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Natural Radioactivity Levels in Surface Soil of Ogba/Egbema/Ndoni Oil and Gas Fields

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Abstract

The activity concentrations and the gamma-absorbed dose rates of the terrestrial naturally occurring radio nuclides viz. ^{226}Ra, ^{232}Th and ^{40}K were determined in soil samples collected from twelve oil fields and their host communities, using gamma ray spectrometry. The soil activity ranges from 10.10 to 41.23 Bq/kg for ^{226}Ra, 7.42 to 30.31 Bq/kg for ^{232}Th and 92.42 to 482.79 Bq/kg for ^{40}K with mean values of 19.16, 21.26 and 224.29 Bq/kg, respectively for host community soil. In the field soil sample, the activity concentration ranges from 16.27 to 52.19 Bq/kg for ^{226}Ra, 9.72 to 34.13 Bq/kg for ^{232}Th and 134.50 to 395.15 Bq/kg for ^{40}K with mean values of 29.61, 17.41 and 262.63 Bq/kg, respectively. The concentrations of these radionuclides are compared with the values of the control samples and the UNSCEAR, 2000 standards of 35.0, 30.0 and 400 Bq/kg for ^{226}Ra, ^{232}Th and ^{40}K respectively. The measured activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in soil is lower than the world average except in two oil fields that ^{226}Ra and ^{40}K exceeded the world average. Radium equivalent activities are calculated from the results to assess the radiation hazards arising due to the use of these soil samples in the construction of dwellings. All the soil samples have radium equivalent activities lower than the limit set in the UNSCEAR report (370 Bq/kg). The overall mean outdoor Absorbed Dose rate are 32.17 and 35.45nGy•h^{-1} respectively for host community soil and field soil samples. The corresponding effective dose calculated has mean values less than 1.0 mSvy^{-1}, the limit set by WHO (2008). The hazard indices calculated were all less than unity (1) showing that all the soil/sediment samples sampled are still safe for building purpose since their radiological impact is minimal. The percentage contribution of each of these radionuclide are; 64.77% for radium-226, 3.13% for thorium-232 and 32.10% for potassium-40. The entire radiation hazard indices are within the acceptable limit therefore, no immediate health risk as a result of these radionuclide but continuous exposure may result to a significant health impact.

Key words: Gamma ray spectrometry; Soil samples; Specific activities; Effective dose; NORM; Absorbed dose; Onelga

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INTRODUCTION

Human beings have always been exposed to natural radiations arising from within and outside the earth. The exposure to ionizing radiations from natural sources occurs because of the naturally occurring radioactive materials (NORM) in the soil and rocks, cosmic rays entering the earth's atmosphere from outer space and the internal exposure from radioactive elements through food, water and air. Natural radioactivity is wide spread in the earth's environment and it exists in various geological formations in soil, rocks, plants, water and air (Surinder, Asha, & Rakesh, 2004). The natural radioactivity in soil comes from U and Th series and natural K. Artificial radionuclides can also be present such as ^{137}Cs, resulting from fallout from weapons testing. NORM encountered in hydrocarbon exploration and production operations originate in subsurface formations that may contain radioactive materials such as Uranium and thorium and their daughter products, ^{226}Ra and ^{228}Ra. This can be

brought to the surface in the surface in the produced water in conjunction with oil and gas. In addition, radon gas a radium daughter, may be found in produced natural gas. In gas processing activities, NORM generally occurs as radon gas in the natural gas stream (Ajayi *et al.*, 2009; Mokobia *et al.*, 2006).

During exploration and extraction processes, various operational practices contribute to or induce NORM occurrence, namely remote sensing methods of mapping and explosives associated with seismic exploration, drilling equipment and activities and down – the – hole geophysical logging methods. In some instances, radioactive marker bullets are employed as an aid in relative depth determinations. The gamma ray log is used to locate the bullets after casing has been set. Radioactive tracers are also used in evaluating the effective of well cementing and under ground water and crude oil flow direction for the purpose of correlation (Ajayi *et al*., 2009). In some cases, various amounts of radioisotopes are injected with the secondary recovery flooding fluids to facilitate flow. The wastes originated from these activities are released into the environment, hence an environmental management of the highest quality is needed to reduce the resultant safety problems for both the environment and population. So far under Nigerian legislation, there were no radiological controls on the operation of these industries or restrictions on how waste is discharged (to atmosphere, to landfill, to cellar pits etc) which relate to its radionuclide content.

The radiological implication of these radionuclides is due to the gamma ray exposure of the body and irradiation of lung tissue from inhalation of radon and its daughters. The growing worldwide interest in natural radiation exposure has lead to extensive surveys in many countries. External gamma dose estimation due to the terrestrial sources is essential not only because it contributes considerably (0.46 $mSvy^{-1}$) to the collective dose but also because of the variations of the individual doses related to this pathway. These doses vary depending upon the concentrations of the natural radio nuclides, ^{238}U, ^{232}Th, their daughter products and ^{40}K, present in the soils and rocks, which in turn depend upon the local geology of each region in the world (Ajayi *et al.*, 2009; Mokobia *et al.*, 2006).

To evaluate the terrestrial gamma dose rate for outdoor occupation, it is very important to estimate the natural radioactivity level in soils. The natural radioactivity of soil samples is usually determined from the ^{226}Ra, ^{232}Th and ^{40}K contents (OECD, 79). Since 98.5% of the radiological effects of the uranium series are produced by radium and its daughter products, the contribution from the ^{238}U and the other ^{226}Ra precursors are normally ignored (Zastawny *et al*., 1979).

