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Radiological Evaluation of Soil in Some Selected Oil and Gas Producing Communities in Delta Central, Delta State Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Authors CEM and OE designed the study. Authors OE and EEO performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors EEO and OE managed the analyses of the study. Authors EEO and OE managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The radionuclides present in soils from selected oil and gas producing communities in Delta Central, Delta State, Nigeria, were qualitatively and quantitatively determined using gamma-ray spectrometry with a view of evaluating the radiological health hazard fallout of the oil and gas activities in these areas. The results revealed the presence of ^{238}U, ^{232}Th and ^{40}K respectively. The minimum values for these radionuclides activity concentrations are 83.76±4.10, 4.10±0.12 and 1.92±0.09 $Bqkg^{-1}$ respectively. The corresponding maximum values are 373.02 18.25, 89.49±2.09 and 30.61±1.47 $Bqkg^{-1}$. Their respective obtained mean values are 180.61±2.79, 44.24±1.53 and 15.58±0.72 $Bqkg^{-1}$ respectively. It was observed that the activities of ^{40}K and ^{232}Th are higher than that of ^{238}U. The specific activities of ^{40}K and ^{232}Th are below the worldwide average while that of the values obtained from ^{238}U is above standard. These values equally agree with other studies carried out in parts of

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Nigeria and the world. The high level of ^{238}U concentration in the region may be attributed to oil exploration and exploitation activities in the areas. The calculated mean for the radiological hazard indices revealed Raeq (80.42)$Bqkq^{-1}$, absorbed dose D (37.95)$nGyh^{-1}$ (effective dose equivalent value 0.038 $mSvy^{-1}$), AEDE(outdoor) (53.58) and (indoor) (186.06) $mSvy^{-1}$, Hex (0.216), Hin (0.336) and finally, ELCR(0.016 x 10^{-3}) respectively. The obtained results are below their respectively international radiological health standards. The implication is that the populace are not radiologically overexposed.

Keywords: Soil; radionuclide; concentration; Delta Central; oil exploration; radiological.

1. INTRODUCTION

Several scientific researchers have studied and revealed the adverse effects of natural radioactivity in the environment and particularly to the man living in the environment. The released of natural radioactivity in form of cosmic radiation from the atmosphere into the environment has significantly increased the amount of background ionising radiation. This has aftermath effects on man as a result of daily exposure [1]. The major radionuclides that produce radiation are ^{40}K, ^{238}U and ^{232}Th [2]. Radionuclides are largely present in the soil, with about an average of 3 parts per million (ppm) of ^{238}U and 10 (ppm) of ^{232}Th and a sum of 30 (ppm) or more of each in some granites [3].

During oil and gas exploration, exploitation and production activities, waste such as product water, scales, sludge, used dilled mud are being discharged into the land of the study location. The area under study is known for its abundance, availability of natural resources such as crude oil and other mineral deposits. This has led to the establishment of oil and gas companies and industries which are involved in exploration and exploitation activities widely acclaimed to have the potential of enhancing radionuclide concentration in their environments [4]. With the sole purpose of exploration and exploitation in the study site; this work seeks to carry out a radiological evaluation of the study location which according to literature appear to be scare [5].

2. MATERIALS AND METHODS

2.1 Description of Study Area

The study area (Fig. 1) consists of ten (10) oil producing communities from two local government areas; these communities are as follows: Ovwor, Ophorigbala, Oguname, Okpare, Ogoni-Olomu, Agbarha-otor, Afiesere, Orogun, Ekiugbo and Oteri. It is located in oil mining leasie (OML, 30) onshore of Niger Delta [6] and lies within latitude 05°27N and 05°56N and longitude 05°56E and 05°41E.

2.2 Sample Collection and Preparation

Fifty soil samples were collected from the study area, five each from a community. The samples were collected in accordance with standard methods [7]. At each sampling point, the collected samples were emptied into properly sealed labelled black polythene bags to avoid cross contamination. They were then each homogenised, oven dried at 100°C for 15 hours and sieved into weighed special plastic containers. Thereabout the containers were properly sealed using masking cello tape and reweighed. The sealed containers were then stored for 28 days according to acceptable practice so that ^{238}U and its progenies will attain circular equilibrium.

2.3 Activity Measurement

Gamma counting was carried out using a NaI(TL) gamma spectrometer for each of the sample as well as the standard source and background. The detector was enclosed in a 100mm thick lead smelt to ensure that the radiation from the laboratory environment is screened off. The purpose of the background counts is to afford that appropriate correction in the quantified activities are affected [8] while the standard count allows the quantification of the identified radionuclide using the less error prone absolute method [9].

