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ASSESSMENT OF NATURAL RADIOACTIVITY LEVELS AND RADIATION HAZARDS IN THE TERTIARY INSTITUTIONS IN MINNA, NIGER STATE, NIGERIA

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ABSTRACT

Activity concentrations of natural radionuclides in 30 surface soil samples collected across the three campuses of the two tertiary institutions in Minna, Niger State, Nigeria, were studied and evaluated. This survey was carried out using gamma spectrometric technique which employs NaI(Tl) gamma detector at the Center for Energy Research and Training (CERT), Ahmadu Bello University, Zaria, Nigeria. The mean values for the activity of ^{226}Ra, ^{232}Th and ^{40}K were found to be 7.8±1.3Bqkg^{-1}, 29.4±0.9Bqkg^{-1} and 229.4±1.8Bqkg^{-1} respectively. The activity profile of the primordial radionuclides in the soil samples investigated showed the existence of low level activity across the three campuses. The mean value of the annual effective dose equivalent obtained from this study is 0.04mSvyr^{-1}, with mean external hazard index of 0.2. These average values fall within the internationally provided safety range for outdoor radiation exposure. The values obtained from this investigation for all the radiation parameters for the studied soil samples showed that none of the campuses investigated pose any significant radiological threat to the public.

KEYWORDS: Natural radioactivity, gamma ray spectrometry, annual effective dose equivalent, external hazard index, Federal University of Technology Minna, Niger State College of Education, Minna.

INTRODUCTION

Naturally Occurring Radioactive Materials (NORMs) are and have always been a part of our world. Radiation is present in every environment of the earth's surface, beneath the earth, in the atmosphere (Kannan *et al*., 2002), and even in our human body. Various geological formations, including rocks, plants, water, air and soils contain NORMs at various trace levels. According to Karahan and Bayulken (2000), natural radionuclides in soils generate a significant component of the background radiation exposure of the population. Soils not only acts as a source of continuous radiation exposure to humans, but also as a medium of migration for transfer of radionuclides to biological systems (Mehra *et al*., 2010), and hence, the basic indicator of radiological contamination in the environment (Ibrahim and Mohammad, 2009).

Humans are constantly exposed to natural radiation from two prominent sources: internal exposure from radionuclides in food and inhaled radon gas; and the external radiation exposure from cosmic rays and terrestrial gamma rays due to NORMs in soils, rocks and building materials (Alberto, Laura and Valerio, 1996; Alatise, Babalola and Olowofela, 2008). The earth and the atmosphere contains various levels of radionuclides, but only those with half lives comparable with the age of the earth and their corresponding decay products existing in terrestrial materials, such as ^{40}K, ^{238}U and ^{232}Th are of great interest, since gamma radiation from these represents the main external source of human exposure. The level of natural radioactivity in soils and in the surrounding environments as well as the associated external exposure due to gamma radiation depends primarily on the geological and geophysical conditions of the region (UNSCEAR, 1998; 2000). Since these radionuclides are not uniformly distributed, the knowledge of their distribution in soils and their measurement id very important, not only to determine the amount of change of the natural background activity with time, but also for radiation protection issues.

Minna, the capital of Niger State, is the home of two tertiary institutions of the state: the Federal University of Technology, and Niger State College of Education. Minna and the entire state are covered by two major rock formations-the sedimentary and basement complex rocks. Other secondary geological formations in the state may suggest a radiation level slightly above background. Data on the natural radioactivity concentrations in Minna city and the entire state are still scarce and so a comprehensive study with the objective to systematically measure the terrestrial gamma radiation and determine its contribution to annual effective dose equivalent to the population in these campuses is highly needed.

In order to assess the radiological hazards due to natural radioactivity of soils of these campuses, calculations of the radium equivalent activity, absorbed gamma dose rate in air out doors and the external hazard index are presented and discussed. Hopefully, the results of this study and the interpretations presented would serve as base line data for radioactivity levels in this environment.