In Nigeria and other countries, many studies have been carried out on the natural radioactivity matrices (Tchokossa, 2006; Ajayi *et al.*, 2009; Diad *et al*., 2008; Fatima *et al.*, 2008; Chukwuocha & Enyinna, 2010; Isinkaye & Shitta, 2010; Senthilkumar *et al.*, 2010). It has been noted that radiation is part of the natural environment and it is estimated that approximately 80% of all human exposure comes from naturally occurring radioactive materials. Hydrocarbon exploration and production activities have the potential to increase the risk of radiation exposure to the environment and humans by concentrating the quantities of naturally occurring radiation beyond normal background levels (Ajayi *et al*., 2009). The knowledge of the distribution and of the behavior of the radionuclides in soil, in particular of the radium isotopes and its daughter products is important in understanding several aspects of the natural radiation environment, as the exchange of radionuclides between the soil solid matrix and surface and ground waters, the uptake of radioactive nuclides by vegetation, the exchange of radionuclides between the upper soil layers and the atmosphere. Furthermore, the knowledge of the soil radioactivity is important in evaluating the average human exposition to the natural radioactivity.

EPA (2005) on environments, health and safety online stated that the more radiation dose a person receives, the greater the chance of developing cancer, leukemia, eye cataracts, Erithemia, hematological depression and incidence of chromosome aberrations. This may not appear until many years after the radiation dose is received (typically, 10-40 years). Ogba/Egbema/Ndoni local government area oil fields produce about 80% of the total crude oil and gas supply in the Niger Delta region of Rivers state. Yet none of the research works done so far has addressed the natural radioactivity in soil samples of oil fields and its health implication on the workers and the general public. This study therefore, seeks to evaluate the natural radioactivity in surface soil samples and also estimate its radiological health implication to the general public and oil/gas workers.

1. GEOLOGY OF THE AREA

Figure 1 shows the geographic location of the Ogba/Egbema/Ndoni (Onelga) oilfields as well as the location of the sampling points. The geographic location of the study area lies within latitude 5°13' N and 5°22' N and longitude 6°33' E and 6°42' North West of the Niger Delta region of Nigeria (UNDP, 2006). It is one of the onshore oil producing area of Rivers State. The area which is one of the highest oil and gas production onshore of Niger Delta has over 900 oil wells with over thirteen active oil fields and playing a host to three multinational companies (Abali, 2009). The area is criss-cross with network of pipelines carrying either oil or gas to the flow stations from the different oil wells (UNDP, 2006). Gas flaring and oil spillage due to rupture of oil/gas pipeline has been the major environmental pollutant in the area.

Ogba/Egbema/Ndoni (Onelga) has topography of flat plains netted in a web of rivers-the Niger, Sombreiro (Nkissa), Orashi and their tributaries as well as dotted creeks. The tertiary lithostratigraphic sequence of the Niger Delta consists in an ascending order of the Akata, Agbada and Benin formations respectively. With the Benin formation making up an overall clastic sequence of about 9000-12,000 m thick deposits (Ajayi *et al*., 2009). The paralytic Agbada formation is a sequence of alternating sandstone and shales. Major hydrocarbon accumulations are found in the intervals between the Eocene and the Pliocene. The lowest unit (the Akata formation) is a uniform marine shale unit that may contain lenses of abnormally over pressured siltstones or fine grained sandstones. Oil and gas occurrence in the Niger delta are concentrated mainly in the sand stones reservoir at various levels of the Agbada formation (Ajayi *et al*., 2009).