Prior to the radioactivity counting, energy calibration of the spectrometer was carried out using caesium-137 ($^{37}C_s$), Cobalt – 60 ($^{60}C_o$), Eurobrium – 152 ($^{152}E_u$) and Americium – 241 (^{241}Am) [10].

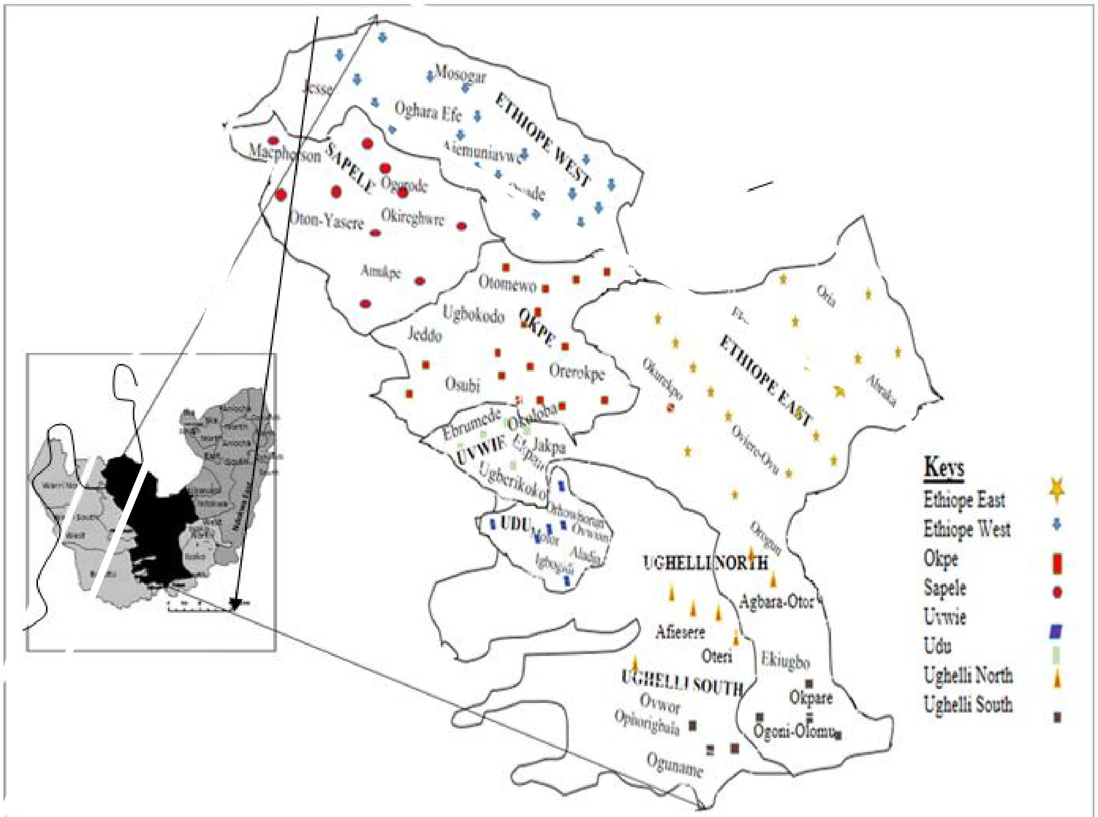

Fig. 1. Map of the study area

The obtained spectrum for each sample container (the acquired gamma (r) energies for each sample) was analysed using a sampo 90 computer software. This program matches the energies in each particles spectrum to a library of plausible radioisotopes. This enables the qualitative identification of the radionuclides. The identified isotopes were quantified using the relation [9].

$$C_s = \frac{(E_\gamma)_s\, M_d A_d}{(E_\gamma)_d\, M_s} \quad (1)$$

C_s – is the specific ($Bqkg^{-1}$) of the radionuclide contained in the samples.

$(E_r)_s$ – the net photopeak area (the r – energy of the particular radionuclide

M_dA_d – the product of the mass (kg) and activity (Bq) of the standard source

$(E\,\gamma)_d$ – The net photopeak area (γ – the energy of the particular radionuclide contained in the standard source and

M_s – the mass of soil sample

The radiological health parameters such as: Radius equivalent activity (Re_{aq}), Annual effective dose equivalent for indoor and outdoor environments, internal and external hazard indices (H_{in} and H_{ex}) and Excess Lifetime Cancer Risk (ELCR) were calculated using their respective appropriates expressions [11,12,13,14,15].

