ASSESSMENT OF GAMMA DOSE RATE OVER ARABLE LANDS OF ESA-OKE FARM SETTLEMENT OSUN STATE, SOUTH-WESTERN NIGERIA.

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ABSTRACT

The absorbed gamma-dose rate in air was calculated from activity concentrations of gamma-emitting radionuclides in arable soil samples collected from ten locations within Esa-Oke farm settlements, Esa-Oke in Osun State, South-Western Nigeria. The natural radioactivity concentrations of ^{40}K, ^{238}U and ^{232}Th were measured using high resolution gamma-spectrometry and mean absorbed rate was evaluated. The radiological hazards incurred from the farming activities in this Farm Settlement were estimated through various radiation hazard indices. The average activity concentrations obtained were 295.7 ± 3.9 $Bqkg^{-1}$ for ^{40}K, 15.7 ± 2.2 $Bqkg^{-1}$ for ^{238}U and 14.09 ± $Bqkg^{-1}$ for ^{232}Th and the absorbed dose ranged from 10.88±22.56 to 17.83±2.08 $nGyh^{-1}$ with average absorbed rate of 28.45 ± 4.05 $nGyh^{-1}$ was obtained. The mean effective dose for the settlement is between 29.06 and 41.35 $\mu Svyear^{-1}$ respectively. The mean value is 0.34 $mSvyear^{-1}$ which is less than the 1 $mSvyear^{-1}$ recommended for normal environment by UNSCEAR in 2000. The measured values from this study are comparable with other global radioactivity measurements.

Keywords: *Radioactivity, activity concentration, absorbed dose rate, radiation hazard, spectroscopy.*

INTRODUCTION

Background radiation is a natural part of the environment in which we live. It consists of radiation doses received from natural and man-made background (UNCEAR, 2000; Hassan et al., 2018).

Background radiation is of three types: Primordial, Cosmogenic and Anthropogenic. Primordial radionuclides are present in the earth crust and found throughout the environment. Cosmogenic radiations are produced when cosmic radiation interacts with elements present in the atmosphere and are deposited through both wet and dry deposition. Anthropogenic sources of radiation result from human activities but are considered background because their presence is ubiquitous.

Primordial radionuclides include isotope of uranium, isotopes of thorium and potassium 40. The natural concentrations of those radionuclide's in soil vary from place to place as a result of underlying rock and soil composition.

Cosmogenic radionuclides are produced in the atmosphere by interaction of cosmic rays with atmospheric argon, oxygen and nitrogen (Radenkovic et al., 2009; Kaleel and Mohanad, 2012). Cosmogenic radionuclide reaches the earth through atmospheric mixing precipitation scavenging and gravitational settling; exposure results primarily from ingestion and is relatively constant throughout the world. The extent to which these radionuclides are taken up by plant and incorporated in animal tissues depends on the level of their presence in the environment; the characteristics of the native soil and the chemical behaviour of the elements or compound involved (Shankland, 1960; Okeyode and Oluseye, 2010; El-Taher and Al-Zahrani, 2014). Anthropogenic radiations which are man-made radiations generated from medical, commercial and industrial activities. Also, work activities, involving naturally occurring radioactive materials are potential sources of radiations to workers and members of public in general (BIER, 2001; Mustapha *et al*., 2007). Radionuclides present in the environment, whether natural or artificial in origin, ultimately result in irradiation of human populations.

In Esa – Oke Farm Settlement, most farmers engaged in perennial farming. The farming activities, includes ploughing that involve turning of top soil surfaces, application of fertilizers and various herbicides which may induce an increase in the level of radiation exposure in an environment has been going on annually. The radioactive isotope ^{40}K in potassium and the natural radionuclides of the uranium, radium decay series in phosphate rock are the radiological relevant radionuclides in

fertilizers (Meserecordias et al., 2014; Gharzwa et al., 2016). The radionuclides accumulated in arable soil can be incorporated metabolically into plants and ultimately get transferred into the body of animals (including human) when contaminated food are consumed. Thus, it is imperative to conduct this study for the evaluation of the natural radionuclide concentrations and radiological impact resulting from farming activities in this Farm Settlement.

