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CHARACTERIZATION OF RADIOACTIVITY FROM PRIMORDIAL RADIONUCLIDES IN THE SOIL OF IKA SOUTH LOCAL GOVERNMENT AREA OF DELTA STATE

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ABSTRACT

This study presents the characterization of the soil in Ika South Local Government Area of Delta State. It presents radiometric (^{40}K, ^{238}U and ^{232}Th) survey of soil samples collected from some selected towns in Ika South Local Government Area of Delta State, Nigeria using gamma-ray [NaI(TI)] spectroscopy.Twenty five representative soil samples from five communities (five soil samples each per community) were collected for the study. The average activity concentration of ^{40}K, ^{238}U and ^{232}Th in soil samples from the selected communities was 510.87 ± 3.068 Bqkg^{-1}, 31.092±2.638 Bqkg^{-1} and 64.662 ± 2.842 Bqkg^{-1} respectively. By comparing the obtained average result of soil samples of ^{40}K, ^{238}U and ^{232}Th with UNSCEAR standard, it was observed that the obtained average results of ^{40}K and ^{232}Th exceeded the standard value limit of 400 Bqkg^{-1} and 30 Bqkg^{-1} respectively while ^{238}U was less than the standard value limit of 35 Bq/kg^{-1}. The calculated radiological hazard values were lower than the world allowable average standard, except for the annual gonadal dose equivalent and the excess lifetime cancer risk which were above than the world recommended average standard value of 300 mSv/yr and 0.29 x10^{-3}Sv/yr standard in some communities. However, contactwith the soils in these communities will not pose much health hazard problem to man and the environment.

Keywords: Characterization, Radioactivity, Radiological, Samples, Spectroscopy

INTRODUCTION

Soil is mineral deposits formed through sedimentation of weathering and erosion of rocks (Amekudzie, Emi-Raynolds, Kpeglo & Mensah,2011).Soil has been a source of structural material to human in the Niger Delta region of Nigeria (Avwiri, Esi, &Ononugbo, 2015). Soil isinvaluable to man, being of great sustainability to cultivation of crops for human and animal consumption as well as urbanization. Consequently man generates different kinds of wastes and deposits same into the environment, thereby altering the natural ecological constituents of the soil (Ukpene,1998) in addition to the naturally occurring radionuclides. Radionuclides are unstable forms of chemical elements that release radiations as they breakdown and become more stable(James, 2006, NCRP 2006). In the unstable form, they release energy in form of ionizing radiation which pose serious danger to living cells.Therefore, this work seeks to determine the level of activity concentrations of primordial radionuclides present in the soil of Ika South local Government Area, Delta State, in order to evaluate the radiological health hazard indices as they affect the health of the individuals living in the region.

Radiation health effects can be acute, chronic or generic causing skin cancers, leukemia, kidney cancers, lung diseases, acute leucopoenia, anemia, pancreatic, hepatic and bone cancers when humans and living organisms are exposed to it for a period of time (Taskin, Karavus, Ay & Topuzoglu *et al.*, 2009). Radioactivity of the soil depends richly on its formation and transport systems.Results have shown that natural radioactive elements existing in the soil are primordial radionuclides from the ^{238}U series, ^{232}Th series and ^{40}K which are the naturally occurring radioactive materials. The ^{40}K radionuclide is a decay series of ^{238}U series and^{232}Th series which occur in rocks, soil and water (Tzortzis & Tsertos, 2004). 87% of the radiation doses received by humans are from natural radiation sources, which come from naturally occurring active isotopes of ^{238}U and ^{232}Th and their progeny as well as ^{40}K (Shetty & Narayana, 2010). In the course of interacting with the environment, humans become directly exposed to these radionuclides or through the consumption of foods from crops exposed to these sources of radiations.

Some human actions that may have increased the occurrence of these naturally available radioactive materials concentration includes but not limited to: oil and gas exploration and exploitation, telecommunication, nuclear testing activities and cement manufacturing.

Manigandan &Natrajan (2014) studied the activity concentrations of natural radionuclides in soils of tropicalrainforest sites in Western Ghats and stated that the obtained results for natural radionuclides calculated from radiological parameters in the forest soils were within the range specified by the United Nations Scientific Committee on the Effects of Atomic Radiation(UNSCEAR, 2000) report for virgin soils except ^{232}Th (Avwiri.,et al 2015).

MATERIALS AND METHOD.

