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ABSTRACT: A study on the radiological dose assessment due to the presence of natural radionuclides in the top soil of Imo state Polytechnic was carried out using a gamma spectroscopic method. From the activity concentrations of natural radionuclides in the topsoil, the absorbed dose rate and annual effects of doses were established. The activity concentrations ranged from 59.20 to 203.78 $Bqkg^{-1}$, 8.74 to 45.78 $Bqkg^{-1}$, and 12.73 to 44.01 $Bqkg^{-1}$ for the radionuclides ^{40}K, ^{226}Ra, and ^{232}Th respectively. The absorbed dose rates ranged from 16.70 to 52.10 $nGyh^{-1}$ while the indoor and outdoor annual effective doses ranged from 20.48 to 63.89 μSvy^{-1} and 81.94 to 255.58 μSvy^{-1} respectively. From the results, it shows that the radiation from natural radionuclides in the top soil posed no radiological threat to the population of the institution.

KEYWORDS: Radiation dose, absorbed dose, Natural radionuclides, annual effective dose, Imo polytechnic

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Introduction

Natural source of radiation remains one of the significant sources through which man is continuously exposed to radiation.[1] This radiation comes from 2 primary sources- cosmic and terrestrial radiation. The former is mainly from an atmospheric origin that is deposited through the action of precipitation and gravitational setting. At the same time, the latter comes from the primordial radionuclides, which have been in existence since the formation of the earth.[2] The terrestrial radiation emanates from the earth crust in the form of naturally occurring radioactive materials (NORMs) present in the soil, water and vegetation. NORMs are majorly composed of ^{238}U, ^{232}Th together with their decay products and non-decay ^{40}K, which are found in certain quantities on the earth surface and in great abundance in an area with significant-high background radiation. Specific amounts of artificial radionuclides such as ^{137}Cs, ^{90}Sr, and ^{131}I have also found their way to the environment via dumping of radioactive waste, industrial waste, research facilities, and nuclear power plants.

Radionuclide isotopes find their way to the human body through the process of ingestion, inhalation (for radon and airborne particles), absorption and injection. Due to the unstable nature of these radionuclides, they quickly disintegrate and release radiation in the process. The radiation emitted is harmful to a living organism. Our body system is primarily composed of water, which is the easy target when the body is exposed to radiation. Ionization of water molecules occurs when radiation interacts with water. This interaction leads to the production of free radicals and reactive oxygen species. The chemical species, some of which are free radicals and hydroxyl ions, can cause damage to chromosome material. Failure for the cells to undergo repair may eventually lead to cell apoptosis and mutation.

The exposure of the human body to radiation for a long time has several health effects such as epilation, chronic lung diseases, acute leukopenia, anemia, skin burn and necrosis of the mouth. Environmental samples such as soils and rocks contain certain quantities of radioactive elements together with their progeny, and this serves as a medium through which radiation is transferred to man. The geographical and geological formation of soil in an environment determines, to some extent, the level of natural radioactivity present.[1] The high levels of thorium and uranium and their decay products in rock and soil in any environment contribute primarily to the associated gamma exposure. These heavy radionuclides are significant sources of high natural background radiation. The quantity of natural background radiation in an environment depends to some degree the man activities, and soil uses[3]

Moreover, research has shown that human activities such as mining, farming, industrial activities, indiscriminate dumping of industrial and laboratory waste, in any environment can enhance the natural background radiation of such an environment.[1] On this basis, periodic monitoring of soil samples and evaluation of natural background radiation of any populated environment is of utmost importance. Imo State Polytechnic is one of the major tertiary institutions in Imo State Nigeria. It was established in 1978 by the Imo State Government as College of Agriculture and later upgraded to the status of Polytechnic in 2007. The institution is situated at Umuagwo town, Ohaji/Egbema Local

