Science World Journal Vol 9 (No 3) 2014
www.scienceworldjournal.org
ISSN 1597-6343

Full Length Research Article

ASSESSMENT OF RADIOLOGICAL HAZARD INDICES FROM SURFACE SOIL TO INDIVIDUALS FROM MAJOR MARKETS AT SAGAMU OGUN STATE, NIGERIA

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ABSTRACT
Assessment of radioactivity concentrations of ^{40}K, ^{238}U and ^{232}Th in surface soil samples of major markets at Sagamu, Ogun State in Nigeria had been determined by gamma spectrometry using Sodium Iodide Thallium doped NaI (TI) detector coupled with a pre-amplifier base to a multiple channel analyzer (MCA). 10 samples each were collected from three major markets: Falawo, Awolowo and Sabo. Highest radioactivity concentrations of ^{40}K, and ^{238}U were obtained from Falawo market soil samples with values 1274.26 ± 4.26 Bq/kg and 40.72 ± 3.12 Bq/kg respectively while that of ^{232}Th was obtained from Sabo soil sample with value 115.62 ± 16.39 Bq/kg. The mean external hazard index (H_{ex}) and mean internal hazard index (H_{in}) for all the soil samples from Falawo market were calculated to be 0.616 Bq/kg and 0.691Bq/kg respectively, and that of Awolowo market were 0.566 Bq/kg and 0.634 Bq/kg respectively. Also for Sabo market the mean values were calculated to be 0.594 Bq/kg and 0.658 Bq/kg respectively. All the values obtained were less than 1.0 Bq/kg as recommended for safety and therefore have no negative radiological health implication to the people within the markets and their environs.

Keywords: Radioactivity concentration, radionuclide, hazard index, surface soil.

INTRODUCTION

All living things are continuously exposed to ionizing radiation from Naturally Occurring Radioactive Materials (NORM). Naturally occurring radioactive materials (NORM) existing in soil could pose potential health physics risk (Wilson, 1993), especially if assisted by natural processes such as weathering deposition and wind erosion (Elles *et al*., 1997). The artificial sources 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 understanding 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 of naturally sourced 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 continuity in increasing 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 levels of 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 impacts, and, typically, NORM in commercial and industrial products has the potential to expose workers and members of the public to some fraction of the recommended annual radiation exposure limit. The main external source of irradiation to the human body is represented by the gamma radiation emitted by naturally occurring radioisotopes, also called terrestrial environmental radiation. 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 Reports). However, it has been observed that the type and concentration vary considerably depending on the soil type. The effects of the radiation emitted by different radionuclides depend on the overlining 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 (from radionuclides) depend primarily on geology (soil type).

The interaction of ionizing radiation with human body leads to various biological effects which may later show up as clinical symptoms (ICRP, 1990).
The study of the radionuclide concentration levels 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 premises were analyzed using the gamma -ray spectrometry. The average absorbed dose rates of the soil samples were 49.27nGy/h, 45.21nGy/h and 42.33nGy/h for Eagle, Atlas and Rock cements respectively while the water values were 22.16nGy/h, 20.75nGy/h and 19.37nGy/h for the respective companies. Mean dose rate equivalents of 0.18mSv/y and 0.39mSv/y were obtained for the water and soil samples. These results are lower than the International Commission on Radiological Protection (ICRP, 1992) maximum permitted limit and therefore, have no significant radiological health burden on the environment and the populace.

The objective of this work however is to determine the radioactivity level of naturally occurring ^{40}K, ^{238}U and ^{232}Th in surface soil samples from major markets at Sagamu, in Ogun State of Nigeria. The measured radioactivity concentrations would thereafter translate to the calculation of the internal and external hazard indices in order to assess the radiological implication to the people within the markets in selling and buying processes, and those involved in other activities.

MATERIALS AND METHODS

Surface soil samples were collected randomly at different points within three major markets: Falawo, Awolowo and Sabo at Sagamu in Ogun State, southwest of Nigeria. Ten (10) samples each were collected from the markets at the same depth from 0.0cm to 20.0cm. A total of thirty soil samples were collected. They were put in different containers and taken to the laboratory to dry for about seventy two hours (72.0hrs) under laboratory temperature of about 27^0C and relative humidity of about 70% (IAEA, 1989). Each dried soil sample was crushed and sieved using a 2 mm mesh screen. The dried samples were then packed 150.0 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, 2007).

