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Assessment of Radiological Hazards Due to Soil Samples at Daily Part-Time School, Osun State Polytechnic, Iree, Nigeria

H. O. Efunwole
Department of Science Laboratory Technology, Osun state Polytechnic, Iree, Nigeria.
Email: hoefunwole@gmail.com
Cont.: 08034031080

O. E. Alaje
Deptt. of Science Laboratory Technology, Osun State Polytechnic, Iree, Nigeria.

R. O. Salako
Deptt. of Mathematics and Statistics, Osun State Polytechnic, Iree, Nigeria.

A. M. Raimi
Deptt. of Science Laboratory Technology, Osun state Polytechnic, Iree, Nigeria.

I. O. Abioye
Deptt. of Science Laboratory Technology, Osun State Polytechnic, Iree, Nigeria.

P. A. Oluwafisoye
Department of Physical Sciences, Osun State University, Nigeria

***Abstract* – Rocks and soils habour natural radionuclides in varying proportion depending on the geographical locations of the area under studies all over the earth. Adverse effects are identified with ionizing radiation arising from the radionuclides especially when at high level of concentration. A knowledge of gamma radioactivity is necessary to adopt preventive measures to minimize the associated harmful effects of the radionuclides. Activity concentrations of natural radionuclides, ^{226}Ra, ^{232}Th and ^{40}K, of soil samples at Daily Part-Time school, Osun state polytechnic, were measured using gamma ray spectroscopy. The radiological hazards due to the natural radioactivity in the samples were assessed from the calculation of radium equivalent activity concentrations which ranged from 4.35 to 29.78 Bq/kg. All the values obtained were lower than the recommended limit of 370 Bq/kg. The result indicates an acceptably low radiological risk associated to the soil in the environment.**

***Keywords* – Activity Concentration, Gamma Ray Spectroscopy, Natural Radionuclides, Radium Equivalent.**

I. INTRODUCTION

High percentage of human radiation exposure arises from natural sources such as cosmic radiation, exposure to radon gas and terrestrial radiations as an indication that the world is naturally radioactive. ^{226}Ra (from ^{238}U), ^{232}Th and ^{40}K are main naturally occurring radionuclides present in soil[1]-[4]. Since these radionuclides are not uniformly distributed, the knowledge of their distribution in soils and rocks play an important role in radiation protection and measurement [5], [6]. Some of the exposures are fairly constant and uniform for all individuals everywhere, for example, the dose from ingestion of ^{40}K in foods. Other exposures vary widely depending on location. Cosmic rays, for example, are more intense at higher altitudes and concentrations of uranium and thorium in soils are elevated in localized areas. High levels of uranium and its decay products in rock and soil and thorium in monazite sands are the main sources of high natural background areas that have been identified in several areas of the world, e.g., Yangjiang in China, Rasmar in Iran, Kerala coast of India, etc. [7]–[10]. Therefore, measurements of natural radioactivity in soil are of a great interest for many researchers throughout the world, which led to worldwide national surveys in the last two decades [11], [12]. All of these spectrometric measurements indicate that the three components of the external radiation field, namely from the γ - emitting radionuclides in the ^{238}U and ^{232}Th series and ^{40}K, made approximately equal contributions to the externally incident γ - radiation dose to individuals in typical situations both outdoors and indoors. Since 98.5% of the radiological effects of the uranium series are produced by radium and its daughter products, the contribution from the ^{238}U and the other ^{226}Ra precursors are normally ignored [13], [12].

Population continues to grow year-in year-out; consequently a number of qualified people are from year to year denied admission into higher institution of learning due to inadequate facilities. Among higher institutions of learning in the country is Osun State Polytechnic, which is situated in Iree under Boripe Local Government Area, Osun state. As part of effort to solve students' admission problem, the management of Osun State Polytechnic as taken a bold step to embark on an expansion to accommodate more students. This is a new site located away from the main campus in the outskirts of the town and the area is not far from a big mountain. In fact the school is best described by saying that it is sited at the immediate base of the mountain. It is important as an attempt is being made to bring succor to the people, to equally have concern for their well-being by a way of keeping their environment save for living. To achieve this goal, a pioneering effort has been made by some researchers in the recent past to assess the level of natural radionuclides in the stones used for the buildings in the school [14]. Also a work has been done on the sharp sand used as well on these buildings [15]. However, these materials were fetched elsewhere and not from the site itself. The work is not complete if the environment itself is not properly investigated for the level of natural radionuclides.

