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An evaluation of the soil radioactivity in the top soil of the Polytechnic, Ibadan, southwest Nigeria

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Abstract

The background dose rate and the annual effective dose in soil samples due to natural gamma-emitting radionuclides in the campus of The Polytechnic, Ibadan has been determined in this study. Measurements of the soil natural radioactivity were made using a multi-channel analyzer which derived its input from a NaI (Tl) detector (76mm x 76mm), which is a Canberra plus 10 series detector. The gamma spectrum obtained from a computer coupled to the MCA was used to obtain the activity concentration. The mean activity concentrations obtained for the primordial radionuclides are 125 ±1.55 Bq/kg for ^{40}K; 12.98 ± 0.16 Bq/kg for ^{238}U and 12.48 ± 0.03 Bq/kg for ^{232}Th. The mean absorbed dose rate calculated at a height of 1.0 m above the ground is 19.95 $nGyh^{-1}$ while the annual effective dose rate obtained is 0.0869 $mSvy^{-1}$. The result of the annual effective dose obtained in this study is well below the world average of 0.5 $mSvy^{-1}$. It can therefore be concluded that students and staff of the Institution are not in any danger of aggravated radiation exposure.

Keywords: Radioactivity; Activity concentration; Absorbed dose; Annual Effective Dose

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1. Introduction

Primordial radionuclides are present in the earth crust as a result of magma formation and weathering. These primordial radionuclides disintegrate spontaneously into different daughter nuclides in order to achieve a stable element. However these radionuclides contribute to the average public radiation exposure. The other source of radiation exposure comes from energetic cosmic rays of extra-terrestrial origin. Over 98% of the public exposure to radiation come from natural radionuclides such as ^{238}U, ^{232}Th and ^{40}K and their progenies (Farai and Jibiri, 2000). Two common pathways of radiation exposure consist of both internal and external exposure. External radiation exposure come from direct cosmic and terrestrial radiation while internal exposure come from inhalation and ingestion of radionuclides found in air, water, food and soil. Several factors determine the activity levels and concentrations of radionuclides in any given environment. Such factors include but not limited to geological features of the area, weather conditions, human, economic and technological activities. The decay chain of these primordial radionuclides produces alpha and beta particles accompanied by emission of gamma rays which is also a source of radiation exposure in the environment.

As the human race depend on the environment in which the radionuclides are abundantly present, avoidance of interaction with radionuclides is virtually impossible. The interaction of radionuclides with human biological system leads to different chemical and physical expressions in terms of symptoms which also depend on the severity of exposure. The nature of the exposure depend on the absorbed dose rate as well as the effective dose equivalent. Knowledge of these parameters will enable health care providers to determine the best line of care for patients so diagnosed. Also the knowledge of the dose accruing to the populace assists in forming the basis for the assessment of the degree of radioactive contamination or pollution in the environment.

The Polytechnic, Ibadan was established in 1970. It is located in Ibadan, the capital city of Oyo State, southwest of Nigeria having coordinates of 7.45^0N and 3.85^0E. The city of Ibadan is underlain by a basement complex characterized mainly by metamorphic rock types of Precambrian age but with few intrusions of granite and porphyries of Jurassic age (Adekoya, 2003, Jibiri, 1993). The main types of rocks found within the polytechnic are gneiss, quartzite and magnetite which are of igneous and sedimentary origins.

The objective of this study is to determine the activity concentrations of natural radionuclides (^{238}U, ^{232}Th and ^{40}K) in the top soil within the Institutions' campus. This will result in the determination of the absorbed dose rate which will form the basis for assessing the radiological exposure to the staff and students of the Institution. The campus was divided into grids where twenty representative samples were obtained for the gamma assay with the use of gamma spectrometer.

2. Materials and method

A total of twenty soil samples were collected randomly but at strategic locations covering the Institution's campus at 0 – 5cm depth. The samples were packed in black plastic bags and then taken to the laboratory.

