Measurement of Radon Concentration and Radioactivity in Soil Samples of Aramoko, Ekiti State, Nigeria

Yinka Ajiboye
Afe Babalola University

International Journal of Public Health Research
2016; 4(5): 37-41
http://www.openscienceonline.com/journal/ijphr
ISSN: 2381-4829 (Print); ISSN: 2381-4837 (Online)

Measurement of Radon Concentration and Radioactivity in Soil Samples of Aramoko, Ekiti State, Nigeria

Ajiboye Y.[1, *], Badmus O. G.[1], Ojo O. D.[1], Isinkaye M. O.[2]

[1]Department of Mathematical and Physical Sciences, Afe Babalola University, Ado-Ekiti (ABUAD), Nigeria

[2]Department of Physics, Ekiti State University, Ado-Ekiti, Nigeria

Email address

yinkaajiboye@abuad.edu.ng (Ajiboye Y.), gobadmus@abuad.edu.ng (Badmus O. G.), ojodaniels@gmail.com (Ojo O. D.), matthewisinkaye@eksu.edu.ng (Isinkaye M. O.)

[*]Corresponding author

To cite this article

Ajiboye Y., Badmus O. G., Ojo O. D., Isinkaye M. O. Measurement of Radon Concentration and Radioactivity in Soil Samples of Aramoko, Ekiti State, Nigeria. *International Journal of Public Health Research.* Vol. 4, No. 5, 2016, pp. 37-41.

Received: June 22, 2016; **Accepted**: July 11, 2016; **Published**: August 17, 2016

Abstract

The radon concentration and natural radioactivity in soil of Aramoko, Ekiti State, Nigeria have been determined. The soil gas radon measurement was performed in-situ with Rad7 radon monitor coupled with a soil gas probe. Natural radioactivity measurement in soil samples was carried out using NaI(Tl) gamma spectrometer. This study is aimed at determining the correlation between the radioactivity of the soil and its radon concentration. It was found that the radon concentration of soil gas in the study area ranged from 0.63BqL^{-1} to 35.04BqL^{-1} with an average value of 9.82±0.56BqL^{-1}. The average activity concentrations of ^{238}U, ^{232}Th and ^{40}K were found to be 22.62Bq/Kg, 34.74Bq/Kg and 316.72Bq/Kg, respectively. The average radium equivalent and average absorbed dose rates at a height of 1m above the ground are 95.99±62 BqKg^{-1} and 45.18±27.28 nGyh^{-1} respectively. The mean external and internal hazard indices were also found to be 0.26 and 0.32 respectively. All the determined radiological indices values are within the recommended limits.

Keywords

Radon, Radioactivity, Rad7, Dose

1. Introduction

There are basically three sources of naturally occurring radiation. One is cosmic radiation which is believed to have originated at the birth of the Universe. Cosmic rays are high-energy particles from extraterrestrial sources that bombard the earth. The second is the cosmogenic radioactivity which evolves from the interaction of cosmic radiation with the atmosphere, although its contribution to overall dose from naturally occurring radiation is insignificant. The third is the primordial radioactivity which has been in existence since the creation of the earth. The primordial radioactivity consists of a long series of isotopes of radioactive elements often called radionuclides. They include two isotopes of uranium, ^{235}U and ^{238}U, and one isotope of thorium ^{232}Th [1]. In addition to aforementioned radionuclides, ^{40}K is one of other single long-lived primordial radionuclides, but it is the most important due to its significant contribution to human radiation dose [2].

Radionuclides are present in soil, water, air and even in human being since we are product of our environment by reason of the air we breathe, the food we eat which is from the soil and the water we drink[3, 4].

The concentration of these radionuclides varies from place to place and differs by lithological composition such that higher concentration are associated with granitic rocks and variably lower concentration are associated with sedimentary rocks depending on the source rocks [5, 6].