MATERIALS AND METHODS

Study Area

Farm settlement scheme is an intervention of government to promote efficient utilization of land resources and dignity in farming through provision of infrastructures. The scheme started in the late 50s in Nigeria.

Historically, the three residential farm settlements in Ago-Owu, Esa-Oke and Oyere all in Osun State were established in the 1960s by the late sage and former Premier of the defunct Western Region, Chief Obafemi Awolowo. There are 36 settlements throughout the region. These vary from 2,000 to 8,000 acres which are made available in economic holdings on a leasehold basis to selected young men.

Esa-Oke farm settlement is located on longitude 4^{o} 5^{1} east and latitude 7^{o} 44^{1} North and is within the equatorial climate. It is divided into sections for interested farmers. Each farmer gets a total of 25 acres and a 2 bedroom farm house in the two residential areas in the settlement. Since the establishment of the settlement the farming activities has been going on till date.

Activity Concentration Measurement

Ten soils samples (0-5cm) were collected randomly within Esa-Oke farm settlement. The collected samples were dried at room temperature to a constant weight; this is in a bid to avoid any external factors that might alter the natural contents of the samples. They were further sieved through a 2mm sieve, and hermetically sealed in a suitable container and stored for 28 days to ensure secular equilibrium with their respective progeny. After secular equilibrium was attained, the sealed samples were each counted in a well calibrated NaI (IT) and well shielded detector couple to a computer quantum MCA2100R Multichannel analyzer for 36,000s. An empty container under identical geometric was also counted for the same time. The 146KeV gamma-radiation of ^{40}K was used to determine the concentration of ^{40}K in the samples. The gamma transition energy of 1764.5KeV ^{214}Bi was used to determine the concentration of ^{238}U while the gamma transition energy of 2614KeV ^{208}TI was used to determine the concentration of ^{232}Th while ^{137}Cs was detected by 661,6KeV gamma transition and its activity concentration is about 1Bq/kg. Further study will be needed to verify and clarify its origin.

The efficiency calibration of the detector was done using a reference standard mixed source traceable to Analytical Quality Control Service (AQCS, USA), which has certified activities of the selected radionuclides and has a geometrical configuration identical to sample container. The detector was set inside a massive old lead shield of 10cm thick to reduce background radiation. The activity concentration of the radionuclides in the samples was calculated after decay correction using the expression:

$$A_C = \frac{N_{sam}}{FE.\mu(E)TcMean} \quad (1)$$

Where A is the activity concentration of the radionuclides in eht Bq/kg in the samples; M_{sam} is the mass sample (kg); N_{sam} is the sample net count in the peak range; F_E is the gamma emission probability; T_C is the counting time and $\mu(E)$ is the photopeak efficiency. The Minimum Detectable Activity (MDA) for each radionuclide's, ^{238}U ^{232}Th and ^{40}K was calculated using the following:

$$MDA = \frac{1.645\sqrt{NB}}{FE.\mu(E).tc.M} \quad (2)$$

Where, 1,645 is the statistical coverage factor at 95% confidence level; N_B is the background count at the region of interest; t_c is the counting time, f_E is the gamma emission probability; $\pi(E)$ is the photopeak efficiency and M is the mass of sample. The MDA for each radionuclides were calculated as 0.30Bq/kg for ^{238}U, for 0.12Bq/kg for ^{226}Ra, 0.11 Bq/kg for ^{232}Th and 0.9Bq/kg for ^{40}K respectively.

