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RADIOMETRIC ASSESSMENT OF THE RADIOLOGICAL HEALTH IMPLICATIONS ASSOCIATED WITH THE EXPLOITATION OF MAJOR NIGERIAN FOSSIL FUELS

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ABSTRACT

Gamma spectroscopic technique was used to determine qualitatively and quantitatively the natural radionuclides present in the prominent fossil fuels found in Nigeria (bitumen, coal and crude oil). The radiological health indexes emanating from these radionuclides were then estimated with a view to ascertaining the radiological health consequences associated with the exploitation of these fuels. The results show that the total radioactivity contents are 61.5 $\pm$ 8.2 $Bq\,kg^{-1}$in bitumen, 32.5 $\pm$ 1.5$Bq\,kg^{-1}$in coal and 0.04 $\pm$ 0.01$Bq\,kg^{-1}$in crude oil. The mean radium equivalent values are (30.81, 28.22 and 0.06) $Bqkg^{-1}$ respectively while the respective external and internal hazard indexes are (0.083, 0.076 and 1.51 x 10^{-5}) $Bqkg^{-1}$ and (0.159, 0.123 and 3.03 x 10^{-5}) $Bqkg^{-1}$. The mean annual dose equivalent values are (0.017, 0.016 and 3.06 x 10^{-5}) $mSvyr^{-1}$ respectively. These values are below those stipulated in radiation protection. The radiological health consequences associated with the exploitation of the three major Nigerian fossil fuels therefore is insignificant.

Keywords: Radiometric assessment, Exploitation, Nigeria fossil fuels, insignificant radiological health consequence

INTRODUCTION

Presently the major fossil fuels in Nigeria are coal, crude oil and bitumen of which the most exploited is crude. As geological materials, these are known to be largely associated with naturally Occurring Radioactive Materials (NORM). Thus they contain ^{238}U /^{226}Ra, ^{232}Th and ^{40}K (Balogun et al, 2003). This radioactive contamination of geological materials has become of concern in radiation protection as these NORM are known to have reached hazardous levels (Eldine et al, 2001). In fact they have been found to be capable of resulting in much larger radiological exposure to the public relative to that caused by the nuclear industry for instance (Mokobia et al, 2006). Thus there are health implications of this contamination both on the exploiters and those living in the immediate environments where exploitation is being carried out.

One aspect of this has to do with ^{222}Rn (radon) a member of the ^{238}U/^{226}Ra (Uranium) decay series (Mokobia, 2004a: 2010). This short-lived radioactive gas (0.83days) decays into much shorter-lived ^{218}Po (Polonium) and ^{214}Pb (Lead) emitting α particle which causes cancer of the lungs if breathed in (Mokobia, 2004b). Consequent upon these, this study sought to investigate the radiological implications associated with the exploitation of these major Nigerian fossil fuels. Specifically, the qualitative and quantitative determinations of their natural radionuclide contents were carried out using gamma spectrometric technique. The quantitative data obtained were then used to estimate the associated radiological hazard indexes. The values obtained were then compared with radiological health international stipulations and the associated radiological health implications ascertained.

MATERIALS AND METHOD

Coal samples of the Permian age were obtained from various locations around Enugu (latitude $6^\circ 26' N$ and longitude $7^\circ 30' E$) the major location of Nigerian bituminous coal (Mokobia et al, 2006; Mokobia and Balogun, 2004). Surface samples of bituminous sands of the early cretaceous age were collected from locations lying within the East-West belt stretching across Lagos, Ogun, Ondo and Edo States in South Western Nigeria stretching from latitude $(6^\circ 24' \ to \ 6^\circ 25') N$ and longitude $(3^\circ 48' \ to \ 6^\circ 48') E$. The crude oil samples largely of the cretaceous age were obtained from Mobil Nigeria offshore locations at Eket (latitude $5^\circ 40' N$ and longitude $8^\circ 01' E$) Known masses of these fuels were separately weighed into Marinelli beakers. These beakers were then securely sealed and left for 28 days in accordance with conventional practice (Balogun et al, 2003; Mokobia et al, 2006; Mokobia, 2005). Natural radioactivity measurement was performed using a Canberra vertical high-purity germanium coaxial detector (HPGe) based gamma spectrometer. This semiconductor device having a volume of 155 mm^3 was enclosed in a 100 mm thick lead shield to minimize the interfering effects of the radiation from sources other than the samples and natural radiation from the environment where the counting was carried out. Energy as well as efficiency calibrations of the device was carried out using a mixed source soil standard obtained from the International Atomic Energy Agency (IAEA). Each of the samples as well as the standard and the background were counted for 10 hrs. It was ensured that the sample containers and that of the standard have the same configuration so as to minimize error. Spectra evaluation was carried out using a PC based SAMPO 90 computer program capable of matching the γ- energies at various levels to a library of possible isotopes. The specific activities of the radionuclides detected in each of the studied samples were calculated using the comparative approach:

