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DETERMINATION OF ANNUAL EFFECTIVE DOSE FROM MEASURED SOIL RADIOACTIVITY LEVELS IN AUYO LOCAL GOVERNMENT AREA JIGAWA STATE.

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ABSTRACT

Human beings are persistently exposed to ionizing radiation caused by terrestrial, extra-terrestrial and anthropogenic radionuclides. In order to assess the risks associated with exposure due to the natural radioactivity in soil, a radiological environmental monitoring survey was carried out in Auyo Local Government Jigawa State. In the present study, activities of ^{226}Ra, ^{232}Th and ^{40}K are measured in soil samples, the measured mean specific radioactivity concentration of ^{226}Ra, ^{232}Th and ^{40}K in the studied samples were 31.25 ± 1.17 Bqkg^{-1}, 48.97 ± 2.29 Bqkg^{-1} and 554.78 ± 18.55 Bqkg^{-1}, respectively. From the measured activity concentration, radium equivalent activity, external and internal hazard indices, terrestrial absorbed dose and annual effective dose were calculated. Mean radium equivalent activity (Ra_{eq}), outdoor radiation hazard index (H_{ex}), indoor radiation hazard index (H_{in}) and absorbed dose rate (D) for the area under study were determined as 143.73 Bqkg^{-1}, 0.39, 0.47 and 66.78 nGyh^{-1} respectively. The annual effective dose equivalent (AEDE) varied in the range from 0.10 mSv y^{-1} to 0.16 mSv y^{-1}. On the basis of measured activity and calculated values of hazards indices, it is concluded that the surveyed area does not pose any significant radiological risk to the population and environment.

I. Introduction

Naturally occurring radioactive materials are ubiquitous on earth and their radioactivity may become concentrated in certain region/area as a result of human activities. Natural radiation at the earth's surface consists of two components, namely cosmic and terrestrial radiation. Terrestrial radiation mainly originates from the primordial radioactive nuclides originated in the early stage of the formation of the solar system. Uranium, thorium and potassium are the main elements contributing to natural terrestrial radioactivity. It is an established fact that radioactivity in the soil adds to the background level of radiation and human beings are exposed. The level of contribution to the background radiation depends on the concentration of the radioactive materials in the soil but this amount may vary from area to area, [1 - 3].

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The naturally occurring radionuclides such as ^{238}U, ^{232}Th and ^{40}K are present in rocks and soil are one of the components of external gamma-ray exposure. These radionuclides are not uniformly distributed in the earth's crust and therefore, exposure of human being due the radiation emitted from radioactive materials also changes. The radionuclides released into the environment through several transfer processes and reach the human body. The concentration of these naturally occurring radionuclides in the surrounding environment and associated external exposure due to the gamma radiation depends primarily on the geological origin, environmental parameters and geographical conditions of the region, [4 - 7]. It is now widely accepted that natural radiation accounts for the greatest part of public radiation exposure, [6 - 9]. The exposure of human being to these naturally occurring radionuclides is an unavoidable consequence of their presence in the earth' s crust, soil, air, food and water. To ensure radiological safety of the general public, it is necessary to measure the radiation levels in the environment surrounding humans. The knowledge of naturally occurring radionuclides is useful in order to set the standards and national guidelines in the light of international recommendations. The aim of the present research work is to determine the radioactivity levels in soil samples of Auyo Local Government area Jigawa State.

II. Material and Methods

Ten soil samples were collected from various locations of the political wards of Auyo local government area. The study area Auyo, is the local government headquarters of Auyo local government of Jigawa State with coordinates $12^0$21'36" N $9^0$59'8" E located along river Hadejia valley in North – West part of Nigeria with an average area of 512 Km^2. Auyo has population of 132,001 as of 2006 census.

The study area has a total of ten (10) political wards as: Auyo, Auyakayi, Ayama, Ayan, Gatafa, Gamafoi, Gamsarka, Kafur, Tsidir and Unik.

The selected sampling sites were relatively flat, open and undisturbed. The soil samples were collected from the upper 4-6 cm layer with a coring tool. The collected samples were packed in polyethylene bags and labelled properly with date and place. In the laboratory, the roots and stones were removed from samples and were dried under ambient temperature until the sample weight became constant. The treated soil was then ground and sieved. Soil samples of about 200 g were stored in air tight cylindrical plastic containers for 21 days before counting to attain secular equilibrium between ^{226}Ra and ^{232}Th and their short lived progeny.

