



ASSESSING THE RADIOLOGICAL HEALTH IMPACT OF SOIL USED FOR AGRICULTURE, FEDERAL POLYTECHNIC ILE-OLUJI RESEARCH FARM

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Abstract

This study aims to measure the natural radioactivity concentration of the agricultural soil of the Federal Polytechnic Ile-Oluji research farm using a well-calibrated Canberra NaI (TI) gamma-spectroscopy detector. In addition, the radiological hazard was calculated to evaluate the health impact due to exposure of humans. Twenty (20) soil samples were randomly collected from the agricultural farmland within an area mapped out for the study. The radionuclides of interest in this study are ²³⁸U, ²³²Th, and ⁴⁰K, respectively. The average activity concentration values of ⁴⁰K, ²³⁸U and ²³²Th in the soil samples were 475.13 Bq/kg, 55.11 Bq/kg and 42.85 Bq/kg, respectively. Also, the mean value for the radiological hazard indices was for absorbed dose (71.16 nGy/h), outdoor and indoor annual effective dose (0.09 mSv/y and 0.21 to 0.50 mSv/y), external and internal radiation hazard indices (0.41 and 0.56) and radium equivalent activity index (152.98). While gamma index, annual gonadal dose equivalent and excess lifetime cancer risk were 1.11, 498.61 μSv/y and 1.53 X 10⁻³, respectively. Most radiological parameters calculated for the soil samples of this study are higher than the recommended values for safe soil used for agricultural purposes given by the International Atomic Energy Agency. Thus, environmental monitoring of the study area is highly recommended.

Keywords: Radiological hazard, NORMS, Agriculture, Concentration

Introduction

The earth is radioactive due to the natural radiation sources and man's activities in the environment (Singh et al. 2009). There is a Continuous bombardment of man and his environment by these (radionuclide) ionizing radiations (IAEA, 2000). Hence, the issue of environmental degradation and pollution in the 21st century is of global concern because of its health impact and implications. The quest for agricultural development in the Southwestern States of

Nigeria has led to various activities that tend to perturb the area's fragile ecological, biophysical systems and socio-economic structures. As a case due, the Federal Polytechnic Ile-Oluji research farm continues to experience enormous and rigorous agricultural activities on the farmlands. Natural occurring radioactive materials are present everywhere in our environment. Our body contains some naturally occurring radioactive decay elements such as carbon-14, potassium-40 and Polonium-210 (IAEA,

2000). Radioactive disequilibrium arises in the natural radioactive series due to recent fractionation events (continuous or instantaneous processes) which lead to the loss or gain of mobile radionuclides in ambient environmental conditions (Aditi, 2010). On the other hand, it has been found that such natural radiation constitutes a source of health hazards as its short-lived daughters can cause lung cancer (Fasasi, 2003; UNACEAR, 2000).

Human health status is a function of the immediate environment (Diez, 2001) The level of contamination of our environment dramatically affects the quality of human health. Importantly, human activities have led to an enhanced level of air, soil, and water pollution in our environment Hence, this study aims to study the activity concentration of natural radionuclides in soil used for agriculture purposes at the Federal Polytechnic research farm Ile-Oluji and estimates the equivalent radiological health impacts of such radionuclides to humans and the environment.

Materials and Method

Description of the Study Area

Ile-Oluji is the headquarter of Ile-Oluji/Okeigbo Local Government, Ondo

State, Nigeria and lies between Longitudes 6° 40' N and 7° 14' N, and Latitudes 4° 38' E and 4° 53' E. It has an area of 698 km² and a population of 172,870 as at the 2006 census. Federal Polytechnic is located within the axis of Ipeju Ijesha express way, which lies within 7°14'0"N - 7°14'50"N and 4°51'0"E - 4°52'10"E covering a land area of 1.53 km². The climate of Ile-Oluji Ondo State is broadly of the lowland tropical rain forest type, with distinct derived Savannahs and humid forest and it mean monthly temperature and relative humidity are about 27 °C and 75 %respectively. The Basement complex of southwest Nigeria, which consists of the Migmatite-Older Granite-Gneiss-Quartzite Complex, Slightly Migmatized-Unmigmatized Paraschists and Meta-Igneous Rocks, Charnockitic Rocks, Unmetamorphosed Dolerite Dyke, and the Pan-African Granitoids known as the Older Granites, is the dominant rock type in the study area (Rahaman, 2006; Osotuyi *et al.*, 2020, 2021). Soils in the research region are formed when rocky and mineral particles are exposed to water and air, and then broken down by microorganisms; raw organic substances, such as plant and animal remains, are also added (Oni *et al.* 2020).

