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ASSESSMENT OF RADIOLOGICAL HAZARD INDICES OF NATURAL RADIONUCLIDES EXPOSURE TO INDIVIDUALS IN PUBLIC SCHOOLS FROM SURFACE SOILS AT SAGAMU IN OGUN STATE, NIGERIA

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ABSTRACT

Natural radionuclides are found in soil and are capable of disintegrating leading to the release of ionizing radiations that can have harmful effects on individuals exposed to them most especially when exceeded the recommended limits. Assessment of activity concentrations of ^{40}K, ^{238}U and ^{232}Th, in surface soils samples from some public primary and secondary schools in Sagamu, Ogun State in Nigeria had been determined by gamma spectrometry using NaI (TI) detector coupled with a pre-amplifier base connected to a multiple channel analyzer (MCA) which was used to calculate the radiological indicators. 10 samples were collected from areas that were densely populated based on classrooms, playing ground, assembly ground, staffroom and administrative office. The mean activity concentrations of ^{40}K, ^{238}U and ^{232}Th obtained from the soil samples were 388.61 ± 4.58 $Bqkg^{-1}$, 25.05 ± 3.87$Bqkg^{-1}$ and 39.63 ± 3.59$Bqkg^{-1}$ respectively. The mean external hazard index (H_{ex}) and mean internal hazard index (H_{in}) for all the soil samples were calculated to be 0.3015 and 0.3692 respectively, while the mean radium equivalent activity was obtained to be 111.56 $Bqkg^{-1}$. The mean absorbed dose rate value was calculated to be 53.49$nGyhr^{-1}$ with mean annual effective dose equivalent of 0.0656$mSvy^{-1}$ and the mean excess lifetime cancer risk for outdoor exposure of 0.2297 x 10^{-3}. The values of the radiological parameters: mean external hazard index and mean internal hazard index, mean radium equivalent activity, mean absorbed dose rate, and mean excess lifetime cancer risk are within the limits of 1.0, 370$Bqkg^{-1}$, 55.00nGy/hr, 1.0$mSvyr^{-1}$ and 1.45 x 10^{-3} recommended by European Commission, OECD, UNSCEAR, UNSCEAR and ICRP respectively and therefore have no negative radiological health implication to the people in the study area.

Keywords: Activity concentration, Radiological health implications, soil.

INTRODUCTION

All living things are continuously exposed to ionizing radiation from Naturally Occurring Radioactive Materials (NORM). NORM existing in soil could pose potential health risk (Wilson, 1993), especially when aided by natural processes such as weathering deposition and wind erosion (Elles *et al*., 1997). The artificial sources of radionuclides are largely due to medical and industrial activities. Studies on radiation levels and radionuclide distribution in the environment provide vital radiological baseline information. Such information is essential in estimating human exposure from natural and man-made sources of radiation and necessary in establishing rules and regulations relating to radiation protection (Quindos *et al*., 1994).