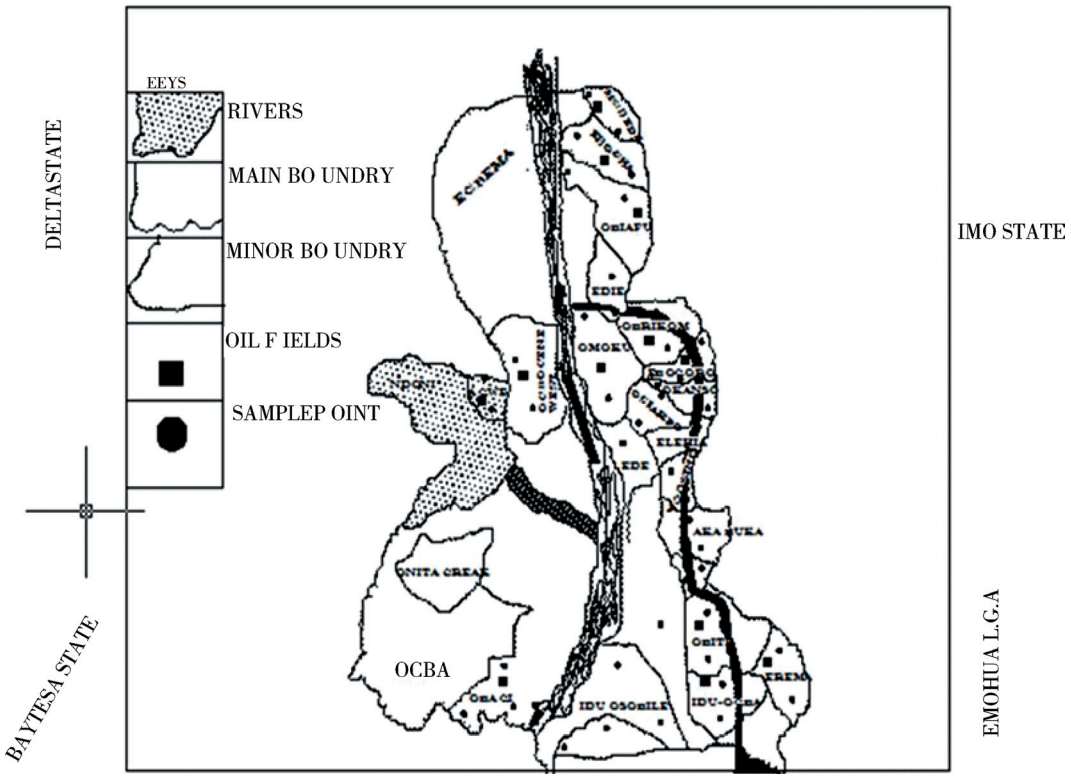


Figure 1
A Sketch of the Onelga Oil Fields Showing Sampling Areas

2. EXPERIMENTAL PROCEDURE

2.1 Estimation of Natural Radioactivity Levels by Gamma Spectrometry Technique

In order to measure natural radioactivity in soil, thirty-six surface soil samples were collected from undisturbed sites at each location. After removing the stones and organic materials, the samples were dried in an oven at about 100 ^{o}C for 1-2 h to remove the moisture content and then crushed to pass through a 150 m mesh sieve to homogenize it. Then, a sample of 250 ± 0.05% was weighed and finally, a split of the prepared sample was packed in a standard plastic container (7.5 cm × 6.5 cm diam.) and after properly tightening the threatened lid, the containers were sealed with adhesive tape and left for at least 4 weeks (>7 half-lives of ^{222}Rn and ^{224}Ra) before counting by gamma spectrometry in order to ensure that the daughter products of ^{226}Ra up to ^{210}Pb and of ^{228}Th up to ^{208}Pb achieve equilibrium with their respective parent radionuclides. The standard sources for ^{226}Ra and ^{232}Th (in secular equilibrium with ^{228}Th) have been prepared using known activity contents and mixing with the matrix material of ophthalmic acid powder. Analar grade potassium chloride (KCl) of a known amount in the same geometry has been used as the standard source for ^{40}K. The radionuclides ^{226}Ra, ^{232}Th and ^{40}K contents have been estimated using a low background gamma spectrometry system, which makes use of a gamma ray spectrometer with a 76´ 76mm NaI (Ti) detector was used.

The detector is enclosed in a massive 10 cm thick lead shielding lined with 1.5 mm thick cadmium followed by 0.8mm thick copper on the inner surfaces to reduce the contribution due to fluorescence X-rays. The dimensions of the free surface within the shielding enclosure are 44 cm × 44 cm × 65 cm deep. Using different disc-type reference standard sources supplied by M/s ECIL, the gamma ray spectrometer is calibrated up to 3 MeV. The counting time for each sample was 12,000s to get a

statistically small error. With appropriate corrections for laboratory background, the activity of ^{226}Ra was evaluated, in all cases, from the 1.76 MeV peak of ^{214}Bi, while the ^{232}Th activity was determined from 2.62 MeV peak of ^{208}Tl, and the ^{40}K peak at 1.46 MeV (Surinder *et al*., 2004). The characteristics of the gamma ray spectrometer used aregiven in Table 1.

Table 1
Characteristics of the Gamma Ray Spectrometer

Parameter	For radio nuclides		
	^{226}Ra	^{232}Th	^{40}K
Gamma lines used (MeV)	1.76 (214Bi)	2.62 (208Tl)	1.46
Background reduction factor	12.3	15.4	18.5
Percentage efficiency	1.39	1.37	4.16
MDA (Bq/kg) (for 12,000 s counting, 7.5 cm × 6.5 cm diam. plastic container geometry)	8	7	5

Equations for elemental counts: Thorium = C_3, Radium = $C_2 - aC_3$, Potassium = $C_1 - bC_3 - c(C_2 - aC_3)$, where C_1, C_2 and C_3 are background subtracted true counts in K, Ra and Th energy bands, respectively, $a = 0.58$, $b = 0.72$, $c = 1.18$

2.2 Radium Equivalent Activity

The distribution of ^{226}Ra, ^{232}Th and ^{40}K in soil is not uniform. Uniformity with respect to exposure to radiation (radiation hazards associated with them), has been defined in terms of radium equivalent activity (Raeq) in Bq/kg to compare the specific activity of materials containing different amounts of ^{226}Ra, ^{232}Th and ^{40}K. It is calculated through the following relation:

$$Raeq = A_{Ra} + 1.43A_{Th} + 0.077A_K, \quad (1)$$

Where A_{Ra}, A_{Th} and A_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Bqkg^{-1}, respectively (Diab *et al.*, 2008; UNSCEAR, 2000). While defining Raeq activity according to Equation (1), it has been assumed that 370 Bq/kg of ^{226}Ra or 259 Bq/kg of ^{232}Th or 4810 Bq/kg of ^{40}K produce the same gamma dose rate.

2.3 Calculation of Absorbed Dose Rates (D)

The absorbed dose rates (D) due to terrestrial gamma rays at 1m above the ground are calculated from ^{226}Ra, ^{232}Th and ^{40}K concentration values in soil assuming that the other radionuclides, such as ^{137}Cs, ^{90}Sr and the ^{235}U decay series can be neglected as they contribute very little to the total dose from environmental background . The conversion factors used to calculate the absorbed dose a rate is given by (UNSCEAR, 2000) as:

$$D = 0.462A_{Ra} + 0.621A_{Th} + 0.0417A_K. \quad (2)$$

In the above conversions, it is assumed that all the decay products of ^{226}Ra and ^{232}Th are in radioactive equilibrium with their precursors.

