# Distribution of $^{232}Th$, $^{238}U$ & $^{40}K$ and variation of gamma dose rate in a Brazilian southeastern beach

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## Abstract

The activities concentration ($Bqkg^{-1}$) of $^{232}Th$, $^{238}U$ and $^{40}K$ in sand samples profiles (0-10, 10-20 and 20-30cm) of Preta Beach in Ilha Grande, Rio de Janeiro - Brazil was measured from gamma ray spectrometry, during a period of twelve months. The activities concentration in the three different profiles ranged of 92-438 for $^{232}Th$, 46-277 for $^{238}U$ and 44-379 for $^{40}K$. The gamma dose rate measured *in situ*, at 1m above the ground level was 125±11nGy $h^{-1}$, corresponding to an annual effective dose of 0.15±0.01 mSv $y^{-1}$, it ranging from 0.07 to 0.28 mSv $y^{-1}$. The primordial radionuclide $^{232}Th$ was the main contributor for the gamma dose rate in the Preta Beach, during the period studied. The results were compared with other studies realized in global scale.

## Introduction

In geophysical studies, the heat produced by radioactive decay in rocks is of fundamental importance in understanding the termal history of the Earth and interpreting the continental heat-flux data (Chiozzi et al., 2000). Primordial radioactive elements present in the Earth's Crust are responsible for that radioactive decay process. These radioactive elements contribute to the natural radioactivity in the environment. There are two sources responsibles to the natural radioactivity in our planet, the first is due to the extraterrestrial radiation from cosmic rays and the second is due mainly to the terrestrial sources from series decay radionuclides $^{238}U$ and $^{232}Th$, besides of $^{40}K$, a non-series decay natural radionuclide (UNSCEAR, 2000). The $^{232}Th$ and $^{238}U$ decay series are commonly associated in nature and together with soil concentration of $^{40}K$, make the major contribution to the total terrestrial gamma flux (Navas, 2002). The amount of radioactive nuclides found in soils and rocks varies widely with differents location. Local geology, rainfall and drainage patterns are, therefore, important factors affecting terrestrial radioactivity (Jibiri, 2001). There are some areas well known for their high background radiation in the west coast of India and certain beaches in Brazil (Brazilian Academy of Science, 1997). The radionuclides distribution and concentration in beach soils has been studied by several authors (e.g. Radhakrishna et al., 1993; Alam et al., 1999; deMeijer et al., 2001). The studied area named Preta Beach (23°07'S 44°10'W) is formed by deposits of dark sands. This initial evidence suggested additional investigation of this area. Preta Beach is located in the Ilha Grande, an island from the Rio de Janeiro State coast (Figure 1). According to DePaula & Mozeto (2001) the bedrock of Ilha Grande is pre-Cambrian, with high to medium metamorphic grade rocks (charnockites, gneisses and migmatites), and basic intrusives represented by diabase, basalt and gabbro dikes. This paper aims to analyse the activities concentration of $^{232}Th$, $^{238}U$ and $^{40}K$ in three differents sand depth profiles (0-10, 10-20 and 20-30cm) and the variation of gamma dose rate in Preta Beach during the period of twelve months.