MATERIALS AND METHODS

Surface soil samples were collected from the three campuses of the tertiary institutions. These are Bosso campus (BSC) and Gidan Kwano campus (GKC) of Federal University of Technology, and the Niger State College of Education (COE) campus. Ten surface soil samples were collected per campus. The choice of the sampling points in the campuses, which include, the boys' and girls' hostels, the central mosques, the chapels, the administrative blocks, libraries and the sports complex, was informed by the daily extensive presence of human life and the existence of portable water sources.

Three sub samples per each sample point, at 5cm depth, were collected after removing the stones and vegetation. These sub samples were thoroughly mixed together to give a correct representation of each sample point. The soil samples, neatly packed in well labeled polythene bags were air-dried for 48 hours under normal ambient temperature to remove the moisture content. The dried soil samples were crushed; grind into fine powder to pass through 500μm sieve. The representative powder samples were filled into cylindrical plastic containers of dimension 7.2cm in diameter and 6.0cm high to satisfy the selected optimal sample container height. The sample containers were then sealed hermetically with adhesive tape and stored for 24 days to allow them attain radioactive equilibrium. This was necessary to ensure that radon gas is confined within the volume and that the daughters will also remain in the sample (Sroor et al., 2001). Each container accommodated average of 275±1g.

The gamma ray spectrometry system used for the measurement consist of 7.62cmx7.62cm NaI(Tl) detector at the Center for Energy Research and Training (CERT), Ahmadu Bello University Zaria, Kaduna State, Nigeria. The detector is housed in a 6cm thick lead shield so as to reduce the background radiation levels many times. The inside of the detector is also lined with cadmium and copper sheets, which according to El-Ayadarous (2007), help to absorb the emitted x-rays from lead which may contain radioactive impurities due to antimony impurirites. The detector assemblage is coupled to a computer based multichannel analyzer (MCA) with ACCUSPEC computer program used for data acquisition and analysis of gamma spectra. The efficiency and energy calibration of the detector were done over energy range using ^{137}Cs, ^{60}Co and ^{54}Mn standard isotopic sources over energy range 0f 200keV to 3MeV, being the energy range of radionuclides to be determined. Also, the IAEA gamma spectrometric reference materials, RGK-1, RGU-1 and RGTh-1 were used to recalibrate the system for quantitative determination of ^{40}K, ^{226}Ra and ^{232}Th in the soil samples. The activity concentration of ^{226}Ra was evaluated from 1764keVgamma line of ^{214}Bi, while 2614keV gamma line of ^{208}Tl was used to evaluate the activity concentration of ^{232}Th. The single 1460keV gamma line of ^{40}K was used for its content evaluation. Each sample was counted for 29000 seconds.

It is known that the distribution of ^{226}Ra, ^{232}Th and ^{40}K in soil is heterogeneous in nature with no specific relation between them (Christa et al., 2011). A common index with respect to radiation exposure, called the radium equivalent activity (Ra_{eq}) has therefore been defined to represent the specific activities of ^{226}Ra, ^{232}Th and ^{40}K in different combinations in soil samples. This index is calculated using the relation (Beretka and Matthew, 1985; Yu et al., 1992; UNSCEAR, 2000)

$$Ra_{eq}\ (Bqkg^{-1}) = C_{Ra} + 1.43C_{Th} + 0.077C_K \quad (1)$$

Where C_{Ra}, C_{Th} and C_K are activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in $Bqkg^{-1}$ respectively. Ra_{eq} is defined according to equation (1) on the assumption that $1Bqkg^{-1}$ of ^{226}Ra, o.7$Bqkg^{-1}$ of ^{232}Th or 13$Bqkg^{-1}$ of ^{40}K yields the same gamma ray dose (Malanca et al., 1993; OECD, 1979).

