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Evaluation of activity concentration of natural radionuclides and lifetime cancer risk in soil samples at two tertiary institutions in Owerri, Imo State, Nigeria

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ABSTRACT

Background: Environmental radioactivity measurement of soil samples from the densely populated community has become imperative considering the radiological exposure associated with primordial radionuclides. ***Materials and Method***: Sixty soil samples were collected at different locations within Alvan Ikoku Federal College of Education (AIFCE) and Federal Polytechnic Nekede (FPN), Owerri. Radioactivity measurements were carried out by the method of gamma-ray spectrometry with thallium doped sodium iodide [NaI(Tl)] detector. ***Results***: The mean activity concentrations of 88.41±1.51, 20.69±3.56 and 25.04±0.71 Bqkg^{-1} for ^{40}K, ^{226}Ra and ^{232}Th, respectively, were obtained in soil samples of AIFCE, while 92.97±1.50, 20.48±3.21 and 22.36±0.70 Bqkg^{-1} for ^{40}K, ^{226}Ra and ^{232}Th, respectively, were obtained in soil samples of FPN. These values are below the average world value of 420, 32 and 45 Bqkg^{-1} for ^{40}K, ^{226}Ra and ^{232}Th, respectively, as recorded in UNSCEAR 2000 report. The calculated absorbed dose, annual effective dose and other radiological hazard indices were below the recommended safe limit. The mean calculated values of the excess lifetime cancer risk for AIFCE and FPN are 0.12±0.03 and 0.11±0.03, respectively. ***Conclusion***: Based on the results from the present study, it is evidence that the activity concentrations and other radiological parameters are within the world's safe limit, indicating that soil samples from the AIFCE and FPN, Owerri are free from radioactive contamination and do not pose a threat to the two communities.

INTRODUCTION

Human beings are constantly exposed to ionizing radiation from natural sources that have become an unavoidable part of life on earth [(1)]. Human exposure to terrestrial radiation is primarily by gamma radiation from radionuclides in the ^{238}U and ^{232}Th series and non-decay ^{40}K. This exposure exceeds that from all artificial sources combined for most people [(1)]. Natural radioactivity can be found in various geological formations, including the earth's crust, rocks, soils, plants, water, and air. Geological and geographical conditions primarily determine the natural radioactive concentration, and it can be found at various levels in soils from different geological regions [(1, 2)].

The radionuclide activity concentration in soil samples is one major determinant in assessing the natural background radiation [(2)]. Radionuclides are delivered to the soil by rain and flows as rocks disintegrate through the activity of weathering [(3)]. The report has shown that various radiation levels exist with different types of rocks. For instance, igneous rocks are usually associated with higher radiation levels and sedimentary rocks with lower radiation levels [(1)].

The relationship between radiation exposure and cancer cases cannot be downplayed, as reports from epidemiological studies indicate a dose-response hypothesis [(4)]. This hypothesis suggests any rise in radiation dose could yield an increase in cancer risk even at a small dose. A linear, no-threshold relationship exists between radiation dose and cancer occurrence [(4, 5)]. That is, the dose of radiation receives by an individual from ionizing radiation tends to initiate cancer. The parameter commonly used to assess the impact of cancer on the population study is excess lifetime cancer risk which is the probability that an individual will develop cancer over their lifetime of exposure [(4, 5)].

Radioactivity measurement of environmental samples remains one significant way to determine the level of natural radionuclide around us and ascertain their level of hazard to man [(6)]. Studies have shown that soil is a continuous source of radiation exposure and acts as a medium of migration to transfer radionuclides to biological systems [(7, 8)].

Alvan Ikoku Federal College of Education (AIFCE) is one of the tertiary institutions in Imo State, Nigeria. The defunct Eastern Nigeria Government established

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the Institution in April 1963. The Federal Polytechnic Nekede (FPN) was created initially as Government Technical College by the Imo State government in 1978 but later metamorphosed into Federal Polytechnic Nekede by the Federal Government of Nigeria on the 7th April 1993.

Environmental radioactivity measurement of soil samples from the densely populated community cannot be downplayed as such measures can be used to estimate the level of radioactive contamination of the environment. In addition, it can serve as a baseline for the epidemiological study of the community in case of any discharge of radioactive material to the environment. Therefore, it becomes imperative to consider the area with a dense population and ascertain their radiation exposure level. Furthermore, to the best of our knowledge, no study has been conducted to determine soil samples' radioactivity level from AIFCE and FPN, Owerri.