2.4 Calculation of Radiation Hazard Parameters

A) Radium Equivalent Action (Raeq)

This is an index used in comparing the specific activities of the radionuclides (^{238}U, ^{232}Th and ^{40}K) containing a single quantity which account for the radiation hazard associated with them [12]. It is a summation of radionuclides which is based on the estimation that produces the same radiation dose rates. The radium equivalent is given by Avwiri et al. [12].

$$Raeq = C_{Ra} + 1.43C_{Th} + 0.077C_K \quad (2)$$

Where C_{Ra}, C_{Th} and C_K are activity concentration in Bq.kg of ^{238}U, ^{232}Th and ^{40}K respectively.

B) Annual Effective Dose Equivalent AEDE (Outdoor and Indoor)

The annual effective dose was calculated using the equation below. Annual effective dose rate (msvy^{-1}) = D (Gyrhj^{-1}) x 8760hyrh-1 x 0.7 x (103 mSv/109) Gy x 0.2 x 10^{-3}.

E_{ff} Dose=D 1.2264 X 10^{-3}. (3)

Effective dose (msvy^{-1}) = D (Gyrhj^{-1}) x 8760hyrh-1 x 0.7 x (103 mSv/109) Gy x 0.8 x 10-^{6} (4)

Where D is effective dose rate, [11] has recommended 0.7 Sv/Gy as the conservation coefficient from the absorbed dose in the air to effective dose are 0.2 (5/24) and 0.8 (19/24) respectively as the value for the outdoor and indoor occupancy factors.

C) External Hazard Index (Hex)

This is the measure of the external effects emanating from radiation hazards in an environment. This effect is as a result of primordial radionuclides (^{238}U, ^{232}Th and ^{40}K) which produces significant effects on human exposure. It is given as

$$Hex = C_{Ra}/370 + C_{Th}/259 + C_K/48103 \quad (5)$$

Where, C_{Ra}, C_{Th} and C_K are the radioactivity of concentrations in Bq/Kg of ^{238}U, ^{232}Th and ^{40}K respectively. Its value must be less than 1 (one) for the radiation hazard to be ineffective [12].

D) Internal Hazard Index (Hin)

The internal hazard index (Hin) is expressed as follow:

$$Hin = C_{Ra}/185 + C_{Th}/259 + C_K/48104 \quad (6)$$

Internal hazard index (Hin) equally should be less than unity for it to be less effective. Gas like radon has hazardous effects when inhaled into the body system and can cause respiratory diseases like asthma and cancer.

E) Excess Lifetime Cancer Risk (ELCR)

The excess lifetime cancer risk (ELCR) is given by [15] as:

$$ELCR = AEDE \times RF \times DL \quad (7)$$

AEDE retain its usual meaning as in above, "DL" is the duration of life (estimated) to be 70 years, and RF is the risk factor i.e. fatal cancer risk per Sievert, for stochastic effects, KRP uses RF as 0.05 for the public.

3. RESULTS AND DISCUSSION

Radiological evaluation of soil in some selected oil and gas producing communities in Delta Central, Delta State, Nigeria has been computed in Table 1. The minimum values for the radionuclides activities concentration (^{40}K, ^{238}U and ^{232}Th) are (83.76$\pm$4.10), (4.10$\pm$0.12) and (1.92$\pm$0.09) Bqkg^{-1} respectively and the maximum values are (373.02$\pm$18.25), (89.49$\pm$2.09) and (30.61 $\pm$ 1.47) BqKg^{-1} respectively. The average concentration for the radionuclide in soil samples are 180.61 $\pm$ 2.79, 44.24 $\pm$ 1.53 and 15.58$\pm$0.72 BqKg^{-1} respectively the areas with maximum values revealed a high level of activities concentration. Comparing these average results with the world population-weighted average of 400 BqKg^{-1} for ^{40}K, 35 Bqkg^{-1} for ^{238}U and 30 Bqkg^{-1} ^{232}Th as quoted by [11], it was observed that the average value for 238U exceeded the international standard limits, but ^{40}K and ^{232}Th are below the standard value as shown in Fig. 2 to 4. The values are also in consonant with those reported by other researchers from other parts of Nigeria [16,17,18,19]. The high concentration of ^{238}U in the study site may be attributed to oil and gas activities in the region. Despite the low average of ^{232}Th and ^{40}K concentration, a high concentration was observed at X_5 which is also attributed to oil exploitation and exploration activities. Table 2 displayed the radiological hazard indices in soil samples from the study site. The radium equivalent varies from (56.44) to (146.47) BqKg^{-1} with a mean value of 80.42 Bqkg^{-1}. The maximum value is observed at X_5 while the minimum is at X_3. The Absorb dose rate (D), varies from (26.87) to (67.50) nGyh^{-1} with a mean of (37.95) nGyh^{-1}. These values are converted to effective dose equivalent since the absorbed dose rate itself does now show possible biological effects. The absorbed dose rate has its highest value as observed at X_5 and the lowest at X_3. The annual effective dose equivalent (outdoor) ranged from (32.95) to (87.17) mSvy^{-1} with the mean value of (53.58) mSvy^{-1}. The lowest and the highest values are observed at X_3 and X_6 respectively. The annual effective dose equivalent (indoor) varies from (131.21) to (333.12) mSvy^{-1} with an average value of (186.06) mSvy^{-1} the minimum and maximum value been observed at X_3 and X_5. The external hazard index calculated varies from

