Physical Sciences

Pak. J. Sci. Ind. Res. 2010 **53** (4) 175-179

Population Dose Distribution due to Soil Radioactivity in Designated and Undesignated Waste Dumpsites in the City of Lagos Nigeria

Ebenezer Babatope Fawey[a]* and Ayo Babalola[b]

[a]Department of Physics, University of Ado-Ekiti, PMB 5363, Ado-Editi, Nigeria

[b]Department of Physics, University of Ibadan, Ibadan, Nigeria

(received September 8, 2009; revised March 10, 2010; accepted March 26, 2010)

Abstract. The radionuclide contents in soil from waste dumpsites in the city of Lagos were determined. The radioactivity concentration level due to ^{40}K, ^{226}Ra and ^{228}Th in the soil were determined using gamma-ray spectrometry system. The average radioactivity level obtained was 1134 Bq/kg (designated dumpsite) and 1045Bq/kg (undesignated) for ^{40}K, 43 Bq/kg (designated) and 85 Bq/kg (undesignated dumpsite) for ^{226}Ra, 34 Bq/kg (designated) and 38 Bq/kg (undesignated dumpsite) for ^{228}Th. No artificial radionuclide was detected in any of the samples. The average outdoor effective dose rate due to gamma exposure was calculated as 0.11 mSv/y at designated and 0.13 mSv/y at undesignated dumpsites. These values are much smaller than 1 mSv/y, the limit recommended for the member of the public by United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).

Keywords: soil, dumpsites, spectrometry, radionuclide, Lagos, Nigeria

Introduction

Main sources of wastes in cities are garbage from households, hotels and restaurants, refuses from offices and business establishments, hospitals and medical clinics; rejects from various leather, rubber, foam, plastic and textile, metallic and automobiles industries, left overs and discarded products from vegetable and fruit markets and slaughter houses (Rajiv, 2008). These broad sources can be divided as follows:

a Domestic wastes from the households and personal human excreta.
b Commercial wastes from the consumer stores, warehouses, offices and institutions.
c Industrial wastes from the manufacturing and processing industries.
d Biomedical wastes from hospitals and public health institutions (Isinkaye and Faweya, 2006; Faweya, 2004).

Contribution of natural radionuclides in surface soil to the overall background radiation burden of an environment has been established (UNSCEAR, 1988).This has not been established in soil from waste dumpsites. However, the contribution, distribution and availability of these radionuclides depend mainly on geological processes, atmospheric conditions and human activities (Wollenberg and Smith, 1990). Apart from the primordial sources of radionuclides, anthropogenic sources have been a major source of concern for radioprotection programmes (Arogunjo, 2007). Phenomena like weapon test, medical researches, mining, industrialization, agriculture, transportation, education, construction, trade, commerce as well as nutrition have disturbed the whole environmental system through increase in the radiation burden in the environment (Arogunjo, 2007; Eddy *et al*., 2006, Isinkaye and Faweya, 2006). The possible radon built up in indoor environment especially when radionuclide enriched soil is used as building materials call for detailed environment monitoring.

Solid waste problem has received attention by many environmental scientists and many studies have been carried out on solid waste. Most of these studies are aimed at evaluating the potential problems associated with solid wastes and their impact on the environment (Jibiri and Adewuyi, 2008; Gilbert, 1987) but not on soil. Despite the best attempts at waste avoidance, reduction, re-use and recovery (recycling, composting and energy recovery) landfill and waste disposal sites are still used for ultimate disposal of refuse and incineration residues, world-wide (Waite, 1995). Hazardous waste can cause pollution, damage to health, death, offensive odour and increase in the ambient temperature (Eddy *et al*., 2006). The overall effect is environmental degradation.

In many parts of Nigeria, major materials used in construction at both urban and rural locations are made from the soil (Ademola and Farai, 2006) and most urban dwellers spend almost 78% of their time indoor (Arogunjo *et al*., 2004). Determining the potency of wastes on soil through soil analysis will be useful in providing the information required for developing the techniques for tackling the problem of soil pollutants such as wastes. On the other hand, data on the radioactivity levels in soil from dumpsites will help us to

*Author for correspondence; E-mail: febdeprof@yahoo.co.uk

determine if buildings, retail complexes and industries could be erected on those sites.

