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Evaluation of Radiological Hazard Indices from Topsoil in Geidam, Yobe State, Nigeria

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ABSTRACT: The activity concentrations in the samples measured, ranged between 49.14 ± 0.8 to 99.27 ± 3.4 Bq kg^{-1}, 68.93 ± 1.3 to 95.11 ± 1.1Bq kg^{-1}, 115.19 ± 0.6 to 217.50 ± 0.6 Bq kg^{-1} for ^{226}Ra, ^{232}Th, and ^{40}K radionuclides respectively, from the ten (10) different soil samples in Geidam,Yobe state, Nigeria. These activity concentrations in these samples were determined through gamma spectroscopy with a Thallium activated Sodium Iodide NaI (TI) detector. Absorbed dose rate in air, annual effective dose, radium equivalent activities, internal and external hazard indicesassociated with the natural radionuclide were calculated. The radium equivalent activity estimated in the soil samples were in the range of 164.00 to 248.43 Bq kg^{-1} and with mean value of 205.6 Bq kg^{-1}. The mean absorbed dose rate was determined to be 91.56 $nGyh^{-1}$, while the annual effective dose rate was estimated, varied in the range from 89.04 to 135.96 μSv y^{-1} with an average value of 112.29 μSv y^{-1}. The internal and external hazard indices estimated for the study area ranged from 0.6 to 0.9 with mean value of 0.8 and from 0.4 to 0.7 with mean value of 0.6 respectively.

KEY WORDS: Hazard Index, Radionuclides, Gamma Spectroscopy, Radioactivity, Geidam.

I. INTRODUCTION

There is no place on the earth that is totally free from radioactivity, soil that contains naturally occurring radionuclides that are above the maximum permitted exposure limit can be very dangerous and can seriously affect the health of people living in that environment (Al Nabhaniet. al.,2016; Alazemi et. al.,2016). Therefore, it is important to estimate the amount of radiation people are exposed to from natural sources so as to estimate the associated health risk that is posed to people (Alazemi et. al.,2016). Radioactivity is a natural phenomenon. It is part of our everyday life. Natural radioactive materials are present in the air we breathe, and the food we eat; even we ourselves are composed of a certain number of radioactive materials (Shahbazi-Gahroueiet. al.,2016). Radioactivity also has some useful applications in different areas including agriculture, medicine, mining, geology, archaeology, biologyetc. (NRC, 1999).

Humans are continually being exposed to radiation that is emitted from the environment because of the presence of radionuclide (O. O. Adewoyinet. al,.2022). This is due to the naturally occurring radioactive materials present in the soil. This can pose as a serious hazard if they are present in high concentrations. This can seriously affect the health of the inhabitants of the community where the radiation is present (El-Arabi, A. M., 2006; El-Arabi, A. M., 2018; Xinwei, L. &Xiaolon, Z, 2008). The concentration of the naturally occurring radionuclides present in the soil can be influenced by man-made activities. Industrial processes such as cement production, coal mining, oil and gas exploration, fertilizer production (phosphate) can enhance the concentration of the radionuclides(Abbady, A. G. E., 2004).

The intensity of radiation depends on the amount of naturally occurring radioactive materials (NORM) present in the soil and also the time of exposure. Possessing the knowledge of the radioactive content in soil is very important in evaluating the radiological hazard it poses to the people within that locality. Soil with high number of radionuclides can be a significant source of exposure due to both internal and external radioactivity. Food crops grown in regions where the soil contains high levels of radionuclide may

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therefore constitute a health hazard (George, A. I. et. al,.2018). It is on this note that this present study was designed to determine the natural radioactive levels (^{226}Ra, ^{232}Th and ^{40} K) in soil.

II. MATERIALS AND METHOD

i. Study Area

Geidam is in semi-arid region located at 12°53′49″N 11°55′49″E in north eastern part of Yobe state, Nigeria. It has an area of 4,357 km² and is characterized sandy clayey soils.