Thus, the study aimed to evaluate the activity concentration of natural radionuclides (^{226}Ra, ^{232}Th, and ^{40}K) in soil samples from AIFCE and FPN. In addition, the study calculated the radiological hazard indices and the excess lifetime cancer risk associated with the soil samples from these institutions.

MATERIALS AND METHODS

Samples collection and preparation

Sixty soil samples were collected randomly from different locations within the campuses; thirty soil samples from AlFCE and the remaining soil samples from FPN. The samples were collected to a depth of 150 mm below the surface, placed in polythene bags, and carefully labelled [9]. The maps of the sample locations are shown in figures 1 and 2. After that, the collected soil samples were transferred to the Radiation and Health Physics Research Laboratory at the Department of Physics, University of Ibadan, Nigeria, where they were prepared for radioactivity counting. Briefly, the soil samples were oven-dried at 110^{0}C to remove the moisture until a constant weight was attained. After which, the soil samples were grounded, homogenized and sieved with a 2.0 mm mesh sieve [9]. The sieved soil samples weighing 0.2kg were packed into cleaned airtight plastic containers of uniform size and sealed. The sealed samples were stored in a dried place and left for a minimum of 28 days to ensure radioactive secular equilibrium between ^{226}Ra, ^{232}Th and their short-lived daughter products [10].

Measuring System

Radioactivity measurement of soil samples was carried out by the method of gamma-ray spectrometry using a lead-shielded 76 mm × 76 mm thallium doped sodium iodide NaI (Tl) detector. The detector was connected with a Canberra Series 10+ Multichannel Analyser (MCA) via a preamplifier. The MCA is a comprehensive system that includes all spectroscopic analysis operations. The spectrometer has a resolution of 8% efficiency at an energy of 0.662 MeV (^{137}Cs), capable of differentiating the radionuclides used for the measurement. The photo-peak energy of 1.460 MeV was used to identify ^{40}K, 1.760 MeV for ^{226}Ra (^{238}U) and 2.614 MeV for ^{232}Th. 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 (36000s). By removing counts attributable to Compton scattering of higher peaks and other background sources from the peaks' total area, the net area under the corresponding peaks in the energy spectrum was determined. Each sealed sample was placed on top of the detector and counted for the same time as the reference sample based on the stored spectra.

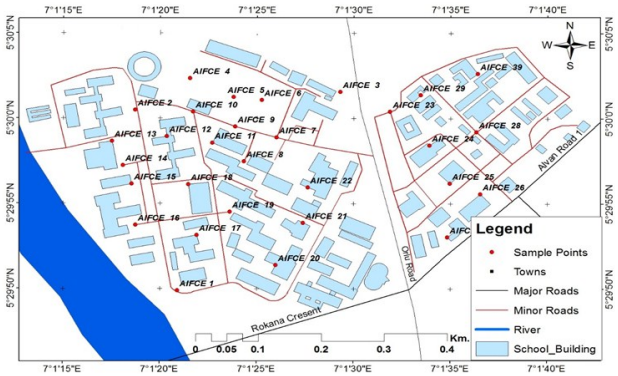

Figure 1. Sample locations at the Alvan Ikoku Federal College of Education, Owerri.

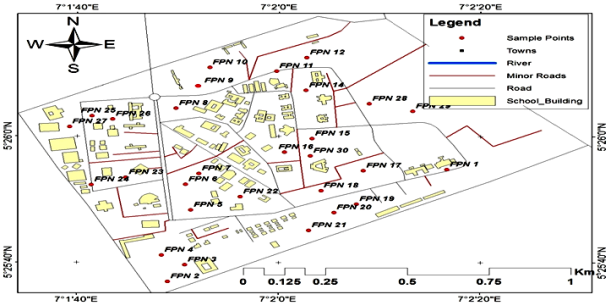

Figure 2. Sample locations at the Federal Polytechnic Nekede, Owerri.

Activity concentration and radiological parameters

The activity concentrations of the radionuclides in the soil samples were calculated using equation (1) [10, 11].

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

where C_n is the count rate under the corresponding peak, $k = \frac{1}{\varepsilon P_\gamma M_s}$, P_γ is the absolute

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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 gamma-ray detector's detection limit (DL) defines its operational capability without the sample's influence [11]. This calculation was performed using equation (2).

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

Where; t_b is the background counting time in second, C_b is the net background count in the corresponding peak, k is the conversion factor given in equation (1). The present study's measurement system showed that soil samples' detection limits 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 below the detector's detection limit (BDL).