This study provides a reference absorbed dose in soil from waste dumpsites in Lagos metropolis as a baseline in case of any future contamination of soil in the area.

Lagos metropolis is located in the far western part of Nigeria on latitude 6.45 °N and longitude 3.47 °E. It is the economic nerve centre of Nigeria and most populated city of the country (NPC, 2006). It has the highest level of urbanization and concentration of manufacturing industries (small, medium and large scale); there are 12 industrial estates in the metropolis. These account for the magnitude of waste produced in the metropolis (Jibiri and Adewuyi, 2008). The discharge of untreated or incompletely treated wastes in these dumpsites could produce leachate that could contaminate the ground water. High water table and sandy soil of Lagos may receive many of specific pollutants whose concentration may reach hazardous levels.

Materials and Methods

Sampling. Samples were collected from 4 designated and 16 undesignated dumpsites in the city of Lagos. Four to six samples were collected from each dumpsite and the average concentrations of individual dumpsites were then calculated and recorded. Also, concentrations of 20 samples, taken from some metre away from the dumpsites, were also recorded. These serve as control samples. Samples of 50 cm × 50 cm were collected at a depth of 25 cm and carried to the laboratory for gamma counting.

Sample preparation. At the laboratory, samples, after drying at room temperature for many days, were crushed to pass through 2 mm sieve(Papp *et al*., 2002). Samples (250 g) were sealed in gas-tight, radon impermeable trap-shape hermetically plastic containers; diameter was of the same matrix as the diameter of the detector head. The samples were sealed for a period of 4 weeks. This was done to allow for Ra and its short-lived decay products to reach secular radio-active equilibrium prior to gamma spectroscopy (Jibiri and Adewuyi, 2008; Beretka and Mathew, 1985).

Measurement. The method of scintillation gamma-ray spectroscopy was employed. The spectrometer comprised of 76 mm × 76 mm NaI(Tl) detector which was coupled through a standard pre-amplifier system to a Canberra series 10 plus multichannel analyzer (MCA). The detector had a resolution of 8% at 0.662 MeV of ^{137}Cs. The detector was maintained in a vertical position in a Canberra lead cylindrical shield of 5 cm thickness and 55 cm height. For the purposes of identifying various radionuclides in the samples, a standard sample from IAEA (ref 375) was used to convert the area under the photopeak to activity concentration.

Gamma counting. After the prepared samples had attained secular equilibrium, the sample container was placed directly on the top of the detector for counting. The counting time for each sample was 36000 s (10 h). This time was chosen for greater accuracy which demands longer time especially when the radioactive content is as low as in the soil under study. Based on the resolution of the detector, radium content of samples was determined from intensity of 1.765 MeV peak from ^{214}Bi; thorium content was determined from 2.615 MeV gamma ray peak of ^{228}Th and potassium content was determined using 1.460 MeV decay of ^{40}K.The net area count after background corrections in each photopeak was used in computation of the activity concentration of each of the radionuclides in the samples using the expression,

$$A_c = \frac{A_{net}}{\varepsilon \gamma t m} \quad \text{(Ibrahim, 1999)} \qquad (1)$$

where:

A_{net} is the net area count after background correction in the spectrum of the radionuclide in the sample,
A_c (Bq/kg) is the activity concentration of the radionuclide in the sample,
ε is the detector efficiency,
t is time of counting,
γ is the absolute transition probability of gamma decay and
m is the mass(kg) of the sample.

The lowest limits of detection (LLD) of the activities of the natural radionuclides in each sample were determined using environmental measurement laboratory procedure (USDOE, 1992).

$$DL(Bq/kg) = \frac{1.96\left[\frac{B}{T} + SD_b^2\right]^{\frac{1}{2}}}{K\varepsilon M} \qquad (2)$$

where:

SD_b is the estimated standard error of the net background count rate in the peak,
B is the background count,
T is the counting time(s),
ε is the counting efficiency (Cps/Bq),
M is the mass of sample,
K is a factor that converts Cps (count per second) to Bq and 1.96 represents 95% confidence level.

The LLD of detector measures its operating ability without the influence of the sample. The LLD values obtained were 17.31, 5.09 and 5.06 Bq/kg for ^{40}K, ^{238}U and ^{232}Th, respectively.

