Estimation of Radiological Risk due to Natural Radioactivity Concentration in Soil Samples from Selected Towns in Isoko, Delta State

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Abstract: *Activity concentrations of Eighteen (18) soil samples from selected towns in Isoko, Delta State of Nigeria were studied. Sodium Iodide NaI(Tl) detector was used for counting and detection of radionuclide content of all samples. Results of the samples analyzed showed that radioactivity concentration in $Bq.kg^{-1}$ of ^{40}k, ^{232}Th and ^{238}U in the soil samples ranged from 58.28 to 584.31 with average concentration of 321.30; 0.21 to 15.72 with an average concentration of 7.97 and 9.27 to 230.80 with an average concentration of 120.04 respectively. The absorbed dose of ^{40}k, ^{238}U and ^{232}Th range from $22.37nGy.h^{-1}$ to $171.52\ nG.h^{-1}$ and the AEDE varied from $27.43\ \mu Sv/y$ to $210.35\mu Sv/y$. The radium equivalent dose values ranged from $41.49\ Bq.kg^{-1}$ to $365.34\ Bq.kg^{-1}$. The H_{ex} ranged from 0.1120 to 0.9865 and the H_{in} range from 0.1222 to 1.0320. The values of the radiological assessment indices obtained were observed to be within the permissible maximum values, hence the radiation hazards in the study area are negligible. Although the concentration at the time of this study poses no risk, further industrial activities in the study area may raise the activity concentration.*

Keywords: *Soil, radioactivity, absorbed dose, Isoko, hazard indices*

1. INTRODUCTION

Humans are primarily exposed to radiation from cosmic rays, naturally occurring radioactive elements found in water, air, soil and plants, and anthropogenic sources. Natural environmental radioactivity and the associated external exposure due to gamma radiation depend primarily on the geological and geographical conditions and appear at different levels in soil of each different region of the world (UNSCEAR, 2000).

Soil is one of the primary sources of radiation exposure to a population through the transfer of radionuclides into the environment (Ahmad et al., 2015, Mustapha et al., 2007). The earth's crust has contained radionuclides with long half-lives such as ^{40}k (Potassium),^{228}U (Uranium), ^{232}Th (Thorium). As a result of their radioactivity, these radionuclides cause natural radiation.

Enhanced radiation levels of thorium, uranium and their progenies might be present in soil in the area that is rich in natural radioactivity or through human activities such as petroleum activities and dumping of waste materials in sites without adequate soil protection measures result in soil as well as, ground and surface water contamination (Eikelboom et al., 2001, Namasivayam et al., 2001).

This study has been carried out to assess the activity concentration in soil samples from selected towns in Isoko area where oil exploitation and exploration activities take place. This activity concentration was used to estimate dose rate and the data generated will provide baseline values of exposure to radiation in the area in case there is contamination.

2. MATERIALS AND METHOD

2.1. Description of Study Area

The study areas covers some parts of Isoko North and Isoko South Local Government Areas of Delta State and the sample locations are Oleh, Irri, Uzere, Olomoro, Owhe, Iyede and Ozoro.

Isoko region is in the tropical rain forest area of Niger-Delta. The region experiences high rainfall and high humidity most of the year. The climate is equational and is marked by two distinct season. The

dry and rainy season, the dry season lasts from about November to –April and is significantly marked by cool harmanttan dust haze from the North-East wind. The rainy season spans may be October with a brief dry spell in August (Eteng Inya, 1997; Etu-Efeotor, 1998). Isoko area is well known for oil exploitation and exploration in the Niger – Delta region of Nigeria.

2.2. Sampling

Soil samples were collected from each of the seven samples sites on 18th April 2018. This area was partition into seven (7) sections and a total of eighteen (18) samples which are the representative of the area were collected with the aid of plastic pipe to scoop 5cm deep below the soil. Soil were collected in plain sterile polythene bags and sealed. The minimum of 2 samples and maximum of 4 samples were collected from each sites.

2.3. Sample Preparation

Soil samples were air dried for 7 – 9 days in a clean and dried environment to avoid contamination and organic debris picked out from the samples. All samples were collected and prepared according to equipment specification. Collected samples were crushed with a mortar and pestle and then sieved using 0.5mm mesh size in a research laboratory. A mass of 250g each of the soil samples were packed in cylindrical plastic containers of uniform size of base diameter 7cm which could sit on the 7.6cm by 7.6cm NaI(Tl) detector. The plastic containers were sealed tightly with caps and wrapped with thick cellotape around their screw necks and kept for 28 days in order for ^{238}U, ^{232}Th and the daughter products to attain secular radioactive equilibrium between the natural radionuclides and their respective progenies.

