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Natural radiation levels and health hazard indices of soil in Owerri Nigeria

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ABSTRACT

The natural radiation of soil samples from three local governments areas that make up Owerri city in Imo state, Nigeria were measured using $NaI(Tl)$ gamma ray spectrometer. The mean values obtained were 167.2 ± 10.5 ($Bq\ Kg^{-1}$), 19.7 ± 1.9 ($Bq\ Kg^{-1}$) and 18.1 ± 3.3 ($Bq\ Kg^{-1}$) for ^{40}K , ^{226}Ra and ^{232}Th respectively. These values were used to evaluate the radiological health hazard indices using standard analytical methods. The results showed that the mean value of radium equivalent activity is 58.5 $Bq\ Kg^{-1}$, while the values of absorbed dose rate (D) and annual effective dose equivalent (E) are 27.1 $nGy\ h^{-1}$and 132.78 $mSvy^{-1}$ respectively. The values of external and internal health hazard indices are 0.16 and 0.21 respectively. All these values obtained are lower than their world permissible United Nations Scientific Committee on the Effect of Atomic Radiation (UNSCEAR) values for such environment. This shows that the risk due to radiation contamination in the city of Owerri is low.

Keywords: *Activity concentration, gamma ray spectrometer, health hazard indices, Owerri, world standard values.*

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I. INTRODUCTION

The human body is continuously exposed to ionizing radiation both from natural and artificial sources [1]. The gamma radiation emitted from naturally occurring radionuclides materials NORMs is called terrestrial background radiation. Materials such as rock, soil, underground water and air contain various NORMs in different concentrations in various locations of the world. Terrestrial background radiation produced during interaction of cosmic rays with the atmosphere is the major natural sources of radiation due to ^{40}K, ^{238}U, ^{232}Th and their decay products. There are also artificial sources of radiation such as $^{137}C_s$, $^{434}C_s$, $^{90}S_r$, which are released due to human activities. The measurement of radionuclide concentrations in the environment is essential to the assessment of possible radiological risk to human [2]. This is because, exposure of humans to natural radiation is through inhalation of radon (^{222}Rn) gases, ingestion of food and direct external exposure [3]. Some radiological indices such as radium equivalent activity, absorbed dose rate, annual effective dose rate, external and internal hazard indices also depend on the activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th. These values of radiological indices for different materials greater than the world average could contribute significantly to health risk [4].

Imo State is one of the thirty six (36) states of Nigeria. It has been the capital of the State since 1967 and it has grown from a small town to become one of the commercial hubs of the Southeastern Nigeria. It is also a gateway city from the Southwestern Nigeria to most of the Southeastern part of the country. As a result of this, there has been a great increase in commercial activities and human settlement over the years. These could bring about an increase in nuclear applications and its attendance risk of abuse or accident [6]. It is important therefore to measure the levels of radiation present in the environment at any given time in order to adequately assess the risk involved to the society.

[6, 7] have done some studies in major cities in Nigeria, but none looked at the radiological hazard indices of Owerri city with the view to accurately ascertain the health risk to the area. The aim of the study therefore is to determine

i The activity concentration of the three radionuclides of ^{40}K, ^{226}Ra and ^{232}Th
ii The radiological health hazard implications to the public.
iii And also to provide a radiometric data for further reference and research in the area.

II. MATERIALS AND METHOD

2.1 Sample collection

Soil samples were collected from 30 different locations in the three local government areas that make up the city of Owerri in Imo state. The local government areas are Owerri Municipal area (OWM), Owerri North (OWN) and Owerri West (OWW). This is to ensure a very good coverage of the entire region. Samples at each site were collected to a depth of about 150 mm to 200 mm below the soil surface. The samples were placed in a labeled waterproof nylon bag and transferred to the laboratory for analysis. Then they were air – dried and homogenized to pass 1mm mesh sieve. About 0.2kg of each sample were weighed and fed into a plastic container of about 8cm in height and 7cm in diameter. The containers were sealed for twenty eight (28) days for the short – lived members of Uranium and Thorium series to reach a secular equilibrium [8]. The samples were placed symmetrically on top of the detector and measured for 10 hours (36000 seconds). The net area under the corresponding photopeaks in the energy spectrum was computed by subtracting count due to Compton scattering of the background source from the total area of the photopeaks. The radionuclides were computed using the algorithm of the multichannel analyzer (MCA).

