Radiological Assessment of Natural Radionuclide Contents in Soils from Omala, Kogi State, Nigeria

M.R.Usikalu[1], A.B.Rabiu[2], O.Awe[2], J.Solomon[2], J.A.Achuka[1], K.D.Oyeyemi[1] and F.O.Olawole[1]
[1]*Department of Physics*
[2]*Centre for Atmospheric Research, NASRDA, Kogi State University, Anyigba, P.M.B 1023, Covenant University, Ota, Nigeria*
moji.usikalu@covenantuniversity.edu.ng, tunderabiu2@gmail.com, justina.achuka@covenantuniveristy.edu.ng

Abstract

High purity germanium detector (HPGe) was employed to assess radionuclide contents of ^{238}U, ^{40}K and ^{232}Th in soils obtained from Omala, Kogi State, Nigeria. The activities measured vary from 9.0 to 82.2, 12.3 to 114.86 and below detector limit (BDL) and 349.0 Bq Kg^{-1} in ^{238}U, ^{232}Th and ^{40}K respectively. Highest activities for the three radionuclides were consistently obtained from soil samples got from Igaliwu. The measured activities were engaged to estimate the absorbed dose, annual outdoor effective dose and gamma index. It was observed from the absorbed dose, annual equivalent dose and the gamma index estimated that soils from Igaliwu, Ijeke-ogene and Bagana were found to be higher than the recommended safe limit for normal background. This suggests that those living or using the soil for construction purposes are exposed to high radiation burden from natural radionuclides.

Keywords: Radionuclides; soil; Omala; radiation burden; gamma index

I. INTRODUCTION

Humans are continually exposed outdoors to the naturally occurring radiation that emanates mainly from the topmost few centimeter of the soil [1]. The amount of radiation from natural terrestrial radionuclides is an important source of radiation which the world's population is exposed to [2]. The primordial radionuclides of great interest are those with long half-lives which can be compared with the age of the earth or having decay products that exist in normal materials example are those under investigation in this study. Individual doses vary with location which depends on type, density and mineral make of soil [3; 4; 5]. Due to the fact that above mentioned radionuclides are not equally spread, the information about their spread in soil and rock is very important in radiation protection [4]. It is therefore vital to estimate radiation dose from the natural radionuclides so as to find the health risk posed by them to people. It equally provides data in case of any increase in soil radioactivity as a result of man-made engagements [6]. It is noteworthy that radiation from these radionuclides under investigation constitutes the bulk of external radiation sources to the populace [7; 8; 9; 10]. Therefore, this study seeks to measure the radionuclide contents of ^{238}U, ^{40}K and ^{232}Th in soils obtained from different towns in Omala Local Government Area, Kogi State Nigeria and to estimate the radiological health risk associated with the soil.

II. MATERIALS AND METHODS

Omala is located within 7°43′N and 7°33′E, with population of 108,402 as at 2006 census and 1,667 km² area. The geology of Omala is more of the basement complex rocks of Nigeria. It was reported that it is more of Anambra Basin, location that is slightly overlaid by older sediment at Albian-Santonian epoch of the Cretaceous [11]. This sediment originated from the Cameroon basement granite, Abakaliki uplift and Oban massif towards the South-East [11]

Five (5) samples were collected from each location from Omala local Government for the radioactivity study. The samples were derived from normal vegetation in locations far from man-made activities and materials like buildings and roads so as to hinder foreign materials that can affect the results. At each point the five samples were obtained by digging 1 m square and sample taken at 4 vertices and centre at depth between least 3cm to 8cm so as to take samples free from debris and vegetation [3]. The samples were properly mixed and packed in Ziplocs bags. It was dried in the oven at 60 - 80°C for one day.

Mortar and pestle was used to ground the dried samples and was sieved. The samples were sealed in radon tight container for one month so as to reach secular equilibrium between ^{226}Ra and its daughters before radiometric counting.