There is the existence of gaseous radionuclides ^{222}Rn (radon) and ^{220}Rn (thoron) in both ^{238}U and ^{232}Th decay series respectively. ^{220}Rn has a short half-life of 56s. Of these gaseous radionuclides, ^{222}Rn is the most important due to its relatively long half-life of about 3.8 days. Radon gas is produced from rocks and soils. When the gas is produced, it moves through cracks in the rocks and pore spaces in the soil to the atmosphere. The concentrations of ^{222}Rn and ^{220}Rn in any soil depend on the Uranium and Thorium content of the soils respectively [7].

Inhalation of radon gas in air however does not constitute health risk in itself, but it does constitute health risk when its solid decay products are inhaled. These decay products attach themselves to air molecules and dust particles in air. The decay products or progenies are basically alpha energy emitters which may cause damage along their path in the airway.

Health risk due to inhalation of radon is very low when radon is diluted to very low concentrations with outdoor air. However, it may accumulate up to dangerous concentrations in places such as mines and caves and may pose significant health risk after long-term exposure.

2. Materials and Methods

2.1. Study Area

The study area, Aramoko-Ekiti is located in the basement complex of southwest Nigeria and is the headquarters of Ekiti West Local Government, Ekiti State. It is bounded by coordinates $7^o41'01.53''$ and $7^o43'51.02''$ on the North, and $5^o00'41.51''$ and $5^o04'37.26''$ on the East. It is an ancient town with access roads to all parts of Ekiti and Osun States.

2.2. Radon Concentration Measurement

The radon concentration in soil was performed with of Rad7 electronic radon monitor with a coupled AMS soil probe. Sampling of radon gas was performed at a depth of 1m from the soil surface. Grab protocol was used in the course of the sampling which enables soil gas to be extracted from the soil for 5 minutes into the electrostatic hemispheric bowl of the equipment. The instrument will wait another five minutes and then count for four five-minute cycles. At the end of the half-hour period, the RAD7 will print out a summary of the measurement, including an average radon concentration in the soil gas from the four 5-minute cycle.

2.3. Activity Concentration Measurement

Measurements of activity concentrations of ^{238}U, ^{232}Th and ^{40}K were carried out using a NaI(Tl) detector with a multichannel analyser. The three radionuclides were considered for the fact that they are important gamma emitting sources. A total of ten soil samples were collected from the two locations – five samples from each location. Each sample was taken such that a homogenous sample within a 1m radius is obtained at depth of 10cm to 20cm. The samples were thereafter dried and pulverized. A sample mass of 200g from each sample was measured into plastic cylindrical containers of dimension 8cmx7cm. The samples were then sealed air-tight and kept for about 21 days for the gaseous decay products of uranium and thorium series to attain secular equilibrium before counting. The sampling time for the each sample is 7200s. Count rates above the background were recorded and the efficiency for each radionuclide determined. The result was thereafter used in determining the concentration of each radionuclide.

2.4. Calculation of Radium Equivalent (Ra_{eq}) and External Gamma Dose Rate

The radium equivalent is a very useful index in determining the radiological health hazards associated with materials containing ^{226}Ra, ^{232}Th, and ^{40}K. The expression for radium equivalent is given as [10, 11]:

$$Ra_{eq}(Bq/Kg) = A_{Ra} + 1.41A_{Th} + 0.077A_K \quad (1)$$

where A_{Ra}, A_{Th}, and A_K are the activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K respectively with the assumptions that 370Bqkg^{-1} of ^{226}Ra, 259 Bqkg^{-1} of ^{232}Th and 4810 Bqkg^{-1} of ^{40}K produces equal gamma exposure rate.

The external gamma absorbed dose rate, (D) in air at a height of one meter above the ground was calculated using the activity concentrations of the soil samples obtained in equation (2) [12, 13]:

$$D(nGyh^{-1}) = DCF_{Ra}.A_{Ra} + DCF_{Th}.A_{Th} + DCF_K.A_K \quad (2)$$

where the dose conversion factors DCF_{Ra}, DCF_{Th}, and DCF_K are 0.461nGyh^{-1}/Bqkg^{-1}, 0.623nGyh^{-1}/Bqkg^{-1} and 0.0414nGyh^{-1}/Bqkg^{-1}, for ^{226}Ra, ^{232}Th and ^{40}K respectively.