The measuring instrument used in this research is the gamma ray spectrometer of $NaI(Tl)$ detector of dimension 7.6cm by 7.6cm housed in a 6cm thick lead shield to minimize background radiation. The choice of the detector was due to its modest resolution. The detector was coupled to a Multichannel Analyzer (MCA) through a photomultiplier tube, which converts the visible light photons produced in the crystal into amplified electrical pulses, and an amplifier. The gamma spectrometry detector was calibrated before it was used for analysis. This was done to ensure that the radiation parameters in the samples could be expressed in physical radiometric units. This calibration was done in two stages. This is energy and efficiency calibrations and efficiency calibrations. The energy calibration converts channel numbers to γ-ray energy in Mev. This was done by placing different gamma sources of known energy on the detector at a distance of 7cm from it. After a preset counting time of 36,000s, the channels of the various photopeaks corresponding to the gamma energies were identified.

The efficiency calibration was to determine the gamma ray counting efficiencies over energy range of 0.662 – 2.615 Mev. This was done by converting the count per seconds under the photopeaks to activity concentration Bq/kg of certified reference standard samples. The certified reference standard samples have activity concentrations of 7.24 Bq/kg for ^{137}Cs (0.662 Mev), 510.00 Bq/kg for 40K (1.460 Mev), 631.00 Bq/kg for 226Ra (1760 Mev of ^{214}Bi) and 11.00 Bq/kg for ^{232}Th (2.615 Mev of 208 Ti). Efficiencies at different gamma energy peaks are represented in Table 1. The reference standard sources were counted for 10 hours (36,000s) after which the counting efficiencies of the different gamma energies were determined

Table 1: Efficiencies at different gamma energy peaks

Standard sources	Energy(MeV)	Efficiency (%)	Channel number
^{137}Cs	0.662	5.57	40
^{40}K	1.460	1.87	72
^{226}Ra	1.760	1.67	84
^{232}Th	2.615	1.35	125

III. RESULTS AND DISCUSSION

3.1 The activity concentration

The activity concentration of the samples could be computed from the count rate (A_{net}) under the photopeak of each of the three primordial radionuclides using equation 1 [7, 9].

$$\varepsilon_\gamma = \frac{A_{net}}{A_S Y_\gamma M_S t} \quad \text{.....1}$$

Where ε_γ = the efficiency of the detector at a particular γ – energy

A_{net} = count rate under the photopeak of the three primordial radionuclides,

A_s = activity concentration in Bqkg-1

Y_γ = the yield of the gamma ray at a particular energy,

M_s = the mass of the samples (0.2kg)

t = the counting time in seconds.

The values of the mean activity concentrations for the three local government areas investigated are in Table 2

Table 2: The mean activity concentration of radionuclides.

Sample location	^{40}K($Bq\ Kg^{-1}$)	^{226}Ra ($Bq\ Kg^{-1}$)	^{232}Th ($Bq\ Kg^{-1}$)
OWN	165.5±10	19.4±1.8	17.9±3.3
OWW	163.5±8.3	19.7±1.9	19.6±3.4
OWM	172.5±13.1	20.1±2.0	16.8±3.2
Mean	**167.2±10. 5**	**19.7±1. 9**	**18.1±3. 3**

3.2 Radium equivalent activity (Ra_{eq})

The radium equivalent activity (Ra_{eq}) was computed in this work in order to assess the gamma radiation risk to human being. This compares the specific activity of the samples containing different amounts of ^{40}K, ^{226}Ra and ^{232}Th. It is defined as an estimation of radiation 370 $Bq\ Kg^{-1}$ of ^{226}Ra, 259 $Bq\ Kg^{-1}$ of ^{232}Th and 4810 $Bq\ Kg^{-1}$ of ^{40}K that produces the same gamma ray dose rate. This index is determined using the equation 2 ([10, 11].

$$Ra_{eq} = 0.077C_K + C_{Ra} + 1.43C_{Th} \qquad (2)$$

Where C_K, C_{Ra} and C_{Th} are the activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th in $Bq\ Kg^{-1}$ respectively. The values of the radium equivalent activity obtained in this research are in Table 3 while the chat is shown in figure 1.

3.3 Absorbed dose rate (D) and annual effective dose equivalent (E)

The absorbed dose rate in air (D) in $nGy\,h^{-1}$ at about 1meter above the ground level due to the activity concentration of ^{40}K, ^{226}Ra and ^{232}Th were computed using equation 3 [11, 12].

$$D(nGy\,h^{-1}) = 0.042C_K + 0.429C_{Ra} + 0.666C_{Th} \qquad (3)$$

Where C_K, C_{Ra} and C_{Th} are the activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th in $Bq\ Kg^{-1}$respectively. The values obtained are presented in Table 3 and the plot for the three LGAs investigated is shown in figure 1.

