Gamma Radioactivity Levels and their corresponding external exposure of some Soil Samples on the Jos - Plateau, Nigeria.

Jwanbot, D.I.[1], Izam, M.M.[1] and Nyam G.G.[2]
[1] Department of physics, University of Jos-Nigeria
[2] Department of physics, University of Abuja-Nigeria
jwanbot2009@yahoo.com

Abstract

The activity concentration of natural occurring radionuclides ^{40}K, ^{226}Ra and ^{232}Th were determined in some soil samples on the Jos Plateau, Nigeria using the Gamma ray spectrometry. The activity concentrations for ^{40}K, ^{226}Ra and ^{232}Th in the soil samples rang from (93.3 ± 29.8 – 121,831.8 ± 2767.8)Bq/kg, (125.4 ± 22.1 – 340,123.2 ± 1425.6)Bq/kg and (57.9 ± 11.6 – 19,358 ±451.8)Bq/kg respectively. The Radium equivalent activities were calculated for all the soil samples to ascertain the radiation hazards arising due to the use of this soil in building construction. Most of the soil samples have radiation equivalent activities higher than the limit set in the OECD report (370Bq/kg). These results showed that the most of the studied soil samples are considered as radiological hazard and the soil cannot be safely used in construction.

Keywords: Radioactivity levels, Soil, Jos-Plateau, Gamma ray, Dose rate, Radium-equivalent.

Introduction

There is a great interest in the study of natural environmental radiation and radioactivity in soil because the population is exposed to natural radioactive minerals in each region in the world (Radhakrishna et al, 1993). The word "soil" has a variety of different meanings depending upon its relevance to the study. Farmers considered it as the part of the earth's surface containing decayed or organic materials in sufficient quantity to grow plants and crops for human consumption. To the engineer, soil includes all earth materials covering the rock crust and contains particles of minerals, gases and liquids. According the Soil Science Society of America (SSSA), soil is a living system that represents finite resources vital to life on earth.

Soil not only consists of organic and inorganic components but also radio nuclides. The naturally occurring radionuclides present in soil include: ^{226}Ra, ^{223}Th, and ^{40}K (Khan *et al.*, 1998). Gamma radiation emitted from those naturally occurring radioisotopes called terrestrial source background radiation represents the main source of irradiation of the human body and constitutes to the total absorbed dose through ingestion, inhalation and external irradiation (Steinhausler, 1992). Natural environmental radioactivity and the associated external exposure due to gamma radiation depends mainly on the geological and geographical conditions, and appear at different levels in the soils of each region of the world (UNSCEAR, 2000). Since then radionuclides are not uniformly distributed, the knowledge of their distribution in soils play an important role in eradication, protection and measurement (Khan *et al.*, 1994). Again, the radioactivity of soils is essential for understanding changes in the natural background.

Materials and Methods

Fifty soil samples were collected from the mineral processing plants in the study area. The soil samples were air dried an later packed to fill cylindrical plastic containers of dimension 7.2cm in diameter 6.0cm high to satisfy the selected optimal sample containers height. The measurement system consists of a 7.62x7.62 cm NaI(TL) detector housed in a 6 cm thick lead shield line with cadmium and copper. The sample containers were subjected to three stages of sealing processes to prevent ^{222}Rn escape. They were stored for minimum secular equilibrium to be attained for a period of 28 days.

Gamma ray spectrometry located at Centre for Energy Research and Training A.B.U, Zaria was employed in the determination of activity concentrations. The soil samples were mounted on the surface of the scintillation detector and each counted for 21,600 seconds in reproducible sample-detector geometry. A computer based multichannel analyzer system with an ACCUSPEC programme (model 2007p) was used for the data acquisition an analysis of gamma spectra. The energy peaks 295, 352 and 09 keV were used to determine ^{226}Ra. Energy peak 911 keV was used to determine 232Th. Energy peak 1461keV was used to determine ^{40}K.

