionuclide result was observed to be higher compared to that of Ugbede and Akpolile. Findings by Nginga et al., (2012) from North-Central Nigeria revealed that our present work possesses higher values of the activity concentration for all the radionuclides investigated.

The differences in the physical, chemical, and geochemical properties of the locations can be factors contributing to these noticeable variations.

**Assessment of Radiological Hazards in Sediments Samples:** Assessment of radiological hazards which includes radium equivalent $R_{eq}$ external and internal hazard indices were performed for the sediment samples and the results are shown in Table 2.

The results showed that $R_{eq}$ values ranged from 122.41 to 222.05 Bq/kg, with an average value of 199.73 Bq/kg. The values were observed to be lower than the recommended limit of 370 Bq/kg as reported by (UNSCEAR, 2000). The quantity that compares the activity concentration of radionuclides contained in a material is provided by the radium equivalent index ($R_{eq}$). This quantity results from the fact that radionuclide concentrations in sedimented materials cannot be uniform, thus finding a single quantity accounting for the associated hazards in the primordial radionuclides is important. The results showed less hazard risk as the $R_{eq}$ values including its average value were within the permissible range. The results of $R_{eq}$ values ranging from 199.13 to 318.39 Bq/kg obtained by Ugbede and Akpolile, (2019) from the South-South region of Nigeria were noticed to be slightly higher than the findings of this study.

**TYONGIGA, S; ATSUE, T; JOSEPH, E.**
The calculated external hazard index $H_{ex}$ ranged from 0.295 to 0.600, with a mean value of 0.429. The external and internal hazard indices account for the hazards arising from being exposed to the external and internal radiations that occur from primordial radionuclides in sediments. The internal hazard index $H_{in}$ ranged from 0.335 to 0.730, with a mean value of 0.527. These values are lower than the UNSCEAR (2000) recommended global limit of 1.00.

The highest values of $H_{ex}$ and $H_{in}$ indices are both recorded at Sample $S_2$, which has the activity concentration of both radionuclides to be maximum. The results obtained showed no hazard threat as the values for all the samples were less than unity, the safe limit for the hazard indices.

These results compared to that of Ugbede and Akpolile, (2019) from the South-South region of Nigeria were in a much safer range. Other radiological hazard indices such as absorbed dose rate, AED, and excess cancer risk in sediment samples were calculated and presented in Table 3. The values of outdoor annual effective dose equivalent (AEDout) in sediments ranged from 68.04 to 132.03 µSv/y, with an average value of 89.654.7 µSv/y, which is higher than the global average of 70 µSv/y. While the values of the indoor annual effective dose equivalent (AEDin) ranged from 128.60 to 242.24 µSv/y with a mean value of 147.55±19.03 µSv/y, which is less than the global limit of 450 µSv/y reported by UNSCEAR (2000). It should be noted that the estimated values of annual effective dose equivalent are on the higher side.

The excess lifetime cancer risk, ELCR for the outdoor and indoor exposure calculated for sediment samples varied between 0.20×10^3 to 0.462×10^3 with an average value of 0.302×10^3. The value is greater than the UNSCEAR, (2000) global limit of 0.29×10^3. The indoor lifetime cancer risk values ranged between 0.459×10^3 to 0.848×10^3, with a value of 0.633×10^3. This value is greater than the set limit of 0.16×10^3, and the average estimated lifetime cancer risk value was obtained as 0.962×10^3, which is lower than the average standard value of 1.45×10^3 as reported by UNSCEAR, (2000). Again, it should be noted that the estimated values of excess lifetime cancer risk are on the higher side indicating a cancer threat to the environment.

### Table 3. The measured radiological hazards indices; absorbed dose rate, AED, and excess cancer risk in for sediment samples in this study.