$$A_s = \frac{N(E_\gamma)_s M_d A_d}{N(E_\gamma)_d M_s} \qquad [1]$$

A_s is the specific activity in Bqkg^{-1} of the identified nuclide having a net photopeak area $N(E_\gamma)_s$ contained in a sample of mass M_s in kg. A_d is the activity of this nuclide contained in the mixed standard of mass M_d in kg. $N(E_\gamma)_d$ is the net photopeak area of the said nuclide. This approach was adopted because it is acclaimed to be relatively more accurate compared with the absolute method (Gilmore and Hemingway, 2002).

Radium – equivalent activity was calculated using the relationship (Tufail et al 2000; Kharter t al, 2001; Frame, 2009):

$$A_{Ra_{eq}} = A_{Ra} + 1.43 A_{Th} + 0.077 A_K \qquad [2]$$

The external and internal health hazard indexes arising from the use of this mineral was determined by employing the equations used in (Mokobia, 2010; Tufail et al, 2000):

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad [3]$$

$$H_{int} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad [4]$$

A_{Ra}, A_{Th} and A_K represent the activity concentrations of $^{238}U/^{226}Ra$, ^{232}Th and ^{40}K in $Bqkg^{-1}$ respectively. The annual effective dose rate ($mSvy^{-1}$) was determined using the relationship:

$$E = TQD_t * 10^{-6} * F_t \quad [5]$$

D_t, the outdoor dose rate in air ($nGyh^{-1}$) was obtained from the relation (Farai and Jibiri, 2000):

$$D_t = 0.446A_{Ra} + 0.662A_{Th} + 0.048A_K \quad [6]$$

10^{-6} represents a conversion factor, T is 8760 hours per year, Q = 0.7 $SvGy^{-1}$ and F_t = 0.2 is the outdoor occupancy factor.

RESULTS AND DISCUSSION

In Table 1, the specific activities of the primordial radionuclides detected in these fuels, their determined radium equivalent activities and the consequent external and internal hazard indexes as obtained in this work for each of them are presented. The radionuclides detected belong to the $^{226}Ra/^{238}U$; $^{228}Ra/^{232}Th$ decay series with specific activities ranging from 0.04 ± 0.01 $Bqkg^{-1}$ in crude to 28.2 ± 3.7 $Bqkg^{-1}$ in bitumen and 7.5 ± 0.4 $Bqkg^{-1}$ in coal to 33.3 ± 4.5 $Bqkg^{-1}$ in bitumen respectively. The non decay series ^{40}K (mean specific activity 7.8 ± 0.2 $Bqkg^{-1}$) was only detected in the coal samples. This shows that ^{40}K is not the major contributor to the radioactivity in these fossils unlike the results obtained for some other geological materials (Turhan et al, 2008; Ngachin et al 2008). The values of the mean specific activities of the primordial radionuclides detected in these studied samples are lower than the values obtained for some other geological materials such as marble (Tufail et al, 2000; Mokobia, 2008; Turhan, 2009), kaolin (Zoltan et al, 2005) and liquid paints (Mokobia et al, 2003). The total radioactivity contents of the fossils are (61.5 ± 8.2, 32.5 ± 1.5 and 0.04 ± 0.01) $Bqkg^{-1}$ for bitumen, coal and crude respectively. Radioactivity content is least in the crude samples. This low radioactivity observed for the crude falls within the range 0.02 to 0.2 $Bq(^{226}Ra)kg^{-1}$ given in the literature (SPIM, 1993).