A total of twenty five (25) representative soil sections were collected for the study, five (5) soil samples each from five communities in the Local Government Area under study. Ika South Local Government Area, Nigeria, is located at gps coordinates of 6^{0} 15'50.7312"N and 6^{0}12' 6.7788"E. The communities under study include Agbor- Alidinma, Agbor-Nta, Agbor-Obi, Emuhu and Ekuku- Agbor. The native inhabitants are mainly civil service workers, farmers, hunters,business men and women.

The soil sections were collected using hand trowel at a depthrange of 0-12cm. A depth range of 0-12 cm was adopted because at this range there is much root activity and most of the soil nutrients are concentrated within this range. At the point of sampling, sampled soil were sealed in a black polythene bag and labelled accordingly to avoid cross contamination. The collected soil samples were then air dried at room temperature for 14 days and sieved through a fin

mesh of about 0.5mm in other to obtain uniform sized particle before being transported to the Gamma Spectrometrylaboratory,Obafemi Awolowo University, Ile Ife, for instrumental analysis using NaI(TI) gamma ray spectrometry, in line with the works of Almayahi (2015).The samples were then packed 200 g each in cylindrical plastic containers and sealed for about 28 days to allow the radionuclides reach secular equilibrium before radiometric analysis were carried out.

Gammaspectrometryanalysis

Each sample was counted for 36,000 seconds so as to achieve minimum counting error in a 7.6 cm x 7.6 cm NaI (Tl) (Thallium Activated Sodium Iodide) detector coupled to a Canberra Series 10 plus Multichannel Analyzer by a preamplifier base. The detector has a resolution of about 8% at 0.662 MeV of ^{137}Cs which has the capability of identifying the gamma ray energies used for the acquisition. Measurement of ^{40}K was done at photo peak of 1.460 MeV, that of ^{238}U done from^{214}Bi at 1.760 MeV photopeak and ^{232}Th done from ^{208}Tl at photopeak 2.614 MeV. The detector has 25% efficiency and calibration was done using an IAEA-375 reference soil supply byInternational Atomic Energy Agency(IAEA, 2003). The analysis of gamma ray spectrometry used has also been employed by other researchers so as to ascertain good quality [Tchokossa, Olomo, & Balogun,2011 and Usikalu, Akinyemi & Achuka, 2014].The activity concentration of the primordialradionuclides present in the collected soils samples were determined using the equation below.$C_s = NE$

$$C_s = \frac{NE_\gamma}{\sum E_\gamma x M v \;\; x t_c x P_{\gamma(Bq/Kg)}} - - - - - - - - \{1\}$$

Where Cs= Sample concentration, NEy= net peak area of a peak at energy, ∑Ey= Efficiency of the detector for a γ-energy of interest, Mv=Sample volume, tc= total counting time, Pγ=Emission probability of radionuclide of interest(Avwiri, Esi & Ononugbo, 2015)

Radiation health hazard indices calculation

i. ABSORBED DOSE RATE (D) IN nGy yr^{-1}

The absorbed dose rate is the amount of energy deposited by radiation in a mass per year, and is calculated as follows:

$$D = 0.048C_k + 0.44C_u + 0.660C_{TH} - - - - - - - \{2\}$$

WhereC_k, C_u and C_{Th} are the activity concentration in Bq/Kg for K, U and Th respectively(UNSCEAR 2000)

ii. ANNUAL EFFECTIVE DOSE H_E

The effective dose provides a measure of the health impact on an individual of exposure to ionizing radiations (Thorne, 2012).

$$H_E = DxTxf - - - - - - - - - - - - - - - - - - \{3\}$$

Where D is the calculated dose rate

T_{out} is outdoor occupancy time = $02x24hx365.25 - -\{4\}$

T_{in} is indoor occupancy time = $0.8x24hx365.25 - -\{5\}$

F is the conversion factor = 0.7 x 10^{-6} SvGyh^{-1}(conversion coefficient from absorbed dose in air to effective dose received) (UNSCEAR 2000)

iii. RADIUM EQUIVALENT ACTIVITY INDEX (Ra_{eq})

Allows a single index or number to describe the gamma output from different mixtures of U, Th and K from different communities$Ra_{eq} = C_u + 1.43C_{Th} + 0.077C_k - - - -\{6\}$

whereC_k, C_u and C_{Th} are the activity concentration in Bq/Kg for U, Th and k respectively (UNSCEAR 2000, 2008)

iv. REPRESENTATIVE LEVEL INDEX (I_{yr})