<table>
<thead>
<tr>
<th>S/ID</th>
<th>$D_{out}$ (nGy/h)</th>
<th>$D_{in}$ (nGy/h)</th>
<th>AED$_{out}$ (µSv/y)</th>
<th>AED$_{in}$ (µSv/y)</th>
<th>ELCR$_{out}$ ×10$^{-3}$</th>
<th>ELCR$_{in}$ ×10$^{-3}$</th>
<th>Total ×10$^{-3}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S_1$</td>
<td>104.88</td>
<td>104.88</td>
<td>128.60</td>
<td>128.60</td>
<td>0.238</td>
<td>0.450</td>
<td>0.688</td>
</tr>
<tr>
<td>$S_2$</td>
<td>197.52</td>
<td>197.52</td>
<td>132.03</td>
<td>132.03</td>
<td>0.462</td>
<td>0.848</td>
<td>1.310</td>
</tr>
<tr>
<td>$S_3$</td>
<td>149.59</td>
<td>149.59</td>
<td>183.46</td>
<td>183.46</td>
<td>0.344</td>
<td>0.662</td>
<td>0.986</td>
</tr>
<tr>
<td>$S_4$</td>
<td>135.56</td>
<td>135.56</td>
<td>166.25</td>
<td>166.25</td>
<td>0.200</td>
<td>0.582</td>
<td>0.782</td>
</tr>
<tr>
<td>$S_5$</td>
<td>176.54</td>
<td>176.54</td>
<td>216.51</td>
<td>216.51</td>
<td>0.397</td>
<td>0.758</td>
<td>1.155</td>
</tr>
<tr>
<td>$S_6$</td>
<td>113.79</td>
<td>113.79</td>
<td>139.55</td>
<td>139.55</td>
<td>0.256</td>
<td>0.488</td>
<td>0.744</td>
</tr>
<tr>
<td>$S_7$</td>
<td>117.78</td>
<td>117.78</td>
<td>144.45</td>
<td>144.45</td>
<td>0.276</td>
<td>0.506</td>
<td>0.782</td>
</tr>
<tr>
<td>$S_8$</td>
<td>141.02</td>
<td>141.02</td>
<td>172.95</td>
<td>172.95</td>
<td>0.323</td>
<td>0.605</td>
<td>0.928</td>
</tr>
<tr>
<td>$S_9$</td>
<td>167.37</td>
<td>167.37</td>
<td>205.26</td>
<td>205.26</td>
<td>0.378</td>
<td>0.718</td>
<td>1.096</td>
</tr>
<tr>
<td>$S_{10}$</td>
<td>123.77</td>
<td>123.77</td>
<td>151.79</td>
<td>151.79</td>
<td>0.284</td>
<td>0.531</td>
<td>0.815</td>
</tr>
<tr>
<td>$S_{11}$</td>
<td>177.21</td>
<td>177.21</td>
<td>217.33</td>
<td>217.33</td>
<td>0.408</td>
<td>0.761</td>
<td>1.169</td>
</tr>
<tr>
<td>$S_{12}$</td>
<td>151.42</td>
<td>151.42</td>
<td>185.70</td>
<td>185.70</td>
<td>0.341</td>
<td>0.650</td>
<td>0.991</td>
</tr>
<tr>
<td>$S_{13}$</td>
<td>150.15</td>
<td>150.15</td>
<td>192.54</td>
<td>192.54</td>
<td>0.351</td>
<td>0.674</td>
<td>1.025</td>
</tr>
<tr>
<td>$S_{14}$</td>
<td>123.71</td>
<td>123.71</td>
<td>151.72</td>
<td>151.72</td>
<td>0.274</td>
<td>0.531</td>
<td>0.805</td>
</tr>
<tr>
<td>$S_{15}$</td>
<td>175.20</td>
<td>175.20</td>
<td>214.87</td>
<td>214.87</td>
<td>0.404</td>
<td>0.752</td>
<td>1.156</td>
</tr>
<tr>
<td>AV</td>
<td>147.89</td>
<td>147.89</td>
<td>147.55</td>
<td>147.55</td>
<td>0.302</td>
<td>0.633</td>
<td>0.962</td>
</tr>
<tr>
<td>UNSCEAR(2000)</td>
<td>59</td>
<td>84</td>
<td>70</td>
<td>450</td>
<td>0.29</td>
<td>0.16</td>
<td>1.45</td>
</tr>
</tbody>
</table>