## Method

The Preta Beach was studied during the period of june/01 to may/02. The gamma dose rate was measured at 1m above the ground level, once a month, making use of a radiation detector (T.70046A). Measurements were performed over a transect which covered all beach area. For statistical purposes, ten instantaneous readings were recorded, at each point of the transect. To analyse the concentration of $^{232}Th$, $^{238}U$ and $^{40}K$ in depth profiles, sand samples were collected from the spot that showed the highest gamma dose rate in each month. One sample was collected from three differents sand depth profiles (0-10, 10-20 and 20-30cm). Sand samples were dried, ground to pass a 2 mm sieve, weighed and finally they were packed in PVC cylindrical containers, sealed with aluminium paper. The containers were kept for one month, in order to obtain secular equilibrium. After that, the samples were subjected to the gamma-ray spectrometry analysis for a counting time of 36000s, using a high-resolution HPGe coaxial detector coupled to a multichannel and an amplifier analyser. The detector system has an efficiency of 25% and a resolution of 2keV, it was calibrated using a NIST standant solution. To reduce the background counting rate, the detector was surrounded with shielding material. The activities concentration ($Bqkg^{-1}$) of $^{232}Th$ and $^{238}U$ were determined from photopeaks 911keV of $^{228}Ac$ and 609keV of $^{214}Bi$ respectively, while the activity concentration of $^{40}K$ was directly determined from the 1461keV photopeak. The cosmic rays contribution was estimated by measurements performed using the radiation detector above the water of approximately 12m depth, on a small boat in the studied area. The outdoor absorbed dose rate was calculated making use of the conversion factor published in UNSCEAR (1988); $D = 0.662\ S_{Th} + 0.427\ S_U + 0.043\ S_k$; where D (in $nGyh^{-1}$) represents the absorbed dose rate due to the activities concentration of $^{232}Th$, $^{238}U$ and $^{40}K$ respectively, collected in sand profile from 0-10cm.

## Results and discussion

The values corresponding to the distribution of natural radionuclides $^{232}$Th, $^{238}$U and $^{40}$K in three different sand profiles are presented in Table 1. Figure 2 shows a graphic representation of this distribution. The activities concentration (in Bqkg$^{-1}$) of the radionuclides range of 92-438 for $^{232}$Th, 46-277 for $^{238}$U and 44-379 for $^{40}$K.

Table 1: Descriptive statistics for the $^{232}$Th, $^{238}$U and $^{40}$K (in Bqkg$^{-1}$) in sand samples from Preta Beach.

| Preta Beach | | Range | Mean | S.D. | Med. | Skew. | Kurt. |
|---|---|---|---|---|---|---|---|
| 0-10 | Th | 128-349 | 239 | 74 | 255 | -0.4 | -0.7 |
| 10-20 | Th | 122-438 | 270 | 88 | 274 | -0.2 | 0.7 |
| 20-30 | Th | 92-433 | 265 | 96 | 283 | -0.5 | 0.3 |
| 0-10 | U | 54-180 | 121 | 33 | 122 | -0.3 | 0.7 |
| 10-20 | U | 51-201 | 137 | 41 | 137 | -0.6 | 0.6 |
| 20-30 | U | 46-277 | 130 | 62 | 117 | 1.2 | 1.8 |
| 0-10 | K | 47-283 | 110 | 62 | 98 | 2.2 | 6.0 |
| 10-20 | K | 44-369 | 120 | 87 | 98 | 2.4 | 6.8 |
| 20-30 | K | 69-379 | 150 | 95 | 117 | 1.5 | 1.8 |

S.D.: stardand deviation, Med.: median, Skew.: skewness and Kurt.:kurtosis.

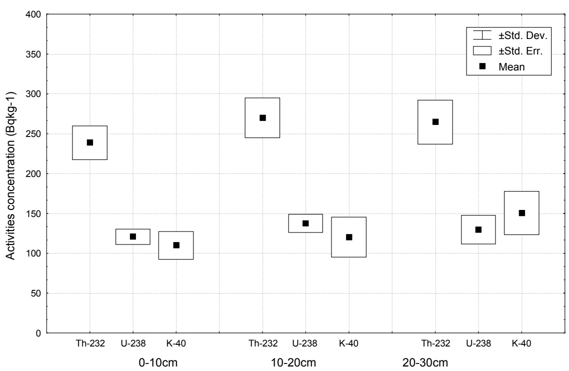


Figure 2: Activities concentration of $^{232}$Th, $^{238}$U and $^{40}$K in the sand profiles.

As can be seen in Figure 2, the activity of $^{232}$Th was the highest in the three differents sand profiles. This result is a reflex of the geological formation from Ilha Grande, which according to Fernandes (2001), in the rocks from Charnockitic Suit Ilha Grande there is enrichment from elements like Th, Rb, Ba, K and Ce. The highest means of $^{232}$Th (270±88 Bqkg$^{-1}$) and $^{238}$U (137±41 Bqkg$^{-1}$) were found at 10-20cm sand profile, while of $^{40}$K (150±95 Bqkg$^{-1}$) was found at 20-30cm. The corresponding frequency distributions from the activities concentration of radionuclides analysed are showed in Figure 3. The activities concentration correponding to $^{232}$Th (0-10, 10-20, 20-30cm), $^{238}$U (0-10, 10-20, 20-30cm) and $^{40}$K (0-10, 10-20, 20-30cm) were fitted to a normal curve.