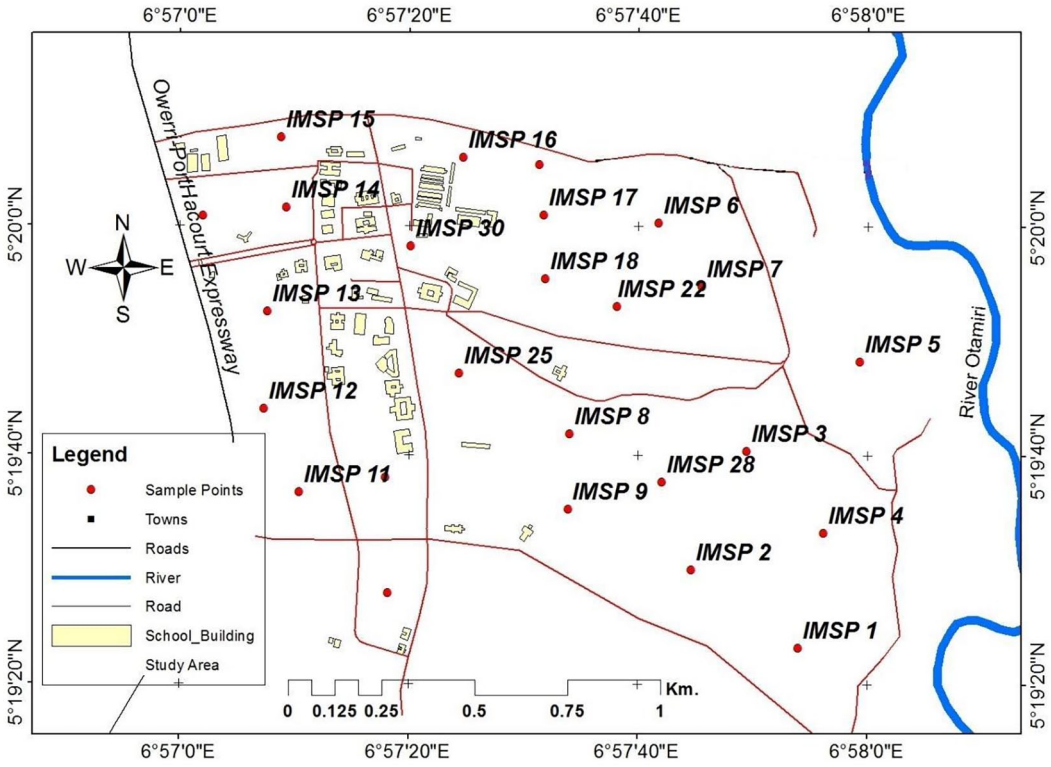

Figure 1. Study areas at the Imo State Polytechnic, Umuagwo.

Government Area of Imo State, Nigeria. The town is about 26 km away from Owerri, the state capital.

Environmental radioactivity measurement of soil samples from the densely populated community cannot be downplayed as the result of such measurement can be used to estimate the level of radioactive contamination of the environment and also serve as a baseline for the epidemiological study of the community in case of any discharge of radioactive material to the environment. Furthermore, to the best of our knowledge, there is no existing literature on the radioactivity level of soil samples from the Imo State Polytechnic Umuagwo. Thus, this study is aimed to evaluate activity concentrations and radiological doses due to the presence of natural radionuclides in the top soils of the institution and estimate their associated radiological health risks to the Polytechnic community.

Materials and Methods

Collection and preparation of soil samples

Thirty representative soil samples were collected at various locations within the campus where human activities exist using soil auger. The collection was done to a depth of 150 mm below the surface and samples were placed in different polythene bags and carefully marked to avoid sample contamination. Figure 1 displays the map of the study area and sample locations. Immediately after collection, samples were taken to the Radiation and Health Physics Research Laboratory at the Department of Physics, University of Ibadan, Nigeria where they were prepared for spectroscopic analysis. In brief, the samples were oven-dried at 110°C to remove the moisture (and without any significant loss in radioactive materials) until a constant weight was attained.[4] The soil samples were then grounded, homogenized and sieved with a 2.0 mm mesh sieve. The sieved soil samples weighing 0.2 kg were packed into a cleaned and washed empty cylindrical Marinelli plastic containers of uniform size (60 mm height by 65 mm diameter, to fit the geometry of the detector) and sealed with wax and tape to avoid the escape of gaseous radon. The sealed samples were stored in a dried place and left for a minimum period of 28 days to attain secular radioactive equilibrium between ^{226}Ra and its short-lived daughter products.[5]

