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Determination of Activity Concentration and Radiological Parameters of Natural Radionuclides for Soil Samples from Kogi State University Staff Nursery and Primary School, Kogi State

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ABSTRACT

The activity concentrations of naturally occurring radionuclides 226Ra, 232Th and 40K, in soil samples collected from the Kogi State University, Anyigba staff Nursery and Primary School were determined by Gamma spectroscopy method. The average activity concentrations of 226Ra, 232Th and 40K for SSN soil samples were found to be 78.67 ± 40.51, 11.50 ± 9.83, 4.15 ± 3.27 Bqkg^{-1}, respectively; and SSP soil samples have average activity concentration values of 81.06 ± 53.28, 16.79 ± 18.00, 6.08 ± 2.73 Bqkg^{-1}, respectively. The results obtained for the corresponding radionuclides are lower than the worldwide average values of 35, 30 and 400 Bqkg^{-1}, respectively. The average absorbed dose rate in air (D) and the annual effective dose rates equivalent (AEDE) due to 226Ra, 232Th and 40K were observed to be 7.30 nGyh^{-1} and 8.95 μSvy^{-1}, respectively for SSN, and 10.26 nGyh^{-1} and 12.58 μSvy^{-1}, respectively for SSP. These values are all below the world average value of 60 nGyh^{-1} and 80 μSvy^{-1}, respectively; the average radium equivalent (Raeq) activity, internal and external hazard indices estimated for SSN were 11.10 Bqkg^{-1}, 0.04 and 0.03; and 15.29 Bqkg^{-1}, 0.07 and 0.04, respectively for SSP. These values are also less than the world average values of 370 Bqkg^{-1} and unity, respectively. These results indicate that there are no associated radiological hazards.

Keywords: Radioactivity, Dose assessment, Anyigba, KSU, Kogi state

INTRODUCTION

The earth is continuously being exposed to cosmic rays, cosmogenic radiation and radiation from naturally occurring substances. These are ubiquitously distributed in terrestrial formations and in living components of the environment. Radioactivity is the property of some atoms to spontaneously give off high-energy radiation in the form of particles or rays [1]. The atoms of unstable nuclides are the sources of radiation, and these unstable nuclides are called radionuclides.

The distribution of the natural radionuclides and their progeny in natural ecosystems is influenced by many factors as chemical properties of the nuclides, physical factors of the ecosystem, physiological and ecological factors. The weathering of bedrocks release primordial radionuclides (^{226}Ra, ^{232}Th and ^{40}K) to the soil. Progenies of ^{226}Ra and ^{232}Th also take part in this transfer.

Naturally occurring radioisotopes are the main sources of both external and internal radiation exposure in humans. Among the terrestrial radioisotopes present in all soil types in varying concentrations, ^{226}Ra, ^{232}Th and ^{40}K are the

longest lived. These radionuclides which are present in all soil types enter the human body primarily by ingestion of foods, contact and inhalation thereby constituting internal dose [2]. These radionuclides are known as carcinogens.

Kogi State University staff school pupils spend a number of hours on the playgrounds thereby getting exposed externally and internally, hence the need to perform this research. This research work is aimed at determining the radioactivity level of soil samples from Kogi State University staff Nursery and Primary school premises with the evaluation of associated radiological hazard.

MATERIALS AND METHODS

Site description

Kogi State University (from where the samples were taken) is located at Anyigba, Dekina Local Government Area of Kogi State, Nigeria. Figure 1 shows the map of Nigeria showing kogi state. Kogi State is located in the North Central region of Nigeria with its capital at Lokoja. Kogi state has two main rock types, namely, basement complex rocks of the Precambrian age in the western half of the state and extending slightly eastwards beyond the lower Niger valley and the older sedimentary rocks in the eastern half. The various sedimentary rock groups extend along the banks of Rivers Niger and Benue and southeastwards through Enugu and Anambra states, to join the Udi Plateau [3].

Anyigba the study area is located on latitude 7.4934° N and longitude 7.1736° E and with an average altitude of 420 meters above sea level [3]. The study area falls within the tropical wet and dry (Aw) climatic region and the guinea savanna, with mean annual temperature of 25°C and rainfall 1600 mm. Anyigba is situated on sedimentary formation of the Anambra basin and dominated by lateritic soil type with patches of hydromorphic and rich loamy soils. Anyigba land areabis an arable land with no history of industrial activities (Figure 1).