The method of gamma spectrometry was adopted for the analysis of the samples collected in order to obtain data on ^{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. According to Jibiri and Farai (1998) the value is good enough for NaI detector to distinguish the gamma ray energies of most radionuclides in the 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 respectively used.

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 because of suspected low activities of the radionuclides in the samples. The areas under the photo-peaks of ^{40}K, ^{238}U and ^{232}Th were computed using the Multichannel Analyzer system.

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

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

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)
External hazard index (H_{ex}) as expressed in equation 2.0 (Hamzah, 2008) and internal hazard

$$H_{ex} = \frac{C_k}{4810} + \frac{C_{Th}}{259} + \frac{C_{Ra}}{370} \leq 1 \qquad 2.0$$

index (H_{in}) as expressed in equation 3.0 were used as radiological indicators to estimate the radiological implications of the natural radionuclides in the surface soil on the people in the market.

$$H_{in} = \frac{C_k}{4810} + \frac{C_{Th}}{259} + \frac{C_{Ra}}{185} \leq 1 \qquad 3.0$$

C_k, C_{Th} and C_{Ra} are the radioactivity concentrations of ^{40}K, ^{232}Th and ^{226}Ra respectively.

RESULTS AND DISCUSSION

The highest radioactivity concentration of ^{40}K from Falawo market soil sample was obtained to be 1274.26 ± 4.26 Bq/kg and the lowest was 785.49 ± 2.23 Bq/kg. For ^{238}U, the highest radioactivity concentration value was 40.72 ± 3.12 Bq/kg and the lowest value was obtained to be 15.48 ± 1.76 Bq/kg. Moreso, ^{232}Th had the highest radioactivity concentration value of 112.83 ± 15.35 Bq/kg and lowest value of 65.31 ± 7.24 Bq/kg as shown in table 1.0. Concerning all the radionuclides, ^{40}K had the highest radioactivity concentration value while the lowest was from ^{238}U. No artificial radionuclide was detected in all the samples.The highest external hazard index (H_{ex}) was obtained to be 0.746 Bq/kg while the lowest was 0.500 Bq/kg . The mean value was calculated to be 0.616 Bq/kg. Furthermore, the highest internal hazard index (H_{in}) was obtained to be 0.823 Bq/kg while the lowest was 0.571 Bq/kg. The mean value was calculated to be 0.691 Bq/kg.

For Awolowo market soil samples, the highest radioactivity concentration of ^{40}K was obtained to be 1064.84 ± 5.36 Bq/kg and the lowest was 568.73 ± 2.86 Bq/kg. For ^{238}U, the highest radioactivity concentration value was 40.26 ± 2.84 Bq/kg and the lowest value was obtained to be 14.08 ± 1.86 Bq/kg. Also, ^{232}Th had the highest radioactivity concentration value of 110.02 ± 14.85 Bq/kg and lowest value of 48.35 ± 6.37 Bq/kg as shown in table 2.0. Concerning all the radionuclides, ^{40}K has the highest radioactivity concentration value while the lowest was from ^{238}U as shown in table 2.0. No artificial radionuclide was detected in all the samples. The highest external hazard index (H_{ex}) was obtained to be 0.688 Bq/kg while the lowest was 0.438 Bq/kg . The mean value was calculated to be 0.566 Bq/kg. Furthermore, the highest internal hazard index (H_{in}) was obtained to be 0.775 Bq/kg while the lowest was 0.485 Bq/kg. The mean value was calculated to be 0.634 Bq/kg.

Also, for Sabo market soil samples, the highest radioactivity concentration of ^{40}K was obtained to be 1124.85 ± 6.58 Bq/kg and the lowest was 748.68 ± 3.01 Bq/kg. For ^{238}U, the highest radioactivity concentration value was 32.34 ± 3.28 Bq/kg and the lowest value was obtained to be 16.64 ± 2.82 Bq/kg. Also, ^{232}Th had the highest radioactivity concentration value of 115.62 ± 16.39 Bq/kg and lowest value of 56.24 ± 8.02 Bq/kg as shown in table 3.0. Concerning all the radionuclides, ^{40}K had the highest radioactivity concentration value while the lowest was from ^{238}U as shown in table 3.0. No artificial radionuclide was detected in all the samples. The highest external hazard index (H_{ex}) was obtained to be 0.735 Bq/kg while the lowest was 0.470 Bq/kg. The mean value was calculated to be 0.594 Bq/kg. Furthermore, the highest internal hazard index (H_{in}) was obtained to be 0.819 Bq/kg while the lowest was 0.521 Bq/kg. The mean value was calculated to be 0.658 Bq/kg. The mean values are less than 1.0 Bq/kg as recommended for safety globally (EC, 1999).