The radon concentrations in water samples, the annual effective dose ingestion AEDing, the excess lifetime cancer risk ELCR are presented in Table 4.6, in which the estimated annual effective dose due to ingestion ranged from 1.320 to 24.3565 µSv/y, with an average value of 10.70551.47 µSv/y. The total effective dose per year was 18.097 µSv/y. This result indicates that the total annual effective dose resulting from $Rn$-222 in intake water is significantly lower than the permissible limit of 0.1 mSv/y or 0.2-0.8 as specified by the Environmental Protection Agency (EPA, 2000), and the United Nations Scientific Committee on Environmental Research (UNSCEAR, 2012), and the annual effective dose inhalation ranged from 0.9148 to 16.8160 µSv/y, with an average value of 7.39 ±1.4 µSv/y. This value is less than the global limit of 0.1 mSv/y, or 0.2-0.8. While the excess lifetime cancer risk ranged from 0.0983-1.8084×10$^{-4}$ with an average value of 0.7948×10$^{-4}$. The value is also lower than the worldwide recommended value of 1.0×10$^{-4}$ (EPA, 2012).
Assessment of Natural Radioactivity in Sediments and Groundwater from Selected Areas in Funtua, Katsina State, Nigeria.

K (2004) Natural Radioactivity of Sediments and Groundwater from Selected Areas in Funtua, Katsina State. The measured radium equivalent activities Raeeq were lower than the recommended values. Both the external and internal hazards (Hex, Hin) indices were below the risk thresholds. The total average value of the annual equivalent dose Raeeq was 4.085 ± 1.28 Bq/L. The measured radon concentrations in sediments and water samples to be below the allowed maximum of 0.2 mSv/y or 2.933 ± 1.28 Bq/L. The overall concentrations of the radionuclides in groundwater (wells), with fifteen samples of sediment and water from selected wells in Funtua, Katsina State. The measured radon concentration and toxic elements in drinking water and Irrigation waters and its implications in Nigeria with elevated activity. J. Environ. Radioact. 100(3):232-40. DOI: 10.1016/j.jenvrad.2008.12.004

Conclusion: The current study aimed at assessing the naturally occurring radionuclides in sediment and groundwater (wells), with fifteen samples of sediment and water collected from some selected wells in Funtua, Katsina State. The measured radium equivalent activities Raeeq were lower than the recommended values. Both the external and internal hazards (Hex, Hin) indices were below the risk thresholds. The total average value of the annual effective dose equivalent AED was lower than the UNSCEAR (2000) and WHO (2011) limit for members of the public of 1 mSv/y. The results revealed radon concentrations in sediments and water samples to be below the allowed maximum contamination level. The overall values of excess lifetime cancer risk in sediment and water were less than the recommended level of 1.45 × 10⁻³ and 1.0 × 10⁻⁴ respectively. The overall concentrations of the radionuclides and radon sediments and groundwater (wells) in Funtua town pose no serious health risks, and thus the study area is considered safe for use by the local population.

REFERENCES


Arogunjo AM; Lirigie VH; Giussani A; Leopold K; Gerstmann U; Veronese I; Oehb U (2009). Uranium and Thorium in soil minerals, sands, water, and food samples in tin mining areas in Nigeria with elevated activity. J. Environ. Radioact. 100(3):232-40. DOI: 10.1016/j.jenvrad.2008.12.004


Table 4: The measured activity concentration of ²²²Rn, AEDinh and AEDing, of the water samples