The Earth is naturally radioactive, and about 90% of human radiation exposure

arises from natural sources such as cosmic radiation, exposure to radon gas and terrestrial radionuclides (Lee *et al*., 2004). There are many sources of radiation and radioactivity in the environment. The earth and atmosphere contain varied levels from naturally radionuclides such as ^{238}U and ^{232}Th decay chains as well as singly occurring types such as ^{40}K. Soil features, geological formations, and human activities related to radiation and radioactivity are important factors enhancing the background levels of natural radiation (Colmerero Sujo et al., 2004). The continual enhancement of these radionuclides in the environment may be attributed to several factors such as the successive utilization of phosphate fertilizer, burning of fossil fuels (crude oil and coal), mining and milling operations, and building materials. Ingesting and inhaling such radionuclides contribute significantly to the radiation dose that people receive (Mart´ınez, 1989). In addition, Mining and milling of both nuclear and non-nuclear materials may cause significant environmental and occupational radiological hazards. Typically, NORM in commercial and industrial products has the potential to expose workers and members of the public to various degree of nuclear radiations. The main external source of radiation exposure to human is the gamma radiation emitted by naturally occurring radioisotopes, also called terrestrial environmental radiation (UNSCEAR 1993, 2000). These radioisotopes, such as ^{40}K and the radionuclides from the ^{232}Th and ^{238}U series and their decay products, exist at trace levels in all ground formations. Therefore, natural environmental radioactivity and the associated external exposure due to gamma radiation depend primarily on the geological and geographical conditions, and appear at different levels in the soils of each different geological region (UNSCEAR 1993, 2000). However, it has been observed that the type and concentration of radionuclides vary considerably depending on the soil type. The effects of the radiation emitted by different radionuclides depend on the over lining soil material (thickness and type), its chelating agents and physio-chemical properties (Believermis *et al*, 2009). Investigation has shown that natural radioactivity and the associated exposure due to gamma radiation depend primarily on soil type (Believermis *et al*, 2009). The interaction of ionizing radiation with the human body leads to various biological effects which may later show up as clinical symptoms (ICRP, 1990). The study of the activity concentration of radionuclides in soil and water samples in Eagle, Atlas and rock cement companies in Port Harcourt was carried out by Avwiri (2005). Soil and water samples collected from the respective locations were analyzed using the gamma -ray spectrometer. The mean absorbed dose rates in the soil samples were 49.27nGyhr^{-1}, 45.21nGyhr^{-1} and 42.33nGyhr^{-1} for Eagle, Atlas and Rock cements companies respectively while the values for water samples were 22.16nGyhr^{-1}, 20.75nGyhr^{-1} and 19.37nGyhr^{-1} for the respective companies. Mean annual effective dose equivalents of 0.18mSvyr^{-1} and 0.39mSvyr^{-1} were obtained for the water and soil samples respectively. The results obtained by Avwiri (2005) are lower than the International Commission on Radiological Protection (ICRP, 1992) maximum permitted limit of 1.0mSvyr^{-1} and therefore, have no significant radiological health burden on the environment and the populace. Also, Sowole (2014) studied the activity concentrations of radionuclides in surface soil samples of major markets in Sagamu and obtained the highest radioactivity concentrations of ^{40}K, and ^{238}U from Falawo market surface soil samples with values 1274.26 ± 4.26Bqkg^{-1} and 40.72 ± 3.12Bqkg^{-1} respectively while that of ^{232}Th was obtained from Sabo market surface soil sample with value 115.62 ± 16.39Bqkg^{-1}. The mean external hazard index (Hex) and mean internal hazard index (Hin) for all the soil samples from Falawo market were

calculated to be 0.616 $Bqkg^{-1}$ and 0.691$Bqkg^{-1}$ respectively, and that of Awolowo market were 0.566 $Bqkg^{-1}$ and 0.634 $Bqkg^{-1}$ respectively. Also for Sabo market the mean values were calculated to be 0.594 $Bqkg^{-1}$ and 0.658 $Bqkg^{-1}$ respectively. All the values obtained were less than 1.0 $Bqkg^{-1}$ as recommended by International Commission on Radiological Protection (ICRP, 1992) and therefore have no negative radiological health implication to the people within the markets and their environs.

The objective of this work however is to measure the activity concentration of ^{40}K, ^{238}U and ^{232}Th in surface soil samples from some public primary and secondary schools in Sagamu, Ogun State, Nigeria and determine the radiological hazard on human due to exposure to these naturally occurring radionuclides. The measured activity concentrations of these natural radionuclides would be used to estimate the internal and external hazard indices, radium equivalent activity and absorbed dose rate in air and risk to individuals within the study area.