2.5. External Hazard Index (H_{ex}) and Internal Hazard Index (H_{in})

As it is the convention in radiation protection, the external hazard index was calculated for the purpose of limiting external gamma radiation dose to 1.5mSvy^{-1} [14, 15, 16] using:

$$H_{ex} = \frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \leq 1 \quad (3)$$

where C_{Ra}, C_{Th}, and C_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Bqkg^{-1} respectively. The expression for H_{ex} is such that the value of H_{ex} is less than unity for the gamma dose rate due to the soil component in building materials to be insignificant.

In similar fashion, the internal hazard index H_{in} was also calculated to quantify the internal hazard due to radon and its short-lived decay products according to Berekta, et. al. [14] using equation (4).

$$H_{in} = \frac{C_{Ra}}{185} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \leq 1 \quad (4)$$

3. Results and Discussion

3.1. Activity Concentration

The result of the activity concentration and radon concentration of the soil samples are presented in Table 1.

The table shows the mean, standard deviation, and range of the activity concentration of ^{238}U, ^{232}Th, ^{40}K and ^{222}Rn in the soils at the study area. The activity concentrations of ^{238}U in all the locations range from 12.84BqKg^{-1} to 34.74 BqKg^{-1} with a mean of 22.62 ± 7.98 BqKg^{-1}. This value is less than the average value reported for southwest Nigeria by Ajayi [8] and the world average of 35BqKg^{-1}. The activity concentrations of ^{232}Th range from 17.04 BqKg^{-1} to 170.15 BqKg^{-1} with a mean value of 37.74 ± 7.40 BqKg^{-1}. The mean concentration value for ^{232}Th is higher than the world average of 30 BqKg^{-1} [9], with the value obtained for sample code Aram 4 about six times greater than the world average. *Fig. 1* shows the distribution of ^{238}U, ^{232}Th and ^{40}K in the study area. Activity concentration of ^{40}K ranges from 214.64 BqKq^{-1} to 424.18 BqKg^{-1} with a mean of 316 ± 84.67 BqKg^{-1}. The mean concentration value obtained for ^{40}K in this study is greater than the mean value for southwest Nigeria reported by Ajayi [8]. Only one sample (sample code Aram 7), representing 10% of the samples has activity concentration of ^{40}K greater than the world average value of 400 BqKg^{-1}.

^{222}Rn concentration varies from 0.63BqL^{-1} to 35.04BqL^{-1} with a mean of 9.82 ± 0.56 BqL^{-1}. In determining the dependency of radon concentration of the concentration of Uranium, a linear regression plot of the two variables was performed with ^{238}U on the vertical axis and ^{222}Rn on the horizontal axis as shown in *fig. 2*. The plot showed no appreciable linearity. A weak positive correlation of 0.22 was obtained between the two variables as presented in *table 3*. Radon concentration of the soil and the soil properties considered: electrical conductivity and soil pH show weak positive relationship.

Table 1. *Activity Concentration, Radon Concentration, pH and Electrical Conductivity of Soil samples.*