(0.152) to (0.395) $mSvy^{-1}$ with an average value of (0.216) $mSvy^{-1}$. The maximum values calculated are observed at X_5 and the minimum X_3. Also, the internal hazard index calculated ranges from (0.169) to (0.637) $mSvy^{-1}$ with the mean value of (0.336) $mSvy^{-1}$. And the excess lifetime cancer risk (ELCR) also ranged from (0.011 x 10^{-3}) to (0.029 x 10^{-3}) with the mean value (0.016 x 10^{-3}), and the maximum and minimum values are observed at X_5 and X_3 respectively. Comparing the calculated mean values of radiological hazard indices in soil samples with their respective international standard (average values), it was observed that absorbed dose rate, annual effective dose equivalent both outdoor and indoor higher than standard while radium equivalent, external hazard index, internal hazard index and excess lifetime cancer risk are low than standard respectively as shown graphically in figure 5 to 11. Although some communities such as Ogoni – Olomu and Agbarha-otor have a high level of activities radionuclide concentrations, these can be attributed to the oil and gas activities that are ongoing in these communities. However, the studied communities are relatively safe radiologically, but long-term exposure may be harmful to man and the environment.

Table 1. Mean activity concentrations of soil samples collected from the study area

Sample code	Communities	Activity		
		^{40}k ($Bqkg^{-1}$)	^{238}U($Bqkg^{-1}$)	^{232}Th($Bqkg^{-1}$)
X_1	Ovwor	118.16±5.78	47.58±1.59	12.66±0.61
X_2	Ophorigbala	373.02±18.25	4.10±0.12	17.95±0.87
X_3	Oguname	142.49±6.98	42.73±2.99	1.92±0.09
X_4	Okpare	314.14±20.15	18.69±0.55	22.19±0.70
X_5	Ogoni–Olomu	171.56±8.40	89.49±2.09	30.61±1.47
X_6	Agbarha -Otor	179.64±3.79	42.39±1.10	10.39±0.50
X_7	Afiesere	083.76±4.10	24.20±0.71	24.8±1.20
X_8	Orogun	141.21±2.02	54.16±1.31	8.72±0.42
X_9	Ekiugbo	108.48±0.42	38.03±2.96	19.55±0.95
X_{10}	Oteri	173.66±3.60	80.98±1.88	7.00±0.34
	Mean	180.61±2.79	44.24±1.53	15.58±0.72
	(UNSCEAR, 2000)	400	35	30

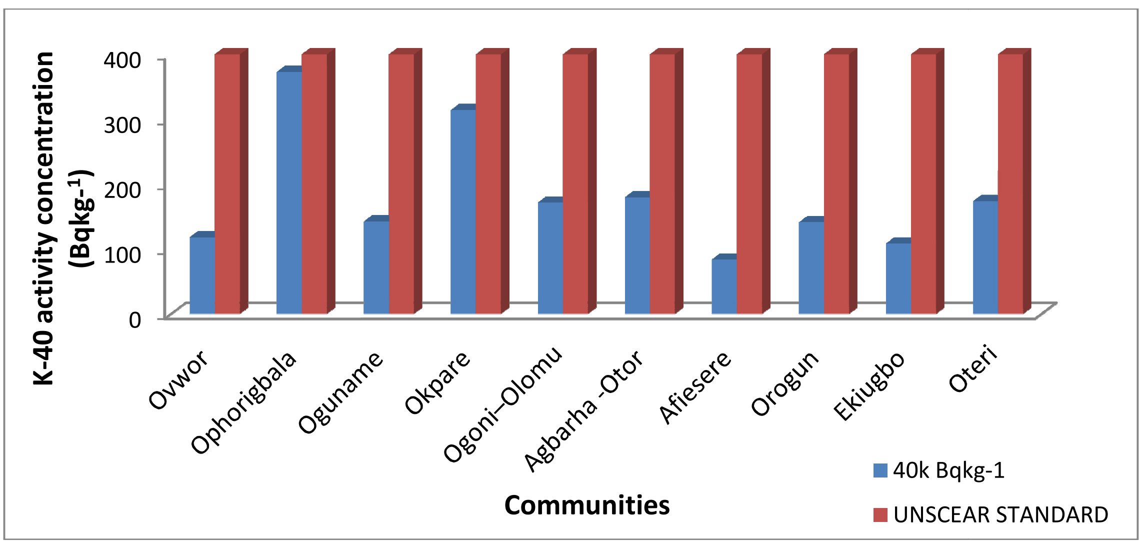

Fig. 2. Comparison of ^{40}K activity concentration ($Bqkg^{-1}$) in soil with UNSCEAR standard in studied communities