Estimate the level of gamma radioactivity hazard associated with different concentration of some radionuclide

$$I_{yr} = \frac{C_u}{150} + \frac{C_{TH}}{100} + \frac{C_k}{1500} - - - - - - - - - - - - \{7\}$$

C_U, C_{Th} and C_K are the activity concentrations in Bqkg^{-1}(NEA-OECD,1979)

v. EXTERNAL HAZARD INDEX (H_{ex})

The external hazard index(H_{ex}) estimate the level of radiological risk of the samples to the immediate environment and this figure must be less than unity (Hamlat,Djeffal, & Kadi , 2001).

$$H_{ex} = \frac{C_u}{370} + \frac{C_{TH}}{259} + \frac{C_k}{4810} - - - - - - - - - - - - \{8\}$$

C_u, C_{Th} and C_K are the activity concentrations of U, Th and K in Bqkg^{-1}(Berekta and Mathew 1985)

vi. INTERNAL HAZARD INDEX (I_{in})

$$I_m = \frac{C_u}{185} + \frac{C_{TH}}{259} + \frac{C_k}{4810} - - - - - - - - - - - - \{9\}$$

where C_u, C_{Th} and C_K are the activity concentrations of U, Th and K in Bq/Kg

(Avwiri *et al*., 2012)

vii. ANNUALGONADAL(GONADAL) EQUIVALENT DOSE (AGED) IN mSv/yr

$$AGED = 3.09C_u + 4.18C_{TH} + 0.31C_k - - - - - \{10\}$$

Where C_u, C_{Th} and C_K are the activity concentrations of U, Th and K in Bq/K (Avwiri et al., 2012)

viii. EXCESS LIFETIME CANCER RISK (ELCR) IN Sv/yr

$$ELCR = AEDExDLxRF - - - - - - - - - - - - \{11\}$$

Where AEDE = D X 8766 X 0.2 X 0.7 X 10^{-6}, DL = 70, RF = 0.05

DL is average duration of life (estimated to be 70years)

RF is the risk factor (Taskin *et al*.,2009).

RESULTS

The results of the study are presented in Tables 1, 2,3 and 4 and Fig.1, 2, 3 and 4 respectively.

Table 1: Specific activity concentration of ^{40}K, ^{238}U and ^{232}Th (Bq/kg) results in soil samples

		SPECIFIC ACTIVITY CONCENTRATIONS IN Bq/Kg		
S/N	**COMMUNITY**	**^{40}K**	**^{238}U**	**^{232}Th**
1	Agbor- Alidinma	497.87 ± 4.3	32.15±1.70	68.35 ± 2.21
2	Agbor - Nta	512.63 ± 2.67	37.10 ± 3.09	58.10 ± 3.43
3	Agbor- Obi	488.77± 3.11	28.13 ± 3.40	61.91 ± 2.98
4	Emuhu	521.60± 3.22	26.93 ± 1.20	71.21 ± 3.10
5	Ekuku-Agbor	533.43 ± 2.91	31.15 ± 3.80	63.74± 2.40
	MEAN	510.866 ± 0.63	31.092 ± 2.638	64.66 ± 2.84
	UNSCEAR STANDARD (2000):	400	35	30

Table 2.Absorbed dose rate D, outdoor/indoor annual effective dose (E) and Radium equivalent activity Ra_{eq} (Bq/Kg)

COMMUNITY	Absorbed dose equivalentrate (D) in $nGyh^{-1}$	Outdoor annual effective dose ($mSv\ yr^{-1}$)	Indoor annual effective dose ($mSv\ yr^{-1}$)	Radium equivalent activity (Bq/kg)
Agbor- Alidinma	83.351	0.103	0.408	80.26
Agbor - Nta	79.51	0.098	0.390	84.88
Agbor- Obi	76.87	0.095	0.377	74.62
Emuhu	84.05	0.103	0.412	77.27
Ekuku-Agbor	81.16	0.100	0.398	81.33
MEAN	81.00	0.099	0.397	79.67
UNSCEAR STANDARD (2000):	60.00	1.00	1.00	370.00

