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

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ABSTRACT: Natural radionuclides, particularly ^{238}U, ^{232}Th, and ^{40}K 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 ^{238}U, ^{232}Th, and ^{40}K of 15 sediment and water samples from selected locations in Funtua town, Katsina state, Nigeria using gamma spectroscopy NaI (TI) and CR-39 Can detectors respectively. Data obtained show that, 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 ^{238}U,^{232}Th, and ^{40}K, respectively. These average values exceeded the worldwide values of 25, 25, and 370 Bq/kg respectively. In water samples, the values of 238U ranged from 0.20 to 36.78 Bq/L ($\bar{x} = 16.12\ Bq/L$); activity concentration values for 232Th radionuclide ranged from 2.75 Bq/L to 76.90 Bq/L ($\bar{x} = 11.71\ Bq/L$) and that of 40K radionuclide ranged from 42.28 Bq/L to 179.95 Bq/L ($\bar{x} = 111.81\ Bq/L$) respectively. These values are higher than the recommended value of 30000 g/L as reported by the EPA. The average activity concentrations of ^{238}U,^{232}Th, and ^{40}K 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 0.0983×10^{-4} to 1.8084×10^{-4} with a mean value of 0.7949×10^{-4}. This value is less than the worldwide limit of 1.0×10^{-4}. 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.

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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 (^{40}K, ^{232}Th, and ^{238}U) 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, ^{40}K has a half-life of approximately 1.2 billion years, ^{232}Th

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has a half-life of ≳1.5 billion years, and ^{238}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, ^{232}Th and ^{238}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}U, ^{232}Th, and ^{40}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 ^{0}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}U and ^{232}Th, as well as the non-series ^{222}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}Ra (a decay series of naturally occurring radionuclides headed by ^{238}U) and ^{222}Rn(a decay series of naturally occurring radionuclides headed by ^{232}Th) were then ascertained using the transition lines of 1764.5 KeV of 214Bi and 2614.7 KeV of ^{208}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

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/cm^3, 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 ^{0}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).

$$\text{Track Density (D)} = \frac{Average\ numbre\ of\ total\ track\ (Nave)}{area\ of\ field\ view\ (A)} \qquad (1)$$

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

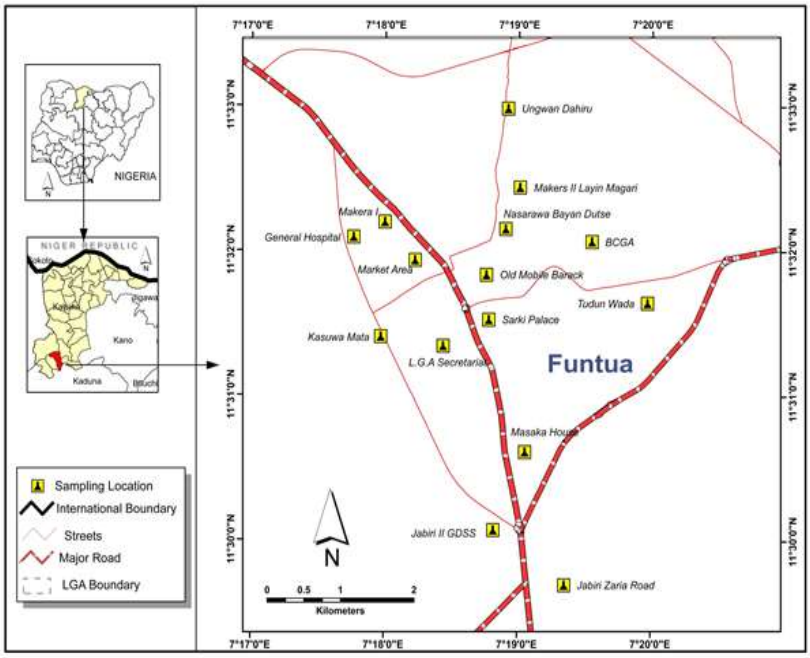

Fig 1: The Map of the study Area showing sampling sites

$$\frac{C_x}{\rho_x} = \frac{C_s}{\rho_s} \qquad (2)$$

Where C_s, C_x; are radon exposure (Bq/m^3) for standard and sample respectively, ρ_s, ρ_x are track density, for standard and sample respectively, and

$$C_x = C_s \frac{\rho_x}{\rho_s} \qquad (3)$$

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

$$Ra_{eq}(Bq/Kg) = A_U + 1.42A_{Th} + 0.077A_K \qquad (4)$$

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)

$$H_{ex} = \frac{Ra_{eq}}{370}\ (Bq/Kg) \qquad (5)$$

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

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

Annual effective dose equivalent (AED): The annual effective dose equivalent (AEDout) and (AEDin) are calculated from the following equations according to UNSCEAR (2000).