To determine the activities concentration of ^{238}U, ^{232}Th and ^{40}K, the samples were taken to energy centre Ahmad University Zaria (ABU) for analysis. The used detector was equipped with 8192-channels and it was shielded in an 8 cm lead chamber with an inner lining of 0.5 cm thick copper plate to reduce the background, [8] and [10]. The results were analysed by using Geni-2000 software (Canberra). The samples were counted for 65000 seconds. ^{40}K was analysed by its single peak of 1460 keV. However, the analysis of ^{238}U and ^{232}Th was based upon the peaks of progeny in equilibrium with their parent radionuclides, [8] and [10].

III. Results and Discussion

The activity of ^{226}Ra, ^{232}Th and ^{40}K in the soil samples have been calculated by High Purity Germanium (HPGe) detector and the correspondence results are shown in Table 1. The large variations in the activity of these radionuclides are due to non-uniform distribution of the different primordial radionuclide in the soil of the study area. Table 1 represents the measured activity of ^{226}Ra, ^{232}Th and ^{40}K in all the sample of soil taken from different areas of Auyo local government. The maximum and minimum activity of ^{226}Ra has been found 42.09 ± 1.29 $Bqkg^{-1}$

in Ayama and 20.02 ± 1.13 Bqkg^{-1} in Ayan, respectively. The mean radioactivity of ^{226}Ra in the study area is 31.25 ± 1.17 Bqkg^{-1}, which is less than the world average value of 50 Bqkg^{-1} [11]. Measured activity of ^{232}Th in all the samples of soil taken from study area are also shown in Table 1. The maximum and minimum activity of ^{232}Th has been found 65.30 ± 2.49 Bqkg^{-1} in Ayama and 33.67 ± 2.28 Bqkg^{-1} in Gamsarka respectively. The mean radioactivity of ^{232}Th in the study area is 48.97 ± 2.29 Bqkg^{-1}, which is less than the world average value, i.e. 50 Bqkg^{-1}. Measured activity of ^{40}K in all the soil sample of the study area, also shown in Table 1. According to the data, the maximum and minimum activity of ^{40}K has been found 635.80 ± 19.60 Bqkg^{-1} in Ayama and 371.77 ± 18.18 Bqkg^{-1} in Tsidir, respectively. The mean radioactivity of ^{40}K in the study area is 554.78 ± 18.55 Bqkg^{-1} and it is higher than the mean value of the world 500 Bqkg^{-1} [11]. In present study, it has been observed that the specific activity of natural radionuclides in the soil is not uniform but varies from area to area depending upon the geological character and different minerals present in the soil.

Gamma Dose Rate(D)

Gamma dose rates were calculated by using the formula given below:

$$D\ (nGyh-1) = 0.427CRa + 0.662CTh + 0.043CK \quad (1)$$

where CK, CRa and CTh are the specific activity concentrations of potassium, uranium and thorium, respectively. The variation in dose rates (D) which was determined by the formula for soil samples was found in the range of 52.76 nGyh^{-1} to 74.12 nGyh^{-1}. The highest absorbed dose was found in sample of Unik while the lowest absorbed dose was found in sample of Ayan. The mean absorbed dose rate of the study area is 66.78 nGyh^{-1}, which is 3.2% lower than world mean value i.e. 70 nGy h^{-1}. Table 2 shows calculated Gamma dose rate (D) of the studied area.

Radium Equivalent Activity (R_{aeq})

The radioactivity has been defined in terms of radium equivalent activity (R_{aeq}) in Bqkg^{-1} to compare the specific activity of materials containing different amounts of ^{226}Ra, ^{232}Th and ^{40}K by using the given equation.

$$Ra_{eq} = A_{Ra} + 1.43A_{Th} + 0.077A_K \quad (2)$$

Where: $A_{Ra,}$ A_{Th} and A_K are the mean activities of ^{226}Ra, ^{232}Th and ^{40}K in Bqkg^{-1}, respectively. Radium equivalent activity (R_{aeq}) calculated for different soil samples investigated in the present study are given in Table 2. Radium equivalent activity (R_{aeq}) is varying in the ranges 111.82 Bqkg^{-1} in Gamsarka to 184.43 Bq kg^{-1} in Ayan. The mean of radium equivalent activity in the current area is 143.73 Bqkg^{-1}, less than the 370 Bqkg^{-1} which is in the safe limit.

External and Internal Hazard Indices

The internal and external hazard indices are calculated by the following expressions

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

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (4)$$

Where: A_{Ra}, A_{Th} and A_K are the activities of ^{226}Ra, ^{232}Th and ^{40}K in Bq.kg^{-1}, respectively. The calculated external hazard index (H_{ex}) values varied from 0.30 to 0.50, calculated from given equation. The current mean external hazard index is 0.39, which is 22% less than world mean value 0.5. Table 2 shows the external hazards of the sampling area. The calculated internal hazard index (H_{in}) values vary from 0.36 to 0.61. The lowest value found in soil sample of Ayan and the highest value represent in soil sample of Ayama. The mean internal hazards index for the area is 0.47 which is less than world means value 0.5 [11].