Radioactivity counting

NaI(Tl) detector was used to count the amount of radionuclides present in the soil samples. The detector was placed inside a lead-shielded block of dimension 76 mm × 76 mm to avoid interference with the background radiation. The detector was connected with a Canberra Series 10 + Multichannel Analyser (MCA) (Model No. 1104) through a preamplifier base. The MCA is a complete system having all the functions needed for spectroscopic analysis. The spectrometer has a resolution of 8% efficiency at energy of 0.662 MeV (^{137}Cs), which is capable of differentiating the gamma-ray energies of the radionuclides of interest. The photo-peak energy of 1.460 MeV was used for the identification of ^{40}K, 1.760 MeV for ^{226}Ra (^{238}U), and 2.614 MeV for ^{232}Th. The fallout radionuclide ^{137}Cs whose presence is usually associated with environmental

pollution was also considered. In order to account for this radionuclide, a fourth region of interest was created at 0.662 MeV for ^{137}Cs[6] A standard reference soil sample from Rocketdyne Laboratories California, USA was used for the efficiency calibration. The reference sample is traceable to a mixed standard gamma source (Ref No 48722-356) by Analytic Inc., Atlanta, GA, USA. The reference sample was placed on top of the detector and counted for 10 hours (36000 second). The net area under the corresponding peaks in the energy spectrum was computed by subtracting counts due to Compton scattering of higher peaks and other background sources from the total area of the peaks. Based on the stored spectra, each sealed sample was placed on top of the detector and counted for the same amount of time as the reference sample. From the net area, the activity concentrations in the samples were obtained using equation (1)[1,5,7]

$$C\left(Bqkg^{-1}\right) = kC_n \quad (1)$$

where C_n is the count rate under the corresponding peak, $k = \frac{1}{\varepsilon P_\gamma M_s}$, P_γ is the absolute transition probability of the specific gamma-ray, C is the activity concentration of the radionuclide of soil samples given in $Bqkg^{-1}$, ε is the detector efficiency at the specific gamma-ray energy, t is the counting time in seconds and M_s is the mass of the sample (kg). The detection limit (DL) of a measuring system describes its operating capability without the influence of the sample. The DL given in $Bqkg^{-1}$, which is required to estimate the minimum detectable activity in a sample, was obtained using equation (2)[7]

$$DL\left(Bqkg^{-1}\right) = 4.65\frac{(C_b)^{1/2}}{t_b}k \quad (2)$$

where C_b is the net background count in the corresponding peak, t_b is the background counting time in second, k is the factor that converts counts per second (cps) to activity concentration ($Bqkg^{-1}$) as given in equation (1). Based on the measurement system adopted in the present study, the detection limits obtained for soil samples were 16.96, 3.65, and 4.43 $Bqkg^{-1}$ for ^{40}K, ^{226}Ra, and ^{232}Th, respectively. Any activity concentration values below these numbers were taken as below detection limit (BDL) of the detector.

Absorbed dose. The absorbed dose rate was calculated using equation (3)[8]

$$D_R\left(nGyh^{-1}\right) = R_U C_U + R_{Th} C_{Th} + R_K C_K \quad (3)$$

Where, C_U, C_{Th} *and* C_K are the radioactivity concentration in $BqKg^{-1}$ and R_U, R_{Th} *and* R_K are dose conversion factors which are 0.462, 0.604, and 0.0417 for ^{238}U, ^{232}Th, and ^{40}K respectively

Annual effective dose. For the purpose of a radiological safe environment, the annual effective dose was calculated using equation (4).[8]

$$AED = D_R \times 8760 \times 0.2\left(or\ 0.8\right) \times 0.7 \times 10^{-3} \quad (4)$$

Where AED is the annual effective dose (μSvy^{-1}); D_R is the dose rate ($nGyh^{-1}$); 8760 is the number of hours per year; 0.7 $SvGy^{-1}$ is for the conversion coefficient from the absorbed dose in the air to the effective dose received by adults; 0.2 and 0.8 are outdoor and indoor occupancy factors respectively.

Results and Discussion

Activity concentration

The activity concentrations for the radionuclides ^{40}K, ^{226}Ra, and ^{232}Th as measured from the samples collected from the study area are presented in Table 1. For ^{40}K, a maximum value of $203.78 \pm 1.38\ Bqkg^{-1}$ and a minimum value of $59.22 \pm 1.47\ Bqkg^{-1}$ were recorded, while ^{226}Ra and ^{232}Th ranged between 8.74 to 45.78 and 12.73 to 44.01 $Bqkg^{-1}$ respectively. The school farm showed the highest activity concentration of ^{40}K, this could be attributed to the use of fertilizer in the farm. With respect to the areas considered in this study, a relatively high activity concentration for the 3 radionuclides ^{226}Ra, ^{232}Th, and ^{40}K were recorded at the maintenance project department; this could also be attributed to the type of activities going on within the area. The mean values of the activity concentrations for ^{40}K, ^{226}Ra, and ^{232}Th obtained in this study were higher than what was obtained in the other parts of Owerri by Nwaka et al[9], with the mean values of 167.2, 19.7, and 18.1 $Bqkg^{-1}$ for the radionuclides ^{40}K, ^{226}Ra, and ^{232}Th respectively. Table 2 shows a comparison of the activity concentrations recorded in this study to that of other parts of the country and the world average. Though the measured activity concentrations were higher than those recorded in some parts of the country (see Table 2), the mean value for the radionuclides ^{226}Ra, ^{232}Th, and ^{40}K were all lower than the world average of 33 $Bqkg^{-1}$ for ^{226}Ra, 45 $Bqkg^{-1}$ for ^{232}Th and 420 $Bqkg^{-1}$ for ^{40}K.[10]