Table 1.0: Radioactivity concentrations, external and internal indices of Falawo soil samples

MARKET	SAMPLE	RADIOACTIVITY CONCENTRATIONS OF SOIL SAMPLES (Bq/kg)			H_{ex} (Bq/kg)	H_{in} (Bq/kg)
		^{40}K	^{238}U	^{232}Th		
FALAWO	C_1	1274.26 ± 4.26	36.58 ± 2.78	65.31± 7.24	0.616	0.715
	C_2	1025.38 ± 3.96	20.17 ± 2.26	95.24 ± 10.46	0.635	0.690
	C_3	865.94 ± 2.54	21.35 ± 2.32	85.10 ± 8.37	0.566	0.624
	C_4	798.16 ± 2.25	15.48 ± 1.76	101.27 ± 11.08	0.599	0.641
	C_5	984.36 ± 3.26	32.74 ± 2.61	104.18 ± 12.14	0.695	0.784
	C_6	1092.47 ± 4.05	40.72 ± 3.12	72.95 ± 8.02	0.619	0.729
	C_7	1126.28 ± 4.15	28.25 ± 2.45	112.83 ± 15.35	0.746	0.823
	C_8	847.32 ± 2.31	18.59 ± 1.84	92.37 ± 10.22	0.583	0.633
	C_9	785.49 ± 2.23	26.24 ± 2.40	68.74 ± 7.63	0.500	0.571
	C_{10}	925.73 ± 3.06	34.62 ± 2.55	82.65 ± 7.98	0.605	0.699

Table 2.0: Radioactivity concentrations, external and internal indices of Awolowo soil samples

MARKET	SAMPLE	RADIOACTIVITY CONCENTRATIONS OF SOIL SAMPLES (Bq/kg)			H_{ex} (Bq/kg)	H_{in} (Bq/kg)
		^{40}K	^{238}U	^{232}Th		
AWOLOWO	D_1	982.29 ± 3.18	17.35 ± 2.36	48.35 ± 6.37	0..438	0.485
	D_2	1046.58 ± 4.12	25.27 ± 2.48	85.21 ± 8.57	0.615	0.683
	D_3	568.73 ± 2.86	15.88 ± 2.02	72.94 ± 9.36	0.443	0.486
	D_4	845.26 ± 3.05	32.26 ± 2.53	110.02 ± 14.85	0.688	0.775
	D_5	785.32 ± 2.37	24.42 ± 2.41	98.68 ± 12.07	0.610	0.676
	D_6	694.38 ± 2.94	26.57 ± 2.43	104.12 ± 13.14	0.618	0.690
	D_7	925.47 ± 3.07	31.04 ± 2.51	52.73 ± 7.76	0.480	0.564
	D_8	1064.84 ± 5.36	40.26 ± 2.84	76.16 ± 10.24	0.624	0.733
	D_9	994.36 ± 3.46	14.08 ± 1.86	68.59 ± 7.92	0.510	0.548
	D_{10}	1004.18 ± 3.71	22.24 ± 2.08	95.34 ± 11.86	0.637	0.697

Table 3.0: Radioactivity concentrations, external and internal indices of Sabo soil samples

MARKET	SAMPLE	RADIOACTIVITY CONCENTRATIONS OF SOIL SAMPLES (Bq/kg)			H_{ex} (Bq/kg)	H_{in} (Bq/kg)
		^{40}K	^{238}U	^{232}Th		
SABO	E_1	898.25 ± 3.42	16.64 ± 2.82	74.37 ± 9.23	0.519	0.564
	E_2	984.37 ± 3.64	19.78 ± 2.96	89.24 ± 10.31	0.603	0.656
	E_3	1082.28 ± 6.01	31.15 ± 3.24	110.19 ± 13.82	0.735	0.819
	E_4	796.43 ± 3.24	24.23 ± 2.99	96.76 ± 11.45	0.605	0.670
	E_5	824.36 ± 3.26	20.76 ± 2.87	68.15 ± 8.75	0.491	0.547
	E_6	1124.85 ± 6.58	27.35 ± 3.14	82.76 ± 9.73	0.627	0.701
	E_7	969.24 ± 3.37	18.92 ± 2.92	56.24 ± 8.02	0.470	0.521
	E_8	748.68 ± 3.01	22.17 ± 2.76	97.34 ± 12.04	0.591	0.651
	E_9	894.46 ± 3.41	32.34 ± 3.28	115.62 ± 16.39	0.720	0.807
	E_{10}	1042.74 ± 5.48	23.86 ± 2.96	77.73 ± 9.35	0.581	0.646