The samples were sundried for 72 hours under temperature gradient of 27^0 – 33^0C and relative humidity of about 70%. Each dried soil sample was grinded and sieved using a 2mm mesh. The fine grain obtained after sieving were packed in plastic containers each with a total mass of 200g. They were sealed and left in this state for four weeks to allow for secular equilibrium between ^{238}U (^{226}Ra) and its progenies and ^{232}Th and its corresponding progenies (Ademola, 2003).

Table 1. Sample locations on the campus

S/N	CODE	SAMPLE LOCATION
1.	P1	Entrance from Apete
2.	P2	Olori Hall of residence
3.	P3	Student Union Building
4.	P4	Geology Department Area
5.	P5	Unity Hall of residence
6.	P6	Information Technology Center
7.	P7	Rectors Office
8.	P8	Faculty of Science area
9.	P9	Central Library
10.	P10	Botanical Garden
11.	P11	Sewage Area
12.	P12	Middle Belt/ Music Department area
13.	P13	Vocational Study Center
14.	P14	U.I – Poly Road
15.	P15	Senior Staff Quarters
16.	P16	Academic Affairs area
17.	P17	Sports Pavilion area
18.	P18	Assembly Hall area
19.	P19	Student Quarters
20.	P20	Main Entrance

The gamma assay was done with the use of a gamma spectrometer which consists of a 76mm x 76mm NaI(Tl) scintillation detector coupled to a Canberra series 10 plus multichannel analyzer (MCA). The detector is housed in a 5cm thick lead shield that minimizes the effect of natural background radiation. The detector is interfaced with the MCA that consists of an analogue to digital converter (ADC), internal amplifier and in-built high voltage power supply (HVPS). The detector was calibrated using a standard reference source sample supplied by IAEA (No. ENV984084). The energy and efficiency calibration of the detector was done after which the same setting was used for the gamma assay of the soil samples (Gilmore and Hemingway, 1995).

The linear equation relating the energy (in MeV) to the channel number was obtained to be:

$$E\ (\text{MeV}) = 1.83 \times 10^{-2} N + 0.3585 \qquad (1)$$

Likewise the reference sample was used to determine the efficiency of the detector at different gamma ray energies. The net area under the photopeak above the background was obtained from the MCA output and related to the activity concentration of the reference source (Jibiri, 1993). The activity concentration was related to the efficiency using equation:

$$E_p = \frac{A}{t * c * Y * m} \qquad (2)$$

where A is the net gamma count, t is the time of counting, c is the activity concentration of the reference sample, Y is the gamma yield per decay and m is the mass of the sample. The efficiency values obtained is given in Table 2.

Table 2. Efficiency values of the detector for the natural radionuclides

Radionuclides	Activity Conc. (Bq/kg)	Energy (MeV)	Yield	Efficiency (X 10^{-2}) (%)
^{40}K	479.15 ± 23.43	1.46	0.107	1.63 ± 0.079
^{238}U	566.47 ± 8.33	1.76	0.159	1.44 ± 0.022
^{232}Th	11.60 ± 0.77	2.614	0.358	0.956 ± 0.013

The 1460 keV gamma ray energy of ^{40}K was used to determine the concentration of ^{40}K in the different samples. The gamma transition energy of 1765 keV (due to ^{214}Bi) was used to determine the concentration of ^{238}U while the gamma transition energy of 2614.5 keV (due to ^{208}Tl) was used to determine the concentration of ^{232}Th in the soil samples (Harb *et al.,* 2014).

3. Results and discussion

The activity concentration of the primordial radionuclides in the top soil of The Polytechnic, Ibadan have been carried out. Table 2 shows the values of the activity concentration with their error band. The activity concentration for ^{40}K ranged from 17.79 ± 2.17 to 840.33 ± 10.25 Bq/kg with a mean value of 125.94 ± 1.55 Bq/kg; that of ^{238}U ranged from 6.10 ± 0.16 to 18.10 ± 0.019 Bq/kg with a mean value of 12.98 ± 0.16 Bq/kg while the activity concentration of ^{232}Th ranged from 6.40 ± 0.02 to 26.18 ± 0.05 Bq/kg with a mean value of 12.48 ± 0.03 Bq/kg.