Calculation of the Absorbed Dose Rate

The external terrestrial Gamma

radiation absorbed dose rate in air at a height of about 1 meter above the ground was calculated by using the conversion factor of 0.0414 $nGyh^{-1}/BqKg^{-1}$ for ^{40}K, 0.461 $nGyh^{-1}BqKg^{-1}$ for ^{226}Ra, and 0.623 $nGh^{-1}BqKg^{-1}$ for ^{232}Th (UNSCEAR, 1993) assuming that ^{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 (Kocher and Sjoreen, 1985, UNSCEAR, 2000).

$$D(nGh^{-1}) = 0.461C_{Ra} + 0.623C_{Th} + 0.0414_{K} \quad (3)$$

Where C_{Ra}, C_{Th} and C_k are the activity concentrations ($BqKg^{-1}$) of radium, thorium and potassium in the samples

Table 1: Radioactivity in Soil Sample ($Bqkg^{-1}$) of Esa-Oke farm settlement

Locations	^{40}K	^{226}Ra	^{232}Th
1	315.43±38.00	17.43±3.19	12.03±5.16
2	301.18±45.75	18.25±3.99	10.88±2.65
3	304.16±70.01	14.19±3.01	17.83±2.08
4	235.60±35.55	8.49±4.59	16.09±3.01
5	325.16±46.77	10.04±3.38	16.54±3.64
6	304.16±70.01	26.25±3.99	12.03±5.16
7	209.36±2.7	16.92±3.0	12.06±1.4
8	342.31±1.4	10.06±1.9	15.44±2.3
9	312.44±3.2	24.14±2.2	15.45±.12
10	310.60±3.9	14.50±1.7	15.14±1.0
Mean	296.04±31.7	16.03±3.1	14.35±2.76

Calculation of Annual Effective Dose

The annual effective dose to man (H) was calculated using the conversion factor of 0.7 $SvGy^{-1}$ for doses rates in air and an outdoor occupancy ratio of 0.2 (UNSCEAR,1988; Ajayi, 2009). Thus, the annual effective dose equivalent was obtained using equation 4.

$$H = D_R XUXKX24x365x10^{-9} \quad (4)$$

Where H is Annual effective dose measure in μSvy^{-1}; D_R is the total absorbed dose in air measured in $nGyh^{-1}$; U = 0.2 (outdoor occupancy factor), and K = 0.7 Sv/Gy (conversion factor).

Radium equivalent activity (Ra_{eq})

Ra_{eq} is used to assess the gamma radiation hazards associated with materials that contain ^{226}Ra, ^{232}Th and ^{40}K. It is assumed that 370 $Bqkg^{-1}$ of ^{226}Ra, 259 $Bqkg^{-1}$ of ^{232}Th and 4810$Bqkg^{-1}$ of ^{40}K produce similar γ-ray dose rate is given by equation 5 (Beretka and Matthew, 1985)

$$Ra_{eq} = {}^{226}Ra + 1.43\,{}^{232}Th + 0.077\,{}^{40}K \quad (5)$$

External Hazard Index H_{ex}

The external H_{ex} is an assessment of the hazard of the natural gamma radiation. H_{ex} is defined in equation 6 (Lu and Xiolan, 2006).

$$H_{ex} = A_{Ra}/370 + A_{Th}/259 + A_K/4810 \quad (6)$$

Where A_{Ra}, A_{Th} and A_K are the specific activities of ^{226}Ra, ^{232}Th and ^{40}K in $Bqkg^{-1}$ respectively.

Calculation of Lifetime Cancer Risk

Lifetime Cancer Risk was calculated using the equation 7 (Sharma *et al.*, 2014).

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

Where DL is the duration of life (*53.4 year for total population*) (*CIA World Fact book 2015)* and RF is the Risk Factor (Sv^{-1}), it is fatal cancer risk per Sievert. For stochastic effects from low dose background radiation, ICRP 103 suggested the value of 0.057 for the public exposure (ICRP, 2007).

Table 2: Gamma absorbed dose rate due to each radionuclide

Locations	$^{40}K(nGyh^{-1})$	$^{226}Ra\ (nGyh^{-1})$	$^{232}Th(nGyh^{-1})$
1	13.06	8.04	7.49
2	12.47	8.41	6.77
3	12.59	6.54	11.10
4	9.75	3.91	10.02
5	13.46	4.63	10.30
6	12.69	12.10	7.49
7	8.67	7.80	7.51
8	14.17	4.64	9.62
9	12.93	11.13	9. 63
10	12.85	6.68	9.43