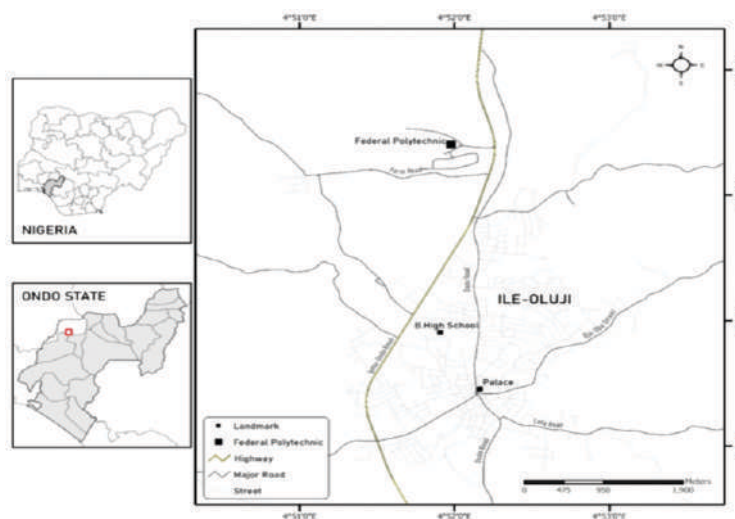


Fig 1: Map of Ile-Oluji, Ondo State where Federal Polytechnic is located

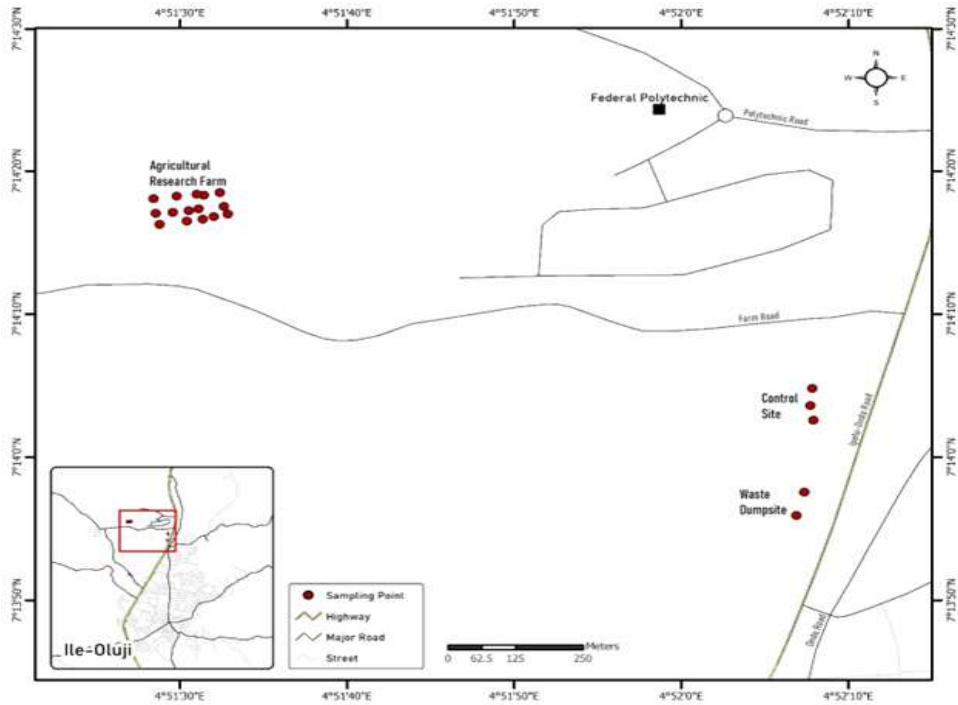


Table 1: Geospatial description of the study area

Sampling Point	GPS description Latitude	Longitude
P1	N07°14.283'	E004°51.548'
P2	N07°14.280'	E004°51.534'
P3	N07°14.277'	E004°51.523'
P4	N07°14.275'	E004°51.507'
P5	N07°14.271'	E004°51.480'
P6	N07°14.284'	E004°51.476'
P7	N07°14.285'	E004°51.493'
P8	N07°14.287'	E004°51.509'
P9	N07°14.289'	E004°51.591'
P10	N07°14.292'	E004°51.544'
P11	N07°14.308'	E004°51.540'
P12	N07°14.305'	E004°51.524'
P13	N07°14.306'	E004°51.517'
P14	N07°14.304'	E004°51.497'
P15	N07°14.301'	E004°51.474'
P16	N07°14.080'	E004°52.131'
P17	N07°14.060'	E004°52.129'
P18	N07°14.043'	E004°52.132'
P19	N07°13.932'	E004°52.115'
P20	N07°13.959'	E004°52.123'

Methodology

Twenty (20) soil samples collected from the root of cassava plants were collected for this study using a hand trowel. The sampling points were geo-located using a Geographical Positioning System (GPS) tool, as shown in Table 1. The collected soil samples were then packed into a polythene bag and labeled appropriately. Soil samples were oven dried at 105°C, to prevent moisture, sieved and weigh. Then samples were packed into containers, sealed, and kept for 28 days before spectroscopy measurement to prevent escape of radon gas.

The samples were sealed in a cylindrical plastic container of the same dimension and geometry as the International Atomic Energy Agency (IAEA) reference sample. Each sealed sample was placed on the shielded NaI (Tl) detector and counted for 18,000 seconds. An empty container of the same geometry and dimension was counted for the same time to determine the background radiation.