Results and Discussion

Table 1: Activity concentrations, radium equivalent (Bqkg^{-1}) and calculated absorbed dose rate (nGy.h^{-1}), effective dose rate (mSv.y^{-1}) for soil samples

	^{40}K	^{226}Ra(^{238}U)	^{232}Th	Raeq	Absorbed dose rate	Effective Dose Rate
1	93.3 ± 30.1	81.1±22.2	171.1±11.4	332.96	144.70	0.17
2	93.3 ± 29.8	92.7 ± 22.7	262.3 ± 22.9	474.97	205.15	0.25
3	217.7 ± 31.1	104.2 ± 23.1	285.1 ± 22.8	528.66	229.42	0.28
4	513.1 ± 46.6	115.8 ± 23.1	262.3 ± 22.8	530.40	223.33	0.29
5	8536.8 ± 31.1	2479.1 ± 92.7	26049.3 ± 136.8	40386.93	17235.11	21.14
6	668.6 ± 93.3	799.3 ± 57.9	3604.0 ± 68.4	6004.50	2573.97	3.16
7	248.8 ± 31.7	81.1 ± 11.6	342.1 ± 22.8	589.46	254.47	0.31
8	233.1 ± 46.6	173.8 ± 23.1	399.2 ± 21.9	762.60	331.13	0.41
9	435.4 ± 46.6	162.2 ± 23.1	353.5 ± 22.6	1002.96	306.61	0.38
10	435.4 ± 46.6	173.8 ± 23.1	182.5 ± 22.8	468.30	208.68	0.26
11	217.7 ± 46.5	231.7 ± 23.1	342.1 ± 22.8	737.67	322.75	0.40
12	202.1 ± 45.6	208.5 ± 34.7	433.4 ± 34.2	843.82	366.53	0.45
13	10231.7 ± 482.0	12025.0 ± 289.6	52588.9 ± 250.9	88014.97	37738.75	46.28
14	9407.5 ± 404.3	2641.3 ±243.3	28706.6 ± 250.9	44416.12	18951.36	23.24
15	4602.7 ± 264.3	1123.7 ± 139.0	16617.2 ± 136.8	25240.70	10747.87	13.18
16	901.9 ± 124.4	1981.0 ± 92.7	5554.3 ± 91.2	9993.10	4307.63	5028
17	388.7 ± 62.2	312.8 ± 23.1	1243.1 ± 22.8	2120.36	967.86	1.19
18	171.0 ± 46.6	127.4 ± 23.1	296.5 ± 22.8	564.56	245.08	0.30
19	10169.5 ± 264.3	405.4 ± 81.1	20027.4 ± 148.2	29827.63	12707.91	15.58
20	3591.9 ± 21.8	868.8 ± 54.8	9819.8 ± 63.7	15187.69	6482.32	7.95
21	11086.9 ± 154.6	2305.4 ± 33.8	33257.3 ± 147.3	50717.03	21614.83	26.51
22	3187.7 ± 186.5	938.3 ± 92.6	11838.5 ± 102.6	18112.81	7716.88	9.46
23	30663.9 ± 590.9	19358.2 ± 451.8	111895.5± 64.9	181729.89	77807.06	95.42
24	121831.8±2767.8	6556.9 ± 1506.0	340123.2±1425.6	502314.12	213544.09	261.89
25	14818.8 ± 450.9	5468.0 ± 266.4	59769.7 ± 262.3	52079.72	39245.06	48.13
26	124.4 ± 15.5	69.5 ± 11.6	228.1 ± 11.5	405.26	175.07	0.21
27	57191.7 ± 730.8	5166.8 ± 440.2	166651.5±490.4	242482.32	105389.42	129.25
28	27678.4 ± 761.9	7692.3 ± 405.4	85572.5 ± 399.2	28132192.21	56393.82	69.16
29	2830.0 ± 202.1	3985.2 ± 162.2	13868.6 ± 136.9	24035.21	10335.81	12.68
30	31628.0 ± 653.1	11237.2 ± 382.3	98722.6 ± 353.5	154845.87	66138.92	81.11