Results and Discussion

The activity concentrations of ^{40}K, ^{238}U and ^{232}Th have been detected and measured in soil samples collected from waste dumpsites in the city of Lagos. ^{134,137}Cs were not detected at any of the sites; it implies that the radioactivity in the city is still due to primordial radionuclides. The result is presented in Table 1 for each of the radionuclides. The activity concentration of ^{40}K was higher than those of the other radionuclides at all the locations. This indicates the trend common to natural environmental radioactivity. A comparison of the results of concentrations in designated and undesignated dumpsites and control sites are seen in Table 1. The enhanced level in waste dumpsites may be attributed to radionuclides in waste. It can be observed that the activity concentration of radionuclides showed dependence on waste.

These activity concentrations are only indication of the level of the radionuclides present and do not relate to the effect on ecosystem. The important quantity to assess radiation risk is the absorbed dose rate. The absorbed dose rate, D(nGy/h) in air, 1 m above the ground level owing to the concentrations of ^{40}K, ^{226}Ra and ^{232}Th in the samples in each site was calculated using the following equation (Ibrahim *et al*., 1993; Deworn *et al*., 1988).

$$D = a.\,C_{Ra} + b.\,C_{Th} + c.\,C_{k} + d.\,C_{Cs} \quad (3)$$

where:

a is the dose rate per unit ^{226}Ra activity concentration (4.27×10^{-10}Gy/h perBq/kg),
C_{Ra} is the concentration of ^{226}Ra in the sample (Bq/kg),
b is the dose rate per unit ^{232}Th activity concentration (6.66×10^{-10} Gy/h perBq/kg),
C_{Th} is the concentration of ^{232}Th in the sample (Bq/kg),
c is the dose rate per unit ^{40}K activity concentration (0.43×10^{-10} Gy/h perBq/kg),
C_K is the concentration of ^{40}K in the sample (Bq/kg),
d is the dose rate per unit ^{137}Cs activity concentration (0.03×10^{-10} Gy/h per Bq/kg) and
C_{Cs} is the concentration of ^{137}Cs in the sample (Bq/kg).

Since ^{134,137}Cs was not detected in any of the samples, the last term in equation (3) becomes zero. Total absorbed dose rate in designated and undesignated waste dumpsites and control sites is presented in the first column of Table 2. The values at each dumpsite were above the world average of 59 nGy/h in

Table 1. Activity concentration (Bq/kg) of ^{40}K, ^{226}Ra and ^{232}Th in waste dumpsites and control (*designated,$^{+}$undesignated, $^{\#}$control)