Canberra S100 gamma ray acquisition software was used for the gamma counting process, after which spectra information was retrieved and the analysis was carried out using the comparative method. This data analysis routine subtracted a linear net background distribution from corresponding net peaks for a particular radionuclide in the spectra of the samples. The 1764 KeV γ -line of ²¹⁴Bi for ²³⁸U was used in the assessment of the activity concentration of ²³⁸U while 2614.5 KeV γ -line of ²⁰⁸Tl was used for investigating the activity concentration of ²³²Th. The single 1460 KeV γ -line of ⁴⁰K was used to determine the concentration of ⁴⁰K in the samples. The photo-peaks observed with regularity in soil samples were identified to belong to the natural radioactive decay series headed by ²³⁸U and ²³²Th, and a third non-series natural

radionuclide ⁴⁰K. Other radionuclides that may be present occurred below the detection limit of the detector used.

The specific radioactivity C_x in the sample and the corresponding specific radioactivity C_s in the standard are related by:

$$C_x = \frac{M_s \cdot A_x}{M_x \cdot A_s}$$

Where M_s is the mass of the standard

A_x is the net peak area of the sample

M_x is the mass of the sample

A_s is the net peak area of the standard

Radiological Impacts Estimation

The Absorbed Dose Rate is the dose (nGy/h) that expresses the received dose in the open air (1m above the ground surface) from the radiation emitted from radionuclide concentrations in environmental media. This was estimated from the activity concentration of the radionuclides present using equation 1 (UNSCEAR, 2000 and UNSCEAR, 2008).

$$D\left(\frac{nGy}{h}\right) = 0.462A_u + 0.604A_{Th} + 0.0417A_k \tag{1}$$

Where A_u , A_{Th} and A_k are the activity concentration of ²³⁸U, ²³²Th and ⁴⁰K, respectively.