From the measured activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in the soil samples, the external gamma absorbed dose rate in air 1m above ground level was calculated following the equation (UNSCEAR, 2000)

$$D\ (nGyh^{-1}) = 0.462C_{Ra} + 0.621C_{Th} + 0.417C_K \qquad (2)$$

Where D is the dose rate in $nGyh^{-1}$, C_{Ra}, C_{Th}, C_K ($Bqkg^{-1}$), and 0.462, 0.621, and 0.417 ($ngyh^{-1}$ per $Bqkg^{-1}$) are the activity concentrations and dose conversion factors of ^{226}Ra, ^{232}Th and ^{40}K respectively. In equation (2) above, it is assumed that all decay products of ^{226}Ra and ^{232}Th are in radioactive equilibrium with their precursors (Prasong and Susaira, 2008).

The annual effective dose equivalent to the students population in the campuses due to soil radioactivity was estimated using the equation (UNSCEAR, 2000)

$$AED\ (mSvyr^{-1}) = D\ (nGyh^{-1}) \times 0.7\ SvGy^{-1} \times 8760hyr^{-1} \times \left(\frac{10^{3}\ mSv}{10^{9}}\right) \times 0.2$$

$$= D\ (nGyh^{-1}) \times 1.2264\times10^{-3} \qquad (3)$$

Equation (3) was calculated using the dose conversion factor, $0.7SvGy^{-1}$, from absorbed dose rate in air to effective dose received by adults, and the occupancy factor of 0.2 proposed by UNSCEAR (2000), bearing in mind that the students spent an average of 20% of their time outdoors.

The external hazard index (H_{ex}), which is an estimate of radiation risk resulting from exposure to gamma rays of the primordial nuclei is evaluated from the equation (UNSCEAR, 2000)

$$H_{ex} = \frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \qquad (4)$$

Where C_{Ra}, C_{Th} and C_K are activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in $Bqkg^{-1}$ respectively. The maximum value for H_{ex} is equal to unity, which corresponds to $370Bqkg^{-1}$, the upper limit of Ra_{eq}. The value of this index must therefore be less than unity so as to keep the radiation hazard insignificant.

RESULTS AND DISCUSSION

The results of the gamma spectrometry analysis for the 30 soil samples collected across the three campuses of the tertiary institutions in Minna, Niger state are presented in Table 1.

Table 1 shows that the activity concentrations in $Bqkg^{-1}$ of ^{226}Ra, ^{232}Th and ^{40}K in all the samples analyzed ranged between 1.0±2.3–26.5±1.9, 2.2±0.3–70.3±0.9, and 43.1±3.1–468.5±3.0, with mean values of 7.8±1.3, 29.4±0.9 and 229.4±1.8 respectively. Although the mean value of ^{40}K in all the measured samples is higher than those of ^{226}Ra and ^{232}Th as can be seen from the table, the obtained results are much lower compared with the world wide average concentration of these radionuclides in soils as reported by UNSCEAR (2000), which are $40Bqkg^{-1}$ for ^{226}Ra, $40Bqkg^{-1}$ for ^{232}Th and $370Bqkg^{-1}$ for ^{40}K. the results therefore shows that the three campuses being investigated have normal levels of natural background and so do not pose any risk to the students.

Table 2 presents a comparison of the mean values of activity concentrations of the natural radionuclides in soil samples of the studied area with those of other literatures and the world wide mean. The comparison shows that the results obtained from this study are in agreement with similar works from other countries.

The values calculated for radium equivalent activity, gamma dose rate, annual effective dose and external hazard index are presented in table 3. The values for Ra_{eq} for all the samples as seen in Table 3 ranged from 11.6 to $131.9Bqkg^{-1}$, with a mean value of $67.5Bqkg^{-1}$. The values are less than the safe limit of $370Bqkg^{-1}$ provided by UNSCEAR (2000). The values for the absorbed gamma dose rate in air fluctuates between $5.6nGyh^{-1}$ and $59.7nGyh^{-1}$ with an average value of $31.3nGyh^{-1}$, while the calculated values for annual effective dose equivalent ranged between 0.01 and $0.07mSvyr^{-1}$, with a mean value of $0.04mSvyr^{-1}$. These values are found to be comparable to the world average of $57nGyh^{-1}$ and $0.48mSvyr^{-1}$ respectively provided by UNSCEAR (2000). The mean value for the external hazard index as seen in table 3 is 0.2, which is lower than unity, indicating that the radiation hazard in the three campuses is really insignificant.