CONCLUSION

The radiological safety of the people within the markets had been assessed and the results obtained show that the mean external and internal hazard indices values are less than 1.0 Bq/kg, the limit recommended by European Commission on Radiation Protection (EC, 1999). This means that the exposure of the people in the markets to the radiation from the surface soils does not pose any negative radiological effect on them and their environs.

REFERENCES

Avwiri, G. O. (2005). Determination of Radionuclide Levels in Soil and Water around Cement Companies in Port Harcourt. Journal of Applied Sciences & Environmental Management, Vol. 9, No. 3, pp. 27-29

Beliverimis, M., Kilic, O., Coytuk, Y., Topcough, S. (2009). The effects of physiochemical properties of gamma emitting natural radionuclides level in the soil profile of Istanbul, Environmental monitoring and assessment 163: 15-16.

Colmenero Sujo, L., Montero Cabrera, M.E., Villalba, L., Renter´ıa Villalobos, M., Torres Moye, E., Garc´ıa Leon, M. Garc´ıa-Tenoro, R., Mireles Garc´ıa, F., Herrera Peraza, E.F. and S´anchez Aroche, D. (2004) Uranium-228 and Thorium-232 Series Concentrations in Soil, Radon-222 Indoor and Drinking Water Concentrations and Dose Assessment in the City of Aldama, Chihuahua, Mexico, Journal of Environmental Radioactivity, 77, 205-219.

EC (1999) European Commission. Radiological Protection Principles concerning the Natural Radioactivity of Building materials, Radiation Protection Report RP-112, Luxembourg.

Elles, M. P., Armstrong, A. Q. & Lee, S. Y. (1997) Characterization and solubility measurements of uranium-contaminated soils to support risk assessment. Journal of Health Phyics, 72, 716–726.

Hamzah, Z., Ahmad, S., Noor, H. M. and She, D. E., (2008) Surface Radiation Dose and Radionuclide Measurement in Ex-Tin Mining Area, Kg Gajah, Perak, The Malaysian Journal of Analytical Sciences, Vol. 12, No. 2, pp. 419-431.

IAEA (1989) International Atomic Energy Agency. Measurements of Radionuclides in Food and the Environment – A Guidebook. STI/DOC/10/295 IAEA Vienna.

ICRP. (1990) International Commission On Radiological Protection. Recommendations of the International Commission on Radiological Commission. ICRP Publication 60. Pergamon Press: New York.

ICRP (1992) International Commission On Radiological Protection. The 1990-91 Recommendations of the International Commission On Radiological Protection, Publication 60, Ann. ICRP 21.

Lee, E. M., Menezes, G, and Flinch, E. C. (2004). Natural radioactivity in building material in the Republic of Ireland. Health Physics, 86: 378-388

Mart`ınez, A. (1989) Medidas de Is´otopes de U, Ray 210Po en Muestras Ambientales. Programa del Tercer Ciclo de F´ısica Atomica Molecular y Nuclear, Unversidad de Sevilla,.

Papaefthymiou, H. Papatheodorou, G. Moustakli, A. Christodoulou, D.and Geraga, M. (2007) Natural Radionuclides and 137Cs Distributions and Their Relationship with Sedimentological Processes in Patras Harbour, Greece Journal of Environmental Radioactivity, Vol. 94, No. 2, pp. 55-74.

Quind´os, L.S., Fernandez, P.L., Soto, J., R´odenas, C. and Comez, J., (1994) Natural Radioactivity in Spanish Soils, Health Physics, 66: 194-200.

UNSCEAR (1993) United Nations scientific Committee on the Effects of Atomic Radiation. Sources and effects of Ionizing Radiation. New York. United Nations

UNSCEAR (2000) United Nations scientific Committee on the Effects of Atomic Radiation. Sources and Effects of Ionizing Radiation. New York. United Nations

Wilson, M.J. (1993). Anthropogenic and naturally occurring radioactive materials detected on radiological survey of properties in Monticello, Utah. Environmental Health Physics; 26th midyear topical meeting, 24-28 January. pp. 564.