Annual Effective Dose

Annual Effective Dose (E) is the sum of the effective dose over a year. It is calculated for both outdoor (E_{out}) and indoor (E_{in}) using equations 2 and 3, respectively (UNSCEAR, 2000 and UNSCEAR, 2008). It is measured in mSv/y .

$$E_{out}\left(\frac{mSv}{y}\right) = D\left(\frac{nGy}{h}\right) \times 24h \times 365days \times 0.2 \times 0.7 \times 0.001 \tag{2}$$

$$E_{in}\left(\frac{mSv}{y}\right) = D\left(\frac{nGy}{h}\right) \times 24hx365days \times 0.8 \times 0.7 \times 0.001 \tag{3}$$

Where D is the absorbed dose rate in nGy/h. The dose conversion factor of 0.7 Sv/Gy with an occupancy factor of 0.2 for outdoors and an occupancy factor of 0.8 for indoors was used to estimate the annual effective dose.

Annual Gonadal Dose Equivalent (AGDE)

This is the dose received by the organs (gonads), bone marrow and bone cells. It was

calculated using the following:

$$AGDE (\mu\text{Sv}/\text{y}) = 3.09A_u + 4.18A_{Th} + 0.314A_k \quad (4)$$

A_u , A_{Th} , and A_k are the activity concentration of ^{238}U , ^{232}Th , and ^{40}K , respectively, in B/kg.

Radiation Hazard Indices

The external hazard index (H_{ex}) is due to external exposure to radiation in the study area. It was calculated using the equation:

$$H_{ex} = \frac{A_u}{370} + \frac{A_{Th}}{259} + \frac{A_k}{4810} \quad (5)$$

Similarly, the risk to respiratory organs from internal exposure to radon and its short-lived daughter nuclei was quantified in terms of the internal hazard index (H_{in}) using equation 6:

$$H_{in} = \frac{A_u}{185} + \frac{A_{Th}}{259} + \frac{A_k}{4810} \quad (6)$$

Where A_u , A_{Th} , and A_k are the activity concentration of ^{238}U , ^{232}Th , and ^{40}K in (B/kg), respectively.

H_{in} and H_{ex} should be less than unity for the radiation hazard to be negligible (Avwiri et al., 2014).

Representative Gamma Index (I_y)

The gamma index is used to estimate the gamma radiation hazard associated with the natural radionuclide in specific investigated samples. The representative gamma index

$$I_y = \frac{A_u}{150} + \frac{A_{Th}}{1500} \quad (7)$$

Where A_u , A_{Th} and A_k are the activity concentrations of ^{238}U , ^{232}Th , and ^{40}K in (B/kg), respectively.

The representative gamma index (I_y) should also be less than unity for the radiation hazard to be negligible (Avwiri et al., 2014).

Radium Equivalent Activity Index (Ra_{eq})

The radium equivalent (Ra_{eq}) activity allows a single index or number to describe the gamma output from different mixtures of ^{238}U , ^{232}Th and ^{40}K in a material. It was calculated using equation by (Issa, et al., 2013).

$$Ra_{eq} = A_u + 1.43A_{Th} + 0.077A_k \quad (8)$$

Where A_u , A_{Th} and A_k are the activity concentration of ^{238}U , ^{232}Th , and ^{40}K in (B/kg), respectively.

Excess Lifetime cancer risk (ELCR)

The Excess Lifetime cancer risk (ELCR) was calculated using equation 8 (Avwiri, et al., 2014).

$$ELCR = AED \times DL \times RF \quad (9)$$

Where, AED is the Annual Equivalent Dose Equivalent, DL is the average duration of life (estimated to 70 years), and RF is the Risk Factor (Sv-1), i.e. fatal cancer risk per Sievert. For stochastic effects, ICRP uses RF as 0.05 for public (Avwiri et al., 2014).

Results and Discussion

The results of the activity concentration of ^{238}U , ^{232}Th and ^{40}K in the soil sample collected from the Agricultural Research Farm of the Federal Polytechnic Ile-Oluji, Ondo State, Nigeria and the associated radiological hazard parameters are presented in Tables 2 and 3, respectively.

Table 2 presents the results of the gamma spectrometry measurements and their estimated mean, Skew, Kurt and world average value given by IAEA, which serve as the recommended limit. The radionuclide observed with reliable regularity belonged to the decay series chain headed by ^{238}U and ^{232}Th and the non-series ^{40}K . As expected, ^{40}K activity concentration dominated over the ^{238}U and ^{232}Th elemental activities in all the locations. The measured values for all the parameters (i.e., ^{238}U , ^{232}Th and ^{40}K) were moderately skewed as the distribution was moderately symmetric since most of the measure of the asymmetry of their probability distribution about their means is in the range of -2 and +2 (Normality Testing, 2019).

