Natural radionuclides in beach sands of Ilha Grande, Rio de Janeiro, Brazil

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Abstract

By using a radiation detector, the gamma dose rates of 10 beaches from Ilha Grande were measured. The results (in $nGyh^{-1}$) were 69±14 for Abraãozinho, 65±9 for Biquinha, 79±14 for Caxadaço, 68±12 for Crena, 62±7 for Dois Rios, 68±12 for Guaxuma, 67±9 for Julia, 64±19$nGyh^{-1}$ Parnaioca, 126±24 for Preta and 67±9$nGyh^{-1}$ for Sobradinho. The annual effective doses of Preta Beach was 0.15±0.03mSv y^{-1} and in Caxadaço Beach was 0.10±0.02 mSv y^{-1}, while in the others beaches the mean value of gamma dose rate was 0.08 mSv y^{-1} and did not present significant statistic difference. The activities concentration ($Bqkg^{-1}$) of primordial radionuclides ^{232}Th, ^{238}U and ^{40}K in three differents sand profiles (0-10cm, 10-20cm and 20-30cm) from each beach were measured using gamma ray spectrometry. In the most of cases analysed (8 beaches) in this paper, the primordial radionuclide ^{40}K was the first contributor for the local gamma dose rate calculated. None of beaches analysed were considerated to be radiological risk.

Introduction

Studies of natural background radiation are important to establish reference levels from relative radiological hazards due to the release of radioactive material to environment (Ramli, 1997) and to identify new areas with high natural radiation (Roser & Cullen, 1962). This natural background radiation is mainly because of activities concentration from primordial radionuclides ^{232}Th, ^{238}U and their product of decay, besides of ^{40}K, present in our planet (UNSCEAR, 2000). Around the world, several authors have been studied the levels of natural background radiation through the activities concentration of primordial radionuclides or through *in situ* measurements (e.g. Radhakrishna et al., 1993; Selvasekarapandian et al., 2000; Navas et al., 2002). In Brazil there are two types of areas well known for their high background radiation: the region of volcanic intrusives in the State of Minas Gerais and the region of monazite sands along the Atlantic coast (Penna-Franca et al., 1965; Malanca et al., 1996). The establishment of reference levels is especially important in areas where there is a higher hazard of radioactive material to be released. For that reason, the present study was accomplished in ten beaches of the island named Ilha Grande, located in the Rio de Janeiro coast, near the Nuclear Complex Almirante Alvaro Alberto (CNAAA). This island presents pre-Cambrian bedrock, with high to medium metamorphic grade rocks (charnockites, gneisses and migmatites), and basic intrusives represented by diabase, basalt and gabbro dikes (DePaula & Mozeto, 2001). The beaches studied are known by: Abraãozinho, Biquinha, Caxadaço, Crena, Dois Rios, Guaxuma, Julia, Parnaioca, Preta and Sobradinho; their geografic locations at Ilha Grande are showed in Figure 1. The aim of this study was to stablish the reference level for gamma dose rate and to analyze the activities concentration of ^{232}Th, ^{238}U and ^{40}K in three differents sand depth profiles (0-10cm, 10-20cm and 20-30cm), in studied beaches.

Methodology

The sand samples collection and gamma dose rate maesurements were performed during the months of July until October/01. Measurements of gamma dose rate were performed at 1m above the ground level, over a transect which covered all sand area of the beaches. In each point of the transect, ten readings were recorded using a radiation detector (T.70046A). Sand samples were collected, in each beach, from the spot that showed the highest gamma dose rate measured *in situ*. One sample was collected from three differents depth profiles (0-10cm, 10-20cm and 20-30cm), in order to analyse the concentration of natural radionuclides ^{232}Th, ^{238}U and ^{40}K. All samples were returned to the laboratory where they were dried for 48h at a temperature of 60° C, sieved through a 2 mm mesh, weighed and finally they were stored in a PVC cylindrical container that was hermetically sealed with aluminium paper and kept aside for 30 days in order to obtain secular equilibrium. After that period, all sand samples were submited to gamma spectrometric analysis for a counting time of 36000s, making use of a high-resolution HPGe coaxial detector, with a resolution of 2keV and an efficiency of 25%, coupled to a multichannel and an amplifier analyser. This detector was calibrated using a NIST standant solution. It was set inside a massive old lead shield 10cm thick and with an inner sheet of copper to reduce the background radiation. The photopeaks 609keV of ^{214}Bi and 911keV of ^{228}Ac were used to determine activities concentration ($Bqkg^{-1}$) of ^{238}U and ^{232}Th respectively, while the activity concentration of ^{40}K was directly determined from the 1461keV photopeak (IAEA, 1989). The outdoor absorbed dose rate in each beach was estimated using the conversion factor; $D = 0.662\ S_{Th} + 0.427\ S_U + 0.043\ S_k$ (UNSCEAR, 1988), where D (in $nGyh^{-1}$) represents the absorbed dose rate due to the activities concentration of ^{232}Th, ^{238}U and ^{40}K respectively. In order to achieve this, it was used the sand sample collected from profile of 0-10cm. The background contribution of cosmic rays was

estimated by measurements executed with the detector positioned above the water, at a point where the depth reached 12 m, in the studied area.