Against this background, the paper aimed to collect soil samples from the new school with the objectives of measuring the activity concentrations of Ra-226, Th-232 and K-40 of the soil samples and to estimate the radiation hazard level in the area.

II. Materials And Methods

Sample Preparation

The sampling technique adopted here was based on the principal structures available in the study area. The structures comprises five different buildings each with two lecture halls (coded as A, B, C, D and E), students' union building (F), gate (G) and administrative building (H). Four soil sampleswere collected from each building with each at a corner of the buildings and two from the gate, one in front of and outside the gate; and the other one in front of and inside, making a total of thirty samples. The samples were dried and pulverized to avoid self absorption. 200g of each was packed in a non radioactive plastic container, hermetically sealed and left for four weeks to allow the radionuclides and their daughter products to reach secular equilibrium.

The counting Assembly and counting process: The counting system used for this analysis of the natural radiological content of the soil sample consisted of scintillation detector or photomultiplier tube and a Canberra multichannel analyzer (MCA). The scintillation detector is connected to the multichannel analyzer (MCA). The MCA is a microproccesor used in spectroscopic analysis. The scintillation detector is a 76cm x 76cm NAI (Tl) manufactured by Bicron. This is connected to the MCA through coaxical cables. The MCA consisted of analogue to digital converter (ADC),control logic(CL) with input and output devices, memory, display and analysis logic (DAC) unit with an on-screen Display(SD) unit. The MCA has an inbuilt high voltage power supply (HVPS), and for convenience, it has rechargeable batteries of nickel Cadmium (for that can run for at least 6 hours, if there is power outage and counting will not be interrupted)or it can be powered from a 12V automobile battery.

Initial measurement and calibration of equipment: Each height of a given pulse and its corresponding channel is directly proportional to the gamma energy producing it. This forms the basis of our measurement and calculation. The system was tested for its linearity and calibrated with standard source samples potassium, thorium and uranium (K_2SO_4 IAEA/RGK-1, Th-ore IAEA/RGTH-I). These were Geological certified Reference material for Radiometric Measurement from international Atomic Energy (IAEA),Vienna. Equal quantity of these standard sources of known energy were mixed together, placed inside the gamma- ray spectroscopy and counted for 36,000sec(10 hrs).

Using the system, the curved fitting was carried out and the equation obtained is as given in equation (1):

$$E(MeV) = 0.0084n - 0.0655 \quad (1)$$

Where E is the energy and the channel number, the equation 1 was stored in the memory of the operational system and it remained as the operational setting of the system throughout the experimental observation. Three regions of interest were created for the purpose of this work. Region one was photo peak corresponding to gamma energy 1.465 MeV of ^{40}K, region two was the photo peak of energy 1.765 MeV for ^{238}U, while region three was the photo peak of ^{232}Th with corresponding energy 2.615 MeV. The energy peak were obtained from region of interest (ROI) created in the neighborhood of observed energies.

Background shielding and counting process: For effective and reliability of the measurement in gamma spectroscopy, effective shielding against the natural radiation background has been accomplished in the study by building a lead shield castle around the source-detector combination (Farai, 1988). The sample being measured also provides additional shielding from the residual radiation emanating from the lead castle itself. The lead castle has dimension of 5cm x 10cm x 20cm lead block arranged such that the thickness is 5cm. The counting assembly described earlier was employed for the counting procedures. Necessary adjustment were carried out on the MCA, for example the high voltage (1000V) settings, gain and memory settings, time settings (36,000 seconds). The region of interest (ROI) for each radionuclide observed was defined with the aid of corresponding channel number in which the peak occurs. After 36,000 seconds of counting the area under each photo peak under the region of interest computed and presented by MCA for each of the 30 soil samples.

III. Results

Specific activity concentration and radium equivalent determination: The area under the photopeak counted for each radionuclide by the MCA is a measure of the activity concentration of the radionuclide in the soil. In this study, a fixed geometry was maintained for all the samples measured and since the sensitivity of the Canberra system used was constant, the activity concentration is proportional to the net area under the photopeak [16].

Therefore $C = kA \quad (2)$

$k = C/A \quad (3)$

Where C is the concentration and A is the net area, k is multiplicative factor which is constant for each radionuclide at constant geometry; k is determined by the detector efficiency of the assembly. The calibration factors for the three radio nuclides were calculated using a standard soil sample (Geological Certified Reference Material for Radiometric Measurement) obtained from international Atomic Energy Agency, Vienna using equation (2).