Sample Code	^{238}U (Bq/Kg)		^{232}Th (Bq/Kg)		^{40}K (Bq/Kg)		^{222}Rn (Bq/L)		Soil pH	Electrical Conductivity
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.		
Aram 1	18.80	7.48	22.04	8.76	316.67	94.44	2.70	0.13	3.98	142
Aram 2	20.05	8.54	18.84	6.86	313.70	64.26	16.90	0.60	3.99	155
Aram 3	12.84	3.22	17.04	6.83	375.54	70.15	7.81	0.63	5.79	182
Aram 4	18.45	6.59	170.15	6.46	289.97	86.66	1.14	0.24	5.16	149
Aram 5	15.23	5.42	20.01	5.86	297.86	64.92	23.68	1.26	5.98	187
Aram 6	30.42	12.86	18.48	8.46	392.30	130.76	1.03	0.21	6.33	174
Aram 7	19.02	6.24	18.25	7.44	424.18	86.60	0.73	0.22	5.14	145
Aram 8	28.02	8.42	19.02	6.72	243.71	87.60	8.51	0.48	4.93	112
Aram 9	28.66	8.56	20.37	7.79	298.64	82.53	0.63	0.38	1.32	32
Aram 10	34.74	12.46	23.16	8.84	214.64	78.82	35.04	1.45	5.28	162
Mean	22.62±7.98		34.74±7.40		316.72±84.67		9.82±0.56		4.79	144
Standard Deviation	6.89		45.17		61.54		11.20		1.37	42.70
Range	12.84-34.74		17.04-170.15		214.64-424.18		0.63-23.68		1.32-6.33	32-187
World Average	35.00		30.00		400.00		-------------		-----------	-----------