Radiological dose assessment

The energy deposited by ionizing radiation per unit mass in a medium describes the absorbed dose rate; it is used to assess the potential for biochemical changes in specific tissues. The absorbed dose rate for the environment under study is shown in Table 3. The absorbed dose rates ranged from 16.70 to 52.10 $nGyh^{-1}$. For all the locations considered in this study, the absorbed dose rates were all lower than the world average of 55 $nGyh^{-1}$.[16] The mean absorbed dose obtained from this study were higher than what was obtained previously in other parts of Owerri by Nwaka et al[9] of 27.1 $nGyh^{-1}$ but lower than what was obtained in Warri (an oil producing town), Nigeria by

Table 1. Activity concentrations of radionuclides.

SAMPLE ID	SAMPLE LOCATIONS	^{40}K (BQKG^{-1})	^{226}RA (BQKG^{-1})	^{232}TH (BQKG^{-1})
IMSP1	Department of Estate Management	151.13 ± 1.30	20.11 ± 3.01	39.44 ± 0.79
IMSP2	Department of Food Science Technology I	133.27 ± 1.51	31.37 ± 2.99	37.21 ± 0.57
IMSP3	Department of Food Science Technology II	153.36 ± 1.33	18.96 ± 4.21	44.01 ± 0.62
IMSP4	Department of Nutrition and Dietetics (Food Lab I)	114.20 ± 1.40	38.43 ± 2.08	37.71 ± 0.67
IMSP5	Department of Nutrition and Dietetics (Food Lab II)	99.11 ± 1.61	16.67 ± 3.11	27.48 ± 0.52
IMSP6	School of General Studies I	101.32 ± 1.29	27.01 ± 2.10	BDL
IMSP7	School of General Studies II	105.62 ± 1.41	26.37 ± 3.77	12.73 ± 0.87
IMSP8	Love Garden	118.01 ± 1.55	38.76 ± 4.43	37.23 ± 0.91
IMSP9	Entrance of Back Gate	104.88 ± 1.49	27.77 ± 3.27	25.44 ± 0.54
IMSP10	Field I	163.23 ± 1.38	38.85 ± 3.66	29.66 ± 0.87
IMSP11	Back Gate Pedestrian Walk-Way	89.25 ± 1.53	26.66 ± 2.49	42.11 ± 0.77
IMSP12	End Point of Back Gate	118.99 ± 1.45	33.97 ± 4.41	31.22 ± 0.54
IMSP 13	Field II	166.33 ± 1.52	32.74 ± 4.33	27.88 ± 0.64
IMSP 14	Field III	141.80 ± 1.39	15.75 ± 3.88	29.11 ± 0.57
IMSP 15	Field IV	109.77 ± 1.44	37.33 ± 2.98	25.61 ± 0.87
IMSP 16	Field V	158.21 ± 1.54	27.65 ± 4.07	30.12 ± 0.45
IMSP 17	Department of General Studies	88.37 ± 1.36	39.32 ± 3.89	BDL
IMSP 18	Department of Horticulture and Landscape Tech	189.11 ± 1.29	25.67 ± 4.43	29.53 ± 0.91
IMSP 19	Department of Agric Management and Ext	100.43 ± 1.32	37.79 ± 3.78	31.11 ± 0.65
IMSP 20	Student Affairs Unit	BDL	37.10 ± 2.97	39.13 ± 0.75
IMSP 21	Poultry	155.71 ± 1.53	33.11 ± 4.12	41.91 ± 0.89
IMSP 22	Administrative Office	59.22 ± 1.47	BDL	29.12 ± 0.55
IMSP 23	Director's Office	95.11 ± 1.39	8.47 ± 4.99	15.44 ± 0.62
IMSP 24	Registrar's Office	132.66 ± 1.37	32.24 ± 3.76	27.36 ± 0.75
IMSP 25	Maintenance Project Department	179.07 ± 1.45	45.78 ± 3.88	38.88 ± 0.92
IMSP 26	School Farm	203.78 ± 1.38	28.11 ± 3.75	37.77 ± 0.53
IMSP 27	Stores Unit	88.65 ± 1.62	37.33 ± 2.87	27.19 ± 0.87
IMSP 28	Hostel A	104.77 ± 1.49	21.12 ± 3.93	20.11 ± 0.89
IMSP 29	Hostel B	99.63 ± 1.33	28.45 ± 4.97	25.87 ± 0.74
IMSP 30	Business Center	119.47 ± 1.70	42.17 ± 3.36	29.73 ± 0.88
Mean		121.48 ± 1.39	29.17 ± 3.51	29.00 ± 0.67