The calibration factors were found to be $k(^{40}K)$ =0.275Bq/kg/cps, $k(^{226}Ra)$ = 0.284Bq/kg/cps and $k(^{232}Th)$ = 0.273Bq/kg/cps.

The calibration factor, $k(^{40}K)$, $k(^{226}Ra)$, $k(^{232}Th)$ were multiplied by the area under the photopeak to get the corresponding activity concentration ^{40}K, ^{226}Ra and ^{232}Th for the different sample locations.

Exposure to radiation can be defined in terms of many parameters. It is well known that, Radium equivalent activity (Ra_{eq}) is also a widely used Radiation hazard index [17]. The radium equivalent activity is based on the assumption that each of 10 Bq/kg of ^{226}Ra, 7 Bq/kg of ^{232}Th and 130 Bq/kg of ^{40}K produces the same amount of

gamma ray dose [18]–[21]. The index was defined as below [18], [22], [20], [23]–[25].

$$Ra_{eq} = A_{Ra} + 1.43A_{Th} + 0.077A_K \quad (4)$$

where A_{Ra}, A_{Th} and A_K are activity concentrations, in Bq/kg, of ^{226}Ra, ^{232}Th and ^{40}K respectively.

The results of the activity concentrations (Bq/kg) and radium equivalent Ra_{eq} of the samples were displayed in Table 1 with their corresponding bar chart in Fig. 1.

The mean radium equivalent activity of the samples from the environment of each of the eight buildings was also computed using equation (4). The corresponding bar chart is shown in Fig. 2.

Table 1. Activity concentrations (Bq/kg) and radium equivalent Ra_{eq} of the samples

S/N	Code	^{40}K	^{226}Ra	^{232}Th	Ra_{eq}
1	A_1	129.12	3.1	0.87	14.28
2	A_2	110.18	1.22	0.66	10.65
3	A_3	178.35	4.6	0.98	19.73
4	A_4	118.03	3.08	0.63	13.07
	Mean	133.92±30.62	3.00±1.38	0.79±0.17	14.43±3.84
5	B_1	268.7	2.15	1.06	24.36
6	B_2	315.99	3.2	0.77	28.63
7	B_3	33.57	1.53	0.16	4.35
8	B_4	314.35	4.49	0.34	29.18
	Mean	233.15±134.85	2.84±1.30	0.58±0.41	21.63±11.72
9	C_1	269.47	2.04	0.71	23.81
10	C_2	259.91	3.09	0.56	23.9
11	C_3	301.76	4.07	0.48	27.99
12	C_4	284.01	1.13	0.96	24.37
	Mean	278.79±18.24	2.58±1.27	0.68±0.21	25.02±2.00
13	D_1	280.99	1.14	0.46	23.44
14	D_2	305.99	4.84	0.96	29.78
15	D_3	254.82	2.56	0.42	22.78
16	D_4	241.89	4.42	0.9	24.34
	Mean	270.92±28.48	3.24±1.72	0.69±0.28	25.09±3.19
17	E_1	152.26	6.61	1.06	19.84
18	E_2	173.11	3.87	1.52	19.36
19	E_3	255.96	1.62	0.14	21.54
20	E_4	10.23	2.41	0.91	4.51
	Mean	147.89±102.12	3.63±2.20	0.91±0.57	16.31±7.92
21	F_1	271.53	4.48	0.82	26.57
22	F_2	270.34	2.93	0.9	25.04
23	F_3	232.61	2.67	0.85	21.8
24	F_4	198.75	3.64	0.63	19.84
	Mean	243.31±34.77	3.43±0.81	0.80±0.12	23.31±3.05
25	G_1	74.39	2.81	0.57	9.35
26	G_2	93.38	6.51	0.42	14.3
	Mean	83.89±13.43	4.66±2.62	0.50±0.11	11.83±3.50
27	H_1	207.54	2.01	0.33	18.47
28	H_2	245.27	1.8	0.2	20.97
29	H_3	216.35	2.72	0.5	20.09
30	H_4	184.82	1.02	0.39	15.81
	Mean	213.50±25.00	1.89±0.70	0.36±0.13	18.84±2.27