Gamma ray spectrometric method was used for the radioactivity measurement (model GC8023). The detector was coupled with multi channel analyzer (MCA) through pre amplifier base. The detector is properly shielded with lead to prevent external radiation from environment. International Atomic Energy Agency (IAEA) standard reference soil sample (MGS6M315) with specific activity, was engaged in calibrating the detector. The peak 1.46 MeV was employed for ^{40}K; 2.61 MeV (^{208}Ti) for ^{232}Th and 1.76 MeV (^{214}Bi) for ^{238}U respectively were used to estimate radionuclide contents of the samples using the Genie 2000 software [12; 13; 14]. Each sample was counted for 36,000 seconds to reduce the statistical uncertainty. Counting for each sample was done for 10 hours for good statistics.

III. RESULTS AND DISCUSSION

The radionuclides contents obtained in this study is displayed in Table 1. The activities measured from the soil from Omala Local Government vary with location which shows the difference in geological settings of the studied area. Figure 1 is the correlation of the concentration of ^{238}U and ^{232}Th with a trend line was drawn between the points using regression analysis technique. The correlation coefficient of ^{238}U and ^{232}Th was high. The positive correlation obtained may be due to the retaining capability of the soil of these radionuclides under differ atmospheric conditions. The image maps of the radionuclides measurements in the area localising each soil sample with their geographical coordinates is presented in Figs 2, 3 and 4 using Suffer 11 software. Highest concentrations for all the radionuclides were consistently got from Igaliwu soils. Lowest concentration of both ^{238}U and ^{232}Th were obtained in Olokwu while three towns (Ijeke-Ogane, Icheke-Ajokpachi and Bagana) activities are below detection limit for ^{40}K. The activity of ^{232}Th measured was by far greater than that of ^{238}U , which varies between 12.3 Bq kg^{-1} and 114.9 Bq kg^{-1} with an average value of 52.1 Bq kg^{-1}. The concentration of ^{238}U measured ranges between 9.0 Bq kg^{-1} and 82.2 Bqkg^{-1} with mean value of 44.3 Bq kg^{-1}. The measured concentration of ^{40}K is found to be greater than that of ^{232}Th and ^{238}U in all the locations studied. It varied from below detection limit (BDL) and 349.0 Bq kg^{-1} having a mean value of 84.0 Bq kg^{-1}. The distribution of radionuclides in the studied soil samples are asymmetrical (Table 1).

The concentrations of ^{232}Th and ^{238}U are considerably high when compared with the average world value of 45 Bq kg^{-1} in the following towns Igaliwu, Ijeke-Ogane, Icheke-Ajokpachi, Bagana and Abegikolo [15]. The observed pattern in the obtained concentration of ^{232}Th and ^{238}U in the areas can be attributed to the presence of metamorphic rocks such as Hornblende-biotite gneiss, shale and Quartzo-feldspathic gneiss in Omala and environs. The concentrations of ^{40}K are generally low in nearly all the locations except for Igaliwu and Ijeke-Ogane. The low activity of ^{40}K may be accountable for poor farm products observed in the towns; hardly can plants and shrubs be found in the locations except for Igaliwu and Ijeke-Ogane.

Absorbed dose rate, D (nGy h^{-1}) is an important quantity when considering health risk the radiation pose to humans [12]. The absorbed dose rates were estimated using the equation 1.

$$D(nGyh^{-1}) = 0.461K_U + 0.623K_{Th} + 0.0414K_K \quad (1)$$

$D(nGyh^{-1})$ is the dose rate, K_U, K_K and K_K are the measured activities of ^{238}U, ^{40}K and ^{232}Th in Bq kg^{-1} respectively. The calculated absorbed dose rates ranged between 11.9 and 122.0 $nGyh^{-1}$. It was observed from the calculated absorbed dose rates that Igaliwu, Ijeke-Ogane, Icheke-Ajokpachi, Bagana and Abegikolo were greater than the average world value (60 $nGyh^{-1}$). The annual effective dose $\mathrm{H_E}(\mu Svy^{-1})$ was calculated using equation 2 [15].

$$\mathrm{H_E}(\mu Svy^{-1}) = D \times O_c \times F_c \times 8760 \quad (2)$$

D stand for absorbed dose, O_c is the outdoor occupancy factor taken as 0.2 and F_c is coefficient of conversion used in translating the absorbed dose rate to effective dose incurred by adult taken as 0.7 [15]. The estimated annual effective dose varied between 14.6 and 149.65 μSvy^{-1}. The calculated outdoor annual effective dose obtained for Igaliwu, Ijeke-Ogane, Bagana and Abegikolo were higher than the recommended limit of 70 μSvy^{-1} [15].