^{40}K has the highest activity concentration of 836.39 Bq/kg and the lowest value of 257.21 Bq/kg, with a mean value of 475.13 Bq/kg. The highest and lowest activity concentrations of ^{238}U and ^{232}Th were (90.67,

25.54 Bq/kg) and (79.46, 17.04 Bq/kg), respectively. The overall mean of activity

Table 2: ^{238}U , ^{232}Th and ^{40}K activity concentration in Agricultural Research Farm Federal Polytechnic Ile-Oluji and Environs, Ondo State, Nigeria.

S/N	Samples	U-238 (Bq/kg)	Th-232 (Bq/kg)	K-40 (Bq/kg)
1	P1	25.54±1.02	22.34±1.55	430.46±2.50
2	P2	36.67±1.17	25.04±0.87	324.41±1.40
3	P3	42.87±1.16	33.96±0.19	534.63±2.18
4	P4	75.06±1.5	27.46±1.42	725.21±1.58
5	P5	29.12±2.04	40.48±0.51	426.07±2.78
6	P6	38.36±1.17	42.41±0.12	740.83±2.57
7	P7	87.78±1.28	21.11±0.5	826.51±1.57
8	P8	40.92±1.10	17.04±0.10	452.71±2.53
9	P9	49.74±1.26	25.33±0.26	836.39±2.37
10	P10	35.46±1.64	21.37±0.07	421.07±2.24
11	P11	62.54±1.42	32.34±1.55	412.46±5.50
12	P12	90.67±1.97	78.04±0.87	294.41±14.40
13	P13	59.87±1.46	23.96±0.19	514.63±25.18
14	P 14	85.06±3.57	59.46±1.42	257.21±12.58
15	P15	72.12±2.43	40.48±0.51	486.07±23.78
16	P16	52.36±3.17	72.41±0.12	440.83±21.57
17	P17	62.54±1.42	72.34±1.55	312.46±5.50
18	P18	40.67±1.97	58.04±0.87	294.41±14.40
19	P19	59.87±1.46	63.96±0.19	514.63±25.18
20	P20	55.06±3.57	79.46±1.42	257.21±12.58
Min - Max		25.54 - 90.67	17.04 - 79.46	257.21 - 836.39
Mean		55.11	42.85	475.13
Skew		0.40	0.55	0.84
Kurt		-0.81	-1.26	-0.17
RL		32.00	45.00	420.00

RL is recommended limit.

concentrations of the measured radionuclides in the soil samples for ^{238}U and ^{232}Th were 55.11 and 42.85 Bq/kg, respectively. The variation in activity the estimated mean value for ^{40}K and ^{238}U were slightly higher than the global average of 42.00 and 32.00 Bq/kg, respectively given by ICRP (1991), IAEA (1996) and UNSCEAR (2000) reports. Geological conditions of the environment, natural deposition of oil around the sample site and human

developmental activities may influence the high values of these radionuclides. Similarly, radionuclides concentration level depends on the local geology.

The results of the activity concentrations of these radionuclides were used to estimate the corresponding radiation impact parameters. Table 3 shows the results of the radiation impact parameters.

The absorbed dose rate varied from 43.24 to 101.30 nGy/h with a mean of 71.16 nGy/h.

Table 3: Radiological Impact Parameters due to the Presence of Natural Radionuclides in the Soil Samples at the Agricultural Research Farm of Federal Polytechnic Ile-Oluji, Ondo State, Nigeria.