2.4. Gamma Ray Spectrometry Set Up

The gamma-ray spectrometry set up used in the analysis consist of a highly shielded and well calibrated 7.6cm $\times$ 7.6cm NaI(Tl) (ORTEC) detector enclosed in a 10cm thick lead shield, to assist in reducing background radiation. The energy resolution of the NaI (TI) detector was determined to be 6.3% at 661.7kev. In addition, the detector was coupled with a computer based multichannel analyzer (MCA) with the MAESTRO (ORTEC) program which was used for data acquisition and analysis of the gamma spectra. The radionuclides in the soil samples, the energy values, upon which the measurement were to be based on the gamma counting system, the activity concentration of ^{40}K was determined using only its gamma energy of 1460KeV while the activity concentration of the ^{238}U and ^{232}Th radionuclides were determined using the energy of their daughter products that occurred during their deep series, the gamma energies were 1764KeV (^{214}Bi) for ^{238}U, and 2614.5KeV (^{208}Tl) for ^{232}Th. All samples were counted for 108, 000s using the same geometry.

The activity concentration per unit mass (B) of each samples were calculated using equation (1).

$$B = C.\left(EI_{\gamma}tm\right)^{-1} \tag{1}$$

Where C = the total net counts under the photo-peaks, after correcting for the background.

E = the measured photo-peak efficiency

Iγ = the gamma ray intensity

t = sample measurement time

m = the sample weight

The error calculations for activity were determined with a quadratic formula and the results were presented together with the measurement result.

2.5. Radium Equivalent Dose (Ra$_{eq}$)

A common index used to compare the specific activities of materials containing ^{238}U, ^{232}Th and ^{40}K by simple quality, also takes into account the radiation hazard associated with them. (Gregory et al., 2013 and Diab et al., 2008). The radium equivalent is related to both the external γ-dose and the internal γ-dose from radon and its progeny. The activity index provides a useful guideline in regulating the safety standards. The radium equivalent activity index is calculated as given in equation (2)

$$Ra_{eq} = C_{Ra} + 1.43C_{Th} + 0.077C_K \qquad (2)$$

Where C_{Ra}, C_{Th} and C_K are the radioactivity concentrations in Bq.kg^{-1} of ^{226}Ra, ^{232}Th and ^{40}K respectively.

^{238}U was used in place of ^{226}Ra in the calculations, although there may be disequilibrium between these radionuclides. This disequilibrium is given as 1.03 by UNSCEAR (2000).

Equation (2) is based on the assumption that 370 Bq.kg^{-1} of ^{238}U, 259 Bq.kg^{-1} of ^{232}Th and 4810 Bq.kg^{-1} of ^{40}K produce the same gamma ray dose rate. (UNSCEAR, 2000).

2.6. Absorbed Dose

Absorbed dose is calculated by introducing the dose conversion factor for each radionuclide being considered.

$$\text{Total absorbed dose} = 0.043C_k + 0.662C_{Th} + 0.427C_U \qquad (3)$$

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

2.7. Annual Effective Dose Equivalent (AEDE)

In estimating the annual effective dose equivalents, the co-efficient from the absorbed dose in aired and outdoor occupancy factor were considered. A value of 0.7Sv/Gy was used for the conversion coefficient from the absorbed dose in air to an effective dose received by adults and 0.2 for the outdoor occupancy factor (UNSCEAR, 2000).

The annual effective dose equivalent was calculated using (4)

$$AEDE(\mu sv/yr) = D(nGy -h^{-1}) \times 8760h\text{-}y^{-1} \times 0.2 \times 0.7Sv\text{-}Gy^{-1} \times 10^{-3} \qquad (4)$$

The world average annual effective dose equivalent (AEDE) from outdoor (UNSCEAR, 2000) is 70 μSv/y.

2.8. External Hazard Index (H_{ex})

The external hazard index, a relation that quantifies the exposure factor is an evaluation of the hazard of the natural gamma radiation and given by the equation (5).

$$H_{ex} = \frac{C_K}{4810} + \frac{C_{Th}}{259} + \frac{C_{Ra}}{370} \qquad (5)$$

Where $C_{Ra} = C_U$, C_{Th} and C_K are the activity concentration of ^{238}U, ^{232}Th and ^{40}K respectively in Bq/kg. (Girigius et al., 2013, Mujahid et al., 2008).