In assessing the radiation risk from the primordial nuclide in the soil sample representative gamma index (I_γ) was used. Gamma index was calculated with equation 3 [16] which serve as a shielding tool in order to identify materials that might pose health challenge when used for construction and building purposes.

$$I_\gamma = K_U/150 + K_{Th}/100 + K_K/1500 \qquad (3)$$

K_U, K_K and K_{Th} are the measured activities of ^{238}U, ^{40}K and ^{232}Th respectively in $(Bq\,kg^{-1})$. Gamma index obtained in this study vary between 0.19 and 1.93. Soil samples from Igaliwu, Ijeke-ogene and Bagana were observed to have a gamma index value that is greater than unity (1) the recommended permissible limit [15]. This suggests that construction of buildings with these soil samples may expose the dwellers to high radiation burden.

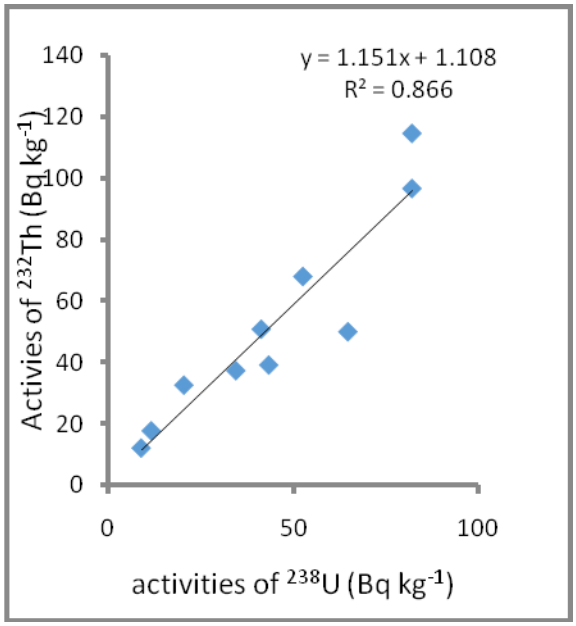

Figure 1: Correlation of ^{232}Th and ^{238}U Activities

Table 1 Measured Activity concentrations

Location	^{238}U (Bq kg^{-1})	^{232}Th (Bq kg^{-1})	^{40}K (Bq kg^{-1})
Ogodu	11.87±0.97	17.93±1.35	3.38±0.50
Olokwu	9.02±0.65	12.32±1.25	6.89±0.48
Igaliwu	82.22±1.99	114.86±4.72	349.04±7.87
Ijeke-Ogane	82.22±1.99	96.90±4.11	349.04±7.88
Icheke-Ajokpachi	41.48±1.64	51.06±3.93	BDL
Ibado	20.56±1.71	32.83±2.30	BDL
Iga	43.51±2.56	39.38±3.15	25.16±1.01
Bagana	52.74±1.62	68.23±3.28	BDL
Abegikolo	64.89±1.78	50.21±3.51	73.22±2.73
Ihiame	34.61±2.14	37.55±3.00	33.38±1.61
Mean	44.31±1.35	52.127±2.45	84.011±2.65