Samples collection

A total of fifteen (15) soil samples were collected from only the pupils' playground (where they have most contact with the soil) of Kogi State University Staff School (Nursery and Primary) labeled as SSN (seven samples) and **SSP** (eight samples) respectively, with 450 g of each soil sample was taken using an auger to a depth of about 150 mm. The samples were then transferred into labeled polythene bags. These were then transported to the Nigerian Nuclear Regulatory Agency (NNRA) Ibadan, Nigeria radiation laboratory for preparation and analysis.

Sample preparation

The samples were sun dried to get the dry weight of the sample. These were then grounded with mortar and pestle and sieved using a 2 mm mesh. Sample of 200 g dry-weight were packed into air tight cylindrical plastic container which is of the detector geometry and stored for a period of four weeks before counting, so that secular equilibrium can be attained between ^{226}Ra and its short lived progeny [4].

The radioactivity concentration of radionuclides in soil samples was measured by using a lead-shielded 76 × 76 mm NaI(TI) detector crystal (Model No. 80 series, Canberra Inc.) that is coupled to a Canberra Series 10 plus Multichannel Analyzer (MCA) (Model No.1104) through a preamplifier. It has a resolution (FWHM) of about 8% at energy of 0.662 MeV (^{137}Cs) which is considered adequate to distinguish the gamma ray energies of interest in the present study. The choice of gamma-ray peaks of the radionuclides to be used for measurements was made considering the fact that the NaI(Tl) detector used in this study had a modest energy resolution. This was to ensure that the photons emitted by the radionuclides would only be sufficiently discriminated if their emission probability and their energy were high enough, and the surrounding background continuum low enough. The detector energy and efficiency calibrations were done using standard source **ENV 95050** supplied by International Atomic Energy Agency (IAEA), Vienna. Each source was placed about 7 cm from the detector and counted for 2 h. The energy of the photopeak and the corresponding channel number were recorded and the background count carried out. The soil samples were then counted for 10 h using the calibrated NaI(Tl) detector. The resultant spectrum of each sample was acquired and analyzed using Microsoft Excel software with the appropriate formula to determine their activity concentrations. For this work, the activity concentration of ^{214}Bi (determine from its 1.70 MeV Gamma-Ray peak) was chosen to provide an estimate of ^{226}Ra (^{238}U) in the samples, while that of the daughter radionuclide ^{208}Tl (determine from its 2.615 MeV Gamma – ray peak) was chosen as an indicator of ^{232}Th; ^{40}K was determined by measuring the 1.460 MeV Gamma – rays emitted during its decay.

Instrument validation

The activity concentration, C (Bqkg^{-1}) of the radionuclides in all samples in this research work was computed using [5]:

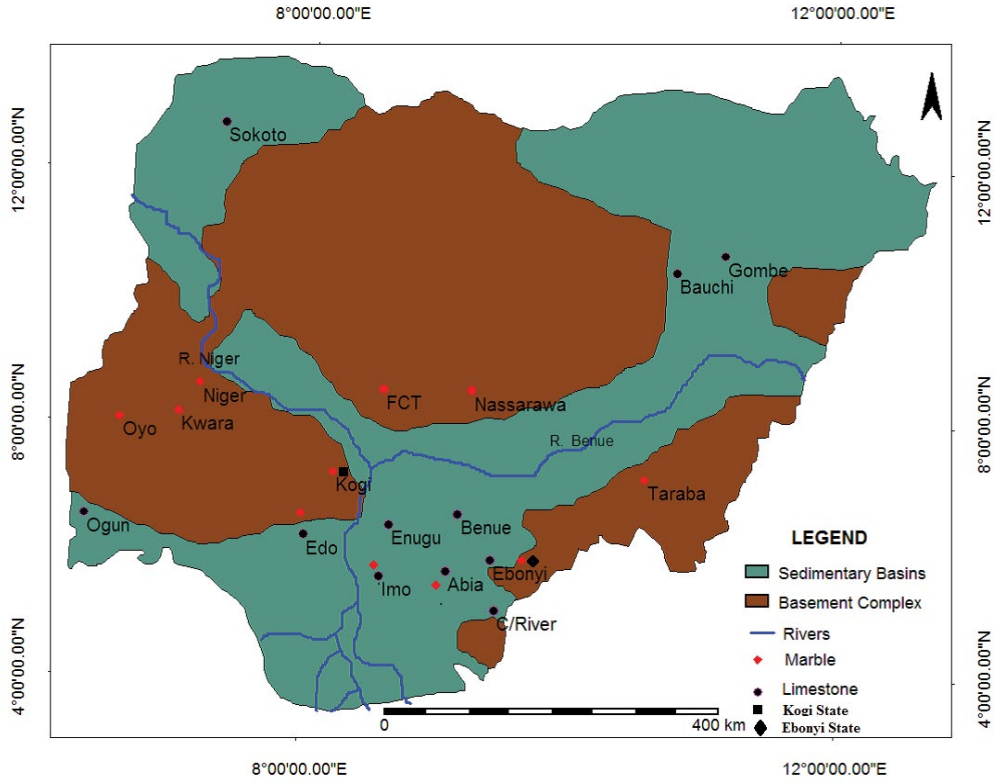

Figure 1: Geological map of Nigeria showing Kogi state

$$C = \frac{\mathrm{A}}{E_{\rho}.\gamma.\mathrm{T}.\mathrm{M}_{s}} \tag{3.1}$$

Where $\boldsymbol{E}_{\mathbf{p}}$ is the detection efficiency at the specific Gamma energy; **T** is counting time; $\boldsymbol{M}_{s}$ is mass of sample (in Kg); A is the net area under the photopeak for each sample and **γ** is the gamma yield at a specific Gamma energy.

Dose assessment parameters

To determine whether or not there are associated health risks, the following dose assessment parameters were evaluated for the samples' results:

Absorbed dose rate in air (D)

The external outdoor absorbed gamma dose rates due to terrestrial γ- rays from the nuclides ^{226}Ra, 232Th and 40K at one meter above the ground level was calculated as [6]:

$$D = (0.0414 + 0.623 + 0.461)\ nGyh^{-1} \tag{3.2}$$

Where, C_K, C_{Th} and C_{Ra} are the average activity concentrations of ^{40}K, ^{232}Th and ^{226}Ra. About 98% of the external Gamma dose rate from ^{238}U series is delivered by the ^{226}Ra sub series.

Outdoor annual effective dose equivalent (AEDE)

The absorbed dose rate can be converted into annual effective dose equivalent by using a conversion factor of 0.7 $SvGy^{-1}$ and 0.2 for the outdoor occupancy factor by considering that the people on the average spent 20% of their time in outdoors. The effective dose due to natural activity in the soil samples was calculated using the following formula:

$$AEDE\ (\mu Sv.y^{-1}) = D\left(nGyh^{-1}\right) \times 8760\ h \times 0.2 \times 0.7\ Sv.\mathrm{G}\ y^{-1}) \times 10^{-3} \tag{3.3}$$

Where, D=the absorbed dose rate in air ($nGyh^{-1}$); 8760=the time in hours for one year; 0.2 is the outdoor occupancy factor; 0.7 $SvGy^{-1}$ is the quotient of effective dose equivalent rate to absorbed dose rate in air and 10^{-6} is the factor that convert nano to milli.

External hazard index (H_{ext})

Numerous radionuclides occur naturally in terrestrial soils and rocks and upon decay, these radionuclides produce an external radiation field to which all human beings are exposed to. In terms of dose, the principal primordial

radionuclides are ^{232}Th, ^{238}U and ^{40}K. Thorium and uranium head series of radionuclides that produce significant human exposure. The external hazard index (H_{ext}) is defined as [7]:

$$H_{ext} = \frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_K}{48103} \quad (3.4)$$

Where: C_{Ra}, C_{Th} and C_K are the radioactivity concentrations in Bqkg^{-1} of ^{238}U, ^{232}Th and ^{40}K respectively. The value of this index must be less than unity for the radiation hazard to be negligible equal to unity corresponds to the upper limit of Ra_{eqn} (370 Bqkg^{-1}) [7].