Table 2. Comparison of mean activity concentrations.

S/N	^{226}RA (BQKG^{-1})	^{232}TH (BQKG^{-1})	40K (BQKG^{-1})	LOCATION	REFERENCE
1.	29.1	29	121.4	Owerri	Present study
2.	2.07	6.89	57.8	Ogwa, Edo, Nigeria	Popoola et al[8]
3.	1.41	4.85	30.19	Igweben, Edo, Nigeria	Popoola et al[8]
4.	11.47	10.44	403.07	Agege, Lagos, Nigeria	Ilori et al[11]
5.	128.05	24.8	455.05	Ijero, Ekiti, Nigeria	Usikalu et al[12]
6.	12.14	23.23	270.14	Fashina, Ile-Ife, Nigeria	Oluyide et al[13]
7.	3.78	2.22	14.3	Port Harcourt, Nigeria	Avwiri et al[14]
8.	29.78	88.84	181.36	Enugu, Nigeria	Amakom et al[15]
9.	33	45	420	World average	UNSCEAR[10]

Table 3. Radiological assessment of radionuclides.

S/N	DR ($nGyh^{-1}$)	AEDE OUTDOOR (μSVY^{-1});	AEDE INDOOR (μSVY^{-1});
1.	39.41	48.33	193.35
2.	42.52	52.15	208.61
3.	41.73	51.18	204.74
4.	45.29	55.54	222.19
5.	28.43	34.86	139.47
6.	16.70	20.48	81.94
7.	24.27	29.77	119.08
8.	45.31	55.57	222.29
9.	32.56	39.94	159.77
10.	42.67	52.33	209.32
11.	41.47	50.86	203.45
12.	39.51	48.45	193.83
13.	38.90	47.70	190.83
14.	30.77	37.73	150.95
15.	37.29	45.73	182.94
16.	37.56	46.06	184.27
17.	21.85	26.79	107.19
18.	37.58	46.09	184.36
19.	40.43	49.59	198.36
20.	40.77	50.00	200.02
21.	47.10	57.76	231.07
22.	20.05	24.59	98.39
23.	17.20	21.10	84.40
24.	36.95	45.31	181.27
25.	52.10	63.89	255.58
26.	44.29	54.32	217.30
27.	37.36	45.82	183.30
28.	26.27	32.22	128.88
29.	32.92	40.37	161.51
30.	42.42	52.02	208.10
Mean	36.01	44.22	176.89

Agbalagba[17], of 141.30 nGyh^{-1}. The mean absorbed dose rate of this study was also lower than what was obtained in countries like the United States (38 nGyh^{-1}), the United Kingdom (60 nGyh^{-1}), Poland (67 nGyh^{-1}), and China (100 nGyh^{-1}), but lower than that New Zealand (20 nGyh^{-1}) as reported by UNSCEAR.[1]

To control and quantify human external and internal exposure to ionizing radiation, the annual effective dose is often employed, this is because it accounts for the weighted sum of equivalent doses in specific organs and tissues of the body and takes care of the type of radiation under investigation. The annual effective dose within the Imo state Polytechnic environment ranged from 20.48 to 63.89 and 81.94 to 255.58 μSvy^{-1} for the outdoor and indoor respectively, this was higher than what was reported in another higher institution in the southwestern part of the country by Popoola et al.[8] The values obtained in this study were below the UNSCEAR[18] standard of 0.07 and 0.41 $mSvy^{-1}$ for both outdoor and indoor effective doses respectively. The values were also less than the ICRP recommendation value of 1 $mSvy^{-1}$.[19]

Conclusion

The naturally occurring radionuclide materials at the Imo state Polytechnic were measured using the gamma spectroscopic method. The results obtained showed that most of the radionuclides were below the world average. The calculated radiation hazard indices show that the radionuclides pose little or no radiation risks to individuals within the environment.

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