Table 3. External hazard index H_{ex} and internal hazard index H_{in}

S/N	COMMUNITY	External hazard index H_{ex}(Sv/yr)	Internal hazard index H_{in}(Sv/yr)
1	Agbor- Alidinma	0.455	0.542
2	Agbor - Nta	0.447	0.532
3	Agbor- Obi	0.417	0.493
4	Emuhu	0.456	0.529
5	Ekuku-Agbor	0.441	0.525
	MEAN	0.443	0.524
	UNSCEAR STANDARD (2000):	1.000	1.000

Table 4.Annual Gonadal equivalent dose (AGED), Excess lifetime Cancer risk (ELCR)

S/N	COMMUNITY	Annual gonadal equivalent dose(mSv/yr)	Excess lifetime cancer risk Outdoor in (ELCR) x 10^{-3}
1	Agbor- Alidinma	541.373	0.358
2	Agbor - Nta	518.458	0.341
3	Agbor- Obi	499.174	0.330
4	Emuhu	544.678	0.361
5	Ekuku-Agbor	530.177	0.349
	MEAN	523.772	0.343
	UNSCEAR STANDARD (2000):	300	0.29 X 10^{-3}

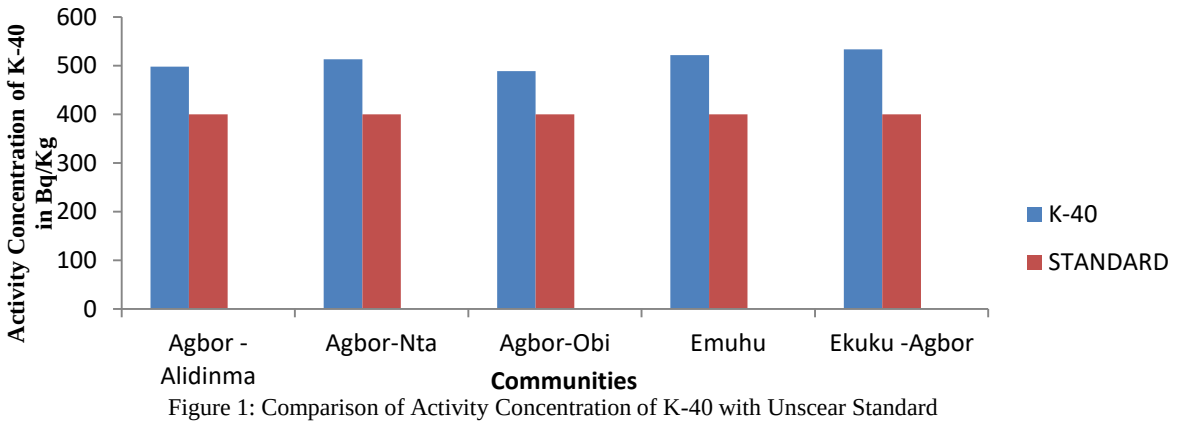

Figure 1: Comparison of Activity Concentration of K-40 with Unscear Standard

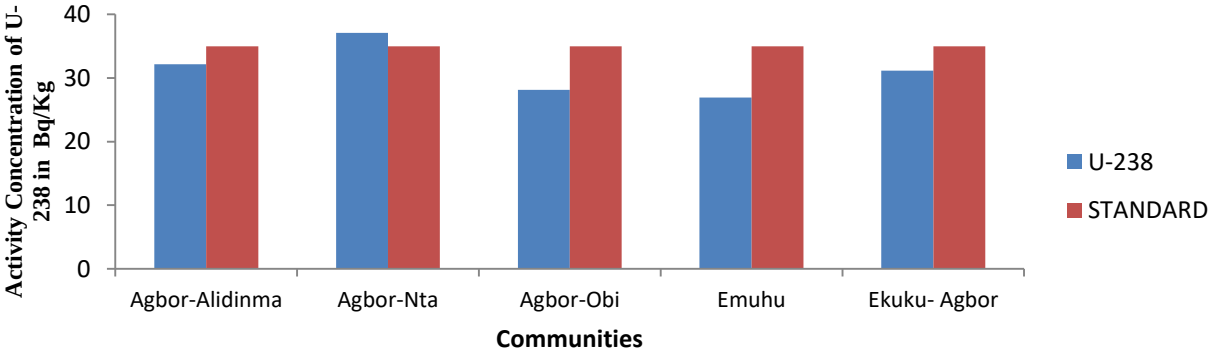

Figure 2: Comparison of U-238 activity concentration with UNSCEAR STANDARD

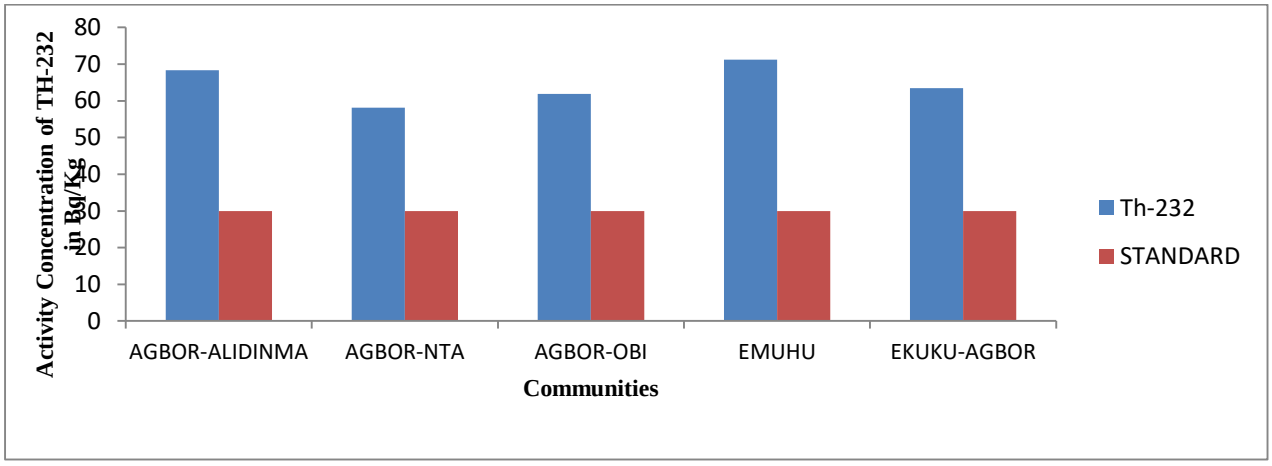

Figure 3: Comparison of activity concentration of Th-232 with UNSCEAR STANDARD

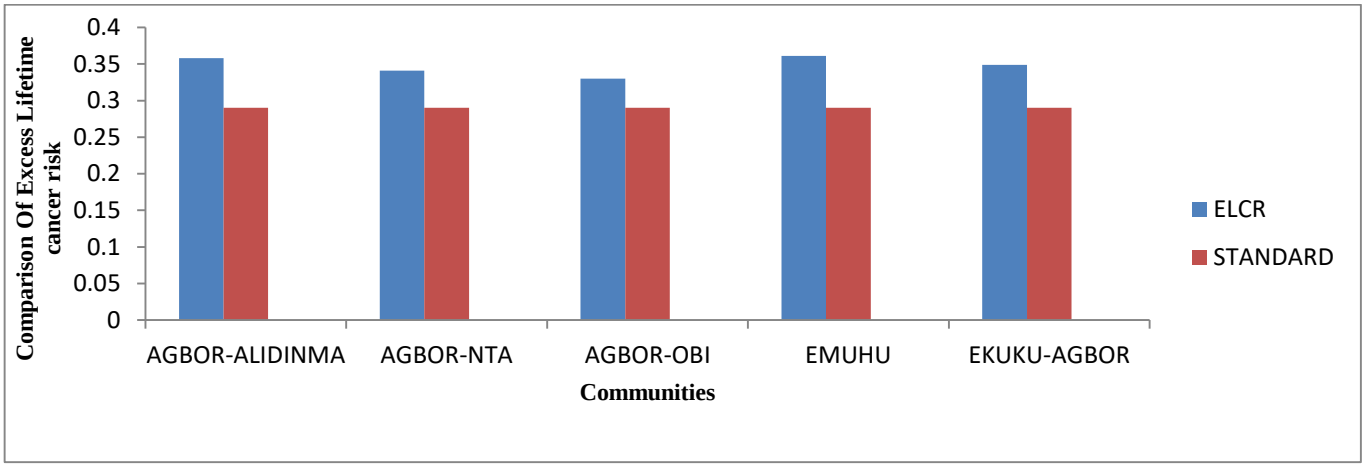

Figure 4: Comparison of ExcessLifetimeCancer Risk with UNSCEAR STANDARD.