Radium equivalent activity

Radionuclides of ^{226}Ra, ^{232}Th and ^{40}K are not homogeneously distributed in soil. The inhomogeneous distribution from these naturally occurring radionuclides is due to disequilibrium between ^{226}Ra and its decay products. For uniformity in exposure estimates, the radionuclide concentrations have been defined in terms of radium equivalent activity Ra_{eqn} (370 Bqkg^{-1}). This allows comparison of the specific activity of materials containing different amounts of ^{226}Ra, 232Th and 40K. According to Beretka and Mathew:

$$Ra_{eq} = 370.\ H_{ext} \quad (3.5)$$

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

Internal hazard index (H_{int})

The internal hazard index (Hint) is given as:

$$H_{\text{int}} = \frac{C_{Ra}}{185} + \frac{C_{Th}}{259} + \frac{C_K}{48104} \quad (3.6)$$

H_{int} should be less than unity for the radiation hazard to be negligible. Internal exposures to radon are very hazardous this can lead to respiratory diseases like asthma and cancer.

RESULTS

Tables 1a and 1b show the results for activity concentration (with the activity concentration measurement uncertainty for each value) and Tables 2a and 2b show dose assessment parameters evaluated.

DISCUSSION

Activity concentration

Activity concentrations for nuclides ^{226}Ra, ^{232}Th, ^{40}K in Kogi State University (Nursery and Primary School) soil samples were determined by equation (3.1) and the results are shown in Tables 1a and 1b. The average activity concentrations of ^{226}Ra, 232Th and 40K for SSN soil samples were found to be 78.67 ± 40.51, 11.50 ± 9.83, 4.15 ± 3.27 Bqkg^{-1} respectively; and SSP soil samples have average activity concentration values of 81.06 ± 53.28, 16.79 ± 18.00, 6.08 ± 2.73 Bqkg^{-1}, respectively. The results obtained for the corresponding radionuclides are lower than the worldwide average values of 35, 30 and 400 Bqkg^{-1}, respectively. These low values are in agreement with the agrarian history of the school site; and there is no known industrial history and prior radioactive contamination of the site.

Table 1a: Activity concentrations for **SSN**

S/N	SAMPLE	K-40 (Bqkg^{-1})	U-238 (Bqkg^{-1})	Th-232 (Bqkg^{-1})
1	SSN1	19.75 ± 1.91	BDL (Below Detection Limit)	0.53 ± 0.06
2	SSN2	47.02 ± 4.49	BDL	7.76 ± 0.78
3	SSN3	126.03 ± 11.28	BDL	9.04 ± 0.88
4	SSN4	77.12 ± 7.33	BDL	2.30 ± 0.24
5	SSN5	73.36 ± 7.41	1.67 ± 0.41	1.24 ± 0.14
6	SSN6	56.43 ± 5.50	BDL	3.09 ± 0.33
7	SSN7	150.95 ± 13.64	21.32 ± 4.60	5.12 ± 0.56
	MEAN ± SD	78.67 ± 40.51	11.50 ± 9.83	4.15 ± 3.27
	Range	19.75 ± 1.91–150.95 ± 13.64	1.67 ± 0.41-21.32 ± 4.60	0.53 ± 0.06–9.04 ± 0.88
	World Average Value (UNSCEAR, 2000)	400	35	30

Table 1b: Activity concentrations for SSP

S/N	SAMPLE	K-40 (Bqkg^{-1})	U-238 (Bqkg^{-1})	Th-232 (Bqkg^{-1})
1	SSP1	25.86 ± 2.66	0.84 ± 0.20	3.95 ± 0.41
2	SSP2	15.05 ± 1.56	22.57 ± 4.91	7.08 ± 0.57
3	SSP3	71.01 ± 6.62	BDL (Below Detection Limit)	3.16 ± 0.35
4	SSP4	38.56 ± 4.09	BDL	11.07 ± 1.14
5	SSP5	113.80 ± 10.65	10.45 ± 2.67	4.48 ± 0.46
6	SSP6	171.17 ± 15.95	50.58 ± 12.45	8.96 ± 0.93
7	SSP7	100.63 ± 10.36	8.78 ± 1.92	5.01 ± 0.50
8	SSP8	112.39 ± 11.02	7.52 ± 1.65	4.93 ± 0.49
	MEAN ± SD	81.06 ± 53.28	16.79 ± 18.00	6.08 ± 2.73
	Range	15.05 ± 1.56-171.17 ± 15.95	0.84 ± 0.20-50.58 ± 12.45	316 ± 0.35-11.07 ± 1.14
	World Average Value (UNSCEAR, 2000)	400	35	30