The activities concentration of $^{232}$Th, $^{238}$U and $^{40}$K in Preta Beach compared to the other beaches in the world, is showed in Table 2.

Table 2: Activities concentration (Bqkg$^{-1}$) of $^{232}$Th, $^{238}$U and $^{40}$K in Preta Beach and at different beaches.

| Location | $^{232}$Th | $^{238}$U | $^{40}$K | Refer. |
|---|---|---|---|---|
| Preta Beach | 92-438 | 46-277 | 44-379 | P. s. |
| Cox's Bazar | 36.7 | * | 458.2 | A |
| Ullal | 1842 | 374 | 158 | B |

P.s.: Present study, A: Alam *et al*., 1999, B: Radhakrishna *et al*., 1993.

Comparing the values from this study to the presented by Radhakrishna *et al*., (1993), it is possible to see which values of $^{232}$Th and $^{238}$U were smaller than the values found in Ullal, considered an area with high natural radiation. However, the value of $^{40}$K, at Preta Beach was higher than that one found in Ullal.

The Table 3 gives results of the correlation among $^{232}$Th, $^{238}$U and $^{40}$K in the three differents sand profiles analysed.

Table 3: Radionuclides correlations from 0-10cm, 10-20cm and 20-30cm sand profiles.

| Preta Beach | 0-10cm | | | 10-20cm | | | 20-30cm | | |
|---|---|---|---|---|---|---|---|---|---|
| | Th | U | K | Th | U | K | Th | U | K |
| Th | 1 | * | * | 1 | * | * | 1 | * | |
| U | 0.7 | 1 | * | 0.6 | 1 | * | 0.8 | 1 | * |
| K | -0.5 | -0.6 | 1 | -0.6 | -0.8 | 1 | -0.6 | -0.7 | 1 |

The radionuclides $^{232}$Th and $^{238}$U showed the highest values of correlation coefficient (0.7, 0.6 and 0.8) from 0-10cm, 10-20cm and 20-30cm respectively. This result shows the state of aggregation between these two radionuclides in Preta Beach, especially in the 20-30cm sand profile, where the wave and wind action are smaller. The $^{40}$K showed negative correlation with $^{232}$Th and $^{238}$U in the three differents sand profiles analysed.

The statistics data of the gamma dose rate measured above the ground level in Preta Beach are shown in Table 4. This table also shows the results of gamma dose rate calculated using the conversion factor published in UNSCEAR (1988). For these calculations, it was used the activities concentration of radionuclides from 0-10cm sand profile. These values were added to the contribution from cosmic radiation (36nGyh$^{-1}$) measured in the studied area. The gamma dose rate calculated range 162-348 nGyh$^{-1}$ in Preta Beach, with a mean of 250±58 nGyh$^{-1}$.

Table 4: Statistics data of gamma dose rate (nGyh$^{-1}$) measured and calculated in Preta Beach.

| Preta Beach | GDRM | S.D. | Min | Max | GDRC |
|---|---|---|---|---|---|
| June | 126 | 24 | 75 | 184 | 182 |
| July | 104 | 28 | 54 | 172 | 162 |
| August | 130 | 30 | 62 | 195 | 278 |
| September | 123 | 27 | 73 | 191 | 245 |
| October | 120 | 28 | 65 | 190 | 245 |
| November | 125 | 29 | 63 | 190 | 237 |
| December | 127 | 31 | 62 | 200 | 264 |
| January | 107 | 31 | 60 | 190 | 272 |
| February | 131 | 31 | 66 | 196 | 287 |
| March | 131 | 30 | 59 | 184 | 162 |
| April | 141 | 28 | 71 | 228 | 348 |
| May | 137 | 33 | 58 | 215 | 318 |

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

The correlation between the gamma dose rates calculated through the activities concentration of radionuclides in sand samples were compared with the *in situ* measurements and are showed in Figure 5. For the comparison, it was used the maximum values (Table 4) measured at 1m above ground level, at the points with the highest gamma dose rate.