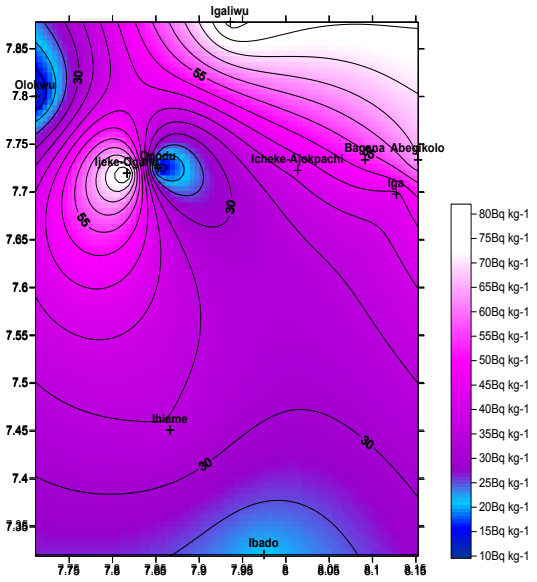

Figure 2: Map of ^{238}U Activities for the Locations

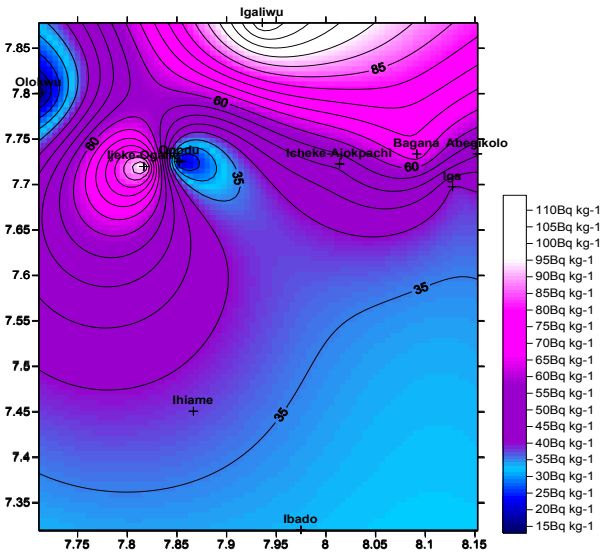

Figure 3: Map of ^{232}Th Activities for the Locations

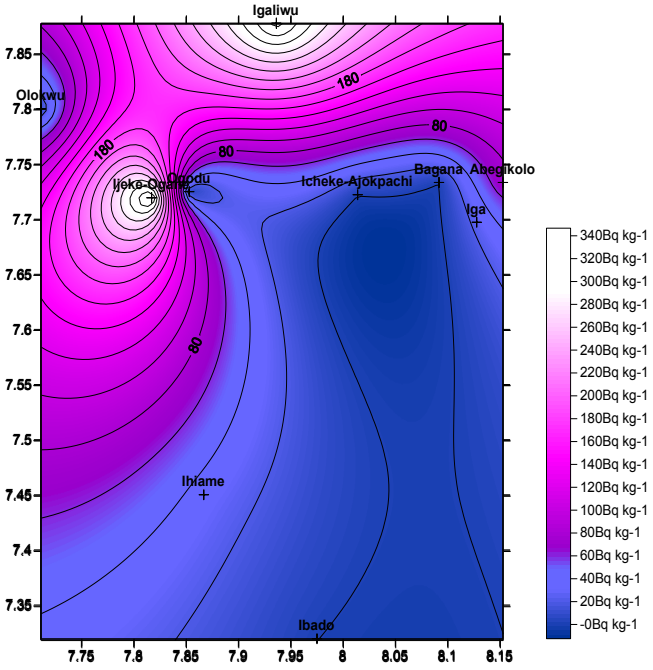

Figure 4: Map of ^{40}K Activities for the Locations

IV. CONCLUSION

The activities of the natural radionuclides from the soil samples collected in Omala Local Government was measured using germanium detector. It was found that the nuclides were not evenly distributed in all the locations which may be attributed to the pattern of land use and geological settings. This differs from one area to another and from one location to another in the same environment. It was revealed that the activities of ^{40}K were generally low in the studied area which may the reason for the poor farm crops yield from the Local Government. The absorbed dose rates, annual outdoor effective doses and gamma index estimated for Igaliwu, Ijeke-ogene and Bagana were found to be higher than the recommended safe limit for normal background [15]. This suggests that those living and using the soil samples obtained from these areas for construction purposes are exposed to natural radiation above the recommended safe limit.

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