$$\mathrm{AED_{out}}(\mu Sv/y) = \mathrm{D_{out}}(nGy/h) \times 8760(h/y) \times 0.20 \times 0.7(SvG/y) \times 10^{-3} \quad (7)$$

$$\mathrm{AED_{in}}(\mu Sv/y) = \mathrm{D_{\boldsymbol{in}}}(nGy/h) \times 8760(h/y) \times 0.80 \times 0.7(SvG/y) \times 10^{-3} \quad (8)$$

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).

$$ELCR = \mathrm{AED_{out}} \times DL \times RF \quad (9)$$

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 ($\mathrm{AED_{ing}}$ and $\mathrm{AED_{inh}}$) 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):

$$\mathrm{AED_{ing}}(\mu Sv/y) = CR_n \times CR_w \times DC_w \quad (10)$$

Where CRn 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 $5 \times 10^{-9}\ Sv/BL$ (UNSCEAR, 2000) and

$$\mathrm{AED_{inh}}(\mu Sv/y) = CR_{n-w} \times R_{a-w} \times EqF \times ExT\ 9n\ Sv\ [KBqh/L] \quad (11)$$

Where CRn-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 (kBqh/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):

$$ECR = Ac \times R \quad (12)$$

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-1 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 ^{238}U, ^{232}Th, and ^{40}K Radionuclides in Sediments and Water Samples: The activity concentrations of ^{238}U, ^{232}Th, and ^{40}K 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 914.73Bq/kg for ^{238}U, ^{232}Th, and ^{40}K, 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 ^{238}U 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 W_{10}, which is higher compared to the worldwide value of 10.0 Bq/L as reported by WHO, (2011). The activity concentration values for ^{232}Th 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 ^{40}K 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).

Table 1: Measured activity concentration of ^{238}U, ^{232}Th, and ^{40}K in sediments and water samples of the sampling sites.

Sediment Samples				Water Samples			
S/ID	**^{238}U (Bqkg^{-1})**	**^{232}Th (Bq/kg)**	**40K (Bq/kg)**	**S/ID**	**U-238 (Bq/L)**	**Th-232 (Bq/L)**	**K-40 (Bq/L)**
S_1	23.88± 2.63	16.37 ± 0.95	801.02±39.82	W_1	3.32 ± 0.2	3.53 ± 0.19	116.62±5.63
S_2	48.10 ± 4.73	73.73 ± 4.19	890.97±41.95	W_2	0.2 ± 0.02	3.86 ± 0.22	152.89±7.74
S_3	33.72 ± 3.71	35.13 ± 2.05	986.77±48.87	W_3	14.42±1.11	6.95±0.39	142.87±6.89
S_4	11.50 ± 1.49	41.91 ± 2.40	973.8 ± 48.33	W_4	24.33±1.84	3.71±.0.21	92.85±4.48
S_5	42.76 ± 4.41	69.46 ± 3.96	750.6 ± 37.51	W_5	27.79±3.24	76.90±4.48	63.98±3.24
S_6	36.92 ± 3.89	25.00 ± 1.44	646.01±32.04	W_6	-	-	-
S_7	19.04 ± 2.20	30.56 ± 1.75	822.77±40.79	W_7	29.79±3.42	5.88±0.34	42.28±2.14
S_8	32.27 ± 3.43	31.24 ± 1.79	950.17±46.85	W_8	6.82±0.83	9.61±0.56	179.95±9.07
S_9	55.94 ± 5.70	34.83 ± 2.0	957.91±47.33	W_9	7.42±0.59	7.21±0.40	165.47±7.98
S_{10}	25.87 ± 2.95	26.69 ± 1.53	871.78±43.27	W_{10}	36.78±3.86	15.34±0.89	94.45±4.84
S_{11}	28.73 ± 3.04	36.32 ± 2.08	1368.33±67.17	W_{11}	-	-	-
S_{12}	54.20 ± 5.16	31.11 ± 1.79	831.35±41.26	W_{12}	3.72±0.3	5.10±0.28	108.75±5.24
S_{13}	61.89 ± 6.04	27.03 ± 1.55	868.27 ± 42.88	W_{13}	11.57±0.89	4.59±0.26	148.68±7.17
S_{14}	40.81 ± 4.66	7.15 ± 0.42	966.69 ± 47.77	W_{14}	20.89±1.64	6.79±0.38	77.61±3.75
S_{15}	41.56 ± 4.21	48.34 ± 2.77	1034.47±51.06	W_{15}	22.52±1.77	2.75±0.15	67.12±3.24
Av	37.15 ± 3.88	35.66 ± 2.04	914.73 ± 45.11	A_V	16.12±1.52	11.71±0.67	111.81±5.49
A[1]	25	25	370	A[2]	10 Bq/L,	1Bq/L	30000 g/L (A[3])

References: A[1] = UNSCEAR, (2000); A[2] = WHO, (2011); A[3] = 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 Ra_{eq}, external and internal hazard indices were performed for the sediment samples and the results are shown in Table 2.

Table 2: Radiological hazards for sediment samples in this study.