Results and discussion

Table 1 shows the statistics data of the gamma dose rate measured 1m above the ground level in the studied beaches. Besides, this table shows the results of gamma dose rate calculated through the activities concentration of radionuclides collected in 0-10cm sand profiles. The value of 36nGyh^{-1}, from cosmic contribution measured in the studied areas, was added to the gamma dose rate calculated.

Table 1: Statistics summary of measured and calculated gamma dose rate (nGyh^{-1}) in the studied beaches.

	GDRM				GDRC
	Mean	S.D.	Min	Max	
Abraãozinho	69	14	42	127	114
Biquinha	65	9	47	88	98
Caxadaço	79	14	53	116	142
Crena	68	12	40	102	102
Dois Rios	62	7	39	81	81
Guaxuma	68	12	41	96	105
Julia	67	9	42	106	72
Parnaioca	64	19	42	169	271
Preta	126	24	75	184	183
Sobradinho	67	9	46	92	67

G.D.R.M: gamma dose rate measured, S.D.: standard deviation, G.D.R.C: gamma dose rate calculated.

The Preta Beach showed the highest mean value (126±24 nGyh^{-1}) of gamma dose rate measured among the studied beaches. As can be seen in Figure 2, the others beaches showed mean values range of 62nGyh^{-1} found in Dois Rios Beach and 79nGyh^{-1} found in Caxadaço Beach.

As described above, the sand samples in all studied beaches were collected from the spots that showed the highest gamma dose rate measured *in situ*. Some beaches such as like Caxadaço, Guaxuma, Parnaioca and Preta, have got different levels of dark sands deposits, due probably, to the high concentration of primordial radionuclides. This was corroborated for the values of gamma dose rate calculated (142nGyh^{-1}, 105nGyh^{-1}, 271nGyh^{-1} and 183nGyh^{-1}, respectively) which were higher than the maximum values of gamma dose rate measured in these beaches.

The results of gamma dose rate measured *in situ* were compared with the gamma dose rate calculated through the activities concentration of ^{232}Th, ^{238}U and ^{40}K in sand samples from the studied beaches. Thus, it was used the maximum values (see Table 1) measured at 1m above ground level, at the points with the highest gamma dose rate. According to Malanca et al. (1996), generally there is not a good agreement between calculated and measured gamma-ray activities, however our results show a positive correlation (R = 0.85) between this gamma dose rates as can be seen in Figure 3, indicating that the field and laboratory measurements are mutually corroborative.

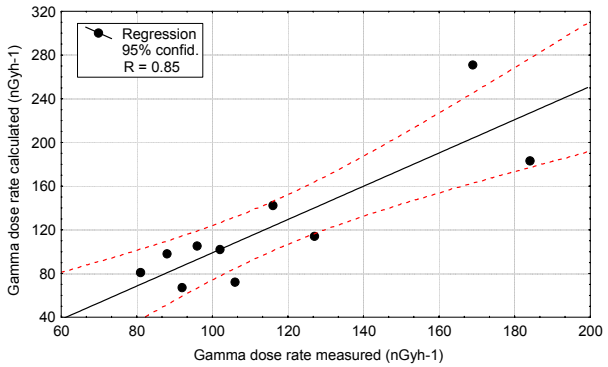

Figure 3: Correlation between measured and calculated gamma dose rate in studied beaches.

The results of annual effective dose rate (mSv y^{-1}) calculated from the dates of the gamma dose rate measured in each studied beach were determined as recommended by UNSCEAR (2000) and they are showed in Table 2.

Table 2: Statistics data of annual effective dose rate (mSv y^{-1}) in the analysed beaches.