Absorbed dose rate

The absorbed dose rate in the air from exposure to natural primordial radionuclides was calculated using the activity concentration of radionuclides results. The absorbed dose rate (D (nGyh^{-1})) in the air helps quantify the amount of radiation absorbed by a body at 1 m above the ground due to ^{40}K, ^{226}Ra and ^{232}Th. The absorbed dose rate in the air was calculated using equation (3) as given in the UNSCEAR report [1, 10].

$$D(nGyh^{-1}) = 0.462C_{Ra} + 0.604C_{Th} + 0.0417C_k \quad (3)$$

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

Annual effective dose (AED)

To assess the annual effective dose by a member of the community, we considered two factors. Firstly, the absorbed dose rate in nGyh^{-1} was converted to human effective dose Svy^{-1} using the conversion factor of 0.7 SvGy^{-1}. Secondly, the average time an individual is exposed to outdoor or indoor radiation was put into consideration. The United Nations Scientific Committee on the Effects of Atomic Radiation [1] recommended 0.2 and 0.8 for outdoor and indoor occupancy factors, respectively. This study considered only outdoor exposures from gamma-ray sources due to the concentrations of naturally occurring radioactive materials (NORMs). The annual effective dose resulting from the absorbed dose rate values was calculated using equation (4) [1].

$$AED = D\ (nGyh^{-1}) \times 8760hy^{-1} \times 0.2 \times 0.7SvGy^{-1} \quad (4)$$

Where; AED is the annual effective dose (μSvy^{-1}), D is the absorbed dose rate in the air.

Radium equivalent activity (Ra_{eq})

Radium equivalent is a regular radiological index often used to compare the specific activities of soil samples containing ^{40}K, ^{226}Ra, and ^{232}Th, radionuclides by a single quantity, which considers the radiation hazards associated with them [10, 12-15]. Ra_{eq} was calculated using equation (5):

$$Ra_{eq}\ (Bqkg^{-1}) = C_{Ra} + 1.43C_{Th} + 0.077C_K \quad (5)$$

Where C_{Ra}, C_{Th} and C_K are as defined in equation (3). Radiation hazard from soil samples can only be negligible if the value of Ra_{eq} is less than 370 Bqkg^{-1}.

External and internal hazard index

External hazard index (H_{ex}) and internal hazard index (H_{in}) are essential criteria used to measure the level of exposure to radon (^{222}Rn), a daughter of ^{226}Ra in the ^{238}U decay series. Radon has been known to be dangerous to respiratory organs if inhalation takes place. This radionuclide and its radioactive progenies pose severe internal exposure. Equations (6) and (7) were used to calculate external and internal hazard indices.

$$H_{ex} = \frac{C_{Ra}}{370Bqkg^{-1}} + \frac{C_{Th}}{259Bqkg^{-1}} + \frac{C_K}{4810Bqkg^{-1}} \quad (6)$$

$$H_{in} = \frac{C_{Ra}}{185Bqkg^{-1}} + \frac{C_{Th}}{259Bqkg^{-1}} + \frac{C_K}{4810Bqkg^{-1}} \quad (7)$$

Where C_{Ra}, C_{Th} and C_K are as defined in equation (3). Radiation hazard from soil samples is considered negligible if the value of both indices is less than unity [1].

Annual Gonadal Dose Equivalent (AGDE)

The annual gonadal dose equivalent considers the radiation dose received by the reproductive organs, bone marrows and bone cells due to activity concentrations of natural radionuclides in soil samples. The purpose is to determine the extent of radiation hazard to these organs, which happens to be the body's highly radiosensitive organs. Research has shown that an increase in AGDE could damage the bone marrow, causing the destruction of red blood and white blood cells replenished. This condition causes leukaemia, a type of blood cancer that is lethal. AGDE was estimated using equation (8) [4, 16, 17].

$$AGDE(\mu Svy^{-1}) = 3.09C_{Ra} + 4.18C_{Th} + 0.314C_K \quad (8)$$

Where; C_{Ra}, C_{Th} and C_K are the activity concentrations of radium, thorium and potassium, respectively in Bq.kg^{-1}, 3.09, 4.18 and 0.314 are conversion factors.