2.9. Internal Hazard Index (H_{in})

In addition to external hazard index, radon and its short line products are also hazardous to the respiratory organs. The internal exposure to radon and its daughter produces is quantified by the internal hazard index (H_{in}) as given by equation (6).

$$H_{in} = \frac{C_K}{4810} + \frac{C_{Th}}{259} + \frac{C_{Ra}}{185} \qquad (6)$$

Where C_{Ra}, C_{Th} and C_K are the activity concentration of ^{238}U, ^{232}Th and ^{40}K respectively in Bq/kg (Lu, 2004).

3. RESULTS AND DISCUSSION

The activity concentration (BqKg^{-1}) of the naturally occurring ^{238}U, ^{232}Th and ^{40}K, radionuclides were determined in the soil samples from Isoko LGA's Delta State and the results were presented in table 1.

Table1. *Coordinates of sampling locations, samples ID and activity concentration of natural radionuclides in soil samples in Isoko, Delta State.*

Sample ID	Latitude (N)	Longitude (E)	Activity concentration in Bq.Kg^{-1}		
			^{40}K	^{238}U	^{232}Th
Irri 1	5^{0}26.629"	6^{0}12.800"	110.00± 0.10	3.76±93.98	75.95±19.77
Irri 2	5^{0}26.283"	6^{0}12.392"	117.57± 28.58	9.96±78.83	21.70±25.97
Iyede 1	5^{0}28.620"	6^{0}07.357"	150.37± 25.37	5.53±45.91	10.40±16.29
Iyede 2	5^{0}27.214"	6^{0}06.396"	137.37± 22.91	BDL	9.27±17.20
Iyede 3	5^{0}26.648"	6^{0}06.100"	161.72± 22.55	BDL	86.13±15.26
Oleh 1	5^{0}26.924"	6^{0}11.422"	108.74± 32.64	13.95±74.35	114.38±18.52
Oleh 2	5^{0}26.978"	6^{0}11.814"	127.66± 30.73	2.87±75.21	53.35±17.95
Oweh 1	5^{0}31.110"	6^{0}08.905"	115.05± 45.64	BDL	BDL
Oweh 2	5^{0}31. 461"	6^{0}08.699"	150.37± 33.53	15.72±45.64	55.61±15.36
Oweh 3	5^{0}30.286"	6^{0}07.984"	107.48± 38.87	11.29±47.43	31.87±20.97
Oweh 4	5^{0}30.552"	6^{0}07.996"	234.89± 24.89	0.21±87.91	BDL
Ozoro 1	5^{0}34.196"	6^{0}18.278"	106.22± 32.43	3.31±61.72	19.44±20.47
Ozoro 2	5^{0}34.365"	6^{0}18.103"	88.56± 31.53	4.20±64.10	22.83±23.62
Olomoro 1	5^{0}24.941"	6^{0}08.288"	231.10± 17.15	7.74±73.75	212.72±15.19
Olomoro 2	5^{0}24.718"	6^{0}08.671"	584.31± 17.90	25.91±42.10	230.80±14.43
Uzere 1	5^{0}22.284"	6^{0}13.439"	154.15± 26.54	6.86±44.65	42.05±19.75
Uzere 2	5^{0}20.573"	6^{0}13.508"	367.34± 22.64	13.50±62.14	14.92±25.64
Uzere 3	5^{0}21.605"	6^{0}13.365"	58.28± 39.64	10.85±52.99	28.48±22.10

Table2. *Range of activity concentration, mean concentration, absorbed dose and annual effective equivalent dose of ^{40}K, ^{238}U and ^{232}Th in soil samples in Isoko, Delta State.*