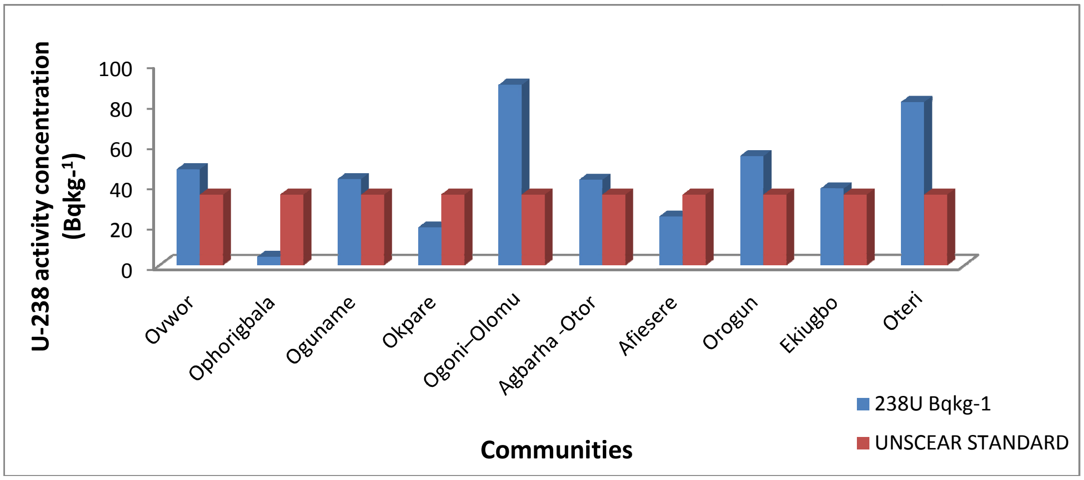

Fig. 3. Comparison of ^{238}U activity concentration (Bqkg^{-1}) in soil with UNSCEAR standard in studied communities

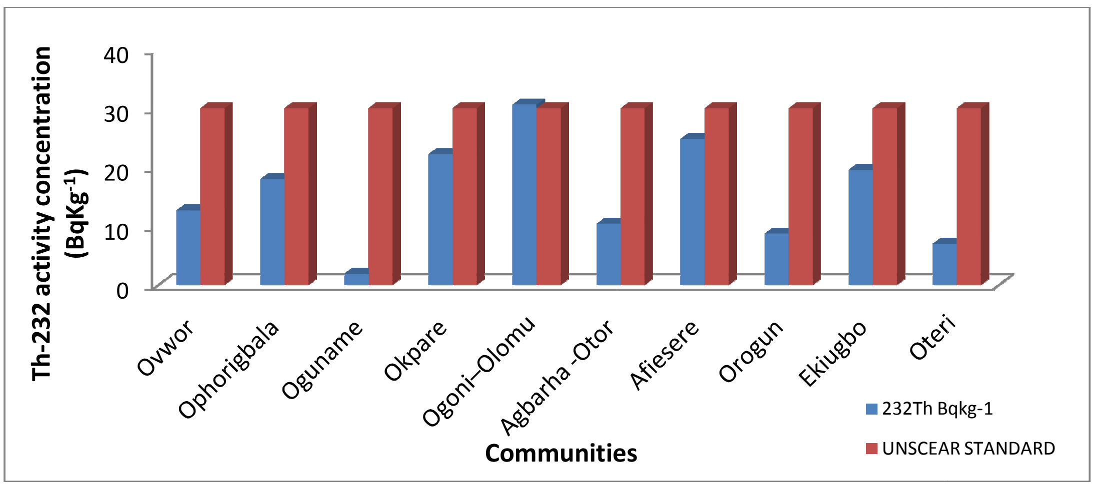

Fig. 4. Comparison of ^{232}Th activity concentration (Bqkg^{-1}) in soil with UNSCEAR standard in studied communities

Table 2. Calculated mean values for radiation hazard indices (mSvy^{-1})) in soil samples