Excess Lifetime Cancer Risk (ELCR)

Excess lifetime cancer risk is a parameter that

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measures the probability of cancer risk to any population due to radiation exposure. It is expressed as a number representing the number of additional cancers expected in a given number of people exposed to a carcinogen at a specific dose. It was calculated based on the estimated annual effective dose. Equation 9 was used to calculate ELCR as provided by International Commission on Radiological Protection (ICRP) publication 60 [3, 4, 17-19].

$$ELCR = (AED \times DL \times RF) \times 10^{-3} \quad (9)$$

Where; AED is the annual effective dose, DL is the average duration life span (taken as 70 years), and RF is the risk factor given as $0.05Sv^{-1}$ that is a fatal cancer risk for stochastic effects in any given population based on ICRP.

Statistical analysis

Statistical package for social science (SPSS 20.0) was used for the statistical analysis of data. Results are reported as means ± SD (standard deviation).

RESULTS

The results of the activity concentration of the natural radionuclides as well as absorbed dose and annual effective dose in measurements of the soil samples from AIFCE are presented in table 1. The activity concentrations varied from 27.85±1.28 $Bqkg^{-1}$ to 122.10±1.68 $Bqkg^{-1}$ for ^{40}K with a mean value of 88.41±1.51 $Bqkg^{-1}$, whereas for ^{226}Ra, it ranged from BDL to 32.74±3.92 $Bqkg^{-1}$ with a mean value of 20.69±3.56 $Bqkg^{-1}$, and for ^{232}Th, it varied from BDL to 39.10±0.54 $Bqkg^{-1}$ with a mean value of 25.04±0.71 $Bqkg^{-1}$.

The activity concentration values for soil samples at FPN ranged from 30.90±1.47 to 147.18±1.51 $Bqkg^{-1}$ with a mean value of 92.97±1.50 $Bqkg^{-1}$, BDL to 31.11±4.28 $Bqkg^{-1}$ with a mean value of 20.48±3.21 $Bqkg^{-1}$, BDL to 37.15±0.81 $Bqkg^{-1}$ with a mean value of 22.36±0.70 $Bqkg^{-1}$ for ^{40}K, ^{226}Ra and ^{232}Th respectively (table 3).

Table 1 presents absorbed dose rate result, which ranged from 7.31 to 38.72 $nGyh^{-1}$ with a mean value of 28.75±10.39 $nGyh^{-1}$ and the annual effective dose that varied from 8.97 to 47.52 μSvy^{-1} with a mean value of 35.28±12.74 μSvy^{-1} in soil samples of AIFCE. Similarly, the absorbed dose rate and the annual effective dose of soil samples in FPN are presented in table 3. The absorbed dose value ranged from 14.49 to 38.24 $nGyh^{-1}$ with a mean value of 26.27±5.99 $nGyh^{-1}$, and the annual effective dose value varied from 17.79 to 46.92 μSvy^{-1} with a mean value of 32.24±7.35 μSvy^{-1}.

Tables 2 and 4 present the average radium equivalent results in soil samples as 59.79±16.98 $Bqkg^{-1}$and 56.78±13.12 $Bqkg^{-1}$ for AIFCE and FPN, respectively. The external radiation hazard index of soil samples in AIFCE varied from 0.04 to 0.23 with a mean value of 0.16±0.05, and that of internal radiation hazard index varied from 0.05 to 0.31 with a mean value of 0.22±0.06. Moreover, external and internal radiation indices of soil samples in FPN ranged from 0.08 to 0.22 and 0.09 to 0.30, with mean values of 0.15±0.04 and 0.21±0.05, respectively.

The average annual gonadal dose equivalent and average excess lifetime cancer risk due to activity concentrations of natural radionuclides in soil samples at AIFCE is 186.00±50.65 μSvy^{-1} and 0.12±0.03, respectively. At the same time, the average annual gonadal dose equivalent and average excess lifetime cancer risk due to radiation exposure at FPN is 177.47±39.20 μSvy^{-1} and 0.11±0.03, respectively.

Table 1. Activity concentration of naturally occurring radionuclides, absorbed dose and annual effective dose in soil samples from Alvan Ikoku Federal College of Education.