MATERIALS AND METHOD

Surface soil samples were collected randomly at different locations within the schools in the study area, Ten (10) samples were collected at the depth ranging from 0.0cm to 20.0cm putting into consideration areas that are densely populated based on classrooms, playing ground, assembly ground, staffroom and administrative office. The samples were put in different containers and taken to the laboratory to oven dry for about seventy two hours (72.0hrs) at a temperature of about 110^0C at a constant weight and relative humidity of about 70% as recommended by IAEA (1989). Each dried soil samples was crushed and sieved using a 2 mm mesh screen.

$$A = \frac{N(E_\gamma)}{\varepsilon(E_\gamma) I_\gamma M t_c} \quad \text{---------- 1.0}$$

The dried samples were then packed 175.0 g by mass in labeled cylindrical plastic containers of uniform base diameter of 5.0 cm which could sit on the 7.6 cm by 7.6 cm NaI (Tl) detector. The plastic containers were tightly covered, sealed and left for 28 days prior to counting, for attainment of secular equilibrium between ^{238}U and ^{232}Th and their respective progenies (Papaefthymiou *et al*, 2007).

The method of gamma spectrometry was adopted for the analysis of the samples collected in order to obtain the activity concentration of ^{40}K, ^{238}U and ^{232}Th. The spectrometer used was a Canberra lead shielded 7.6cm x 7.6cm NaI (Tl) detector coupled to a multichannel analyzer (MCA) through a preamplifier base. The system was calibrated using standard point sources of gamma emitting isotopes. The resolution of the detector is about 10% at 0.662MeV of ^{137}Cs. The value is good enough for NaI detector to distinguish the gamma ray energies of most radionuclides in samples. For the analysis of ^{40}K, ^{238}U and ^{232}Th, the photo peak regions of ^{40}K (1.46 MeV), ^{214}Bi (1.76 MeV) and ^{208}TI (2.615 MeV) were used respectively.

The cylindrical plastic containers holding the samples were put to sit on the high geometry 7.6cm x 7.6cm NaI (TI) detector. High level shielding against the environmental background radiation was achieved by counting in a Canberra 10cm thick lead castle. The counting of each sample was done for 10.0 hours. Spectral analysis was performed and the areas under the photo-peaks of ^{40}K, ^{238}U and ^{232}Th were analyzed using the Multichannel Analyzer system.

The activity concentrations of the radionuclides were calculated based on the measured efficiency of the detector and the net count rate under each photo peak over a period of 10.0 hours using equation 1.0 (IAEA, 1989)

Where: $N(E_\gamma)$ = Net peak area of the radionuclide of interest, $\varepsilon(E_\gamma)$ = Efficiency of

the detector for the γ- energy of interest, I_γ = Intensity per decay for the γ- energy of interest, M = Mass of the sample, t_c = Total counting time in seconds (36000s)

The radiological indicators which are parameters used to assess the radiological implications to individuals exposed to the soil are: radium equivalent activity (Ra_{eq}), internal hazard index (H_{in}) and external hazard index (H_{ex}). The Ra_{eq} was calculated by the equation described by Beretka *et al*(1985) and Yang *et al*(2005) as indicated by equation 2.0

$$Ra_{eq} = \frac{10}{130}C_k + \frac{10}{7}C_{Th} + C_{Ra} \quad \text{---------- 2.0}$$

Where C_{Ra}, C_{Th} and C_K were the activity concentrations in $Bqkg^{-1}$ of ^{226}Ra, ^{232}Th and ^{40}K respectively. The external hazard index (H_{ex}) commonly used to evaluate radiation dose rate due to external exposure to gamma radiation from natural radionuclides in soil samples as reported by Hamzah *et al* (2008) was presented in equation 3.0.

$$H_{ex} = \frac{C_k}{4810} + \frac{C_{Th}}{259} + \frac{C_{Ra}}{370} \quad \text{---------- 3.0}$$

The internal hazard index (H_{in}) is a parameter for estimating the negative effect of radioactive materials on lungs and other respiratory organ. The risk internal exposure due to the natural radionuclides ^{40}K, ^{226}Ra and ^{232}Th can be assessed from the value of H_{in} using equation 4:

$$H_{in} = \frac{C_k}{4810} + \frac{C_{Th}}{259} + \frac{C_{Ra}}{185} \quad \text{---------- 4.0}$$