Table 2a: Results of dose assessment parameters for SSN

S/N	SAMPE	External Hazard Index (Hext)	Internal Hazard Index (Hint)	Absorbed DoseRate in Air D (*nGyh^{-1}*)	Outdoor Annual Effective Dose Equivalent AEDE(μSv.y^{-1})	Radium Equivalent (Raeq) (Bqkg^{-1})
1	SSN1	0.00	0.00	1.14	1.4	0
2	SSN2	0.03	0.03	6.65	8.15	0
3	SSN3	0.04	0.04	10.72	13.14	14.8
4	SSN4	0.01	0.01	4.61	5.65	3.7
5	SSN5	0.01	0.02	4.58	5.61	3.7
6	SSN6	0.01	0.01	4.22	5.17	3.7
7	SSN7	0.08	0.14	19.19	23.54	29.6
	MEAN	0.03	0.04	7.30	8.95	11.10
	Range	0.00-0.08	0.00-0.14	1.14–19.19	1.40–23.54	0–29.6
	World Average Value (UNSCEAR, 2000)	≤ 1	≤ 1	60	80	≤ 370

Table 2b: Results of dose assessment parameters for SSP

S/N	SAMPE	External Hazard Index (Hext)	Internal Hazard Index (Hint)	Absorbed Dose Rate in Air D (*nGyh^{-1}*)	Outdoor Annual Effective Dose Equivalent AEDE (μSv.y-1)	Radium Equivalent (Ra_{eq}) (Bqkg^{-1})
1	SSP1	0.02	0.02	3.85	4.72	7.4
2	SSP2	0.09	0.15	15.28	18.75	33.3
3	SSP3	0.01	0.01	4.87	5.97	3.7
4	SSP4	0.04	0.04	8.29	10.17	14.8
5	SSP5	0.05	0.08	12.26	15.03	18.5
6	SSP6	0.17	0.31	35.82	43.92	62.9
7	SSP7	0.05	0.07	11.26	13.81	18.5
8	SSP8	0.04	0.06	11.12	13.64	14.8
	MEAN	0.04	0.07	10.26	12.58	15.29
	Range	0.01-0.17	0.01-0.31	3.85-35.82	4.72–43.92	3.70-62.90
	World Average Value (UNSCEAR, 2000)	≤ 1	≤ 1	60	80	≤ 370

Dose assessment

In order to assess the health effects, the radiation hazards such as absorbed dose rate (D), effective dose rates (E), external hazard index (Hex) and radium equivalent activity (Ra_{eq}) have been calculated from the activity of radionuclides ^{226}Ra, ^{232}Th, ^{40}K using the equations (3.2), (3.3), (3.4) and (3.5), respectively and the values are as shown in Tables 2a and 2b for **SSN** and **SSP** respectively. The average absorbed dose rate in air (D) and the annual effective

dose rates equivalent (AEDE) due to ^{226}Ra, ^{232}Th and ^{40}K were observed to be 7.30 $nGyh^{-1}$ and 8.95 μSvy^{-1} respectively for SSN and 10.26 $nGyh^{-1}$ and 12.58 μSvy^{-1} respectively for SSP. These values are all below the world average value of 60 $nGyh^{-1}$ and 80 μSvy^{-1}, respectively; the average radium equivalent (Ra_{eq}) activity, internal and external hazard indices estimated for SSN were 11.10 $Bqkg^{-1}$, 0.04 and 0.03; and 15.29 $Bqkg^{-1}$, 0.07 and 0.04, respectively for **SSP**. These values are also less than the world average values of 370 $Bqkg^{-1}$ and unity respectively.

CONCLUSION

In this research work, the results of the activity concentrations and radiological health risk assessment parameters were all lower than world average mean values. Therefore, pupils of Kogi State University (Nursery and Primary School) are at no radiological risk.

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