Sample code	Communities	(Ra_{eq}) (Bq/kg)	Absorbed dose (D) (nGyh^{-1})	AEDE Outdoor (mSvy^{-1})	AEDE (Indoor) (mSvy^{-1})	H_{ex}	H_{in}	ELCR (X 10^{-3})
X_1	Ovwor	74.78	37.77	34.05	185.28	0.202	0.330	0.016
X_2	Ophorigbala	58.49	28.59	71.73	140.25	0.157	0.169	0.012
X_3	Oguname	56.44	26.87	32.95	131.81	0.152	0.268	0.011
X_4	Okpare	74.61	35.51	43.54	174.19	0.201	0.252	0.015
X_5	Ogoni – olomu	146.47	67.50	82.78	331.12	0.395	0.637	0.029
X_6	Agborha – otor	71.07	33.52	87.16	164.43	0.192	0.306	0.014
X_7	Afiesere	66.17	30.09	36.90	147.60	0.179	0.244	0.012
X_8	Orogun	77.50	36.32	44.54	178.17	0.200	0.355	0.015
X_9	Ekiugbo	74.33	34.32	42.09	167.36	0.200	0.303	0.014
X_{10}	Oteri	104.36	49.00	60.09	240.37	0.281	0.500	0.021
	Mean	80.422	37.95	53.58	186.06	0.216	0.336	0.016

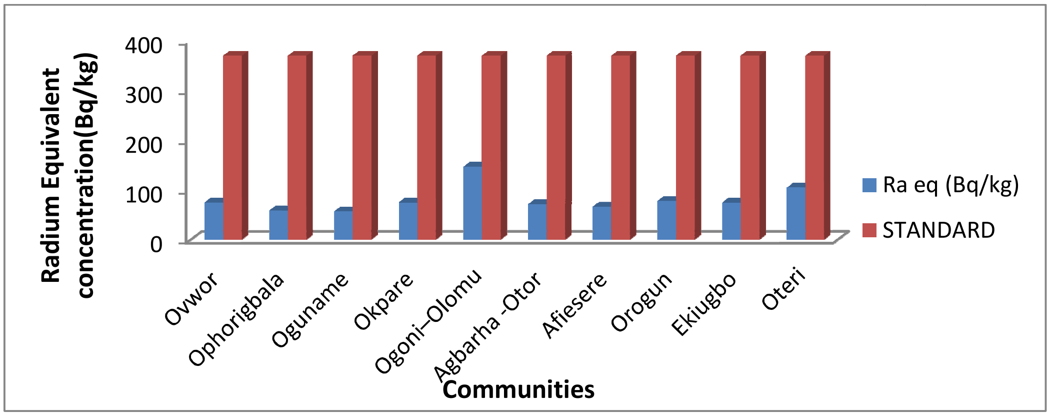

Fig. 5. Comparison of radium equivalent concentration in soil with standard in studied communities

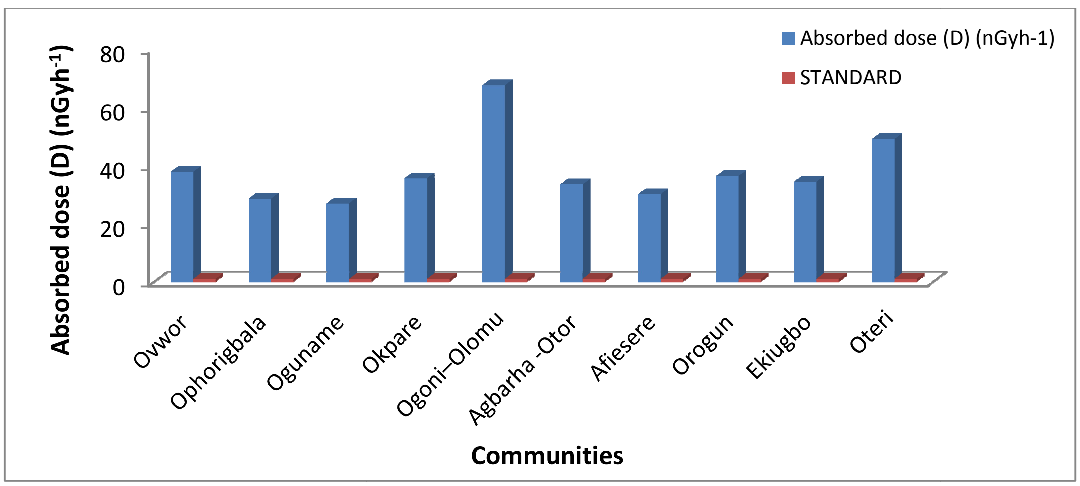

Fig. 6. Comparison of absorbed dose rate in soil with standard in studied communities