Sample ID	^{40}K ($Bqkg^{-1}$)	^{226}Ra ($Bqkg^{-1}$)	^{232}Th ($Bqkg^{-1}$)	Absorbed Dose ($nGyh^{-1}$)	Effective Dose (μSvy^{-1})
AIFCE 1	108.14±1.21	15.10±4.10	27.40±0.77	29.24	35.89
AIFCE 2	69.11±1.43	23.11±2.11	39.10±0.54	38.72	47.52
AIFCE 3	75.44±1.59	14.90±3.44	23.45±0.73	25.13	30.84
AIFCE 4	79.24±1.61	9.61±4.10	BDL	10.42	12.79
AIFCE 5	86.58±1.70	16.44±4.24	30.15±0.61	30.7	37.68
AIFCE 6	100.10±1.34	21.22±4.15	25.74±0.73	30.41	37.32
AIFCE 7	111.25±1.49	15.74±4.37	5.12±0.84	14.89	18.27
AIFCE 8	86.15±1.43	8.62±2.07	15.11±0.74	17.39	21.34
AIFCE 9	75.34±1.52	13.10±2.19	24.20±0.88	24.85	30.49
AIFCE 10	93.30±1.61	25.54±2.54	21.73±0.72	29.3	35.96
AIFCE 11	97.94±1.70	20.17±3.78	25.77±0.64	29.88	36.67
AIFCE 12	92.23±1.63	31.15±4.11	29.64±0.53	36.88	45.26
AIFCE 13	110.44±1.55	25.50±4.27	30.11±0.61	35.57	43.65
AIFCE 14	98.45±1.37	30.10±3.10	27.45±0.72	35.26	43.27
AIFCE 15	53.22±1.48	16.17±2.55	29.12±0.80	28.47	34.94
AIFCE 16	98.15±1.33	18.44±3.98	19.87±0.72	25.25	30.99
AIFCE 17	102.25±1.41	17.30±3.74	BDL	14.43	17.71
AIFCE 18	92.40±1.57	28.10±3.01	28.12±0.66	34.59	42.45
AIFCE 19	107.77±1.64	21.83±3.98	23.81±0.71	29.72	36.47
AIFCE 20	87.10±1.68	14.51±4.17	25.93±0.73	27.11	33.27
AIFCE 21	121.24±1.59	23.66±4.28	21.91±0.81	29.82	36.59
AIFCE 22	27.85±1.28	25.37±3.17	20.69±0.59	25.73	31.58
AIFCE 23	79.41±1.31	18.33±2.18	27.10±0.64	29.18	35.81
AIFCE 24	99.12±1.48	27.68±4.44	23.74±0.77	31.79	39.01
AIFCE 25	73.15±1.51	17.82±4.78	29.11±0.79	30.03	36.85
AIFCE 26	51.78±1.59	32.74±3.92	30.97±0.81	36.71	45.05
AIFCE 27	87.23±1.67	25.10±4.10	31.17±0.64	35.1	43.08
AIFCE 28	100.25±1.38	23.58±2.36	14.12±0.72	23.73	29.12
AIFCE 29	65.55±1.53	BDL	BDL	6.3	7.73
AIFCE 30	122.10±1.68	19.14±4.15	25.48±0.69	65.87	80.83
Minimum	**27.85±1.28**	**BDL**	**BDL**	**7.31**	**8.97**
Maximum	**122.10±1.68**	**32.74±3.92**	**39.10±0.54**	**38.72**	**47.52**
Mean±SD	**88.41±1.51**	**20.69±3.56**	**25.04±0.71**	**28.75±10.39**	**35.28±12.74**

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Table 2. Radium equivalent, hazard indices, annual gonadal dose equivalent and excess lifetime cancer risk in soil samples from Alvan Ikoku Federal College of Education.

Sample ID	Ra(Bqkg^{-1})	H_{in}	H_{ex}	AGDE(μSvy^{-1})	ELCR
AIFCE 1	62.61	0.21	0.17	195.15	0.13
AIFCE 2	84.34	0.29	0.23	256.55	0.17
AIFCE 3	54.24	0.19	0.15	167.75	0.11
AIFCE 4	22.05	0.09	0.06	73.09	0.04
AIFCE 5	66.22	0.22	0.18	204.01	0.13
AIFCE 6	65.74	0.23	0.18	204.59	0.13
AIFCE 7	31.63	0.13	0.09	104.97	0.06
AIFCE 8	36.86	0.12	0.1	116.85	0.07
AIFCE 9	53.51	0.18	0.14	165.29	0.11
AIFCE 10	63.8	0.24	0.17	199.05	0.13
AIFCE 11	64.56	0.23	0.17	200.80	0.13
AIFCE 12	80.64	0.3	0.22	249.11	0.16
AIFCE 13	77.06	0.28	0.21	239.33	0.15
AIFCE 14	76.93	0.29	0.21	238.66	0.15
AIFCE 15	61.91	0.21	0.17	188.40	0.12
AIFCE 16	54.41	0.2	0.15	170.86	0.11
AIFCE 17	31.51	0.13	0.09	104.08	0.06
AIFCE 18	75.43	0.28	0.2	233.38	0.15
AIFCE 19	64.18	0.23	0.17	200.82	0.13
AIFCE 20	58.3	0.2	0.16	180.57	0.12
AIFCE 21	64.33	0.24	0.17	202.76	0.13
AIFCE 22	57.1	0.22	0.15	173.62	0.11
AIFCE 23	63.2	0.22	0.17	194.85	0.13
AIFCE 24	69.26	0.26	0.19	215.89	0.14
AIFCE 25	65.08	0.22	0.18	199.71	0.13
AIFCE 26	81.01	0.31	0.22	246.88	0.16
AIFCE 27	76.39	0.27	0.21	235.24	0.15
AIFCE 28	51.49	0.2	0.14	163.36	0.10
AIFCE 29	15.03	0.05	0.04	50.38	0.03
AIFCE 30	64.98	0.23	0.18	203.99	0.13
Minimum	**15.03**	**0.05**	**0.04**	**50.38**	**0.03**
Maximum	**84.34**	**0.31**	**0.23**	**256.55**	**0.17**
Mean±SD	**59.79± 16.98**	**0.22± 0.06**	**0.16± 0.05**	**186.00± 50.65**	**0.12± 0.03**