<table>
<thead>
<tr>
<th>S/ID</th>
<th>P(track/mm²)</th>
<th>Rₐ(Bq/L)</th>
<th>AEDing (µSv/y)</th>
<th>AEDinh (µSv/y)</th>
<th>Cd(Bq/L)</th>
<th>Ac(Bq/L)</th>
<th>ECR×10⁻⁴</th>
<th>Eₐ(mBq/m³h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>W₁</td>
<td>601.23</td>
<td>0.602</td>
<td>2.1973</td>
<td>1.5170</td>
<td>11.794</td>
<td>0.1457</td>
<td>0.11609</td>
<td>0.449</td>
</tr>
<tr>
<td>W₂</td>
<td>362.58</td>
<td>0.363</td>
<td>1.3250</td>
<td>0.9148</td>
<td>7.1120</td>
<td>0.0878</td>
<td>0.0993</td>
<td>0.271</td>
</tr>
<tr>
<td>W₃</td>
<td>261.18</td>
<td>2.615</td>
<td>9.5448</td>
<td>6.5898</td>
<td>51.231</td>
<td>0.6327</td>
<td>0.7086</td>
<td>1.952</td>
</tr>
<tr>
<td>W₄</td>
<td>434.88</td>
<td>4.354</td>
<td>15.8921</td>
<td>10.9721</td>
<td>85.300</td>
<td>1.0535</td>
<td>1.1799</td>
<td>5.414</td>
</tr>
<tr>
<td>W₅</td>
<td>489.21</td>
<td>4.898</td>
<td>17.8777</td>
<td>12.3430</td>
<td>95.958</td>
<td>1.1852</td>
<td>1.3274</td>
<td>3.655</td>
</tr>
<tr>
<td>W₆</td>
<td>5397.52</td>
<td>5.404</td>
<td>19.7246</td>
<td>13.6181</td>
<td>105.871</td>
<td>1.3076</td>
<td>1.4645</td>
<td>4.033</td>
</tr>
<tr>
<td>W₇</td>
<td>122.55</td>
<td>1.227</td>
<td>4.4786</td>
<td>3.0920</td>
<td>24.038</td>
<td>0.2968</td>
<td>0.3324</td>
<td>0.916</td>
</tr>
<tr>
<td>W₈</td>
<td>134.43</td>
<td>1.346</td>
<td>4.9129</td>
<td>3.3919</td>
<td>26.369</td>
<td>0.3256</td>
<td>0.3647</td>
<td>1.005</td>
</tr>
<tr>
<td>W₁₀</td>
<td>674.19</td>
<td>0.675</td>
<td>2.4638</td>
<td>1.701</td>
<td>13.224</td>
<td>0.1633</td>
<td>0.1829</td>
<td>0.504</td>
</tr>
<tr>
<td>W₁₁</td>
<td>209.55</td>
<td>2.098</td>
<td>7.6577</td>
<td>5.2870</td>
<td>41.102</td>
<td>0.5076</td>
<td>0.5685</td>
<td>1.566</td>
</tr>
<tr>
<td>W₁₂</td>
<td>378.44</td>
<td>3.789</td>
<td>13.8299</td>
<td>9.5483</td>
<td>74.231</td>
<td>0.9116</td>
<td>1.0226</td>
<td>2.828</td>
</tr>
<tr>
<td>W₁₃</td>
<td>409.39</td>
<td>4.085</td>
<td>14.9103</td>
<td>10.2942</td>
<td>80.301</td>
<td>0.9918</td>
<td>1.1108</td>
<td>3.049</td>
</tr>
<tr>
<td>W₁₄</td>
<td>1241.55</td>
<td>2.933±1.28</td>
<td>10.7055±1.48</td>
<td>7.3912±1.4</td>
<td>57.4822</td>
<td>0.7099</td>
<td>0.7947</td>
<td>2.356</td>
</tr>
<tr>
<td>EPA</td>
<td>11 Bq/L</td>
<td>0.1 mSv/y</td>
<td>0.2-0.8</td>
<td>0.2-0.8</td>
<td>1.0×10⁻⁴</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TYONGIGA, S; ATSUE, T; JOSEPH, E.
Assessment of Natural Radioactivity in Sediments and Groundwater from Selected……


Jibiri NN; Isinkaye MO; Bello IA; Olaniyi PG (2016). Dose assessments from the measured radioactivity in soil, rock, clay, sediment, and food crops samples of an elevated radiation area in South-Western Nigeria. Environ Earth Sci., 75(2), 107. DOI: https://doi.org/10.1007/s12665-015-4819-3


Njinga RL; Jonah A; Oladipo MOA; Ewa IOB; Alfa B (2012). Use of K0-ENAA technique for evaluation of Thorium, Uranium, and potassium in sediments for archaeometry studies. J. sci. Tech. 1(8) 391-99


Ugbede FO; Akpolile AF (2019). Determination of Specific Activity of $^{238}$U, $^{232}$Th, and $^{40}$K and Radiological Hazard Assessment of Tuomo River Sediments in Burutu, Delta State, Nigeria. J. Appl. Sci. Environ. Manage. Vol. 23 (4) 727-733. DOI: https://dx.doi.org/10.4314/jasem.v23i4.24


TYONGIGA, S; ATSUE, T; JOSEPH, E.