Name of site	^{40}K		^{226}Ra(^{238}U)		^{228}Th(^{232}Th)	
	WD	Control	WD	Control	WD	Control
Alimosho	$^{+}$1451 ± 135	$^{\#}$118 ± 26	$^{+}$52 ± 15	$^{\#}$40 ± 16	$^{+}$35 ± 13	$^{\#}$19 ± 9
Oke afa	$^{+}$1397 ± 129	68 ± 29	$^{+}$37 ± 14	21 ± 10	$^{+}$9 ± 4	13 ± 6
Ojota	*1064 ± 82	251 ± 98	*43 ± 3	38 ± 10	*40 ± 14	9 ± 3
Cele exp.way	$^{+}$1120 ± 118	285 ± 25	$^{+}$135 ± 13	32 ± 9	$^{+}$27 ± 8	16 ± 5
Agunlejika	$^{+}$1400 ± 10	173 ± 15	$^{+}$71 ± 16	43 ± 11	$^{+}$47 ± 3	19 ± 6
Abule Egba	*1274 ± 17	113 ± 97	*38 ± 3	18 ± 6	*32 ± 5	6 ± 1
Iyana Ipaja	$^{+}$1345 ± 11	241 ± 21	$^{+}$66 ± 11	15 ± 4	$^{+}$8 ± 1	6 ± 1
Yaba	$^{+}$2075 ± 13	664 ± 58	$^{+}$45 ± 10	16 ± 3	$^{+}$7 ± 1	7 ± 1
Ikorodu	*1043 ± 77	367 ± 33	*59 ± 4	43 ± 20	*34 ± 5	19 ± 4
Gbagada	$^{+}$950 ± 17	121 ± 27	$^{+}$162 ± 8	62 ± 19	$^{+}$15 ± 1	37 ± 25
Isolo	$^{+}$843 ± 11	328 ± 49	$^{+}$65 ± 9	39 ± 9	$^{+}$7 ± 1	38 ± 10
Oshodi	$^{+}$968 ± 14	302 ± 28	$^{+}$81 ± 28	62 ± 33	$^{+}$19 ± 9	18 ± 3
Igando	*1153 ± 24	75 ± 7	*29 ± 3	13 ± 4	*29 ± 5	5 ± 1
Agege	$^{+}$750 ± 10	271 ± 29	$^{+}$69 ± 13	31 ± 11	$^{+}$55 ± 20	15 ± 7
New Garage	$^{+}$1175 ± 66	70 ± 20	$^{+}$42 ± 3	43 ± 11	$^{+}$30 ± 3	18 ± 5
Berger	$^{+}$1190 ± 41	497 ± 31	$^{+}$110 ± 33	68 ± 19	$^{+}$47 ± 3	55 ± 27
Ojodu	$^{+}$770 ± 39	206 ± 48	$^{+}$93 ± 25	65 ± 14	$^{+}$71 ± 15	51 ± 11
Ikeja	$^{+}$450 ± 14	350 ± 12	$^{+}$114 ± 24	37 ± 14	$^{+}$74 ± 23	29 ± 11
Mushin	$^{+}$320 ± 14	141 ± 52	$^{+}$142 ± 11	7 ± 1	$^{+}$76 ± 21	6 ± 2
Iseri	$^{+}$520 ± 13	212 ± 37	$^{+}$70 ± 17	89 ± 18	$^{+}$88 ± 11	34 ± 13
Mean	*1134 $^{+}$1045	$^{\#}$243	*43 $^{+}$85	$^{\#}$39	*34 ± $^{+}$38	$^{\#}$22

WD = waste dumpsites; * = government approved dumpsites; + = illegal dumpsites; # = non-eroded sites.

Table 2. Dose rates, annual effective dose, collective dose (*designated, +undesignated, #control)

S. no.	Name of site	Dose rate (nGy/h)		Effective dose (mSv/y)		Collective dose (S_Ex10^2 manSv/y)	
		WD	NES#	WD	NES#	WD	NES#
1.	Alimosho	+105 ± 20	35 ± 14	+0.13	0.04	+12	4
2.	Oke Afa	+81 ± 14	21 ± 9	+0.10	0.03	+9	3
3.	Ojota	*87 ± 18	34 ± 11	*0.11	0.04	*10	4
4.	Cele exp.way	+126 ± 16	37 ± 8	+0.15	0.04	+14	4
5.	Agunlejika	+119 ± 10	38 ± 9	+0.14	0.05	+13	5
6.	Abule Egba	*90 ± 13	15 ± 7	*0.11	0.02	*10	2
7.	Iyana Ipaja	+92 ± 16	19 ± 3	+0 .11	0.02	+10	2
8.	Yaba	+112 ± 6	40 ± 5	+0.14	0.05	+13	5
9.	Ikorodu	*92 ± 12	46 ± 13	* 0.11	0.06	*10	5
10.	Gbagada	+124 ± 5	68 ± 25	+0.15	0.08	+14	7
11.	Isolo	+66 ± 5	55 ± 12	+0. 08	0.07	+7	6
12.	Oshodi	+89 ± 21	52 ± 19	+0.11	0.06	+10	5
13.	Igando	*79 ± 14	12 ± 3	*0.10	0.01	*9	1
14.	Agege	+97 ± 18	35 ± 11	+ 0.12	0.04	+11	4
15.	New Garage	+86 ± 6	34 ± 9	+0.11	0.04	+11	4
16.	Berger	+129 ± 19	85 ± 26	+0.16	0.10	+14	9
17.	Ojodu	+118 ± 23	70 ± 8	+0. 14	0.09	+13	8
18.	Ikeja	+116 ± 26	49 ± 18	+0.14	0.06	+13	5
19.	Mushin	+125 ± 18	13 ± 4	+0.15	0.01	+14	2
20.	Iseri	+107 ± 15	71 ± 18	+0.13	0.09	+12	8
	Mean	*87	41	*0.11	0.05	*+11	5
		+106		+0.13			