2.4 Calculation of annual effective dose

To estimate the annual effective dose rates, the conversion coefficient from absorbed dose in air to effective dose (0.7SvGy^{-1}) and outdoor occupancy factor (0.2) proposed by UNSCEAR (2000) are used. Therefore, the annual effective dose rate (mSvy^{-1}) was calculated by the following formula (UNSCEAR, 2000):

Effective dose rate (mSvy-1) = D (nGyh^{-1})′ 8760hy-1 ′0.7 ′(10^3 mSv/10^9) nGy ′ 0.2 = D′ 1.21 ′10^{-3} (mSvy^{-1}) (3)

2.5 External and Internal Hazard Indices (Hex and H_{in})

A widely used hazard index (reflecting the external exposure) called the external hazard index H_{ex} is defined as follows:

$H_{ex} = (A_{Ra}/370) + (A_{Th}/259) + (A_K/4810)$ (UNSCEAR, 2000) (4)

In addition to external hazard index, radon and its short lived products are also hazardous to the respiratory organs. The internal exposure to radon and its daughter products is quantified by the internal hazard index H_{in}, which is given by the equation.

$$H_{in} = A_{Ra}/185 + A_{Th}/259\ A_K/4810 \quad (5)$$

The values of the indices (H_{ex}, H_{in}) must be less than unity for the radiation hazard to be negligible.

3. EXPERIMENTAL RESULTS AND DISCUSSION

The results for the activity concentrations of natural radionuclides ^{226}Ra, ^{232}Th and ^{40}K in soil samples of different locations of the oilfields and the host communities are reported in Tables 2 and 3. The ± values shown are because of the 1σ variation due to counting errors. The activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in host community soil of Table 2 ranges from 10.10 ± 1.32 Bq/kg to 41.23 ± 4.60 Bq/kg , 7.42 ± 1.08 Bq/kg to 30.31 ± 1.94 Bq/kg, 92.42 ± 7.23 Bq/kg to 482.79 ± 18.25 Bq/kg respectively. Except Ebegoro and Erema communities, the obtained results for ^{226}Ra, and ^{40}K have lower values of activity concentrations when compared with worldwide average values of 35.0, 30.0 and 400 Bq/kg (UNSCEAR, 2000). The relative high values of ^{226}Ra, ^{232}Th and ^{40}K obtained

at Ebegoro and Erema community soil could be attributed to oil spillage due to pipeline explosion at Ebegoro and Erema oilfield which led to removal and replacement of old oil pipeline, scales from the oil pipeline and so on.

From Table 3, the specific gamma activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in field soil samples ranges from 16.27 ± 2.04 to 52.19 ± 3.62 Bq/kg, 9.72 ± 1.08 to 34.13 ± 3.92 Bq/kg and 134.50 ± 10.24 to 395.15 ± 10.54 Bq/kg respectively. Except samples from Erema, Ogbogene and Agwe oilfields, the activities concentrations of ^{226}Ra, and ^{40}K have lower values of activity concentrations, when compared with worldwide average values of 35.0, 30.0 and 400 Bq/kg (UNSCEAR, 2000) as shown in Figures 2, 3 and 5. However, the higher activity concentration of ^{226}Ra and ^{40}K in field soil at Ogbogene and Agwe could be mainly due to fallout of radionuclide during oil well development which may be rich in radium. The high activity was observed from soil samples collected around the industrial waste pits, near oil wells and around gas stack areas at Erema oil fields. Similarly the mean activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in host community soil is 59.69%, 79.56% and 37.44% respectively higher than the control values while in the field soil, it is 71.95%, 75.59% and 43.93% higher than the control soil samples. This could be attributed to radioactive wastes and effluent from oil and gas exploration and production activities. The overall result indicates that the activity concentration of ^{40}K is higher than that of ^{226}Ra and ^{232}Th in all the host communities soil samples and field soil samples. The high activity of ^{40}K is consistent with Ajayi *et al.*, (2009) who noted that the activity of ^{40}K in sedimentary rocks depends on the relative amounts of feldspar, mica and clay mineral aggregate sediment. The high activity concentration of ^{40}K therefore could be attributed to the presence of feldspar and clay that characterize the formation of the Niger Delta.

Table 5 compares the reported values of natural radionuclides in the soil samples, obtained in other countries (UNSCEAR, 2000), with those determined in the present study. On comparison, it is found that the range of ^{226}Ra and ^{232}Th almost match those of the other countries. However, the values of ^{40}K are lower than that of other countries of the world. This could be attributed to the type of rock present in the geological formations of the area which could be rich in potassium and also the type of radionuclide inputs in the industrial activities in the area. With the exception of samples collected from Ebegoro oilfield, the average absorbed dose rates due to the presence of ^{226}Ra, ^{232}Th and ^{40}K in the rest of the soil samples studied were found to be slightly lower than the world average value of 60 nGyh^{-1} but in the field soil, it is 6.54% higher than the average value of 31.1 nGyh^{-1} reported in soil around fertilizer factory in Egypt by Diab *et al.*, (2008). The values obtained are comparable with 51.0 nGyh^{-1} reported in soil around two oilfields in Romania by Elena and Grecea (2004). The average annual effective doses are also within the worldwide average value of 0.07 mSvy^{-1} (UNSCEAR, 2000) except in Ebegoro oilfield. The high annual effective dose rate along Ebegoro community estimated to be 0.738 mSv which is higher than the World Health Organization maximum (WHO, 2008) safe limit of 0.1 mSvy^{-1} could be due to local high activity concentration of ^{226}Ra, ^{232}Th and ^{40}K because of oil spillage in the area due to oil pipeline explosion. The experimental results of radium equivalent activity as shown in Tables 2 and 3 indicates that the average Ra_{eq} in host community soil and field soil samples are below the internationally acceptable value of 370 Bq/kg. The estimated internal and external hazard indices, alpha and gamma indices were all less than unity (1). This implies that activities involving the use of soil from the host community and oilfields are safe and do not attract any high level of radiation exposure.