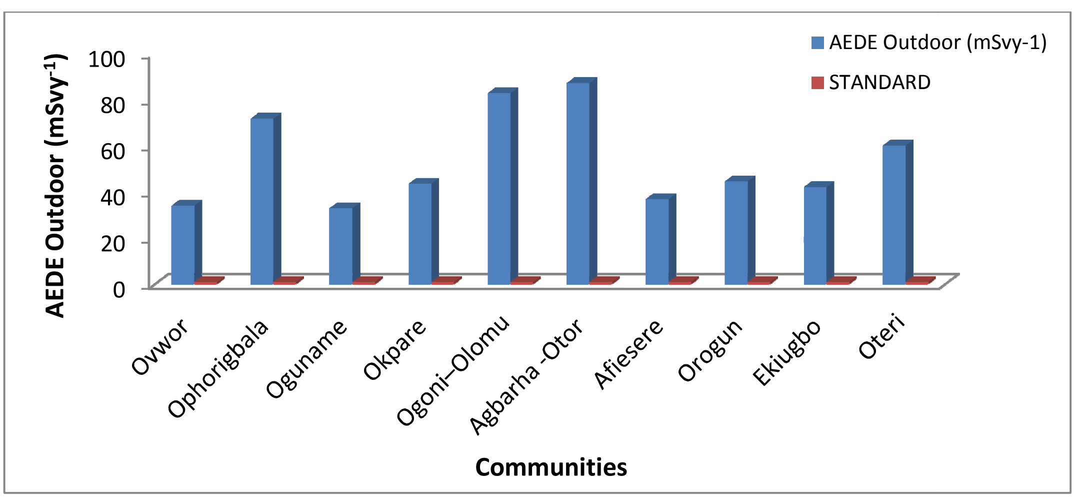

Fig. 7. Comparison of annual effective dose (outdoor) ($mSvy^{-1}$) in soil with standard in studied communities

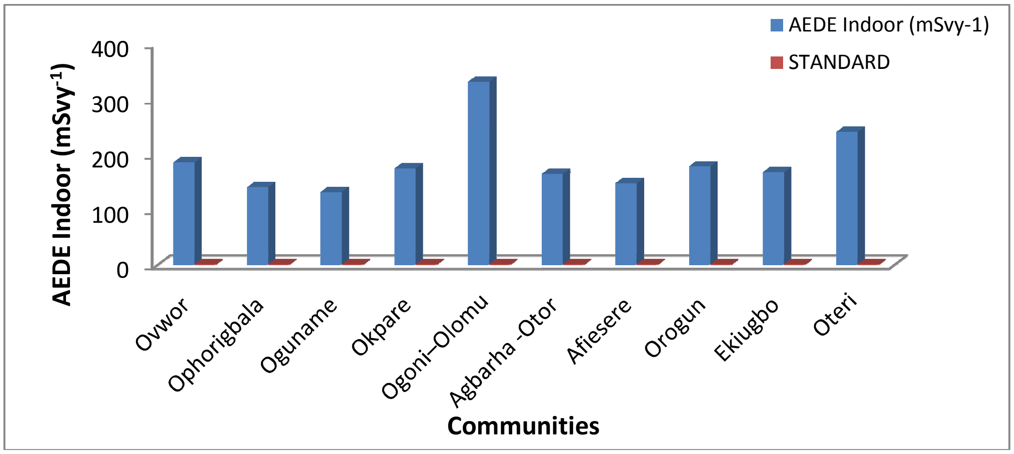

Fig. 8. Comparison of annual effective dose (indoor) ($mSvy^{-1}$) in soil with standard in studied communities

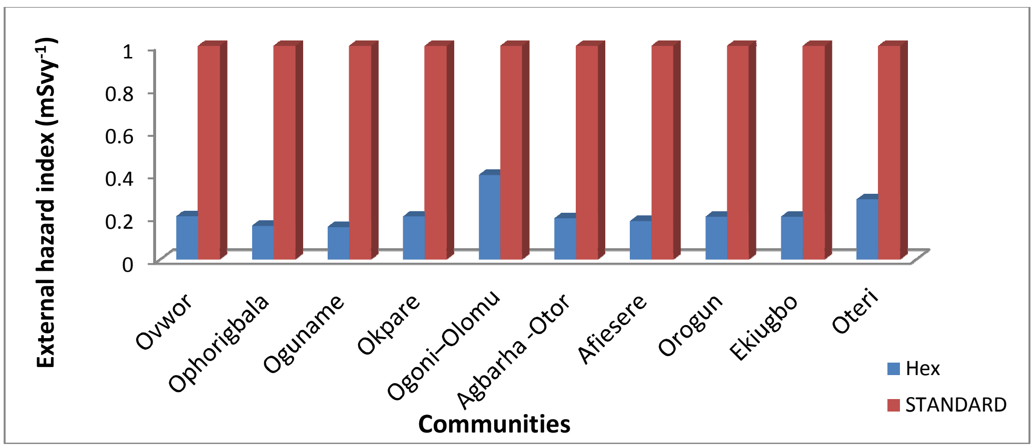

Fig. 9. Comparison of external hazard index values ($mSvy^{-1}$) in soil with standard in studied communities