WD = waste dumpsites; NES = non-eroded sites;* = government approved dumpsites; + = illegal dumpsites.

soil (Charles, 2001) and higher than control sites. The average dose rate in designated site is calculated as 87 nGy/h, while that of undesignated sites is calculated as 106 nGy/h. This indicates improper control of waste, contributing to the dose received by people. The control sites oscillate from 12 to 85 nGy/h with a mean of 41 nGy/h. The absorbed dose rates are shown in Fig. 1. Applying the conversion factor of 0.7 Sv/Gy, which converts absorbed dose in air to human effective dose and outdoor occupancy factor of 0.2 (Faweya, 2009; 2007; Moeller and Sun, 2006; Charles, 2001), the average annual effective dose due to gamma-radiation from these dumpsites can be assessed. The average outdoor effective dose is therefore calculated as 0.11 mSv/y for designated), 0.13 mSv/y (undesignated) and 0.05 mSv/y (control).

In any epidemiological study, the population size involved is very important as it determines the actual number of people that are expected to suffer a given health effect. When the effective dose (E_{air}) is multiplied by the population size (N), collective dose (S_E) is obtained (Charles, 2001), that is:

$$S_E = E_{air} \times N \quad (4)$$

The values of S_E in the unit of manSv/y for the cities have been calculated using the value of E_{air} and the projected population figure, N, from the 2006 National census based on an annual growth rate of 2.83% (NPC, 2006). Based on the fact that both designated and undesignated sites are within the cities, the calculated collective dose for all the selected

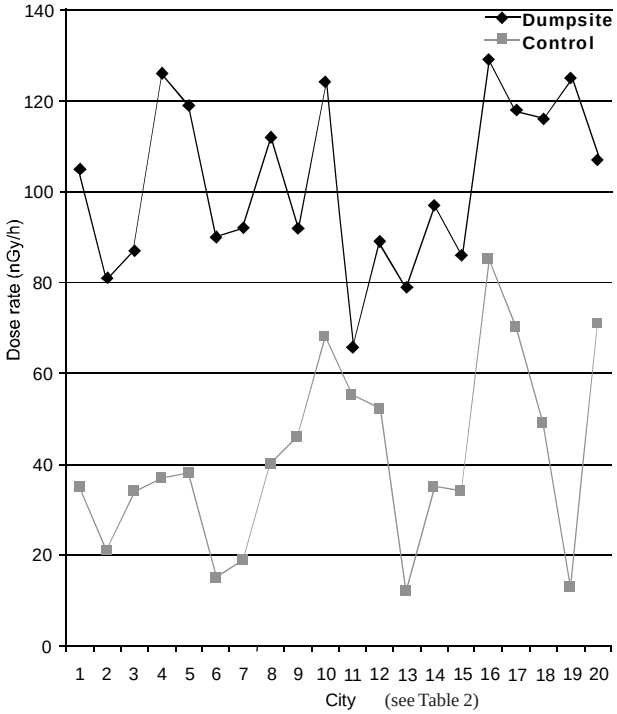

Fig. 1. Absorbed dose rates.

dumpsites in the city is 11×10^2 manSv/y; while the control sites have 5×10^2 manSv/y as the mean collective dose. The variations in these doses in the city are shown in Table 2.

Conclusion

The activity concentrations of ^{40}K, ^{238}U and ^{232}Th have been detected and measured in soil samples collected from waste dumpsites across the city of Lagos. The activity concentration levels were related to gamma absorbed dose rate in air. The average outdoor effective dose 0.11 mSv/y (designated) and 0.13 mSv/y (undesignated) is in agreement with 0.13 mSv/y obtained for solid waste in the city (Jibiri and Adewuyi, 2008). Results of this investigation establish the existence of wide range of variation in ^{232}Th series, ^{238}U and ^{40}K activities which may be attributable to solid wastes. From radiation protection point of view and for the purpose of this study, the doses obtained are low and harmful health effects are not likely on the population in the metropolis. Therefore, the results of the measurement have been taken to represent baseline values of these radioactive elements in soil from waste dumpsites in the metropolis.

References

Ademola, J.A., Farai, I.P. 2006. Gamma activity and radiation dose in concrete building blocks used for construction of dwellings in Jos, Nigeria. *Radiation Protection Dosimetry*, **121:** 395-398.