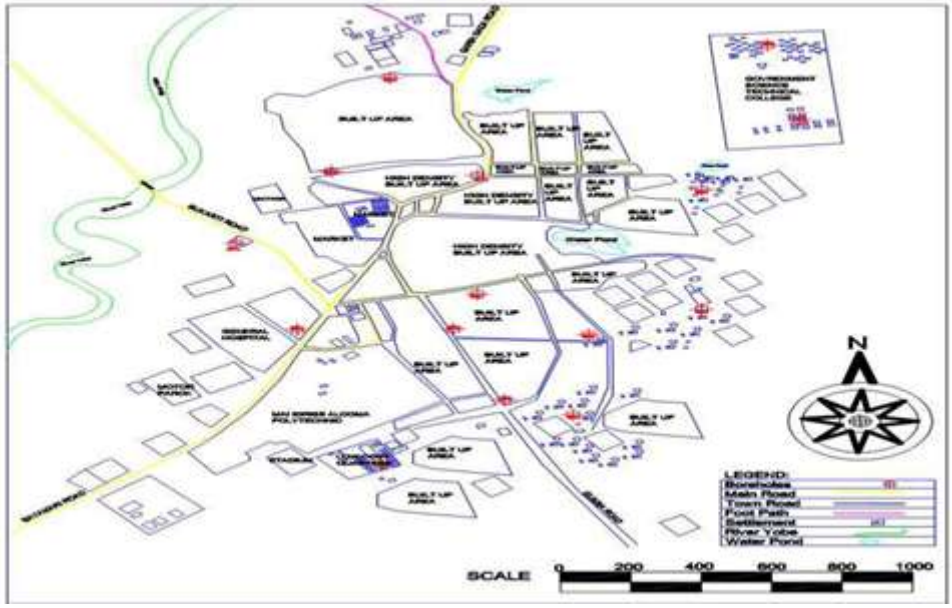

Fig. 1. Map of the study area.

ii. Samples Preparation and Analysis

Ten (10) soil samples were collected in ten different locations across the study area. Samples were collected from about 25 cm deep from the surface of the soil each weigh approximately 400.0 g. They were put in different containers and taken tothe laboratory to dry for about seventy-twohours under laboratory temperature of about 27°C and relative humidity of about 70% (IAEA, 1989). Each dried soil sample was crushed and sieved using a 2mm mesh screen. The dried samples were then packed 150.0 g by mass in labelled cylindrical plastic containers of uniform base diameter of 5.0 cm which could sit on the 7.6 cm by 7.6 cm NaI (Tl) detector. The plastic containers were tightly covered, sealed and left for 28 days prior tocounting, for attainment of secular equilibrium between ^{238}U and ^{232}Th and their respective progenies (Papaefthymiou,2007). The method of gamma spectrometry was adopted for the analysis of the samples collected in order to obtain data on (^{226}Ra, ^{232}Th and ^{40} K) The spectrometer used was a Canberra lead shielded 7.6cm x 7.6cm NaI (Tl) detector coupled to a multichannel analyzer (MCA) through a preamplifier base.

iii. Radiological Parameters

Radium equivalent activity (Ra_{eq})

Radium equivalent activity (Ra_{eq}) is an index, which represent the gamma yield from mixture of ^{226}Ra, ^{232}Th and ^{40}K in the samples. The radium equivalent activity index was given as in equation

$$Ra_{eq}\ (Bq\ kg^{-1}) = A_{Ra} + 1.43\ A_{Th} + 0.077\ A_K \quad (1)$$

Where A_{Ra}, A_{Th} and A_K were the activity concentration in Bq kg^{-1} of ^{226}Ra, ^{232}Th and ^{40}K respectively. The radium equivalent activity (Ra_{eq}) was calculated based on the estimation that 370 Bq kg^{-1} of ^{226}Ra, 259 Bq kg^{-1} of ^{232}Th and 4810 Bq kg^{-1} of ^{40}K all producing the same gamma ray dose rate (Beretka& Mathew, 1985).

Internal hazard index (H_{in})

The internal hazard index (H_{ex}) due to the gamma ray dose rate.

$$H_{ex} = A_{Ra}/185 + A_{Th}/259 + A_K/4810 \quad (2)$$

where A_{Ra}, A_{Th}, and A_K are the activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in Bq kg^{-1}, respectively.

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External hazard index (H_{ex})

The external hazard index (H_{ex}) due to the gamma ray dose rate for each sample was calculated according to the following formula (UNSCEAR, 1988)

$$H_{ex} = A_{Ra}/370 + A_{Th}/259 + A_K/4810 \quad (3)$$

where A_{Ra}, A_{Th}, and A_K are the activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in Bq kg^{-1}, respectively. (Beretka& Mathew, 1985).

Absorbed dose rate

The absorbed dose rate D (nGyh^{-1}) in air at 1 m above the ground surface due to the radioactivity concentration of ^{226}Ra, ^{232}Th, and ^{40}K (Bq kg^{-1}) in the collected samples, can be calculated using the following formula reported by (UNSCEAR, 2000).

$$D\ (nGyh^{-1}) = 0.462\ A_{Ra} + 0.604\ A_{Th} + 0.0417\ A_K \quad (4)$$

Where D is air absorbed dose rate, 0.462, 0.604 and 0.0417 are the dose rate conversion factors (Saito and Jacob,1995) and A_{Ra}, A_{Th} and A_K are the concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in the samples respectively.

Annual effective dose rate (D_{eff})

The gamma absorbed doses in nGy h^{-1} were converted to annual effective dose in mSv y^{-1}, as proposed by UNSCEAR (2000). The annual effective dose rate (D_{eff}) was computed using the following equation:

$$D_{eff}(\mu Sv\ y^{-1}) = D\ (nGy\ h^{-1}) \times 8760\ (hy^{-1}) \times 0.2 \times 0.7(SvGyh^{-1}) \times 10^{-3} \quad (5)$$

where D is the absorbed dose rate in air (nGy h^{-1}), 0.7 is the dose conversion factor (SvGyh^{-1}), 0.2 is the outdoor occupancy factor, and 8760 is the time conversion factor (hy^{-1}).