The calculated mean values for the external hazard indexes are (0.08, 0.08 and 1.51 $\times10^{-4}$) $Bqkg^{-1}$ for coal, bitumen and crude oil respectively. These values are each less than unity. This suggests that the exploitation of these fossils does not constitute any radiological effect of threat to the public around the locations of the exploitation. Indoor ^{226}Ra accumulation has been established to cause exposure to persons through the inhalation of its progeny ^{222}Rn (Mokobia, 2004b; Hizem et al, 2005). The estimated internal hazard indexes following the indoor exposure of members of the public around the immediate locations where exploitation is carried out are (0.12, 0.16 and 3.03 x 10^{-4}) $Bqkg^{-1}$ in that order. These values are each less than unity. This indicates that indoor radiological health implication is insignificant.

The mean annual effective dose equivalent determined for coal and bitumen are each 0.02 $mSvy^{-1}$. This value is less than the recommended value of 1$mSvy^{-1}$ (2%) for non radiation workers (members of the public) by the International Commission on Radiological Protection (ICRP, 1990). The value obtained for the crude samples is 0.0003 $mSvy^{-1}$ (.03%). The fact that these values of dose equivalent are less than the recommended unity also suggests that radiation dose to members of the public resulting from the exploitation of these Nigeria fossils has negligible radiological consequence. As shown in Figure 1, of these three fossil fuels studied, the exploitation of crude oil is associated with the least radiological hazard relative to coal and bitumen.

CONCLUSION

From the results, it is concluded that the radiological health consequences associated with the exploitation of the three major Nigerian fossil fuels from the standpoint of radiation protection is insignificant.

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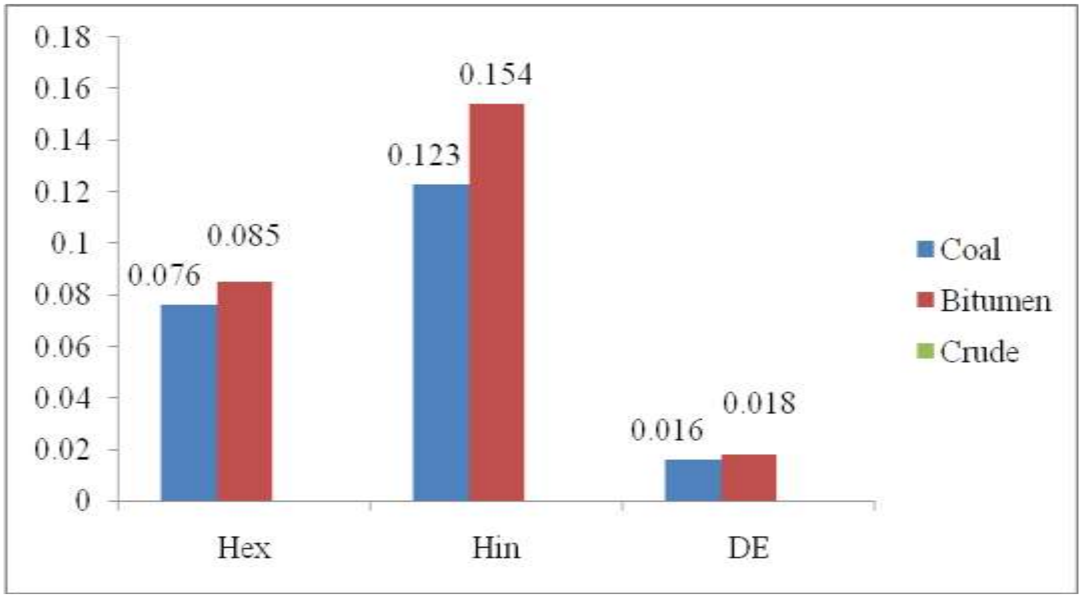
Table 1: Activities of Nuclides in Nigerian Fossils and the Corresponding Determined Hazard Indexes