The correlation coefficient factor (R^2), showed that ^{226}Ra contributed 65%, ^{232}Th contributed 3% while ^{40}K contributed 32% of the total absorbed dose of radiation. The least contribution to the total dose rate of the soil/sediment sampled is made by ^{232}Th. In contrast to ^{226}Ra, ^{232}Th is highly insoluble under all geochemical conditions. This means that it would have been more difficult to mobilize ^{232}Th than to mobilize ^{226}Ra from the source from which they get into the soil and other environmental media even if they had occurred with the same concentration in the source material. This agrees with the NCRP (1987) that radium is more mobile than thorium, and would explain the observation that radium concentration contributed the highest radiation doses more than thorium and potassium soil sampled. The over all result showed an elevated NORM content of the hydrocarbon exploration and production oilfields which was strictly not from the geological formations of the area but might be affected by the radiological degradation and modification due to radionuclide input in daily industrial activities in the oilfields.

Table 2
Specific Gamma Activity of ^{226}Ra, ^{232}Th and ^{40}K and Radiation Hazard Parameters Measured in Host Community Soil Samples

Oil fields	Specific activity			Ra_{eq} (Bq/kg)	D ($nGyh^{-1}$)	H_E ($mSvy^{-1}$)	H_{ex}	H_{in}
	^{226}Ra	^{232}Th	^{40}K					
Ebocha	10.25±2.41	7.42±1.08	261.11±12.8	40.96	20.23	0.024	0.111	0.138
Mgbede	24.37±3.01	16.32±2.30	178.04±12.3	61.42	28.82	0.035	0.166	0.232
Obiafu	9.24±1.42	20.31±2.75	194.51±10.2	53.26	24.99	0.030	0.144	0.169
Obrikom	8.62±1.06	23.14±2.13	186.32±9.96	56.06	26.12	0.032	0.151	0.175
Ebegoro	41.23±4.60	24.41±2.24	421.31±17.0	108.58	61.03	0.738	0.293	0.405
Omoku	17.38±2.02	29.47±3.42	209.86±11.2	75.68	35.08	0.424	0.161	0.251
Erema	33.46±3.30	19.6±2.15	482.79±18.2	77.93	47.76	0.058	0.266	0.357
Idu-Ogba	10.1±1.32	17.75±2.04	92.42±7.23	42.6	19.54	0.024	0.115	0.142
Obagi	14.64±1.79	18.37±1.97	144.2±6.92	48.2	24.19	0.029	0.147	0.18
Ogbogene	15.62±1.67	18.22±1.56	163.24±10.5	51.24	25.33	0.306	0.16	0.189
Odugiri	20.74±3.28	29.83±3.21	108.43±9.62	47.8	32.53	0.039	0.182	0.25
Agwe	24.27±2.36	30.31±3.65	248.92±15.1	65.31	40.42	0.049	0.234	0.3
Mean	19.16±1.23	21.26±1.41	224.26±10.1	60.75	32.17	0.149	0.178	0.234

Table 3
Specific Gamma Activity of ^{226}Ra, ^{232}Th and ^{40}K and Radiation Hazard Parameters Measured in Oil Field Soil Samples

Oil fields	Specific activities			Ra_{eq} (Bq/kg)	D ($nGyh^{-1}$)	H_E ($mSvy^{-1}$)	H_{ex}	H_{in}
	^{226}Ra	^{232}Th	^{40}K					
Ebocha	17.01±3.12	11.42±1.40	268.14±10.36	53.99	26.13	0.032	0.146	0.192
Mgbede	22.64±2.93	9.72±1.08	188.29±9.32	51.04	24.35	0.029	0.138	0.199
Obiafu	27.49±3.21	10.68±1.72	395.15±10.54	73.26	35.81	0.043	0.198	0.272
Obrikom	21.34±2.15	31.21±2.26	276.23±9.54	87.24	40.84	0.049	0.236	0.293
Ebegoro	32.29±3.06	14.34±1.28	322.14±10.25	77.6	37.25	0.045	0.21	0.297
Omoku	26.65±3.42	20.43±1.80	304.27±8.44	79.29	37.69	0.046	0.214	0.286
Erema	38.92±3.25	12.76±1.10	266.29±12.21	62.57	37.01	0.045	0.21	0.315
Idu-Ogba	32.19±3.63	14.0±1.26	134.5±10.24	52.02	29.17	0.035	0.169	0.256
Obagi	27.36±2.11	34.13±3.92	278.57±8.33	97.62	45.45	0.055	0.264	0.338
Ogbogene	40.98±3.84	14.57±1.26	339.52±9.63	71.74	42.14	0.051	0.238	0.348
Odugiri	16.27±2.04	12.53±1.41	176.76±8.59	89.27	22.67	0.027	0.129	0.173
Agwe	52.19±3.62	23.17±1.20	201.68±9.24	100.85	46.91	0.057	0.272	0.413
Mean	29.61±1.21	17.41±1.06	262.63±10.23	74.71	35.45	0.043	0.202	0.282

Table 4
Mean Specific Gamma Activity of ^{226}Ra, ^{232}Th and ^{40}K Together with Mean Radiation Hazard Parameters Measured in Control Samples Collected from Non-Oil Bearing Community