These values are well below the ranges obtained in other parts of the world where similar studies have been done. Table 4 compares results of work done in other parts of the world with the present study. The values obtained in this work are well below the world wide average of activity concentrations of these natural radionuclides in soil sample as reported by UNSCEAR (2000).

The distribution of the natural radionuclides on the campus of the Institution is not uniform and the relatively low level of ^{40}K can be attributed to the fact that farming activities which may involve use of potassium based fertilizers are very limited on the campus. Farming activities in which fertilizers containing potassium are frequently used have been found to be a source of high level of the radionuclide isotope of ^{40}K (Harb *et al.,* 2014).

Table 3. Activity concentration (in $Bqkg^{-1}$) for the natural radionuclides in soil samples

Code	^{40}K	^{238}U	^{232}Th
P1	43.12 ± 0.52	10.92 ± 0.15	8.89 ± 0.02
P2	17.786 ± 2.17	16.92 ± 0.18	17.61 ± 0.04
P3	77.22 ± 0.94	14.71 ± 0.17	11.32 ± 0.03
P4	47.33 ± 0.58	13.49 ± 0.16	11.23 ± 0.03
P5	39.32 ± 0.48	12.36 ± 0.15	9.13 ± 0.02
P6	92.15 ± 1.12	10.54 ± 0.15	10.67 ± 0.03
P7	58.21 ± 0.71	12.36 ± 0.15	6.74 ± 0.02
P8	67.13 ± 0.82	10.45 ± 0.15	10.67 ± 0.03
P9	24.90 ± 0.03	16.15 ± 0.18	15.85 ± 0.04
P10	840.33 ± 10.25	14.28 ± 0.17	11.91 ± 0.03
P11	179.10 ± 2.18	17.08 ± 0.19	17.14 ± 0.04
P12	82.96 ± 1.01	13.53 ± 0.17	9.86 ± 0.03
P13	48.38 ± 0.59	9.41 ± 0.15	12.62 ± 0.03
P14	65.16 ± 1.09	13.05 ± 0.16	9.99 ± 0.03
P15	89.06 ± 1.09	7.93 ± 0.16	14.26 ± 0.03
P16	30.66 ± 0.37	18.10 ± 0.02	26.18 ± 0.05
P17	21.52 ± 0.26	9.97 ± 0.15	6.40 ± 0.02
P18	101.51 ± 1.24	6.10 ± 0.16	10.12 ± 0.03
P19	87.21 ± 1.06	13.23 ± 0.15	12.81 ± 0.03
P20	109.05 ± 1.33	16.26 ± 0.18	13.13 ± 0.03
Mean Value	125.94 ± 1.55	12.98 ± 0.16	12.48 ± 0.03

Table 4. reported mean values of gamma activity (in Bq/kg) in soil samples from different regions of the world compared with present study

Region	^{238}U	^{232}Th	^{40}K	References
Amman, Jordan	56.4	28.8	501	Ahmed *et al.,* 1997
Karak, Jordan	22.9	27.2	410	Ahmed *et al,.* 1997
Agaba- Amman Highway	44.4	36.3	208	Al-Jundi *et al.,* 2003
Rajasthan, India	30 – 78.0	43 – 106	50 – 137	Nageswara *et al.,* 1996
Instanbul, Turkey	21.0	37.0	342	Karahan *et al.,* 2000
Taiwan	54.0	32.4	794	Chen *et al.,* 1993
Taiwan	30.0	44.0	431	Yu-Ming *et al.,* 1987
University of Ibadan	50.01±29.00	84.66±37.88	261.37±192.17	Egunyinka *et al.,* 2009
The Polytechnic, Ibadan	12.98 ± 0.16	12.48 ± 0.03	125.94 ± 1.55	Present study

The absorbed dose rates (D) due to gamma radiation in air at 1m above the ground have been obtained with use of the guideline according to UNSCEAR 2000:

$$D(nGyh^{-1}) = 0.462A_U + 0.621A_{Th} + 0.0417A_K \quad (3)$$

where A_U, A_{Th} and A_K are the activity concentrations of the radionuclides ^{238}U, ^{232}Th and ^{40}K respectively.