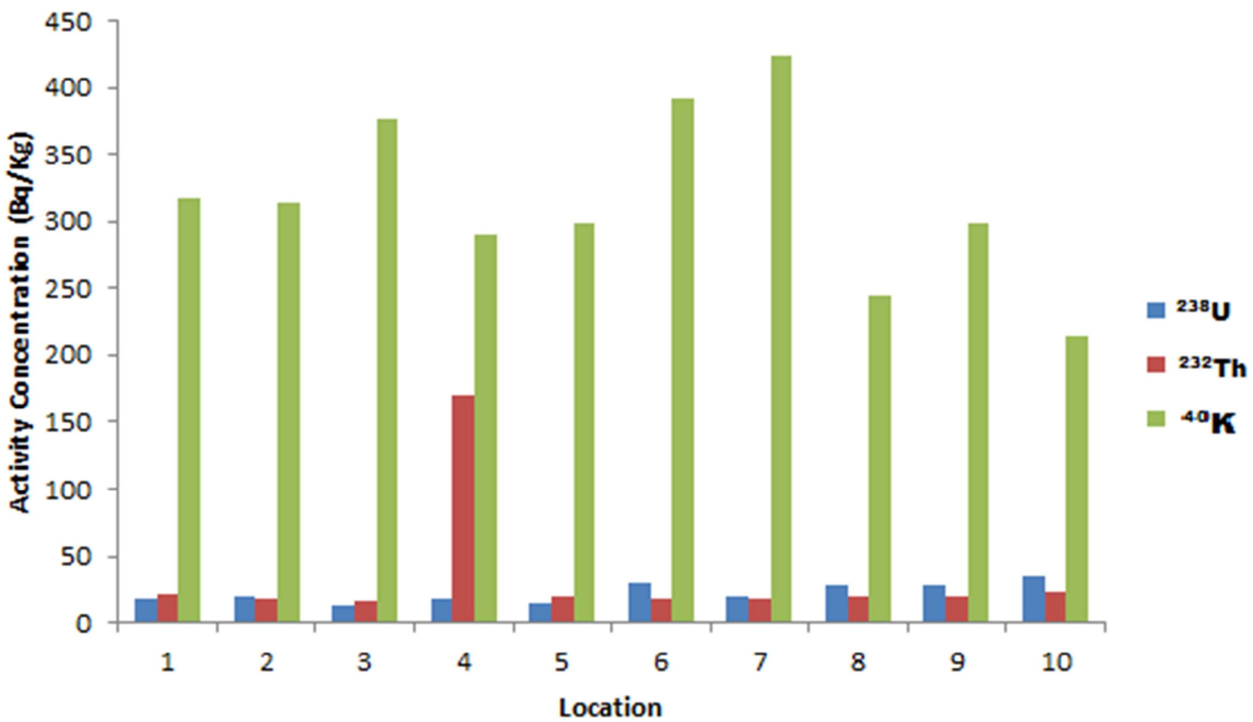

Figure 1. *Distribution of ^{238}U, ^{232}Th and ^{40}K in the study area.*

3.2. Radium Equivalent (Ra_{eq}) and External Gamma Dose Rate

Radium equivalent (Ra_{eq}) describes the total activity concentration due to the three radionuclides: ^{238}U, ^{232}Th and ^{40}K. The radium equivalent values obtained for the soil samples are shown in the second column of Table 2. Ra_{eq} varies from 65.78 $BqKg^{-1}$ to 280.69 $BqKg^{-1}$ with an average value of 95.99$\pm$6.91 $BqKq^{-1}$. The average value obtained for Ra_{eq} is lower than the maximum permissible value of 370 $BqKg^{-1}$ set by the United Nations Scientific Committee on Effects of Atomic Radiation (UNSCEAR). The external gamma dose rate values obtained for the soil samples range from 31.82$nGyh^{-1}$ to 126.51$nGyh^{-1}$ with a mean value of 45.18$\pm$27.28$nGyh^{-1}$. The mean value of the external gamma dose rate obtained for the soil samples is less than the world average value of 56$nGyh^{-1}$ [9]. Only one sample, representing 10% of the total soil samples has dose rate above the world average.

3.3. External Hazard Index (H_{ex}) and Internal Hazard Index (H_{in})

The calculated external hazard index H_{ex} values range from 0.18 to 0.76 with a mean value of 0.26 and standard deviation of 0.02. Since H_{ex} value of 1 which has an equivalent dose of 1.5$mSvy^{-1}$ is the upper limit of the acceptable value of H_{ex}, and all the soils in the study area fall within the specified limit, the soils are therefore deemed acceptable for use as building material. In similar manner, the internal hazard index values which range from 0.21 to 0.82 with mean and standard deviation values of 0.32 and 0.17 respectively falls within the acceptable limit value of 1. H_{ex} is based on the risk due to ^{222}Rn and its decay products.

Table 2. *Radium Equivalent and Absorbed Dose Rate at study sites.*

Sample Code	Ra_{eq} (Bq/Kg)	D $(nGyh^{-1})$	H_{ex}	H_{in}
Aram 1	74.26	35.51	0.20	0.25
Aram 2	70.77	33.97	0.19	0.25
Aram 3	65.78	32.08	0.18	0.21
Aram 4	280.69	126.51	0.76	0.81
Aram 5	66.38	31.82	0.18	0.22
Aram 6	86.68	41.78	0.24	0.32
Aram 7	77.41	37.70	0.21	0.26
Aram 8	73.60	34.86	0.20	0.28
Aram 9	80.38	38.27	0.22	0.30
Aram 10	83.92	39.33	0.23	0.32
Mean	95.99	45.18	0.26	0.32
Standard Deviation	61.91	27.28	0.02	0.17
Range	65.78-280.69	31.82-126.51	0.17-0.76	0.21-0.82