III. RESULTS

Table 1. The activity concentrations A in (Bq kg^{-1}) in the soil samples.

Activity concentration (Bq kg^{-1})			
Sample	^{226}Ra	^{232}Th	^{40}K
S 1	53.17 ± 1 .4	92.08 ± 1.2	165.22 ± 0.5
S 2	89.01 ± 2.1	75.10 ± 2.2	180.18 ± 1.0
S 3	49.14 ± 0.8	72.19 ± 1.2	151.12 ± 0.7
S 4	95.12 ± 3.2	69.28 ± 2.7	183.50 ± 0.6
S 5	82.33 ± 1.0	88.74 ± 1.9	141.57 ± 0.5
S 6	90.92 ± 2.4	72.46 ± 1.7	146.50 ± 0.7
S 7	64.96 ± 3.6	77.07 ± 2.7	184.85 ± 0.6
S 8	60.40 ± 2.3	95.11 ± 1.1	115.19 ± 0.6
S 9	98.79 ± 1.5	68.93 ± 1.3	156.10 ± 0.8
S 10	99.27 ± 3.4	92.60 ± 2.3	217.50 ± 0.6
Mean	78.31	80.36	164.17

Table 2. Radium equivalent activities, internal hazard index, external hazard index, absorbed dose rates, and annual effective dose rates of the soil samples

Sample	Ra_{eq}(Bq kg^{-1})	H_{in}	H_{ex}	D (nGyh^{-1})	D_{eff}(μSv y^{-1})
S 1	197.58	0.7	0.5	87.07	106.79
S 2	210.27	0.8	0.6	93.99	115.27
S 3	164.00	0.6	0.4	72.61	89.04
S 4	208.32	0.8	0.6	93.44	114.60
S 5	220.14	0.8	0.6	97.54	119.63
S 6	205.83	0.8	0.6	91.88	112.69
S 7	189.39	0.7	0.5	84.27	103.34
S 8	205.28	0.7	0.6	90.16	110.57
S 9	209.38	0.8	0.6	93.78	115.02
S 10	248.43	0.9	0.7	110.9	135.96
Mean	205.86	0.8	0.6	91.56	112.29

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IV. DISCUSSION

The activityconcentrations of radionuclides of ten (10) soil samples measured varied in the range from 49.14 ± 0.8 to 99.27 ± 3.4 Bq kg^{-1} with mean value of 78.31Bq kg^{-1} for ^{226}Ra, 68.93 ± 1.3 to 95.11 ± 1.1Bq kg^{-1} with mean value of 80.36 Bq kg^{-1} for^{232} Th and 115.19 ± 0.6 to 217.50 ± 0.6 Bq $kg^{-1}$with mean value of 164.17 Bq kg^{-1} for ^{40}K. Average activity concentration of ^{226}Ra determined in this study is higher than the global average of 35 Bq kg^{-1}, average activity concentration of ^{232}Th is greater than that of global average of 30 Bq kg^{-1}, but for average activity concentration of ^{40}K is lower compared to that global average 400 Bq kg^{-1} (UNSCEAR, 2000).

The internal hazard index ranges between 0.6 to 0.9 with the mean value of 0.8 was determined, which is less than 1.

The external hazard index of the study area ranges from 0.4 to 0.7 with an average of 0.6 were estimated. This value is less than unity (1) as desired. Therefore, it is within the permissible limit.

The Radium equivalent activity (Ra_{eq}) of the samples due the mixture of the three radionuclides were in the range between 164.00 to 248.43 Bq kg^{-1} and with mean value of 205.6Bq kg^{-1}. Fig. 3. Shows the distribution of radium equivalent activity across the sample sites of the study area.

The absorbed dose rate D ($nGyh^{-1}$) in air at 1 m above the ground surface due to the radioactivity concentration of ^{226}Ra, ^{232}Th, and ^{40}K (Bq kg^{-1}) in the collected samples varied between 72.61 to 110.9 $nGyh^{-1}$ with an average value of 91.56 $nGyh^{-1}$ for the 10 samples. It is greater than world average of 59 $nGyh^{-1}$ as reported by (UNSCEAR, 2000).

The annual effective dose rate (D_{eff}) was estimated, it ranged from 89.04 to 135.96 μSv y^{-1} with an average of 112.29 μSv y^{-1}, which was higher than that of world average of 70 μSv y^{-1} (UNSCEAR, 1988).

V. CONCLUSION

The result shows that the mean values for both the internal and external hazard indices are less than unity(1.0)and is within permissible limitrecommended by European Commission on Radiation Protection (EC,1999). Hence, that the exposure of the inhabitants in the study area to theradiation from the soils does not constitute any negative radiologicaleffect on them and their environment. However, repeating similar studies suggested for the study area due to the fact that agricultural activities around the study area where phosphate fertilizer, herbicides, pesticides etc. are involved. Since, these chemicals affect the soil constituents.

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