Table 1: Measured radioactive concentrations of ^{226}Ra, ^{232}Th and ^{40}K in soil samples

Locations	^{262}Ra (BqKg^{-1})	^{232}Th (BqKg^{-1})	^{40}K (BqKg^{-1})
Auyo	32.680 ± 1.02	49.540 ± 2.33	599.71 ± 18.92
Auyakayi	33.741 ± 1.13	43.847 ± 2.11	586.72 ± 17.45
Ayama	42.092 ± 1.29	65.301 ± 2.49	635. 80 ± 19.60
Ayan	20.022 ± 1.13	33.711 ± 2.20	566.11 ± 18.86
Gatafa	25.490 ± 1.15	45. 370 ± 2.25	584.54 ± 18.72
Gamafoi	30.957 ± 1.18	57.039 ± 2.33	602.97 ± 18.59
Gamsarka	27.619 ± 1.22	33.671 ± 2.28	522.01 ± 19.39
Kafir	31.440 ± 1.23	48.940 ± 2.35	488.85 ± 18.23
Tsidir	31.130 ± 1.20	58.460 ± 2.37	371.77 ± 18.18
Unik	37.329 ± 1.15	53.827 ± 2.18	589.30 ± 17.52
Mean	31.25 ± 1.17	48.97 ± 2.29	554.78 ± 18.55

Table 2: Hazard indices and annual effective dose of the studied area

Locations	Dose Rate (nGyh^{-1})	Ra_{eq} Activity (Bq Kg^{-1})	H_{EX}	H_{IN}	AEDE (MSvy^{-1})
Auyo	71.54	153.84	0.41	0.50	0.14
Auyakayi	66.17	141.62	0.38	0.47	0.12
Ayama	85.28	184.43	0.50	0.61	0.16
Ayan	52.76	111.82	0.30	0.36	0.10
Gatafa	63.24	135.38	0.36	0.43	0.12
Gamafoi	73.72	158.95	0.43	0.51	0.14
Gamsarka	54.46	115.96	0.31	0.39	0.10
Kafir	62.18	134.74	0.36	0.44	0.11
Tsidir	64.29	140.87	0.38	0.46	0.12
Unik	74.12	159.68	0.48	0.53	0.14
Mean	66.78	143.73	0.39	0.47	0.13

Annual Effective Dose Equivalent (AEDE)

Annual effective dose equivalent (AEDE) was calculated from the formula given below.

$$E = O\ x\ T\ x\ D\ x\ Q\ x\ 10^{-6} \qquad 5$$

Where "O" is the occupancy factor for outdoor, this factor has been estimated for the rural areas in Nigeria using an appropriate occupancy factor model that suites the above environmental condition. An outdoor occupancy factor of 0.3 has been estimated for rural areas as against the UNSCEAR factor of 0.2 recommended for the world. for "T" termed number of hours in one year equals 8760h, "Q" equals to 0.7 SvGy^{-1} is the quotient of effective dose rate "D" to absorb dose rate in air and 10^{-6} is the conversion factor between nano and milli. Conversion factor of 0.7 SvGy^{-1} converts absorbed dose in air to human effective dose in adults. The variation in annual effective dose equivalent was found to be varied from 0.10 mSv y^{-1} to 0.16 mSv y^{-1}. The lowest value found in soil samples of Ayan and Gamsarka and the highest value in Ayama. The mean annual effective dose for the study area is 0.13, which is less than the world mean value. Table 2 shows the AEDE value of the sampling area.

IV. **Conclusions**

The soil samples analysed in the present study shows ^{226}Ra activity ranging from 20.02 ± 1.13 Bqkg^{-1} to 40.092 ± 1.29 Bqkg^{-1} and activity of ^{232}Th varies from 33.67 ± 2.28 Bqkg^{-1} to 65.30 ±

2.49 Bqkg^{-1}. The activity measured for ^{40}K in all soil samples is ranged from 371.77 ± 18.18 Bqkg^{-1} to 635.80 ± 19.60 Bqkg^{-1}. Therefore, the natural radionuclide ^{226}Ra and ^{232}Th are detected in less quantity, while ^{40}K, which is an essential constituent of all cellular material, was detected in higher amount. The mean radium equivalent activity for the measured soil samples was 142.18 Bq kg^{-1}. The calculated mean value of external radiation hazard index and internal radiation hazard was 0.39 and 0.47 respectively. The values of the radium equivalent activity and the external hazard index determined in the soil of the study area are less than the recommended safe levels. The mean absorbed dose rate and annual effective dose equivalent for the area under study was found to be 66.78 nGy h^{-1} and 0.13 mSv y^{-1}, respectively.

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