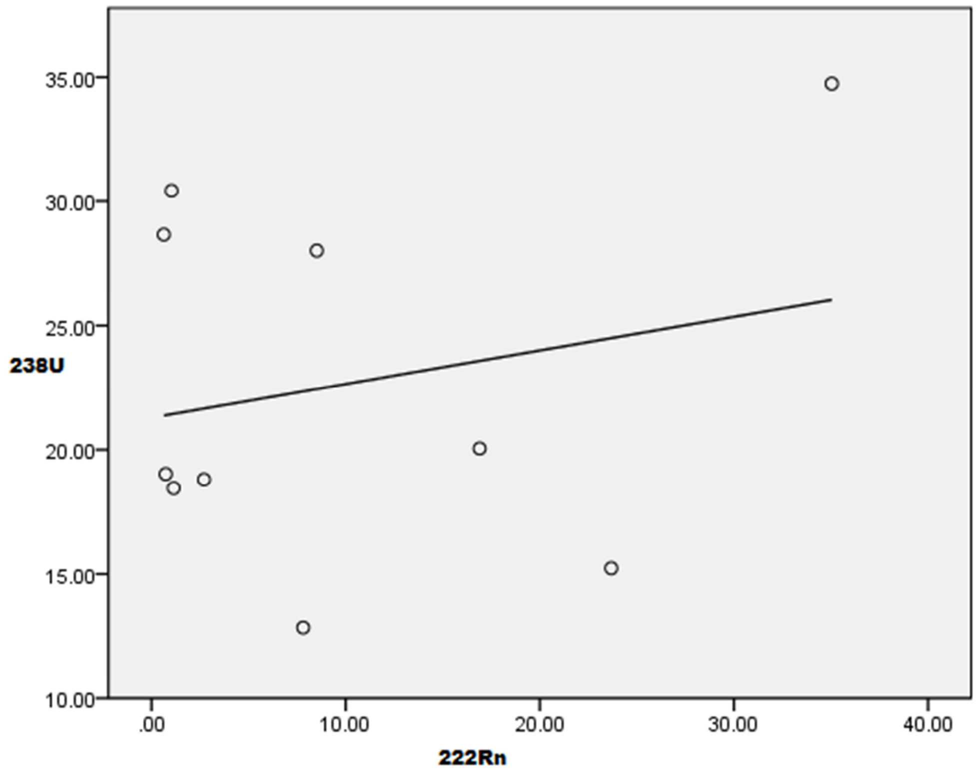

Figure 2. *Plot of Linear Regression between ^{238}U and ^{222}Rn.*

Table 3. *Pearsson Correlation Coefficient of soil radioactivity and soil properties.*

	^{238}U (Bq/Kg)	^{232}Th (Bq/Kg)	^{40}K (Bq/Kg)	^{222}Rn (Bq/L)	Soil pH	Electrical Conductivity
^{238}U (Bq/Kg)	1.00					
^{232}Th (Bq/Kg)	-0.18	1.00				
^{40}K (Bq/Kg)	-0.44	-0.17	1.00			
^{222}Rn (Bq/L)	0.22	-0.24	-0.60	1.00		
Soil Ph	-0.20	0.08	0.22	0.25	1.00	
Electrical Conductivity	-0.38	0.03	0.23	0.38	0.90	1.00

4. Conclusion

Natural radioactivity and radon concentration of soil samples in Aramoko, Ekiti State, Nigeria were measured. The mean activity concentrations of ^{238}U, ^{232}Th and ^{40}K are 22.62Bq/Kg, 34.74Bq/Kg and 316.72Bq/Kg, respectively. All these values are below the world average values for all the radionuclides. The mean activity concentration of ^{222}Rn in the soils was found to be 9.82 BqL^{-1}. The pearsson correlation coefficient of radon concentration and ^{238}U was found to be 0.22, which implies that there is a weak positive linear relationship between the two radionuclides in the study area. The absorbed dose rate at 1m from the surface was found to have an average value of $45 \pm 27.28 nGyh^{-1}$. The obtained average radium equivalent and external gamma dose rate values for all the soil samples are $95.99 \pm 61.91 BqKg^{-1}$ and 45.18 ± 27.28nGyh^{-1} respectively. These results among other radiological indices considered indicate that the general public is not exposed to any significant radiological health hazard due to the soil and inhalation of radon.

References

[1] Lehto, J., and Hou, X., "Chemistry and Analysis of Radionuclides". (2011) ISBN: 978-3-527-32658-7.

[2] Pereira, W., Kelecom, A., and Py-Junior, D., "Activity of Natural Radionuclides and their contribution to the absorbed dose in fish cubera snapper on the coast of Ceara, Brazil,": Brazilian Journal of Oceanography 2010; 58: pp25-32.