The annual effective dose equivalent due to the absorbed dose rate in air was computed using 8760 hours for one year, an indoor occupancy factor of 0.8 and the conversion coefficient of 0.7$SvGy^{-1}$ using equation 4. [11, 13].

$$E(Svy^{-1}) = D(nGy\ h^{-1}) \times 8760h\ y^{-1} \times 0.8 \times 0.7Sv\ Gy^{-1} \times 10^{-6} \qquad (4)$$

The values of the effective dose equivalent (E) are presented in Table 3 and the plot is shown in figure 1

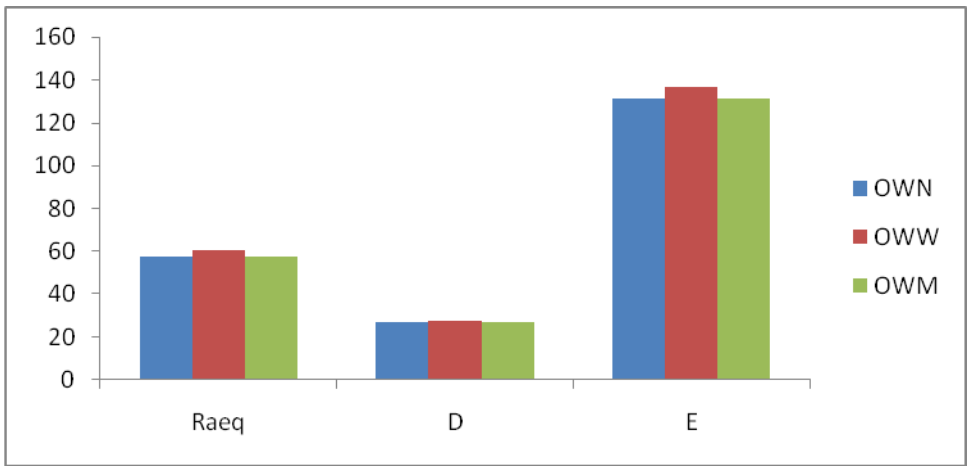

Figure 1: The distribution of the mean values of radium equivalent activity (Ra_{eq}), absorbed dose rate (D), annual effective dose (E) in the three LGAs that made up Owerri. (Note that the absorbed dose rate (D) in the graph is a multiple of 10^{-9} and annual effective dose equivalent (E) is a multiple of 10^{-6}.)

3.4 External and internal health hazard indices (H_{ex}) and(H_{in})

The concept of the hazard indices was used to assess the potential radiological risk associated with human. Gamma radiation emitted by the radionuclides concern is an estimate of external hazard index that is determined using equation 5 [11].

$$H_{ex} = \frac{C_K}{4810} + \frac{C_{Ra}}{370} + \frac{C_{Th}}{259} \leq 1 \qquad (5)$$

Radon (^{222}Rn) is a gaseous product of the decay of Radium (^{226}Ra). It is short-lived and constitute a major source of internal radiation exposure [14, 15]. The internal exposure of living cells to radon and its daughter products is referred to as internal hazard index (H_{in}) and was estimated using equation 6 [11]

$$H_{in} = \frac{C_K}{4810} + \frac{C_{Ra}}{185} + \frac{C_{Th}}{259} \leq 1 \qquad (6)$$

Where C_K, C_{Ra} and C_{Th} are the activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th in $Bq\,Kg^{-1}$ respectively in both equations 5 and 6. The values of external and internal health hazard indices are recorded in Table 3 and the plot of their comparison to the world standard value is shown in figure 2

Table 3: The values of Ra_{eq}, D, E H_{ex} and H_{in} compared to the world standard values

Sample location	Number of samples	Ra_{eq} Bq/kg	D 10^{-9} (Gy/h)	E 10^{-6} (Svy-1)	H_{ex}	H_{in}
OWN	10	57.7	26.7	130.98	0.16	0.21
OWW	10	60.3	27.8	136.38	0.17	0.22
OWM	10	57.4	26.7	130.98	0.15	0.20
Mean Values		58.5	27.1	132.78	0.16	0.21
World standard Values		370	60	450.00	1	1

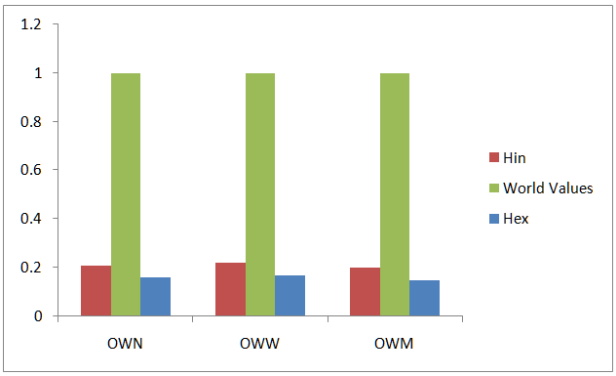

Figure 2. The distribution of the internal and external hazard indices compared to their world standard value.