S/ID	Ra_{eq} (Bq/kg)	H_{ex}	H_{in}
S_1	108.97	0.295	0.335
S_2	222.05	0.600	0.730
S_3	159.94	0.432	0.523
S_4	146.47	0.396	0.426
S_5	199.88	0.540	0.655
S_6	122.41	0.331	0.430
S_7	126.09	0.341	0.392
S_8	150.11	0.406	0.493
S_9	179.51	0.485	0.636
S_{10}	131.16	0.354	0.424
S_{11}	186.04	0.503	0.580
S_{12}	162.70	0.440	0.586
S_{13}	167.40	0.452	0.619
S_{14}	125.47	0.339	0.449
S_{15}	190.34	0.514	0.626
AV	199.73	0.429	0.527
Worldwide UNSCEAR (2000)	370	≤1	≤1

The results showed that Ra_{eq} values ranged from 122.41 to 222.05 Bq/kg, with an average value of 199.731 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 (Ra_{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 Ra_{eq} values including its average value were within the permissible range. The results of Ra_{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.

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

S/ID	D_{out} (nGy/h)	D_{in} (nGy/h)	AED_{out} (μSv/y)	AED_{in} (μSv/y)	ELCR_{out} ×10^{-3}	ELCR_{in} ×10^{-3}	Total ×10^{-3}
S_1	55.48	104.86	68.04	128.60	0.238	0.450	0.688
S_2	107.66	197.52	132.03	242.24	0.462	0.848	1.310
S_3	80.09	149.59	98.22	183.46	0.344	0.642	0.986
S_4	74.53	135.56	91.40	166.25	0.200	0.582	0.782
S_5y	92.52	176.54	113.47	216.51	0.397	0.758	1.155
S_6	60.09	113.79	73.69	139.55	0.256	0.488	0.744
S_7	63.74	117.78	78.17	144.45	0.276	0.506	0.782
S_8	75.32	141.02	92.37	172.95	0.323	0.605	0.928
S_9	88.13	167.37	108.08	205.26	0.378	0.718	1.096
S_{10}	66.21	123.77	81.20	151.79	0.284	0.531	0.815
S_{11}	95.15	177.21	116.69	217.33	0.408	0.761	1.169
S_{12}	79.49	151.42	97.49	185.70	0.341	0.650	0.991
S_{13}	81.66	157.00	100.15	192.54	0.351	0.674	1.025
S_{14}	63.74	123.71	78.17	151.72	0.274	0.531	0.805
S_{15}	94.23	175.20	115.56	214.87	0.404	0.752	1.156
AV	78.54	147.89	89.65	147.55	0.302	0.633	0.962
UNSCEAR(2000)	59	84	70	450	0.29	0.16	1.45

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 sedimented materials. 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 132.0.3Sv/y, with an average value of 89.654.7 Sv/y, which is higher than the global average of 70 Sv/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 x 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.

Assessment of Radiological Hazards in Water Samples: The radon concentrations in water samples, the annual effective dose ingestion AEDing, the annual effective dose inhalation AEDinh 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).

Table 4: The measured activity concentration of ^{222}Rn, AEDE_{ing} and AEDE_{inh}, of the water samples

S/ID	P(track/mm^2	R_n(Bq/L)	AEDing (µSv/y)	AEDinh (µSv/y)	Cd(Bq/L)	Ac(Bq/L)	ECR×10^{-4}	E_A(mBq/m^{2}h)
W_1	601.23	0.602	2.1973	1.5170	11.794	0.1457	0.11609	0.449
W_2	362.58	0.363	1.3250	0.9148	7.1120	0.0878	0.0983	0.271
W_3	261.18	2615	9.5448	6.5898	51.231	0.6327	0.7086	1.952
W_4	434.88	4.354	15.8921	10.9721	85.300	1.0535	1.1799	5.414
W_5	489.21	4.898	17.8777	12.3430	95.958	1.1852	1.3274	3.655
W_6								
W_7	5397.52	5.404	19.7246	13.6181	105.871	1.3076	1.4645	4.033
W_8	122.55	1.227	4.4786	3.0920	24.038	0.2968	0.3324	0.916
W_9	134.43	1.346	4..9129	3.3919	26.369	0.3256	0.3647	1.005
W_{10}	6664.98	6.673	24.3565	16.8160	130.732	1.6146	1.8084	4.980
W_{11}								
W_{12}	674.19	0.675	2.4638	1.701	13.224	0.1633	0.1829	0.504
W_{13}	209.55	2.098	7.6577	5.2870	41.102	0.5076	0.5685	1.566
W_{14}	378.44	3.789	13.8299	9.5483	74.231	0.91168	1.02268	2.828
W_{15}	409.39	4.085	14.9103	10.2942	80.301	0.9918	1.1108	3.049
AV	1241.55	2.933±1.28	10.7055±1.48	7.3912±1.4	57.4822	0.7099	0.79477	2.356
EPA (2012)		11 Bq/L	0.1 mSv/y or 0.2-0.8	0.1 mSv/y or o.2-0.8.			1.0×10^{-}	

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 Raeq 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 UNSCAER (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.

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