[3] Abd El-mageeb, A. I., El-Kamel, A. H., Abbady, A., Harb, S., Youssef, A. M. M., Saleh, I. I., "Assessment of natural and anthropogenic radioactivity levels in rocks and soils in the environments of Juban town in Yemen." Radiation Physics and Chemistry, 2011; 80(6): pp. 710-715.

[4] Moreno, V., Bach, J., Baixeras, C., Font, L., "Radon levels in groundwaters and natural radioactivity in soils of the volcanic region of La Garrotxa, Spain," Journal of Environmental Radioactivity, 2014; 128: pp 1-8.

[5] Wang J., Liu, J., Chen, Y., Song, G., Chen, D., Xiao, T., Wu, S., Chen, F., Yin, M., "Technologically elevated natural radioactivity and assessment of dose to workers around a granitic uranium deposit area, China," Journal of Radioanalytical and Nuclear Chemistry, 2016; March: pp 1–9.

[6] Schafenberg, L., Wall, D., Schobel, S., Minor, A., Maurer, M., Pandit, M. K., Sharma, K. K., "In situ gamma radiation measurements in the Neoproterozoic rocks of Sirohi region, NW India," Journal of Earth System Science, 2015; 124(6): pp 1223-1234.

[7] Haanes, H., Finne, I. E., Kolstad, T., Mauring, A., Dahlgren, S., Rudjord, A., "Outdoor thoron and progeny in a thorium rich area with old decommissioned mines and waste rock," Journal of Environmental Radioactivity, 2016; 162-163: pp 23-32.

[8] Ajayi, O. S., "Measurement of activity concentrations of ^{40}K, ^{226}Ra, and ^{232}Th for assessment of radiation hazards from soils of the southwestern region of Nigeria," Radiation and Environmental Biophysics, 2009; 48: 323-332.

[9] United Nations Scientific Committee on Effects of Atomic Radiation (UNSCEAR). Report to the general assembly. Sources and effects of ionizing radiation. United Nations, New York, 2000 Vol. 1.

[10] Ravisankar, R., Chandrasekaran, A., Vijayagopal, P., Venkatraman, B., Senthilkumar, G., Eswaran, P., Rajalakshmi, A., "Natural Radioactivity in Soil samples of Yelagiri Hills, Tamil Nadu, India and associated radiation hazards," Radiation Physics and Chemistry, 2012; 81(12): 1789-1795.

[11] Tufail, M., "Radium equivalent in the light of UNSCEAR report. Environmental Monitoring and Assessment," 2012; 184(9): pp 5663-5667.

[12] Mehra, R., Singh, S., and Singh, K., "Assessment of the average effective dose from the analysis of 226Ra, 232Th and 40K in soil samples from Punjab, India," Geochemical Journal, 2011; 45: pp 497–503.

[13] Faanu, A., Adukpo, O. K., Tettey-Larbi, L., Lawluvi, H., Kpeglo, D. O., Darko, E. O., Emi-Reynolds, G., Awudu, R. A., Kansaana, C., Amoah, P. A., Efa, A. O., Ibrahim, A. D., Agyeman, B., Kpodzro R. and Agyeman, L., "Natural radioactivity levels in soils, rocks and water at a mining concession of Perseus gold mine and surrounding towns in Central Region of Ghana," SpringerPlus 2016; 5: pp 98 DOI 10.1186/s40064-016-1716-5.

[14] Beretka, J., Mathew, P. J., "Natural radioactivity of Australian building materials, industrial wastes and by-product. Health Physics,"1985; 48:87-95.

[15] Almayahi B. A., Tajuddin, A. A., Jaafar, M. S., "Radiation hazard indices of soil and water samples in Northern Malaysian Peninsula B. A.," Applied Radiation and Isotopes, 2012;70: 2652–2660.

[16] Ademola, A. K., Bello, A. K., Adejumobi, A. C., "Determination of natural radioactivity and hazard in soil samples in and around gold mining area in Itagunmodi, south-western, Nigeria," Journal of Radiation Research and Applied Sciences 2014; 7: 249-255.