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ASSESSMENT OF RADIOACTIVITY LEVEL IN SOIL SAMPLES FROM GEIDAM TOWN

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Abstract

The activity concentrations of elemental occurring radionuclides (^{226}Ra, ^{232}Th and ^{40}K) from the 10 different soil samples in Geidam, Yobe state, Nigeria were measured. The activity concentrations in these samples were determined through gamma spectroscopy with a Thallium activated Sodium Iodide NaI (TI) detector. The activity concentrations in the 10 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. 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 external hazard indexes estimated for the study area ranged from 0.4 to 0.7 with mean value of 0.6.

Key words: Activity concentration, Absorbed dose rate, External hazard index, Gamma Spectroscopy, Geidam.

INTRODUCTION

Natural radioactivity is proliferating in the ecosystem in various formations such as soil, sediment, rock, water, plants and air. The main radioactive materials contained in the environment are long-life radionuclides known as NORMs (Naturally Occurring Radionuclide Materials), especially ^{238}U (^{226}Ra) series, ^{232}Th series and ^{40}K. Humans are continuously exposed to ionizing radiations emitted by a radioactive substance that can come from external and internal sources (Nurokhim et al 2020). External sources are in the form of terrestrial radiation and cosmic rays' radiation, while internal sources come from radioactive substances that enter the body along with the entry of food, drinks and breathing (Singh J et al. 2009). The estimated average radiation dose received by the world population 85% comes from natural radioactivity while the remaining 15% comes from artificial sources. The radioactive dose received by the inhabitants in an area depends on the constituent of radionuclides present in the area. Many radionuclides can be found in the ecosystem, which are classified: Primordial, cosmogenic, and human produced which are of lesser amounts compared to natural. The total dose received by the population in a particular area depends on the content of radioactive NORMs present in the area. Soil is a source of sustained exposure to radiation in humans and also as a medium for the transfer of radioactive substances to other environmental media, therefore an analysis of the concentration of radioactive substances in the soil is particularly importance to estimate the total and effective doses received by the community in certain areas (Mubarak F, Fayez-Hassan M, Mansour NA, Ahmed TA and Ali A 2017). Accumulation of these natural radionuclides in soil could pose potential health hazard. (Singh S, Rani A, Mahajan 2005). Therefore, the assessment of radioactivity level from natural sources is of particular importance as natural radiation is the largest contributor to the external dose of the world population. (UNSCEAR 2008). Geidam being one of the strategic town in northern Yobe and it has large number of inhabitant living in the town their health is of paramount importance. Geidam happens to share the same geography with the neighbouring Niger republic which have large deposits of radioactive materials, there is greater possibility of having the deposits as well.

MATERIALS AND METHODS

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 among the largest town in the state which is strategic in both economic and politics. Geidam is characterized sandy clayey soils.

Sample collection

Ten (10) soil samples were collected in ten different locations across the study area. Samples were collected from about 20 cm deep from the surface of the soil each weigh approximately 1.0 kg and considered representative of the sampling sites. Each sample were packed inside a container and labelled.

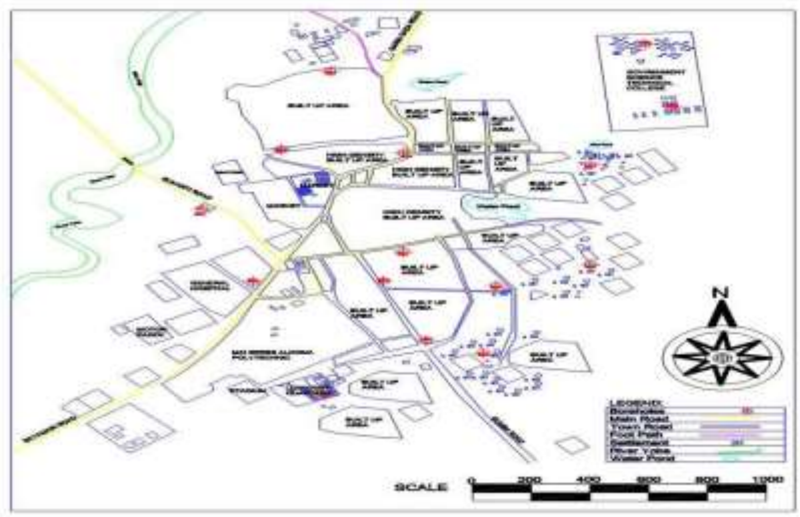

Fig. 1. Map of the study area (Geidam)

Samples preparation and analysis

These samples were left open to dry and then taken to laboratory for analysis. The major nuclear technique employed in the analysis of samples for background activity is the Gamma spectrometry using NaI(Tl) detector obtained at Centre for Energy Research and Training (CERT) Zaria, Kaduna state, Nigeria.

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).