Table 1: Activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in all the soil samples (Bq/kg)

SAMPLE ID	^{226}Ra	^{232}Th	^{40}K
BSC1	3.5±0.5	8.0±0.1	357.3±2.2
BSC2	21.0±0.1	20.2±0.6	292.7±1.2
BSC3	1.4±2.2	44.5±9.8	437.4±0.8
BSC4	13.3±0.8	14.0±0.1	395.0±1.7
BSC5	1.0±2.3	30.3±1.8	286.0±1.6
BSC6	2.6±2.3	55.8±0.5	468.5±3.0
BSC7	26.5±1.9	3.8±0.5	291.6±1.2
BSC8	8.6±0.2	20.9±0.8	378.2±0.9
BSC9	7.2±0.5	16.3±0.1	270.7±3.7
BSC10	8.8±2.0	70.3±0.9	292.5±5.0
GKC1	1.5±0.2	32.6±0.7	416.9±4.4
GKC2	4.9±0.5	51.8±1.0	207.1±0.8
GKC3	5.9±1.6	44.4±0.9	143.1±1.6
GKC4	4.3±2.1	2.3±0.7	187.7±0.8
GKC5	3.6±0.6	3.1±0.1	216.8±0.2
GKC6	4.1±1.5	18.8±0.1	198.9±0.3
GKC7	2.8±0.2	7.9±0.8	259.1±3.7
GKC8	9.6±1.3	12.7±0.3	220.5±0.2
GKC9	1.3±1.0	21.1±0.3	216.8±0.2
GKC10	6.3±0.7	57.8±0.8	177.9±0.5
COE1	10.9±2.2	30.1±0.5	115.2±0.3
COE2	13.7±1.5	13.6±0.2	108.7±0.2
COE3	11.9±1.7	47.0±1.7	137.5±4.8
COE4	9.0±1.7	66.8±0.7	207.6±3.4
COE5	2.3±2.9	40.7±0.3	169.0±0.9
COE6	2.4±0.4	8.7±0.6	43.1±3.1
COE7	16.8±1.3	52.8±0.8	61.6±1.6
COE8	22.8±1.9	49.4±0.7	19.6±2.2
COE9	2.8±1.6	33.3±1.3	241.3±1.1
COE10	3.5±0.7	2.2±0.3	64.4±1.1
RANGE	1.0±2.3 -26.5±1.9	2.2±0.3-70.3±0.9	43.1±3.1-468.5±3.0
MEAN	7.8±1.3	29.4±0.9	229.4±1.8

Table 2: Comparison of activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Bq/kg, obtained in present study with that reported for other countries

Region	^{226}Ra	^{232}Th	^{40}K	Reference
India (Punjap)	19.7	220.5	920.2	Mehra *et al.*, (2010)
Thailand	68	45	213	Prasong and Susaira (2008)
India (Tamilnadu)	42.9	43.9	96.0	Saravanan *et al.*, (2003)
Nigeria (Delta region)	16.2	24.4	34.8	Arogunjo *et al.*, (2004)
Vietnam (south-East)	19.6	31	34.6	Huy and Luyen (2006)
Madagascar	29	95	294	Naivo *et al.*, (2008)
Botswana	34.8	41.8	432.7	Murty and Karunakara (2008)
Turkey	115	1192	1207	Merdanoglu and Altinsoy (2006)
China	112	71.5	672	Yang *et al.*, (2005)
Jordan	84	82	560	Al-jundi *et al.*, (2003)
World average	33	36	474	UNSCEAR (2000)
Nigeria (Minna)	7.8	29.4	229.4	Present study

UNSCEAR (1988) considered bone marrow and the bone surface cells as the organs of interest. Therefore, the annual gonadal dose equivalent (AGDE) in $\mu Svyr^{-1}$ due to the activity concentrations of 226Ra, 232Th and 40K was calculated using the equation (Mamont-Ciesla et al., 1982; Ibrahim and Mohammad, 2009)

$$AGDE\ (\mu Svyr^{-1}) = 3.09C_{Ra} + 4.18C_{Th} + 0.314C_K \quad (5)$$

Where C_{Ra}, C_{Th} and C_K are activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in $Bqkg^{-1}$ respectively. The results calculated for AGDE for all the samples investigated are presented in Table 3.