31	2099.2 ±217.5	845.7 ± 81.1	9352.2 ± 91.2	14380.98	6126.98	7.51
32	5582.3 ± 279.9	2259.0 ± 173.8	19149.2 ± 148.2	30072.19	12842.56	15.75
33	10915.9 ± 373.2	2687.7 ± 231.7	33542.4 ± 148.2	51493.86	21956.52	26.93
34	10216.1 ± 357.6	1981.0 ± 208.5	31979.9 ± 193.9	48498.90	19317.20	23.69
35	9034.3 ± 497.2	11283.8 ± 324.4	39712.6 ± 285.1	68768.46	29576.26	36.27
36	2099.0 ± 139.9	753.0 ± 92.6	7208.0 ± 91.2	11222.06	4789.05	5.87
37	10946.9 ± 388.7	2942.5 ± 254.8	39336.2 ± 228.1	60036.18	25574.99	31.37
38	28829.1 ± 699.7	9036.1 ± 359.1	100501.8±353.5	154973.51	66079.94	81.04
39	23013.5 ± 544.2	12129.3 ± 440.2	88583.5 ± 353.5	140575.74	60067.83	73.67
40	357.6 ± 31.3	92.7 ± 11.5	319.3 ± 22.8	576.83	250.60	0.31
41	248.8 ± 46.6	81.1 ± 11.6	125.4 ± 22.1	279.58	123.58	0.15
42	295.4 ±46.6	115.8 ± 23.1	159.7 ± 22.7	366.92	162.28	0.20
43	730.8 ± 46.6	104.2 ± 23.1	262.3 ± 22.7	535.56	237.04	0.29
44	108.8 ± 15.5	57.9 ± 11.6	182.5 ± 11.4	327.25	141.52	0.17
45	108.8 ± 13.6	115.8 ± 19.8	330.7 ± 21.3	597.08	257.78	0.32
46	108.8 ± 14.9	92.7 ± 10.9	239.5 ± 19.0	443.56	192.02	0.24
47	186.6 ± 31.2	46.3 ± 11.3	136.8 ± 11.4	256.29	111.80	0.14
48	171.0 ± 30.9	104.2 ± 23.1	307.9 ± 11.1	557.66	241.24	0.30
49	730.8 ± 93.2	393.9 ± 46.3	1676.5 ± 45.6	2847.57	1225.06	1.50
50	435.4 ± 46.6	162.2 ± 23.6	866.8 ± 22.8	1435.25	616.64	0.76

The ^{40}K, ^{232}Th and ^{226}Ra activity concentrations measured in soil samples on the Jos- Plateau are shown in Table 1. The activity concentration of ^{40}K, ^{232}Th and ^{226}Ra in the soil samples ranges from (93.3±29.8 – 121,831.8 ± 276.8) Bq/kg, (125.4±22.1 – 340, 123.2 ±1425)Bq/kg and (57.9±11.6 – 19,358.2±451.8) Bq/kg respectively. With the soil samples from the study area, the ^{232}Th radionuclide is most predominant followed by the ^{226}Ra and then ^{40}K. This shows that the trend in the activity concentrations is $^{232}Th > ^{226}Ra > ^{40}K$.

Comparing the Jos Plateau (Nigeria) soil data with the Penang (Malaysia) soil activity concentration data, the two results follow the same trend (Ibeanu, 1999). Malaysia and Nigeria being world tin producers may have the same soil texture in the mining areas. It has been observed that both derived their tin ores from alluvial deposits hence the high recorded "NORMS" activity concentration levels in the soils. The enrichment of Thorium in tin mining areas has been observed by Babalola (1984), Chong et al (1985) and Suleiman (1995). They individually observed that thorium is the most prominent natural radionuclides in each of the tin ore associates followed by ^{226}Ra. The world mean values of ^{40}K, ^{226}Ra and ^{232}Th activity concentration are 370, 25, and 25 Bq/kg (Ibeanu, 1999) respectively as against the derived minimum values of 93.3 ± 30.1) Bq/kg, (46.3±11.3)Bq/kg and (125.4±22.1)Bq/kg. Comparing the data obtained from this work with the world mean, it shows that the data derived from this study are far higher than the world mean standard values. Based on the data obtained from this work and the background classification criterion, this work supports the idea that Jos -Plateau is a high background area. It is important to assess the gamma radiation hazards to human associated with the used of the soil for buildings; this is done by calculating the different radiation hazard indices. In order to compare the radiological effects from the sand samples containing Ra, Th and K. a common index called the radium equivalent (Raeq) has been introduced (Berekta and Mathew, 1985).

$$Raeq = C_{Ra} + 1.43C_{Th} + 0.070\,C_K \ldots\ldots\ldots (1)$$

Where C_{Ra},C_{Th} and C_K are the specific activities of ^{40}K, ^{226}Ra and ^{232}Th in $Bqkg^{-1}$ respectively while defining Raeq activity according to equation (1), it has been assumed that 370 $Bqkg^{-1}$, ^{226}Ra 259 $Bqkg^{-1}$ or 4810 $Bqkg^{-1}$ ^{40}K, produce the same gamma dose rate.