RESULTS AND DISCUSSION

The activity of natural occurring radionuclides for ten locations as measured from soil samples collected in Esa-Oke Farm Settlements in Esa-Oke, Osun State, South-Western Nigeria is presented in Table 1. ^{40}K activity ranged from 209.36±2.7 to 342.31±1.4 Bqkg^{-1} with mean of 296.04±31.7 Bqkg^{-1}, ^{226}Ra ranged from 8.49±4.59 to 26.25±3.99 Bqkg^{-1} with mean of 16.03±3.1 Bqkg^{-1}, and ^{232}Th ranged from 10.88 ± 2.65 to 17.83± 2.08 Bqkg^{-1} with mean of 14.35±2.76 Bqkg^{-1}. The activity concentration of natural radionuclide in this Farm-settlement is within the global trend on the distribution of natural radionuclide in the soil (UNSCEAR, 2000).

From Table 3, the annual effective dose ranged from 29.06 to 41.35 μSvy^{-1} with mean value of 35.08 μSvy^{-1}. This is lower than world average of annual effective dose of 70.0 μSvy^{-1}.

Table 3: Total Dose (nGyh^{-1}), Annual Effective Dose (mSvy^{-1}), and Lifetime Cancer Risk at each locations

LOCATION	Total Dose D_R (nGyh^{-1})	Annual Effective Dose (μSvy^{-1})	Radium Equivalent Activity Ra_{eq}(Bqkg^{-1})	External Hazard index (H_{ex})	Excess Lifetime Cancer risk (sv^{-1})
1	28.59	35.09	58.99	0.1590	1.04×10^{-4}
2	27.65	33.93	56.99	0.1540	1.03×10^{-4}
3	30.23	37.09	63.11	0.1704	1.13×10^{-4}
4	23.68	29.06	49.64	0.13404	0.88×10^{-4}
5	28.39	34.84	58.73	0.1585	0.86×10^{-4}
6	32.28	39.61	66.86	0.1806	1.06×10^{-4}
7	23.97	29.42	50.29	0.1358	1.02×10^{-4}
8	28.43	34.89	58.49	0.1579	1.06×10^{-4}
9	33.69	41.35	70.29	0.1898	1.26×10^{-4}
10	28.96	35.54	66.07	0.1236	1.08×10^{-4}
Mean	28.59	35.08	59.95	0.1563	1.04×10^{-4}

As shown in Table 3, Ra_{eq} was ranged from 49.64 to 70.29 Bqkg^{-1} with a mean value of 59.95 Bqkg^{-1}. The maximum value must be less than 370 Bqkg^{-1} so as to keep the annual radiation dose below 1.5 mGy year^{-1} (Tufail *et al*., 2006; Muneer *et al*., 2013; Ghazwa et al., 2016). Also, H_{ex} was shown in Table 3, ranged from 0.1236 to 0.1898 with a mean value of 0.1563 which was less than unity indicating the non-hazardous category of the samples. To evaluate the radiological risk, lifetime cancer risks were calculated from annual effective dose values and it was found to vary 0.86×10^{-4} to 1.26×10^{-4} with a mean of 1.04×10^{-4}. These values were lower than world average of Lifetime cancer risks 2.9×10^{-4} (Sharma *et al*., 2014).

CONCLUSION

The absorbed dose, the annual outdoor effective dose and the associated health risk in the Esa-Oke Farm Settlement in Esa-Oke in Osun State South-Western part of Nigeria have been determined. The estimated value of total absorbed dose ranged from 23.97 to 33.69 nGh^{-1} with mean value of 28.59 nGh^{-1} and the effective dose ranged from 29.06 to 41.35 μSvy^{-1} with mean value of 35.08 μSvy^{-1} which is less than world average of 70.0 μSvy^{-1}. The mean Lifetime Cancer Risk for each person living in the Farm Settlement was estimated to be 1.04×10^{-4} Svyear which is lower than world average of Lifetime cancer risk. The analysis from this study shows that the farming activities in the Settlement did not increase the radiation burden of the environment or cause radiological hazard for the local population. The data obtained in this work can reliably serve as base line data for the assessment of any future environmental radioactivity contamination or pollution from any fallout in respect of dose rate.

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