As seen in Table 3, AGDE values vary between 40.1 and 410.1$\mu Svyr^{-1}$ with an average value of 217.8$\mu Svyr^{-1}$. Generally as seen in Table 3, the mean values of D, ADE, H_{ex} and AGDE are all below the permissible safety limits which show that the hazardous effects of these radiations in the three campuses investigated are negligible.

Table 3: Radium equivalent activity (Ra_{eq}), gamma dose (D), effective dose equivalent rate (E), external hazard index (H_{ex}), and annual gonadal dose equivalent (AGDE) in the soil samples

SAMPLE ID	Ra(eq) (Bq/kg)	D (nGy/h)	E (mSv/y)	H(ex)	AGDE ($\mu Svyr^{-1}$)
BSC1	42.5	21.2	0.03	0.1	156.1
BSC2	72.4	34.2	0.04	0.2	240.4
BSC3	98.7	46.2	0.06	0.3	325.9
BSC4	63.7	31.0	0.04	0.2	223.1
BSC5	66.4	31.0	0.04	0.2	218.3
BSC6	118.5	55.1	0.07	0.3	386.2
BSC7	54.4	26.6	0.03	0.1	189.2
BSC8	67.6	32.5	0.04	0.2	231.9
BSC9	51.4	24.5	0.03	0.1	174.7
BSC10	131.9	59.7	0.07	0.4	410.1
GKC1	80.2	38.0	0.05	0.2	270.5
GKC2	94.9	42.9	0.05	0.3	294.6
GKC3	80.4	36.2	0.04	0.2	247.0
GKC4	22.0	11.1	0.01	0.1	81.7
GKC5	24.7	12.5	0.02	0.1	92.0
GKC6	46.3	21.7	0.03	0.1	153.0
GKC7	34.0	16.8	0.02	0.1	122.7
GKC8	44.7	21.4	0.03	0.1	151.5
GKC9	48.2	22.6	0.03	0.1	159.4
GKC10	102.7	46.1	0.06	0.3	314.6
COE1	62.8	28.5	0.03	0.2	194.5
COE2	41.5	19.2	0.02	0.1	132.8
COE3	89.7	40.3	0.05	0.2	274.5
COE4	120.5	54.2	0.07	0.3	369.5
COE5	73.5	33.3	0.04	0.2	228.7
COE6	18.2	8.3	0.01	0.0	57.0
COE7	97.0	43.1	0.05	0.3	289.8
COE8	95.0	42.0	0.05	0.3	281.1
COE9	69.0	31.9	0.04	0.2	222.3
COE10	11.6	5.6	0.01	0.0	40.1
RANGE	11.6-131.9	5.6-59.7	0.01-0.07	0.0-0.4	40.1-410.1
MEAN	67.5	31.3	0.04	0.2	217.8

CONCLUSIONS

This study has analyzed the activity concentrations of terrestrial gamma emitters for soil samples of the three campuses of the two tertiary institutions in Minna, Niger State. The results of this survey provide a pioneering data on the radioactivity levels of the campuses. The obtained results show that the mean values of the radiation hazard parameters calculated for all the soil samples being investigated are lower than the acceptable values for radiation safety provided by UNSCEAR (2000). The calculated dose rates and external hazard indices show that none of the three campuses have any high radiation exposure for either the students or the general public. This means that the radiation hazard is insignificant in the three campuses and so the students and the entire public can freely live and interact on daily basis without any significant radiation threat to the entire population.

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