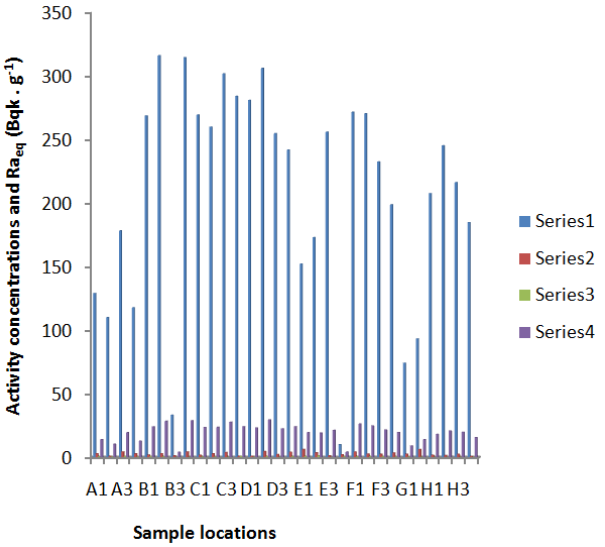

Fig.1. Bar chart of activity concentrations and radium equivalents

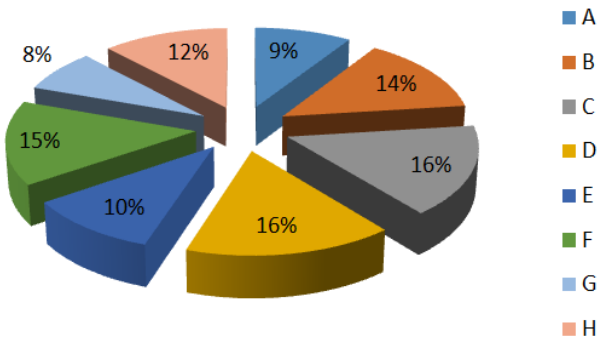

Fig.2. Pie chart of the radium equivalent from each building (Bg . kg^{-1})

IV. Discussion

The activity concentrations of the radionuclides varied from different values of concentration to another with ^{40}K generally high on comparing with ^{226}Ra and ^{232}Th as can be seen in Fig. 1. The use of fertilizer could be responsible for this especially in rural area such as Iree where farming activity is in place. Highest concentration of K-40 is at B_2 with value 315.99Bq/kg and highest mean concentration of K-40 (278.79 ± 18.24Bq/kg) at C which is closer to the mountain than B. The fact that radionuclides are present in rock enriched the immediate environment with K-40 also. Lowest concentration of K-40 was witnessed with E_4 which was also away from the mountain side. None of the activity concentrations of K-40 is up to the maximum permissible level of 370Bq/kg. Contributions of Ra-226 and Th-232 are insignificant; highest of Ra-226 concentration, found with E is 6.61 $Bqkg^{-1}$ while lowest, 1.02 at H. Concentrations of Th-232 are also with range 0.14(at E_3) to 1.52(at E_2).

The results obtained for radium equivalent were given in Table 1 with their corresponding bar chart in Fig. 2. The maximum amount of the radium equivalent is observed with buildingD (25.09 ± 3.19Bq/kg) and minimum with G (11.83 ± 2.27Bq/kg). Although the result obtained for building D is very low when compared with the recommended limit of 370 Bq/kg[25], (Farai and Isinkaye, 2009), D is also close to the mountain which is the source of rock that habours appreciable level of radionuclides. This may explain its highest value among other samples in the rest of the locations. G is the gate area; mean radium equivalent is the least at the gate area which is located far away from D and the mountain. Fig. 2 showed the pie chart of how the mean radium equivalent varied among the locations considered with none of the value attaining the maximum permissible level.

V. Conclusion

The soil samples at daily part-time school, Osun State Polytechnic, Iree have been assessed for level of radionuclides. Activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th; and radium equivalent activities were determined using gamma spectrometry assembly with NaI, activated with Tl, as the detector. The activity concentrations of radionuclides of interest ^{40}K, ^{226}Ra and ^{232}Th ranged as 10.23 to 315.99 Bq/kg, 1.02 to 6.61 Bq/kg and 0.14 to 1.52 Bq/kg respectively. Radium equivalent also ranged from 4.35 to 29.78 Bq . kg^{-1}. All the values of the activity concentrations determined and estimated radium equivalent activities were below 370 Bq/kg which is the maximum permissible level of ionizing radiation that people could be exposed to. With these observations, the study area is free of any radionuclides that can pose a threat to human health as far as ionizing radiation is concerned. It is, however, recommended that regular radiation monitoring should be encouraged to prevent possible introduction of contaminated material to the area in the course of development as the site is yet to witness its full and maximum development.

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