	Annual effective dose			
	Mean	S.D.	Min	Max
Abraãozinho	0.08	0.02	0.05	0.16
Biquinha	0.08	0.01	0.06	0.11
Caxadaço	0.10	0.02	0.06	0.14
Crena	0.08	0.01	0.05	0.13
Dois Rios	0.08	0.01	0.05	0.10
Guaxuma	0.08	0.01	0.05	0.12
Julia	0.08	0.01	0.05	0.13
Parnaioca	0.08	0.02	0.05	0.21
Preta	0.15	0.03	0.09	0.23
Sobradinho	0.08	0.01	0.06	0.11

S.D.: standard deviation

The two highest mean values of annual effective dose rate were found in Preta and Caxadaço beaches with 0.15±0.03 mSv y^{-1} and 0.10±0.02 mSv y^{-1}, respectively. The other beaches show the same mean value (0.08mSv y^{-1}) of annual effective dose, and did not present significant statistic difference. In all beaches studied, especially Preta e Caxadaço, the mean values of annual effective dose were higher than the worldwide average (0.07 mSv y^{-1}) for outdoors annual affective dose, published in UNSCEAR (2000). Nevertheless, none studied beach was considerated to be radiological hazard, for fact that there are no inhabitants.

Table 3 shows the cooresponding values of activities concentration (in Bqkg^{-1}) from ^{232}Th, ^{238}U and ^{40}K in the sand profiles of 0-10cm, 10-20cm and 20-30cm. Figure 4 represents the values of mean, standard deviation and standard error from activities concentration of this primordial radionuclides in all studied beaches. The radionuclide ^{40}K shows the highest contribution for the local gamma dose rate in 8 beaches studied. Only in two beaches, Parnaioca and Preta, the main contributors for the gamma dose rate were ^{232}Th and ^{238}U, respectively.

The activities concentration of radionuclides ^{232}Th, ^{238}U and ^{40}K did not show a pattern in relation to the sand profiles analysed. Only in the Sobradinho Beach, the three radionuclies showed the highest activities concentration in the same profile (20-30cm).

Table 3: Activities concentration (Bqkg^{-1}) of ^{232}Th, ^{238}U and ^{40}K in sand samples profiles (0-10, 10-20 and 20-30cm) of studied beaches.

Beaches	Profiles	^{232}Th	^{238}U	^{40}K
Abraãozinho	0-10cm	51.0	18.0	841.5
Abraãozinho	10-20cm	81.2	43.9	768.6
Abraãozinho	20-30cm	58.5	31.2	885.7
Biquinha	0-10cm	38.0	52.9	335.0
Biquinha	10-20cm	56.4	79.8	229.3
Biquinha	20-30cm	43.5	57.5	280.1
Caxadaço	0-10cm	115.0	56.0	147.1
Caxadaço	10-20cm	22.6	10.6	253.7
Caxadaço	20-30cm	33.2	18.6	304.4
Crena	0-10cm	15.0	19.5	1114.4
Crena	10-20cm	29.8	39.7	624.0
Crena	20-30cm	27.3	41.3	1005.7
Dois Rios	0-10cm	23.0	22.7	472.7
Dois Rios	10-20cm	29.1	31.8	405.8
Dois Rios	20-30cm	20.4	16.7	398.6
Guaxuma	0-10cm	22.0	38.4	883.7
Guaxuma	10-20cm	22.4	30.7	1079.9
Guaxuma	20-30cm	12.0	17.8	1082.2
Julia	0-10cm	14.0	11.6	511.6
Julia	10-20cm	7.2	6.8	483.5
Julia	20-30cm	10.4	12.8	471.8
Parnaioca	0-10cm	235.0	175.8	101.9
Parnaioca	10-20cm	240.2	192.9	97.1
Parnaioca	20-30cm	212.7	170.6	111.3
Preta	0-10cm	128.0	133.0	115.7
Preta	10-20cm	122.2	166.7	91.7
Preta	20-30cm	92.2	115.7	101.5
Sobradinho	0-10cm	2.0	4.6	633.2
Sobradinho	10-20cm	17.8	13.6	640.6
Sobradinho	20-30cm	55.4	41.6	1218.9

These results reflect the geological formation from the island where the beaches are located. That island presents an enrichment of elements like K, Th, Rb, Ba, and Ce (Fernandes et al., 2001).

Conclusions

Despite the high value of gamma dose rate found in Preta Beach, none of the analysed beach was considerated to be radiological hazard, because there are no inhabitants. The radionuclide ^{40}K was in the most cases (8 beaches) the main contributor for the local gamma dose rate. Differences observed in the activities concentration from the radionuclides ^{232}Th, ^{238}U and ^{40}K in relation to the sand profiles analysed, can be due to the differents sand properties, like density, humidity and porosity, in each beach. Besides, factors such as wave and wind action can contribute to this concentration.