	Activity concentration (Bq/kg)			Radiation hazard parameters				
Sample ID	^{226}Ra Bq/kg	^{232}Th Bq/kg	^{40}K Bq/kg	Ra_{eq} Bq/kg	D ($nGyh^{-1}$)	H_E $mSvy^{-1}$	H_{ex}	H_{in}
CSS	3.69	1.67	32.10	10.26	5.01	0.006	0.028	0.038
CSS	4.83	2.42	102.30	9.46	7.99	0.010	0.044	0.057
CSS	8.36	3.56	100.02	21.15	10.25	0.012	0.057	0.080
Mean	5.62	2.55	78.14	13.62	7.75	0.009	0.043	0.058

CSS = Control Soil Sample

Table 5
Comparison of Natural Radioactivity Levels Measured in Soil with Those in Other Countries of the World

Country	Concentration in soil (Bq/kg)						Absorbed dose in air ($nGyh^{-1}$)	
	^{226}Ra		^{232}Th		^{40}K			
Country	Mean	Range	Mean	Range	Mean	Range	Mean	Range
United State	40	8-160	35	4-130	370	100-700	47	14-118
China	32	2-440	41	1-360	440	9-1800	62	2-340
Hong Kong	59	20-110	95	16-200	530	80-1100	87	51-120
India	29	7-81	64	14-160	400	38-760	56	20-1100
Japan	33	6-98	28	2-88	310	15-990	53	21-77
Denmark	17	9-29	19	8-30	460	240-610	52	35-70
Belgium	26	5-50	27	5-50	380	70-900	43	13-80
Poland	26	5-120	21	4-77	410	110-970	45	18-97
Nigeria (present work) field soil	30	16-41	17	10-34	263	135-395	35	23-47
Host comm.	19	9-36	21	7-30	224	92-483	32	20-61
UNSCEAR, 2000 STANDARD	35		30		400		60	53-98

Source: UNSCEAR, 2000

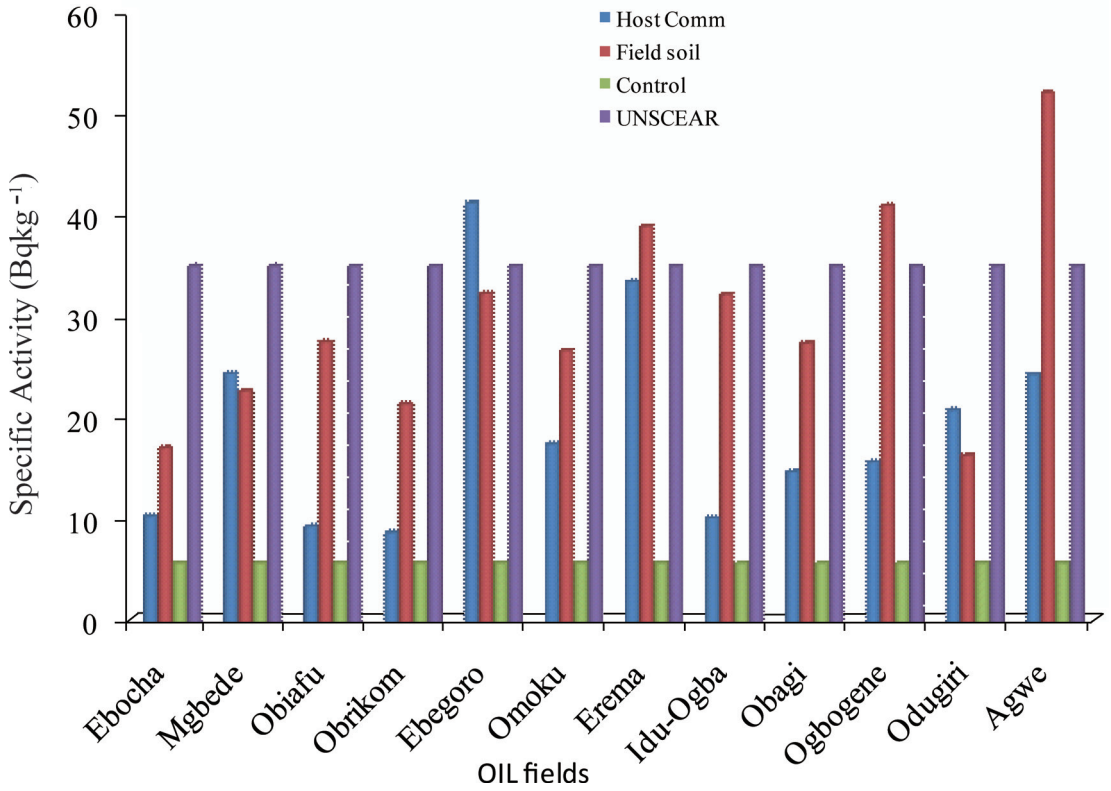


Figure 2
Comparison of ^{226}Ra Activity in Host Comm. Soil, and Field Soil with UNSCEAR, 2000