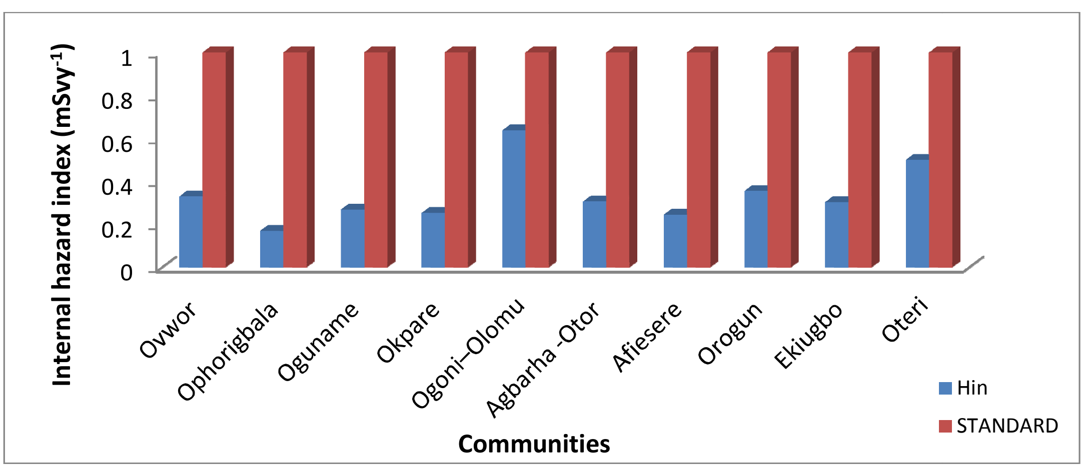

Fig. 10. Comparison of internal hazard index values ($mSvy^{-1}$) in soil with standard in studied communities

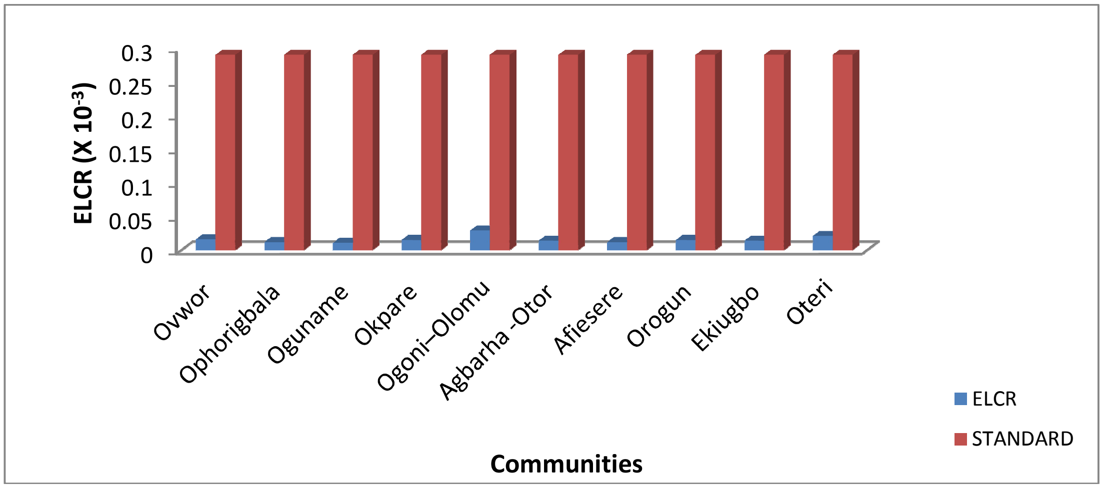

Fig. 11. Comparison of ELCR values in soil with standard in studied communities

4. CONCLUSION

Radiological evaluation of soil in some selected oil and gas producing communities in the central part of Delta State, Nigeria have been carried out. The mean results for the activities radionuclide concentrations and its radiological hazard indices do not have an immediate effect but may have long term effect on the dwellers of the communities. Hence there should be constant monitoring of radioactivity in the area.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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