DISCUSSION

The characterization of radioactivity in the soils in Ika South Local Government Area, Delta State, for radioactive primordial radionuclides using *gamma-ray [NaI(TI)] spectroscopy* revealed the presence of radionuclides in varying proportions. From Table 1, the specific activity concentration (SAC) level for ^{40}kwas variable among soil samples from the various communities, with mean SAC of 510.866± 0.63 Bq/kg. The highest ^{40}k SAC level was recorded in the soils of Ekuku-Agbor (533.43 ± 2.91Bq/kg) while the least SAC level was recorded in the soil samples from Agbor-Obi (488.77 ± 3.11 Bq/kg). All the soil samples examined have ^{40}k SAC levels above the UNSCEAR standard of 400Bq/kg (Fig.1). Usikalu, *et al*., (2014)had reported lower ^{40}k SAC level in the soil samples of Covenant University, Ogun State.

Furthermore, the SAC level of ^{234}U was comparable, with a mean of 31.092± 2.638. The least ^{234}USAC level was recorded in soil samples from Emuhu (26.93 ± 1.20 Bq/kg), while Agbor-Nta recorded the highest ^{234}U SAC level (37.10 ± 3.09). Uranium activity concentration in only Agbor-Nta exceeded the UNSCEAR recommended standard of 35 (Fig.2).

The ^{232}Th SAC levels were higher than the UNSCEAR recommendations (30.00) in all the soil samples examined in the study, with an average of 64.66 ± 2.84 Bq/kg Table 1). Soil samples from Agbor-Nta recorded the least ^{232}Th SAC level (58.10 ± 3.43 Bq/kg), while the highest was noted in soil samples from Emuhu (71.21 ± 3.10). Comparatively, ^{40}k presented the highest mean value of radionuclides among soil samples from all the communities studied with a mean SAC of 510.866± 0.63 (Table 1).

From Table 2, the absorbed dose rate for the five communities studied ranged between 76.87 and 84.05 nGyh$^{-1,}$ with Emuhu community having the highest value. The mean value for absorbed dose for the communities was 81.00 nGyh^{-1} which exceeded the recommended dose limit of 60 nGyh^{-1} by about 12.6%. Furthermore, the outdoor annual effective dose ranged from 0.095 – 0.103mSvyr^{-1} while the indoor effective dose ranged from 0.377 – 0.412 mSvyr^{-1} across the communities studied. These values were all found to be less than the UNSCEAR limit of 1.00 mSvyr^{-1}. In addition, radium equivalent activity in all the communities ranged from 74.62 - 84.Values of absorbed dose rate lesser than recommended world averages were also reported by Usikalu *et. al*., (2014)

Table 3 showed that the external hazard index ranged from 0.417 – 0.456 H_{ex}(Sv/yr) whilethe internal hazard index were between 0.493 – 0.542 H_{in}(Sv/yr) both of which were lower than the world average permissible value of unity, in agreement with Orgun et al., 2007. These indicate that the values might not predispose inhabitants to respiratory disease such skin cancer, lungs cancer, cataracts etc.

From table 4, the annual gonadal equivalent dose recorded from this study was higher in all the communities studied with an average value of 523.772 mSv/yr against the UNSCEAR

value of 300 mSv/yr. These figuresmight pose a relatively high level of threat to sensitive organs like the gonad, thyroid and liver of the human body. In addition,the excess life time cancer risk as seen above ranged from 0.330 mSv/yr to 0.361 mSv/yr (Table 4). The excess life time cancer risk value obtained in this study for all the communities studied exceeded the world average value of 0.29 x 10^{-3}mSv/yr (Taskin et al.,2009) and this indicatesthat the chances of developing cancer by the people of this communitieswas sparingly significant.

CONCLUSION

The evaluation of radionuclides SAC of ^{40}k, ^{232}Th and ^{238}U in soil samples collected from selected communities in Ika South Local Government Area, Delta State showed that ^{40}k and 2^{32}Th exceeded the world recommended average by UNSCEAR, while values for ^{238}U where quite below. Also, the study recorded mean absorbed effective dose higher than world recommended average, but with lower outdoor and indoor annual dose, and radium equivalent activity. This study has established a data base of primordial radionuclides for soil samples from selected communities in Ika South Local Government Area, Delta State. Although some radiations in the communities studied exceeded world recommended averages, the differences are not substantial enough to make the inhabitants of these communities susceptible to health challenges arising from effects of these radiations in the present circumstance.

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