Samples	D nGy/h	E _{out} mSv/y	E _{in} mSv/y	E _{total} mSv/y	AGED μSv/y	H _{ext}	H _{int}	I _γ	Raeq Bq/kg	ELCR (10 ⁻³)
P1	43.24	0.05	0.21	0.27	307.46	0.24	0.31	0.68	90.63	0.93
P2	45.59	0.06	0.22	0.28	319.84	0.26	0.36	0.71	97.46	0.98
P3	62.61	0.08	0.31	0.38	442.29	0.36	0.47	0.98	132.60	1.34
P4	81.50	0.10	0.40	0.50	574.43	0.46	0.66	1.26	170.17	1.75
P5	55.67	0.07	0.27	0.34	392.97	0.32	0.40	0.88	119.81	1.19
P6	74.23	0.09	0.36	0.46	528.43	0.42	0.53	1.17	156.05	1.59
P7	87.77	0.11	0.43	0.54	619.00	0.49	0.73	1.35	181.61	1.88
P8	48.08	0.06	0.24	0.29	339.82	0.27	0.38	0.75	100.15	1.03
P9	73.16	0.09	0.36	0.45	522.20	0.41	0.54	1.14	150.36	1.57
P10	46.85	0.06	0.23	0.29	331.11	0.27	0.36	0.73	98.44	1.01
P11	65.63	0.08	0.32	0.40	457.94	0.38	0.55	1.02	140.55	1.41
P12	101.30	0.12	0.50	0.62	698.82	0.61	0.85	1.58	224.94	2.17
P13	63.59	0.08	0.31	0.39	446.74	0.36	0.52	0.98	133.76	1.36
P 14	85.94	0.11	0.42	0.53	592.14	0.51	0.74	1.33	189.89	1.84
P15	78.04	0.10	0.38	0.48	544.68	0.45	0.65	1.21	167.43	1.67
P16	86.31	0.11	0.42	0.53	602.89	0.51	0.65	1.37	189.85	1.85
P17	85.62	0.10	0.42	0.52	593.74	0.51	0.68	1.35	190.05	1.84
P18	66.12	0.08	0.32	0.41	460.72	0.40	0.51	1.05	146.34	1.42
P19	87.75	0.11	0.43	0.54	613.94	0.52	0.68	1.38	190.96	1.88
P20	84.16	0.10	0.41	0.52	583.04	0.51	0.66	1.33	188.49	1.81
MIN	43.24	0.05	0.21	0.27	307.46	0.24	0.31	0.68	90.63	0.93
MAX	101.30	0.12	0.50	0.62	698.82	0.61	0.85	1.58	224.94	2.17
MEAN	71.16	0.09	0.35	0.44	498.61	0.41	0.56	1.11	152.98	1.53
RL	59.00	0.07	0.41	0.48	300.00	1.00	1.00	1.00	370.00	0.29

The obtained mean value is higher than the global mean of 59 nGy/h and is likely to pose a severe radiation risk. Meanwhile, the values for the outdoor and indoor annual effective doses calculated from the absorbed dose rate ranged from 0.05 to 0.12 mSv/y with a mean of 0.09 mSv/y and 0.21 to 0.50 mSv/y with a mean of 0.35 mSv/y, respectively. The total annual effective dose due to the combination of outdoor and indoor effective doses varied from 0.27 to 0.62 mSv/y with a mean of 0.44 mSv/yr. This mean value obtained slightly falls below the global mean of 0.48 mSv/y. It is to be noted that the mean outdoor annual effective dose (0.09 mSv/y) was higher than the global mean of 0.07 mSv/y due to the high value of the absorbed dose rate.

Also, the mean values of the external and internal radiation hazard indices and the Radium Equivalent Activity Index (Raeq), as shown in Table 2, were 0.41 and 0.56 and 152.98, respectively. These mean values are less than their corresponding global mean of 1, 1 and 370 Bq/kg, respectively and pose a negligible radiation risk. On the contrary the mean values of the representative gamma index, annual gonadal dose equivalent and excess lifetime cancer risk were 1.11, 498.61 μSv/y and 1.53 X 10⁻³ and are higher than their corresponding global mean of unity, 300 μSv/y, 0.29 X 10⁻³, respectively. The high value of this representative gamma index correlates with the annual dose rate due to the excess external gamma radiation caused by superficial materials. This puts the soil at

radiation risk for farming activities and building/construction materials. Also, the estimated value of the excess lifetime cancer risk is exceptionally high, posing a high probability of developing cancer over a lifetime.

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