Sample	^{40}K (Bq kg^{-1})	$^{238}U/^{226}Ra$ (Bq kg^{-1})	$^{232}Th/^{228}Ra$ (Bq kg^{-1})	External hazard index (Bqkg^{-1})	Internal hazard index (Bqkg^{-1})	Annual effective dose (mSvy^{-1})
Coal						
FC1	7.1 ± 0.02	13.2 ± 0.4	7.1 ± 0.1	0.065	0.100	0.013
FC2	8.7 ± 0.02	19.0 ± 1.6	6.4 ± 0.4	0.078	0.129	0.016
FC3	7.6 ± 0.03	16.1 ± 0.6	6.0 ± 0.5	0.068	0.112	0.014
Fc4	8.0 ± 0.01	17.5 ± 0.4	9.5 ± 0.3	0.086	0.133	0.018
FC5	7.5 ± 0.01	20.1 ± 1.8	7.5 ± 0.5	0.085	0.139	0.018
Mean	7.8 ± 0.2	17.2 ± 0.9	7.5 ± 0.4	0.076	0.123	0.016
Crude Oil						
FCO1	ND	0.05 ± 0.004	ND	1.35×10^{-4}	2.70×10^{-4}	2.73×10^{-4}
FCO2	ND	0.07 ± 0.008	ND	1.89×10^{-4}	3.78×10^{-4}	3.83×10^{-4}
FCO3	ND	0.04 ± 0.003	ND	1.08×10^{-4}	2.16×10^{-4}	2.19×10^{-4}
FCO4	ND	0.07 ± 0.004	ND	1.89×10^{-4}	3.78×10^{-4}	3.83×10^{-4}
FCO5	ND	0.05 ± 0.006	ND	1.35×10^{-4}	2.70×10^{-4}	2.73×10^{-4}
Mean	ND	0.04 ± 0.005	ND	1.51×10^{-4}	3.03×10^{-4}	3.06×10^{-4}
Bitumen						
FB1	ND	29.1 ± 4.6	35.9 ± 5.4	0.086	0.165	0.018
FB2	ND	28.2 ± 3.3	36.9 ± 5.7	0.084	0.160	0.018
FB3	ND	26.7 ± 3.2	30.7 ± 3.5	0.079	0.151	0.016
FB4	ND	28.1 ± 4.0	32.6 ± 3.5	0.083	0.159	0.017
FB5	ND	29.1 ± 3.6	30.6 ± 4.6	0.085	0.154	0.018
Mean	ND	28.2 ± 3.7	33.3 ± 4.5	0.083	0.159	0.017

a) **Coal, Bitumen and Crude oil**



b) **Crude oil**

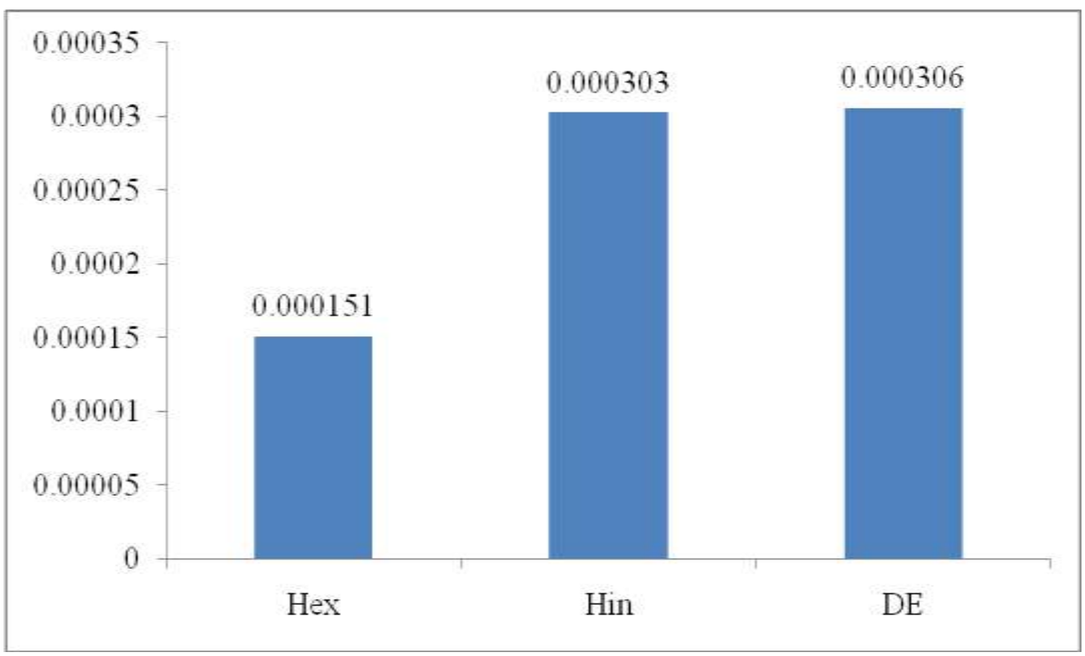


Fig. 1: Graph of the Relative Hazard Indexes of Three Nigerian Prominent Fossil Fuels

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