Location	^{40}K Activity range (Bq-kg^{-1})	^{40}K Mean Activity (Bq-kg^{-1})	^{238}U Activity Range (Bq-kg^{-1})	^{238}U Mean Activity (Bq-kg^{-1})	^{232}Th Activity range (Bq-kg^{-1}).	^{232}Th Mean Activity (Bq-kg^{-1})	Absorbed Dose (nGy.h^{-1})	AEDE (μSvy^{-1})
Irri	110.00 -117.57	113.79	3.76 – 9.96	6.86	75.95 - 21.70	48.83	40.15	49.24
Iyede	137.75 -161.72	149.74	0.00 – 5.53	2.77	9.27 – 86.13	47.70	39.20	48.07
Oleh	108.74 – 127.66	118.20	2.87 - 13.95	8.41	53.35-114.38	83.87	64.20	78.73
Oweh	107.48 – 234.89	171.19	0.21 – 15.72	7.97	31.87 – 55.61	43.74	39.72	48.71
Ozoro	88.56-106-22	97.39	3.31-4.20	3.76	19.44 – 22.83	21.14	22.37	27.43
Olomoro	231.10-584.31	407.71	7.74 – 25.91	16.83	212.72-30.80	221.76	171.52	210.35
Uzere	58.28 – 367-34	212.81	6.86-13.50	10.18	14.92-42.05	28.49	32.36	39.69
Overall average							58.50	71.74

Table3. *Radium Equivalent Dose (Ra$_{eq}$), external hazard index (H$_{ex}$) and internal hazard index (H$_{in}$) in soil samples from the study area*

Location	Ra$_{eq}$(Bq-Kg^{-1})	H$_{ex}$	H$_{in}$
Irri	85.45	0.23	0.24
Iyede	82.51	0.22	0.23
Oleh	137.45	0.37	0.39
Oweh	83.70	0.23	0.25
Ozoro	41.49	0.11	0.12
Olomoro	365.34	0.99	1.03
Uzere	67.31	0.18	0.21
Average	**123.32**	**0.33**	**0.35**

Table 1 shows the coordinates of sampling locations sample ID and activity concentration of the gamma emitting natural radionuclides. The activity value of ^{40}K ranged from 58.28 Bq.Kg^{-1} to 584.31 Bq.Kg^{-1} with an average concentration of 321.30Bq.Kg^{-1}. The value of ^{232}Th ranged from 9.27 Bq.Kg^{-1} to 230.80Bq.Kg^{-1} with an average 120.04Bq.Kg^{-1} . While that of ^{238}U ranged from 9.27 to 230.80 Bq.Kg^{-1} with an average concentration of 120.04 Bq.Kg^{-1}. The worldwide concentrations of the radionuclide ^{40}K, ^{238}U and ^{232}Th have average in soil samples of 420 Bq.Kg^{-1}, 35 Bq.Kg^{-1} and 45Bq.Kg^{-1} respectively (UNSCEAR, 2000).

Table 2 shows the range of activity concentrations, mean concentration, absorbed and annual effective dose equivalent of ^{40}K, ^{238}U and ^{232}Th. The absorbed dose ranged from 22.37nGy-h^{-1}to 171.52nGy-h^{-1} with the overall average of 58.5 nGyh^{-1} which is about the same value as the world average 59nGyh^{-1}.The values of AEDE varied from 27.43msv/y to 210.35msv/y with an average of 71.74µSvy^{-1}. The world average effective dose equivalent (AEDE) for outdoor UNSCEAR (2000) is 70µSvy^{-1}. Therefore, the value obtained in this present study is found to be slightly greater than the world average.

Table 3 shows Radium equivalent dose (Ra$_{eq}$), external hazard index (H$_{ex}$) and internal hazard index (H$_{in}$) of ^{40}K, ^{238}U and ^{232}Th. The Radium equivalent dose values ranged from 41.49 Bq.Kg^{-1} to 365.34Bq.Kg^{-1} with average 123.32 Bq.Kg^{-1}. The permissible maximum value of the radium equivalent activity is 370 Bq.Kg^{-1}(UNSCEAR, 2000). This reveals that, if the soil of the study area is used as components of building materials, it will be of no radiological concern to occupants of such building. The value of H$_{ex}$ ranged from 0.1120 to 0.9865 with an average of 0.33 which is lower than unity. Hence the radiation hazards at study areas are negligible. The values of H$_{in}$ ranged from 0.1222 to 1.0320 with an average which is less than 1.

4. CONCLUSION

The radionuclides activity values of 18 samples of soil collected from Isoko North and Isoko South LGAs in Delta State of Nigeria have been determined and the values differed among the communities in the study area, depending upon the geographical structures and rainfall amounts of the area. The values of the radiological assessment indices obtained was observed to be low and fall within the permissible maximum values, hence the radiation hazard at study area are negligible. This shows that radiation is the study area was within the maximum limits and did not significantly differ from other regions of the world.

Also, since not much work has been done in the area, this study could be considered useful in further studies on natural radioactivity mapping.

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