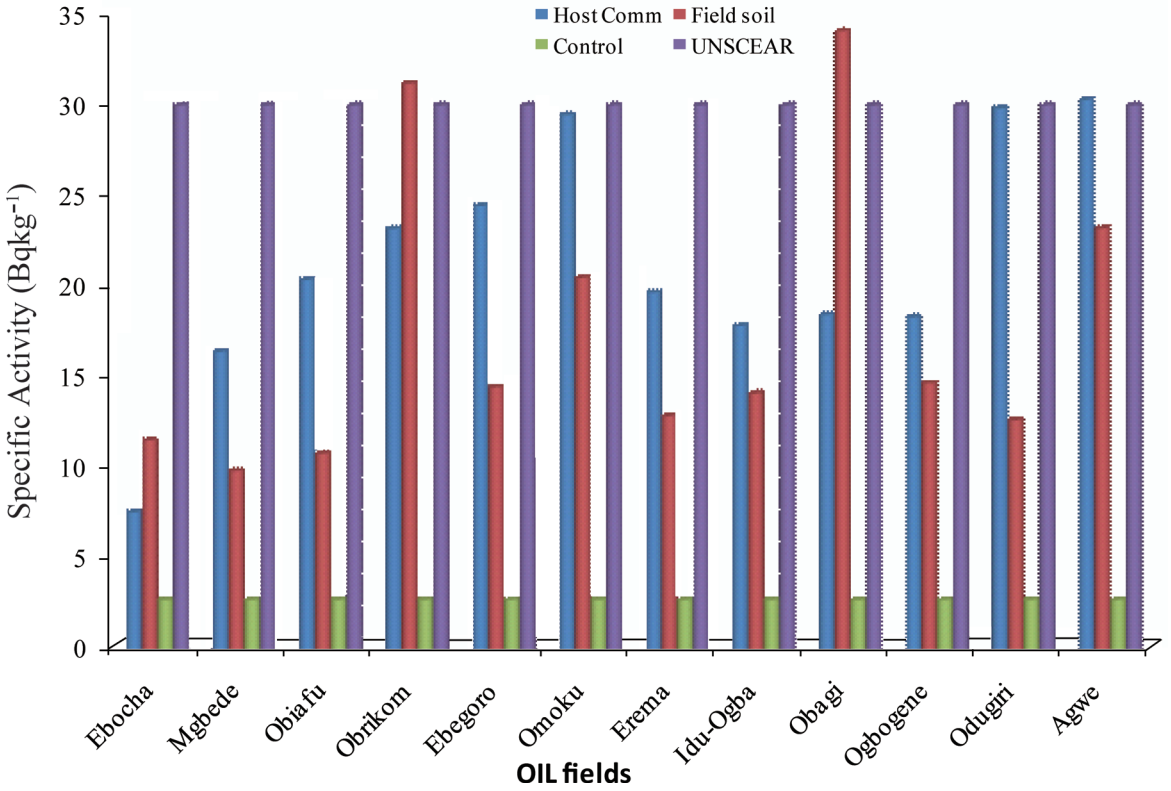
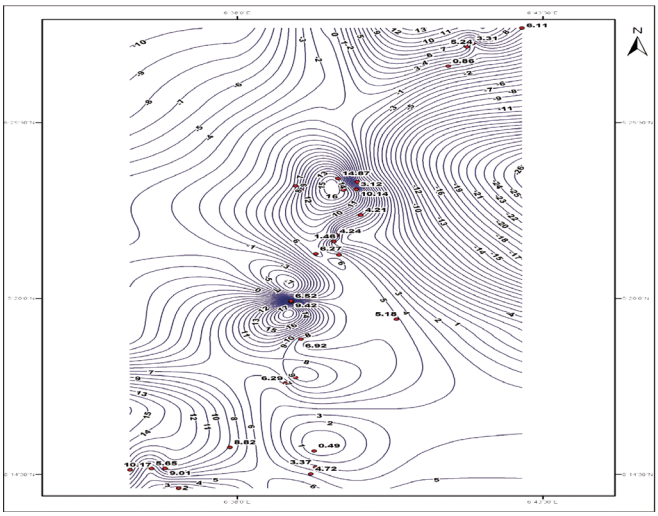
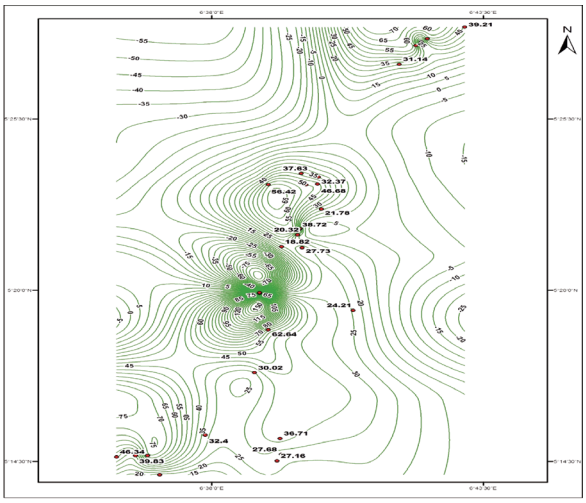


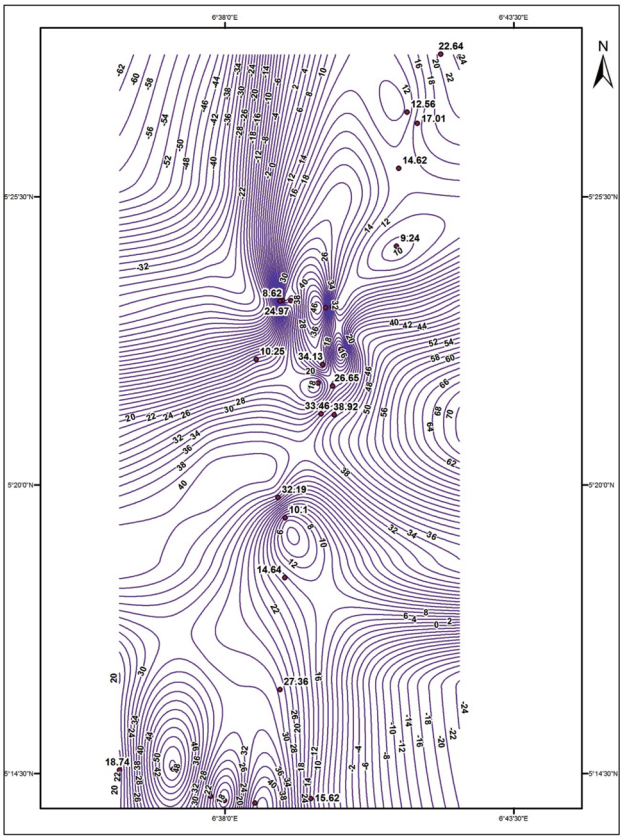
Figure 3
Comparison of ^{232}Th Activity in Host Comm. Soil, and Field Soil with UNSCEAR, 2000