IV. CONCLUSION

The three primordial radionuclides of ^{40}K, ^{226}Ra and ^{232}Th have been measured and detected in all the samples investigated from the three local government areas that make up Owerri city using Gamma ray spectrometer of $NaI(Tl)$ detector. These were used to compute the average terrestrial gamma radiation dose rate, annual effective dose equivalents and the health hazard indices using standard analytical methods. Results showed that the values of absorbed dose rate (D) and annual effective dose equivalent (E) are 27.1 $nGy\ h^{-1}$and 132.78 $mSvy^{-1}$ respectively. The mean value of radium equivalent activity is 58.5 $Bq\,Kg^{-1}$, while the values of external and internal health hazard indices are 0.16 and 0.21 respectively. All these values obtained when compared with the various United Nations Scientific committee on the Effect of Atomic Radiation (UNSCEAR)

permissible values, were found to be below the standard for such environment. This shows that the risk of radiological health hazard to Owerri city is considerably low. The values obtained could represent a baseline study for natural radiation and the health hazard indices for future references and research in the city.

REFERENCES

[1]. Avwiri G.O., Chukwuocha E.O and Onwusika E.A (2011). Assessment of radionuclide concentration with depth in lithology of Port Harcourt, Nigeria. *Sciential Africana*, 10(2):34-41.

[2]. Jibiri., N.N. and Emelue, H.U. (2008). Soil radioactivity concentration and radiological assessment in and around a refining and petrochemical company in Warri, Delta State Nigeria. *Journal of Radiological Protection*, 28:361-368.

[3]. International Atomic Energy Agency Vienna, IAEA(1989): Guild book of the fallout radioactivity monitoring in environment and food programme .

[4]. Odumo O.B., Mustapha, A.O., Patel J.P., Angeyo H.K.(2011). Radiological Survey and assessment of associated activity concentration of the naturally occurring radioactive materials (NORMS) in the Migoriartisanal gold mining belt of Southern Nyanza, Kenya. *Applied Radiation and Isotopes*, 69:912-916.

[5]. Farai, I. P and Jibiri, N.N.(2000). Baseline studies of terrestrial outdoor gamma dose rate levels in Nigeria. *Radiation Protection Dosimetry*, 88(3):247-254.

[6]. Obed, R.I., Farai, I.P. and Jibiri, N.N. (2005). Population dose distribution due to soil radioactivity concentration levels in 18 cities across Nigeria. *Journal of Radiological Protection* 25:305-312.

[7]. Jibiri, N.N. and Okeyode , I.C.(2012). Evaluation of radiological hazards in the sediment of Ogun River South western Nigeria. *Radiation Physics and Chemistry*,81:103-112.

[8]. Jibiri, N.N., Farai, I.P. and Alausa, S.K.(2007). Activity concentrations of ^{226}Ra,^{228}Th and ^{40}K in different food crops from high background radiation area in Bitsichi, Jos, Plateau, Nigeria. *Radiation Environmental Biophysics*,46(1):53-59.

[9]. Beretka, J. and Mathew, P.J.(1985).Natural radioactivity of Australian building materials, industrial wastes and by-products, *Health Physics*, 48(1):87-95.

[10]. United Nations Scientific Committee on the Effect of Atomic Radiation.(2000). Sources, effects and risks of ionizing radiation. UNSCEAR report to the General Assembly, New York.

[11]. Farai, I.P. and Vincent, U.E.(2006). Outdoor radiation level measurement in Abeokuta, Nigeria with thermoluminiscent dosimetry. *Nigerian Journal of Physics*, 18(1):121-126.

[12]. Akkurt, I., Mavi, B., Akyildirim, H. and Gunoglu, K. (2009). Natiral radioactivity 0f coals and its risk assessment. *International Journal of Physical Sciences*, 4(7):403-406.

[13]. Akinloye, M.K. and Okeya, A.C.(2009). Contribution of fibre- cement building material to environmental radioactivity. *Nigeria Journal of Physics*, 21(1):135-143.

[14]. Farai, I.P.(2011). Atomic energy: the myth and the truth. An inaugural lecture delivered at the university of Ibadan on Tuesday 15th , September.Pp36-38.