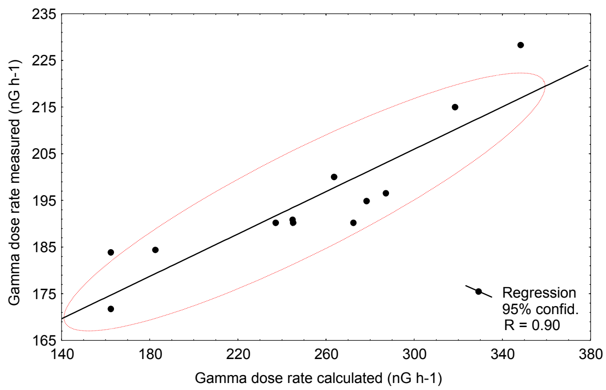


Figure 5: Correlation between calculated and measured gamma dose rates in Preta Beach.

The result shows a high correlation (R = 0.90) between gamma dose rates calculated and measured.

During the studied period, the gamma dose rate measured did not show a high variation, as can be seen in Figure 4. The mean value measured of gamma dose rate in Preta Beach was 125±11nGy $h^{-1}$, with the minimum value found in July (54nGy $h^{-1}$) and the maximum found in April (228nGy $h^{-1}$). The annual effective dose, from Preta Beach was determined as recommended by UNSCEAR (2000), and it varies between 0.07 and 0.28 mSv $y^{-1}$, with a mean of 0.15 ± 0.01 mSv $y^{-1}$.

December is the month, where it was observed the highest volume of rain in that region. The higher means of gamma dose rate (february to may) were observed after the rain period in that province. It is probably due to the enrichment of primordial radionuclides, which may be controlled by inputs from the Abraão brook that drains out into the Preta Beach.

## Conclusions

During the period of study, the activities concentration of $^{232}$Th, $^{238}$U and $^{40}$K did not show a high variation among the three differents sand profiles. In that period $^{232}$Th was the principal contributor for the gamma dose rate in the Preta Beach. The average value to gamma dose rate in air at Preta Beach was 125±11 nGy $h^{-1}$. These values corresponding at an annual effective dose of 0.15±0.01 mSv $y^{-1}$. Although these values are considered high when compared with the world average, Preta Beach is not considered to be radiological hazards, because there are no inhabitants.

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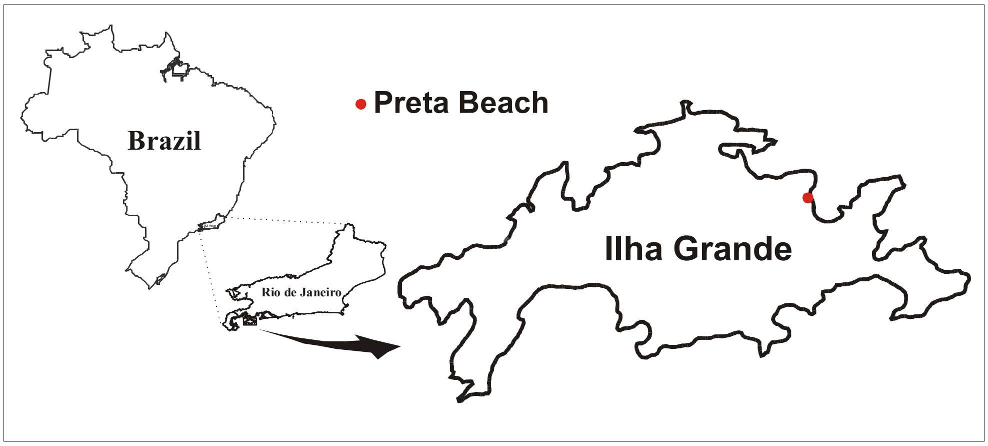


Figure 1: Geographic location of Preta Beach at Ilha Grande, Rio de Janeiro, Brazil.