(a)



(b)



(c)

Figure 4
(a) Contour Map of ^{226}Ra in Soil; (b) Contour Map of ^{232}Th in Soil; (c) Contour Map of ^{40}K in Soil

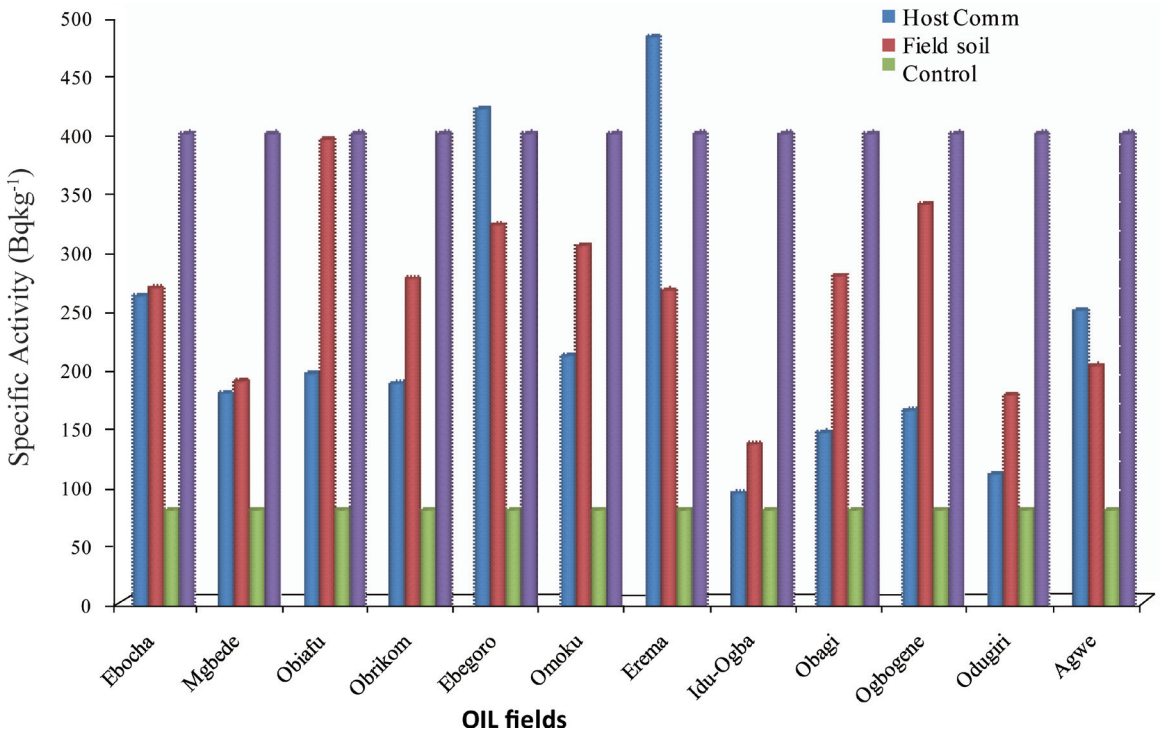


Figure 5
Comparison of ^{40}K Activity in Host Comm. Soil, and Field Soil with UNSCEAR, 2000

From the iso-specific map shown in Figures 4a, 4b and 4c, the activity levels were found to follow lognormal distribution showing that natural radioactivity is randomly distributed at varying concentrations in the surface soil under investigation. Some fields have elevated concentration of this radionuclide while some fields have patches of high and low concentration. Therefore, according to the Radiation Protection 112 (European Commission, 1999) report, soil from these regions is safe and can be used as a construction material without posing any significant radiological threat to population but their cumulative effects may have negative consequence on the environment.

CONCLUSION

An analytical method of determining the specific gamma radioactivity of soil samples in Ogba/Egbema/Ndoni oilfields has been carried out using NAI (TI) detector. The following conclusions were made:

- Comparatively, high value of potassium in all the samples may be due to the presence of feldspar and clay that characterizes the formations in the Niger Delta.
- The high values of ^{226}Ra in soil samples may be due to the presence of Uranium mineralization in the Niger Delta region reported earlier by some workers (Ajayi *et al*., 2009; Makobia *et al*., 2006) and also due to exploration activities in the area.
- The measured mean activity concentrations of terrestrial gamma ray emitters are compared with the world average values. For ^{226}Ra the concentration in host community soil and field soil are 24.52% and 8.34% respectively higher than the world average; for ^{232}Th the activity concentration are 16.95% and 26.56% respectively lower than the world average. For ^{40}K the activity is 28.15% and 20.73% lower than the world average.
- The results show that all the linear fit of the measured parameters were significantly further away from unity (1) which shows that the concentration of NORM were mainly influenced by the oil exploration and production activities in the area and not from the geological consituent of the area.

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