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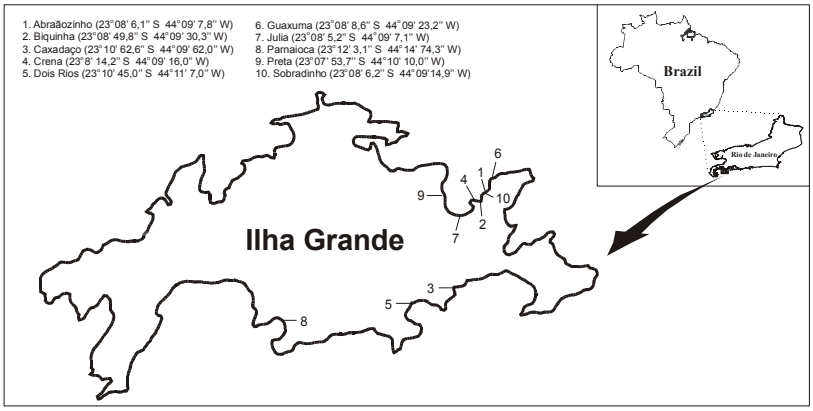

Figure 1: Geographic location of ten studied beaches at Ilha Grande, Rio de Janeiro, Brazil.

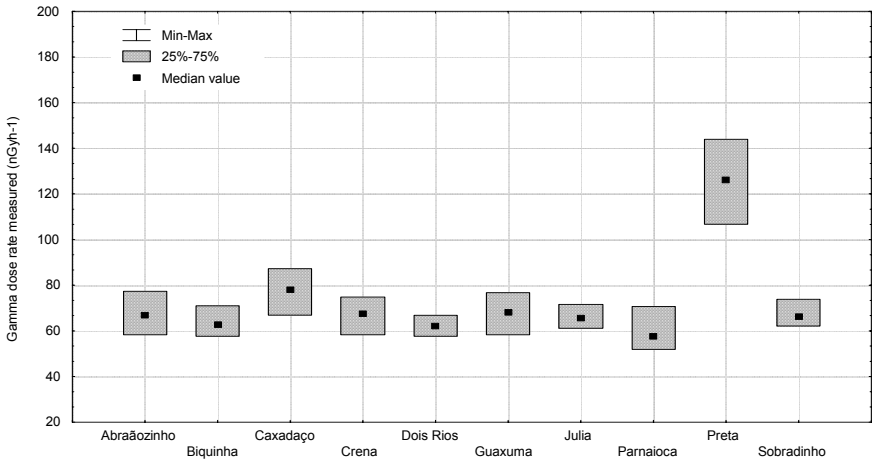

Figure 2: Values of gamma dose rate measured in studied beaches.

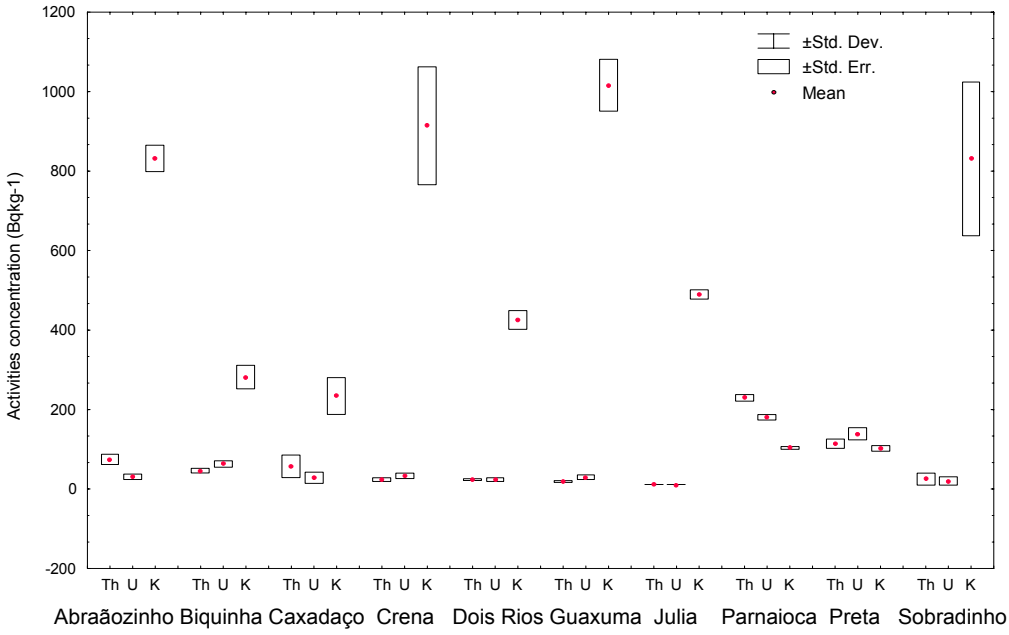

Figure 4: Activities concentration (in Bqkg^{-1}) of ^{232}Th, ^{238}U and ^{40}K in all studied beaches.