Arogunjo, A.M. 2007. Terrestrial gamma radiation and radiological implication in southwestern Nigeria. *Journal of Applied Sciences*, **7:** 1534-1537.

Arogunjo, A.M., Farai, I.P., Fuwape, I.A. 2004. Dose rate assessment of terrestrial gamma radiation in delta region of Nigeria. *Radiation Protection Dosimetry*, **108:** 73-77.

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

Charles, M. 2001. UNSCEAR report 2000: source and effects of ionizing radiations. *Journal of Radiological Protection*, **21:** 83.

Deworn, J.P., Slegers, W., Gillard, J., Flemal, J.M., Culst, J.P. 1988. Survey of the natural radiation of Belgium territory as determined by different methods. *Radiation Protection Dosimetry*, **24:** 347-351.

Eddy, N.O., Odoemelem, S.A., Mbaba, A. 2006. Elemental composition of soil in some dumpsites. *Electronic Journal of Environmental, Agricultural and Food Chemistry*, **5:** 1349-1365.

Faweya, E.B. 2009. Radiation dose estimation from the radioactivity analysis of cement used in Nigeria. *Jurnal Fizik Malaysia*, **30:** (in press).

Faweya, E.B. 2007. Radiological dose implications of natural radioactivity contents of sediments of rivers and streams in the northern part of Ibadan city. *Jurnal Fizik Malaysia*, **28:** 17-21.

Faweya, E.B. 2004. Radioactivity in Sediments of some Selected Rivers and Streams in the Northern Part of Ibadan City. *M.Sc Thesis*, University of Ibadan, Nigeria.

Gilbert, R.O. 1987. *Statistical Methods for Environmental Pollution Monitoring*, van Nostrand Reinheld Co., New York, USA.

Ibrahim, N. 1999. Natural activities of ^{238}U, ^{232}Th and ^{40}K in building materials. *Journal of Environmental Radioactivity*, **43:** 255-258.

Ibrahim, N.M., El Ghani, A.H.Abd, Shawky, S.M., Ashraf, E.M., Farouk, M.A. 1993. Measurement of radioactivity levels in soil in the Nile delta and middle Egypt. *Health Pyhsics*, **64:** 620-627.

Isinkaye, M.O., Faweya, E.B. 2006. Occurrence of natural radionuclides in refuse dumpsites within the city of Ado-Ekiti,southwestern Nigeria. *Central European Journal of Occupational and Environmental Medicine*, **12:** 9-14.

Jibiri, N.N., Adewuyi, G.O. 2008. Radionuclide contents and Physico-chemical characterization of solid waste and effluent samples of some selected industries in the city of Lagos, Nigeria. *Radioprotection*, **43:** 203-212.

Moeller, D.W., Sun, L.S. 2006. Comparison of natural background dose rates for residents of the Amargosa Valley, NV, to those in Leadville, Co, and the states of Colorado and Nevada. *Health Physics*, **91:** 338-353.

NPC, 2006. *Population Census of the Federal Republic of Nigeria*, Report of the National Population Commission of Nigeria.

Odunaike, R.K., Alausa, S.K., Oyebanjo, O.A., Ijeoma, G., C., Alo, A.O. 2008. Measurement of Radiation level in refuse dumps across Lagos metropolis in southwestern part of Nigeria. *Environmental Research Journal*, **2:** 174-176.

Papp, Z., Dezso, Z., Daroczy, S. 2002. Significant radioactive contamination of soil around a coal fired thermal power plant. *Journal of Environmental Radioactivity*, **59:** 191-205.

Rajiv, K.S. 2008. Solid and hazardous waste management; cleaner production, www.google search.

UNSCEAR, 1988. *Sources and Effects and Risk of Ionizing Radiations*, United Nations Scientific Committee on the Effects of Atomic Radiation. Report to the General Assembly with Annexes, United Nations, New York, USA.

USDOE, 1992. *The Environmental Measurement Laboratory Procedures Manual*, 27th edition, (revised), HASL-300, United States Department of Energy, New York, USA.

Waite, R. 1995. *Household Waste Recycling*, Earthscan Publications Limited, London, UK.

Wollenberg, H.A., Smith, R.A. 1990. A geochemical assessment of terrestrial gamma-ray absorbed dose rates. *Health Physics*, **58:** 183-189.