Table 3. Activity concentration of naturally occurring radionuclides, absorbed dose and annual effective dose in soil samples from Federal Polytechnic Nekede.

Sample Code	^{40}K (Bqkg^{-1})	^{226}Ra (Bqkg^{-1})	^{232}Th (Bqkg^{-1})	Absorbed Dose(nGyh^{-1})	Effective Dose (μSvy^{-1})
FPN 1	101.13±1.27	10.13±2.18	29.11±0.71	27.94	34.3
FPN 2	86.18±1.53	24.01±3.70	BDL	16.89	20.73
FPN 3	70.23±1.24	16.51±2.50	19.70±0.71	23.11	28.36
FPN 4	124.11±1.29	19.45±3.11	37.15±0.81	38.24	46.92
FPN 5	90.33±1.67	21.86±4.41	24.90±0.83	29.7	36.45
FPN 6	99.51±1.72	28.73±4.10	BDL	19.48	23.91
FPN 7	72.39±1.54	31.11±4.28	29.05±0.59	35.63	43.72
FPN 8	100.75±1.30	23.48±3.04	25.91±0.73	31.51	38.67
FPN 9	98.37±1.45	16.90±2.84	28.19±0.84	30.11	36.95
FPN 10	87.43±1.61	25.73±3.55	15.48±0.57	24.99	30.67
FPN 11	93.78±1.68	BDL	19.11±0.68	18.24	22.39
FPN 12	72.71±1.28	12.54±2.57	25.86±0.77	25.6	31.42
FPN 13	110.50±1.34	16.97±3.50	13.99±0.53	21.26	26.09
FPN 14	113.96±1.47	20.78±3.94	20.17±0.82	27.13	33.29
FPN 15	147.18±1.51	18.97±2.92	18.57±0.59	26.72	32.79
FPN 16	89.98±1.62	14.12±2.10	27.51±0.71	28.11	34.5
FPN 17	103.74±1.23	25.10±3.43	7.80±0.53	20.34	24.96
FPN 18	59.58±1.69	BDL	15.67±0.66	14.49	17.79
FPN 19	63.55±1.65	19.93±2.48	25.10±0.74	27.86	34.19
FPN 20	110.04±1.31	20.15±3.12	27.81±0.71	31.75	38.96
FPN 21	98.49±1.47	9.47±2.76	19.88±0.83	21.44	26.31
FPN 22	114.40±1.61	21.47±3.84	5.44±0.54	17.69	21.71
FPN 23	69.70±1.66	18.74±2.58	18.37±0.68	23.16	28.42
FPN 24	105.20±1.44	17.70±3.01	29.86±0.71	31.85	39.09
FPN 25	98.94±1.52	14.33±3.27	15.92±0.64	20.91	25.66
FPN 26	104.56±1.61	29.50±4.11	27.70±0.57	35.43	43.48
FPN 27	78.75±1.70	23.10±2.76	20.18±0.80	26.61	32.66
FPN 28	88.23±1.64	30.11±3.91	16.99±0.75	27.9	34.24
FPN 29	104.40±1.59	27.12±2.45	29.17±0.66	35.38	43.42
FPN 30	30.90±1.47	15.39±3.29	31.49±0.83	28.75	35.28
Minimum	**30.90±1.47**	**BDL**	**BDL**	**14.49**	**17.79**
Maximum	**147.18±1.51**	**31.11±4.28**	**37.15±0.81**	**38.24**	**46.92**
Mean ± SD	**92.97±1.50**	**20.48±3.21**	**22.36±0.70**	**26.27±5.99**	**32.24±7.35**

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Table 4. Radium equivalent, hazard indices, annual gonadal dose equivalent and excess lifetime cancer risk in soil samples from Federal Polytechnic Nekede.