In addition, considering the definition of the absorbed dose rate in air for external gamma radiation at about 1.0m above the ground from the natural radionuclides D($nGyhr^{-1}$) given by UNSCEAR (2000),

$$D\ (nGyhr^{-1}) = 0.0417C_k + 0.604C_{Th} + 0.462C_{Ra} \quad \text{---------- 5.0}$$

The absorbed dose rate in air was used to estimate the annual outdoor effective dose equivalent for individuals. The effective dose conversion factor was taken to be 0.7 $Sv.Gyr^{-1}$and an outdoor occupancy factor of 0.2 with the annual occupancy time approximately 8760 hr y^{-1}. Hence the annual effective dose equivalent was estimated using the equation:

$$H_E\ (mSvyr^{-1}) = D\ (nGyhr^{-1}) \times 8760(hryr^{-1}) \times 0.2 \times 0.7(SvGy^{-1}) \times 10^{-6} \quad \text{---------- 6.0}$$

Excess lifetime cancer risk (ELCR) was calculated based on the values of the annual outdoor effective dose equivalent using the equation:

$$ELCR = H_E \times LE \times RF \quad \text{---------- 7.0}$$

where LE is life expectancy taken to be 70 years and RF is fatal risk factor per sievert which is 0.05 (ICRP, 1992)

RESULTS AND DISCUSSION

The activity concentration of ^{40}K, ^{238}U and ^{232}Th from the surface soil samples ranged from 249.15 ± 3.64$Bqkg^{-1}$ to 542.62 ± 6.25$Bqkg^{-1}$ with a mean of 388.61 ± 4.58$Bqkg^{-1}$, 12.54 ± 1.65$Bqkg^{-1}$ to 38.25 ± 6.01$Bqkg^{-1}$ with a mean of 25.05 ± 3.87$Bqkg^{-1}$ and 25.18 ± 2.64$Bqkg^{-1}$ to 55.36 ± 4.95$Bqkg^{-1}$ with a mean of 39.63 ± 3.59$Bqkg^{-1}$ respectively as shown in table 1. ^{40}K has the highest radioactivity concentration while ^{238}U recorded the lowest value. The activity concentrations are within the range of values for normal background area (Akinloye and Olomo, 1995). The external hazard index (H_{ex}) ranged from 0.2456 to 0.3674 with a mean of 0.3015 as shown in table 2. Furthermore, internal hazard index (H_{in}) ranged from 0.2837 to 0.4370 with mean value of 0.3692. The values are within the limit of safety value of 1.0 recommended by European Commission (1999). More so, radium equivalent activity (Ra_{eq}) ranged from 90.88$Bqkg^{-1}$ to 135.95$Bqkg^{-1}$ with a mean

value of 111.56Bqkg^{-1}, and is below the limit of 370Bqkg^{-1} (OECD, 1979; Beretka *et al*, 1985). The study made by Akinloye *et al* (2012) on surface soil of Ore metropolis, Ondo State, Nigeria gave similar result for radium equivalent activity ranging from 33.39 ± 2.44 to 85.07 ± 2. 96 Bqkg^{-1}, though this is lower than the results obtained in this work.

Table 1. Radioactivity concentrations of natural radionuclides in soil samples

SAMPLE	LOCATION	ACTIVITY CONCENTRATION (**Bqkg^{-1}**)		
		^{40}K	**^{238}U**	**^{232}Th**
S_1	Remo Divisional High School	542.62 ± 6.25	24.46 ± 3.25	36.24 ± 2.16
S_2	Remo Divisional High School	465.27 ± 5.78	26.34 ± 4.02	41.26± 3.24
S_3	Wesley Primary School II Oko	386.25 ± 4.62	38.25 ± 6.01	25.18 ± 2.64
S_4	Wesley Primary School II Oko	464.29 ± 3.37	18.46 ± 2.89	42.37 ± 3.01
S_5	Remo Secondary School	482.68 ± 5.46	25.73 ± 3.26	51.16 ± 5.24
S_6	Remo Secondary School	265.23 ± 3.25	31.18 ± 5.24	46.75 ± 4.18
S_7	Methodist Comprehensive High School	327.65 ± 4.21	12.54 ± 1.65	38.29 ± 3.94
S_8	Methodist Comprehensive High School	285.74 ± 3.84	21.36 ± 3.49	55.36 ± 4.95
S_9	Sagamu High School	249.15 ± 3.64	32.79 ± 5.71	27.25 ± 3.64
S_{10}	Sagamu High School	417.26 ± 5.38	19.36 ± 3.21	32.48 ± 2.87
	RANGE	**249. 15 – 542.62**	**12.54 – 38.25**	**25.12 – 55.36**
	MEAN	**388.61 ± 4.58**	**25.05 ± 3.87**	**39.63 ± 3.59**