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)

$$H_{ex} = A_{Ra}/370 + A_{Th}/259 + A_K/4810 \quad (2)$$

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. (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).

$$D\ (nGyh^{-1}) = 0.462\ A_{Ra} + 0.604\ A_{Th} + 0.0417\ A_K \quad (3)$$

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:

$$D_{eff}\ (\mu Sv\ y^{-1}) = D\ (nGy\ h^{-1})\ X\ 8760\ (hy^{-1})\ X\ 0.2\ X\ 0.7 (SvGyh^{-1})\ X\ 10^{-3} \quad (4)$$

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}).

RESULTS AND DISCUSSION

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

	Activity concentration (Bq kg^{-1})		
Sample ID	^{226}Ra	^{232}Th	^{40}K
SP 1	53.17 ± 1 .4	92.08 ± 1.2	165.22 ± 0.5
SP 2	89.01 ± 2.1	75.10 ± 2.2	180.18 ± 1.0
SP 3	49.14 ± 0.8	72.19 ± 1.2	151.12 ± 0.7
SP 4	95.12 ± 3.2	69.28 ± 2.7	183.50 ± 0.6
SP 5	82.33 ± 1.0	88.74 ± 1.9	141.57 ± 0.5
SP 6	90.92 ± 2.4	72.46 ± 1.7	146.50 ± 0.7
SP 7	64.96 ± 3.6	77.07 ± 2.7	184.85 ± 0.6
SP 8	60.40 ± 2.3	95.11 ± 1.1	115.19 ± 0.6
SP 9	98.79 ± 1.5	68.93 ± 1.3	156.10 ± 0.8
SP 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, external hazard indexes, absorbed dose rates, and annual effective dose rates of the soil samples

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

The activity concentrations 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 ± 1.1 Bq 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. Fig. 2. Shows the comparison of activity concentrations of the three radionuclides in the samples of the sites. 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 index 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 205.6 Bq kg^{-1}. Fig. 3. Shows the distribution of radium equivalent activity across the sample sites of the study area.

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 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}) were 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).

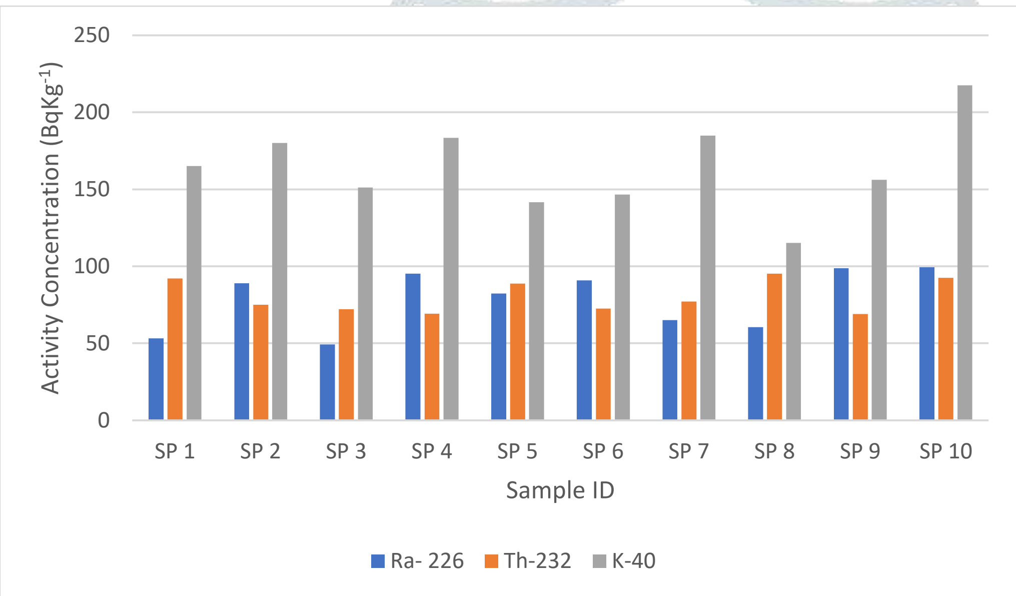

Fig. 2. Comparison of the activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in the soil samples.

Fig. 3. Distribution of radium equivalent activities of the samples.

CONCLUSIONS

The mean activity concentrations of ^{226}Ra and ^{232}Th for the soil samples are above the world mean values. However, the mean activity concentrations for ^{40}K for the samples is below the world mean value, which is connected to the acidity of the soil due agricultural chemicals as the study area is characterised with farming. The average values for radium equivalent activity, absorbed dose rate, annual effective dose rate and external hazard index were evaluated for the 10 different sample sites distributed in the study area (Geidam). The external hazard index is within the permissible limit. The average values of activity concentrations of ^{226}R and ^{232}Th and also absorbed dose and annual effective dose rates are observed higher than the world averages, suggesting the presence of heavy radioactive mineral deposits in the study area. Repeating similar studies for assessment of natural radioactivity is suggested for the study area.

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