The radium equivalent activities of the samples under investigation were calculated on the basis of the above equation and are shown in Table 1. For all, the soil samples under investigation, the radium equivalent values are higher than the acceptable values 370$Bqkg^{-1}$ ranging from 256.29Bq/kg to 154,973.5$Bqkg^{-1}$. The total air absorbed dose rate ($nGyh^{-1}$) was calculated using the formula (Veiga et al, 2006).

$$D\ (nGyh^{-1}) = 0.0417C_k + 0.462C_{Ra} + 0.604C_{Th} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

To estimate the annual effective dose rate, account must be taken of (a) the conversion coefficient from absorbed dose in air to effective dose and (b) the indoor occupancy factor. Using the dose rate data obtained from the concentration values of material radionuclides in sand, adopting the conversion factor from the absorbed close in the air to the effective dose ($0.7SvGy^{-1}$) and the outdoor occupancy factor (0.2) proposed by (UNSCEAR, 2000), the annual effective dose rate was calculated from the formula:

$$Effective\ dose\ rate\ (mSvy^{-1}) = D\ (nGyh^{-1}) \times 8760\ (hy^{-1}) \times 0.2 \times 0.7\ (SVGy^{-1}) \times 10^{-6} \ldots\ldots\ldots (3)$$

The gamma absorbed dose rates in the soil in the study area are far higher than the global terrestrial average of 55nGyh^{-1}. The absorbed dose rates ranged from 111.80 to 66,079.94nGyh^{-1}. And the annual effective dose rates in the air varied from 0.14 to 81.04mSvy^{-1}. The dose rate and external hazard index indicate that there is a high exposure for either inhabitants or workers dealing with the transportation of soil and there is no good safety index for all the building material.

Conclusion

This study has given results of the measurement of the activity concentrations of terrestrial gamma emitters for the soil samples on the Jos-Plateau-Nigeria. The activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th ranged from (93.3 ± 29.8 – 121, 31.8 ± 2767.8)Bq/kg, (125.4 ± 22.1 – 340,123.2 ± 1425.6)Bq/kg and (57.9 ± 11.6 – 19,358 ±451.8)Bq/kg. The absorbed dose rates ranged from 111.80 to 66, 079.94nGyh^{-1} while the annual effective dose rates in air varied from 0.14 to 81.04mSvy^{-1}. The values obtained for the natural radioactivity and γ – absorbed dose rates due to the activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th of the soil in the air indicates that most of the studied samples are considered as radiological hazard and the soil cannot be safely used in construction without posing any significant radiological threat to the population.

References

Babalola, I.A. (1984): Radon measurement and assay of failings from high natural Radioactivity in Plateau state. *Nigerian Journal of Sciences* ***18*** *(1 and 2), 92 – 98.*

Beretka, J and Matthew, P.J. (1985): Natural Radioactivity of Australian building materials industrial wastes and by products. *Health physics* ***48****: 87 – 95.*

Chong, H.F. Fun, H.K and Leong, L.S. (1985) Gamma radioactivity level in SnSlas Dump. *Health physics* ***49*** *(5), 1008 – 1010.*

Ibeanu, I.G.E. (1999): Assessment of Radiological impact of tin mining activities in Jos and its environs. Unpublished Ph.D thesis. Ahmadu Bello University, Zaria, Nigeria 150pp.

Khan K, Khan H.M, Tufact, M and Ahmed N. (1998): Radiometric analysis of hazara phosphate rock and fertilizers. *Journal of Environmental Radioactivity,* ***38****, 77 – 83.*

Radhakrishna, A.P, Somashekarappa, H.M, Naragana K.S. (1993): A New Natural Background Radiation area on the Southwest coast of India. *Health physics* ***65****: 390 – 395.*

Steinhausler, F. (1992): The natural Radiation Environment: Future Perspective. *Radiation protection dosimetry* ***45****, 19 – 23.*

Suleiman, M.Y. (1995): In analysis of Thorium and Uranium in Malasian samples by using EDXRF. *Journal sains Nuclear Malaysia* ***5*** *(8) 22 – 29.*

UNSCEAR (2000): United Nations Scientific Committee on the Effects of Atomic Radiation from Natural Radiation Sources. New York, United Nations.

Veiga, R.N., Sanches, R.M., Anjos, K., Macario, J.R., Iguatemy, M., Aguiar, J.G., Santos, A.M.A,.Mosquera B., Carvalho C., Baptista, M. and Umisedo, N.K. (2006): Measurement of Natural Radioactivity in Brazillian beach sands. *Radiation Measurements* ***41****: 189 – 196.*