Data represent the mean ± standard deviation of replicate readings.

Table 2. Determined values of radiological indicators from surface soil samples

SAMPLE	**Ra_{eq}(Bq.kg^{-1})**	**H_{in}**	**H_{ex}**	**D(nGy.hr^{-1})**	**H_E(mSvy^{-1})**	**ELCR x 10^{-3} (Outdoor)**
S_1	117.97	0.3850	0.3188	57.44	0.0705	0.2468
S_2	121.07	0.3984	0.3272	58.35	0.0716	0.2506
S_3	103.93	0.3843	0.2809	49.44	0.0606	0.2121
S_4	114.70	0.3599	0.3100	55.66	0.0683	0.2391
S_5	135.95	0.4370	0.3674	65.41	0.0802	0.2807
S_6	118.37	0.4042	0.3199	55.68	0.0683	0.2391
S_7	92.44	0.2837	0.2499	44.66	0.0548	0.1918
S_8	122.43	0.3886	0.3309	58.06	0.0712	0.2492
S_9	90.88	0.3343	0.2456	42.71	0.0524	0.1834
S_{10}	97.86	0.3168	0.2645	47.48	0.0582	0.2037
RANGE	**90.88 – 135.95**	**0.2837 – 0.4370**	**0.2456 – 0.3674**	**42.71 – 58.35**	**.0524 – 0.0802**	**0.1834 – 0.2807**
MEAN	**111.56**	**0.3692**	**0.3015**	**53.49**	**0.0656**	**0.2297**

The absorbed dose rate in air; ranged from 42.71nGyhr^{-1} to 58.35nGyhr^{-1} with a mean value of 53.49nGyhr^{-1} which is less than the limit of 55.00nGyhr^{-1} worldwide mean value as reported by UNSCEAR (2000) and the annual outdoor effective dose equivalent ranged from 0.0524mSvyr^{-1} to 0.0802mSvyr^{-1} with a mean value of 0.0656mSvyr^{-1} which is below the limit of 1.0mSvy^{-1} (UNSCEAR, 2000). The excess lifetime cancer risk for outdoor exposure ranged from 0.1834 x 10^{-3} to 0.2807 x 10^{-3} with mean value of 0.2297 x 10^{-3} which is below the world's average of 1.45 x 10^{-3} (ICRP, 1992; Qureshi *et al*, 2014).

Similarly, Ramasamy *et al* (2009) carried out the evaluation of (ELCR) in river sediments of Karnataka and Tamilnadu, India. The average of (ELCR) was found to be 0.20 $x10^{-3}$ which is less than the world's average.

CONCLUSION

The radiological safety of the people within some public primary and secondary schools in Sagamu had been assessed and the results obtained for the radiological parameters were within the safety limits recommended: the external hazard index (H_{ex}) mean value of 0.3015, internal hazard index (H_{in}) mean value of 0.3692. The mean value was calculated to be 0.3692Bqkg^{-1}. The values are within the limit of safety value of 1.0 recommended by European Commission. Radium equivalent activity (Ra_{eq}) had mean value of 111.56Bqkg^{-1}, which is below the limit of 370Bqkg^{-1} as recommended by OECD. The excess lifetime cancer risk for outdoor exposure mean value was below the world's average. These show that there are no significant radiological hazards to individuals from the exposure to natural radionuclides in surface soils from the study area.

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