Sample ID	Ra (Bqkg^{-1})	H_{in}	H_{ex}	AGDE (μSvy^{-1})	ELCR
FPN 1	59.54	0.19	0.16	184.74	0.12
FPN 2	36.98	0.16	0.10	119.77	0.07
FPN 3	50.09	0.18	0.14	155.41	0.10
FPN 4	82.13	0.27	0.22	254.36	0.16
FPN 5	64.42	0.23	0.17	199.99	0.13
FPN 6	42.73	0.19	0.12	138.54	0.08
FPN 7	78.23	0.30	0.21	240.29	0.15
FPN 8	68.29	0.25	0.18	212.49	0.14
FPN 9	64.79	0.22	0.17	200.94	0.13
FPN 10	54.60	0.22	0.15	171.67	0.11
FPN 11	38.20	0.11	0.10	120.61	0.08
FPN 12	55.12	0.18	0.15	169.67	0.11
FPN 13	45.48	0.17	0.12	145.61	0.09
FPN 14	58.40	0.21	0.16	184.30	0.12
FPN 15	56.86	0.20	0.15	182.45	0.11
FPN 16	60.39	0.20	0.16	186.88	0.12
FPN 17	44.24	0.19	0.12	142.74	0.09
FPN 18	30.65	0.09	0.08	95.49	0.06
FPN 19	60.72	0.22	0.16	186.46	0.12
FPN 20	68.39	0.24	0.18	213.06	0.14
FPN 21	45.48	0.15	0.12	143.29	0.09
FPN 22	38.06	0.16	0.10	125.00	0.08
FPN 23	50.38	0.19	0.14	156.58	0.10
FPN 24	68.50	0.23	0.18	212.54	0.14
FPN 25	44.71	0.16	0.12	141.89	0.09
FPN 26	77.16	0.29	0.21	239.77	0.15
FPN 27	58.02	0.22	0.16	180.46	0.11
FPN 28	61.20	0.25	0.17	191.76	0.12
FPN 29	76.87	0.28	0.21	238.51	0.15
FPN 30	62.80	0.21	0.17	188.89	0.12
Minimum	**30.65**	**0.09**	**0.08**	**95.49**	**0.06**
Maximum	**82.13**	**0.30**	**0.22**	**254.36**	**0.16**
Mean±SD	**56.78± 13.12**	**0.21± 0.05**	**0.15± 0.04**	**177.47± 39.20**	**0.11± 0.03**

DISCUSSION

The activity concentrations of primordial radionuclides have been carried out in this study. The mean activity concentrations of radionuclides in soil samples are 88.41±1.51 Bqkg^{-1}, 20.69±3.56 Bqkg^{-1}, 25.04±0.71 Bqkg^{-1} for ^{40}K, ^{226}Ra, and ^{232}Th respectively, as obtained from the AIFCE and 92.97±1.50 Bqkg^{-1}, 20.48±3.21 Bqkg^{-1}, 22.36±0.70 Bqkg^{-1} for ^{40}K, ^{226}Ra and ^{232}Th, respectively as obtained from FPN. These values are comparable to what was obtained from similar tertiary institutions within Nigeria, as shown in table 5. For instance, the research conducted by Eke *et al.* [8] on soil samples at the Federal University of Technology, Owerri, revealed the mean activity concentrations of 90.18 Bqkg^{-1}, 17.88 Bqkg^{-1} and 22.82 Bqkg^{-1} for ^{40}K, ^{226}Ra and ^{232}Th, respectively. Similarly, the study conducted by Egunyinka *et al.* [20] on evaluating primordial radionuclides in the topsoil of the University of Ibadan showed the activity concentrations 261.37±192.17, 50.01±29.00 and 84.66±37.88 Bqkg^{-1} for ^{40}K, ^{226}Ra(^{238}U) and ^{232}Th respectively. Their results are comparable to the findings in the present study.