To evaluate the annual effective dose (AED) rate, an outdoor occupancy factor of 0.2 and the conversion coefficient from absorbed dose in air to effective dose of 0.7 $SvGy^{-1}$ as proposed by UNSCEAR 2000 were used with the formula

$$AED = D(nGyh^{-1}) \times 8760 \times 0.8 \times 0.7SvGy^{-1} \times 10^{-6} \quad (4)$$

The external gamma dose rate obtained by using equation (4) is presented in table 5 and the values obtained for annual effective dose is also presented in table 5.

Table 5. Absorbed Dose Rate and Annual Effective Dose obtained from the soil samples

Code	^{40}K ($nGyh^{-1}$)	^{238}U ($nGyh^{-1}$)	^{232}Th ($nGyh^{-1}$)	Total Absorbed Dose Rate ($nGyh^{-1}$)	Annual Effective Dose (μSvy^{-1})
P1	1.81	4.68	5.92	12.41	0.061
P2	7.47	7.26	11.73	26.46	0.129
P3	3.24	6.31	7.54	11.09	0.054
P4	1.99	5.79	7.48	15.26	0.075
P5	1.65	5.30	6.19	13.14	0.065
P6	3.87	4.52	7.11	15.50	0.076
P7	2.44	5.30	4.49	12.23	0.059
P8	2.82	4.44	7.00	14.26	0.069
P9	1.05	6.93	10.56	18.54	0.091
P10	35.13	6.13	7.93	49.35	0.242
P11	7.52	7.32	11.59	26.43	0.129
P12	3.48	5.80	6.57	15.85	0.076
P13	2.03	4.04	8.40	14.47	0.071
P14	2.74	5.59	6.65	14.98	0.074
P15	3.74	3.40	9.49	16.63	0.082
P16	1.29	7.76	17.44	16.49	0.081
P17	0.90	4.28	4.26	9.44	0.046
P18	4.26	2.62	6.74	13.62	0.069
P19	3.66	5.68	8.53	17.87	0.088
P20	4.58	6.98	8.74	20.30	0.099
Mean Value	4.79	5.61	8.22	19.95	0.087

4. Conclusion

The top soil obtained from the Polytechnic, Ibadan has been measured for their radioactivity content using gamma spectrometry. The obtained values of the activity concentration falls within the world average values as reported by UNSCEAR 2000 which are 35 Bq/kg for ^{238}U, 35 Bq/kg for ^{232}Th and 370 Bq/kg for ^{40}K. However the high value of activity concentration for potassium observed in P10 which corresponds to the botanical garden shows that the high value could be attributed to the use of fertilizers in the garden. Moreover the activity levels measured in this study have been found to be lower than the values reported in other parts of the world. The range of the gamma dose rate is between 9.44 nGyh^{-1} and 49.35 nGyh^{-1} with a mean value of 19.95 nGyh^{-1} which is within the range of values given in UNSCEAR 2000 report.

The outdoor annual effective doses obtained had a range of 0.046 mSvy^{-1} to 0.242 mSvy^{-1} with a mean value of 0.087 mSvy^{-1}. This is below the world average annual effective dose limit which is approximately 0.5mSvy^{-1} (UNSCEAR 2000). This study has provided a baseline data on the natural radioactivity of The Polytechnic, Ibadan located in the capital city of Oyo State, southwest of Nigeria. The information provided in this study will serve as a reference for future work covering the same area.

It is recommended that normal environmental protection measures are adequate to protect against the natural radiological hazard in the area. However further studies will be required in the event of assessing the radiological effect of artificial radionuclide sources in the area under consideration.

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