The activity concentrations of the present study are compared with similar studies in other countries, as shown in table 5. The average activity concentrations of ^{40}K and ^{226}Ra in AIFCE and FPN are much lower than in East China, South India, Egypt, Tanzania and Iraq. However, the activity concentrations of ^{40}K from Tanzania and East China are higher than the average world values of 420, 32, and 45 Bqkg^{-1} for ^{40}K, ^{226}Ra and ^{232}Th, respectively, as given in the UNSCEAR report [1] (table 5). The activity concentrations of ^{226}Ra in the listed countries are higher than the average world value except for Egypt and East China. The activity concentrations of ^{232}Th obtained from the present study and East China, Egypt, Tanzania, and Iraq are lower than the average world value as stated in the UNSCEAR report [1].

The results as presented in tables 1 and 3 indicate that the distribution of activity concentrations of primordial radionuclides in the studied areas are not uniform. The non-uniformity may be partly due to the geochemical, chemical, mineralogical and physical properties of the terrestrial soil and other infrastructural projects that have been ongoing since the establishment of the institutions. The migration of weathered materials from surrounding rocks might have contributed to the enhanced activity concentrations recorded in the studied areas [21, 22].

The present investigation revealed that ^{40}K contributes a significant amount to the total radioactivity of soil in AIFCE and FPN. The high value of ^{40}K could be due to potash feldspar minerals present in soil samples of the studied locations [8, 23]. Moreover, the activity concentrations of ^{40}K from the present study is found to be higher than those of ^{226}Ra and ^{232}Th, which corroborates with the findings of similar studies within Nigeria.

The average absorbed dose estimated for soil samples from the present study due to primordial radionuclides was 28.75±10.39 nGyh^{-1} and 26.27±5.99 nGyh^{-1} AIFCE and FPN, respectively. These values are below the average world value of 59 nGyh^{-1} for an outdoor absorbed dose as reported in UNSCEAR [1] report, indicating that the soil samples within the studied areas are free of radiological threat and they are within the normal background environment. The comparison of the absorbed dose obtained from the two institutions with existing literature indicates that the present values are less than the average value of 32.17 nGyh^{-1} in Niger Delta, Nigeria [24], 38.7±5.0 nGyh^{-1} in Agbara, Ogun State, Nigeria [25] and 42.94 nGyh^{-1} in the non-oil region of Yemen [26].

Other radiological parameters such as radium equivalent activity, external and internal hazard indices have their average values 59.79±16.98 Bqkg^{-1}, 0.16±0.05, 0.22±0.06, respectively, for the AIFCE,

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which are below the recommended safe limit based on UNSCEAR [1] report. Similarly, radium equivalent activity and external and internal hazard indices obtained from FPN have average values of 56.78±13.12 $Bqkg^{-1}$, 0.15±0.04, 0.21±0.05, respectively.

Evaluation of excess lifetime cancer risk (ELCR) revealed that radiation levels from ^{40}K, ^{226}Ra, and ^{232}Th in the studied soil are unlikely to cause cancer. The calculated ELCR ranged from 0.03 to 0.17 with a mean of 0.12±0.03 for soil samples from AIFCE, while ELCR for soil samples in FPN ranged from 0.06 to 0.16 with a mean of 0.11±0.03. The estimated ELCR from the two locations is less than the average world value of 0.290×10^{-3} as reported by [1, 3], indicating the probability of developing radiation-induced cancer from exposure from soil samples over a lifetime exposure of 70 years is low.

CONCLUSION

The gamma-ray spectrometry method has been used to determine the activity concentrations and estimate the radiological health risks associated with soil samples from the AIFCE and FPN, Owerri. The results showed that the activity concentrations in soil samples from the campuses are comparable to the reports from other higher institutions in Nigeria. Moreover, the activity concentrations are below the average world value, as recommended by UNSCEAR [1]. The activity concentrations obtained were used to calculate the absorbed dose rate, annual effective dose equivalent, annual gonadal dose and radium equivalent. The results are below the permissible safe limit.

Furthermore, excess lifetime cancer risks showed that the probability of developing radiation-induced cancer due to exposure to gamma radiation from the naturally occurring radioactive materials in soil samples is insignificant. This suggests that soil samples from the Alvan Ikoku Federal College of Education and Federal Polytechnic Nekede, Owerri are free from radioactive contamination and do not pose a threat to the two communities. However, this study's result represents reference information on radiation dose levels. It could serve as baseline data on the natural radioactivity level and epidemiological studies of the AIFCE and FPN.

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***Authors' contribution*:** B.C.E designed, conceptualized the research and edited the manuscript U.M.U supervised the work I.R.A analyzed the data, wrote the manuscript and edited the manuscript All authors read and approved the manuscript.

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