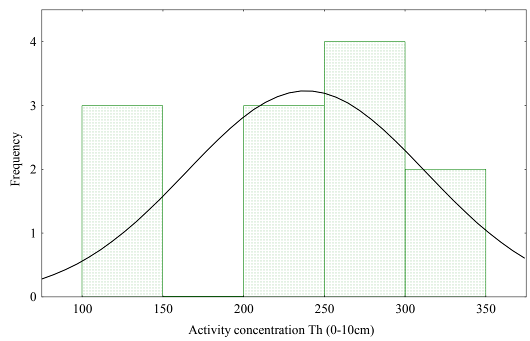


Figure 3 (a)

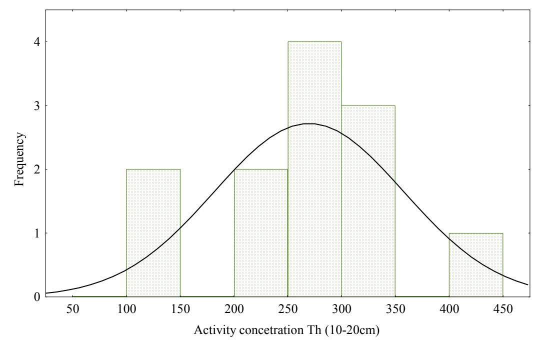


Figure 3 (b)

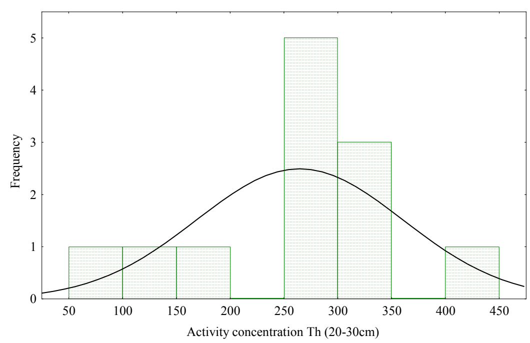


Figure 3 (c)

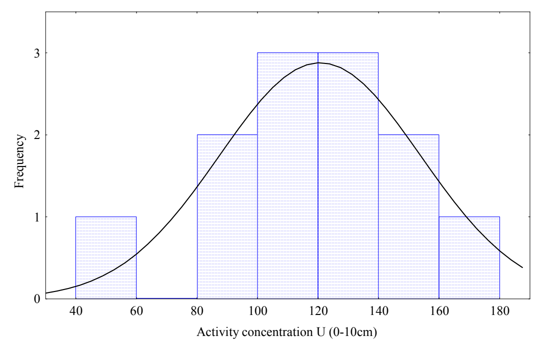


Figure 3 (d)

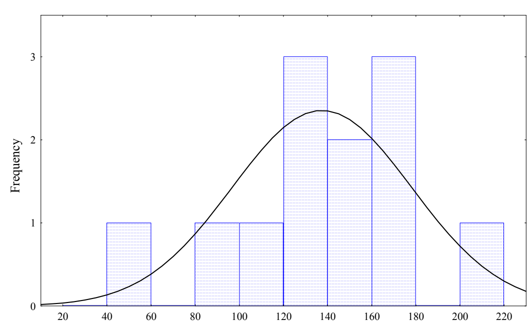


Figure 3 (e)

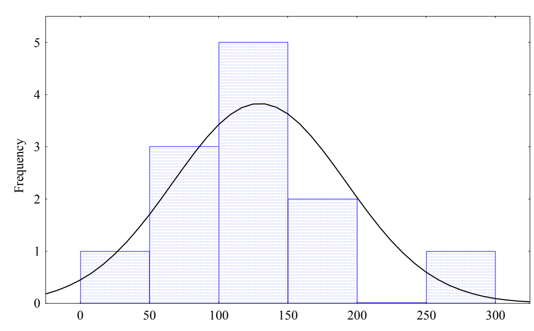


Figure 3 (f)

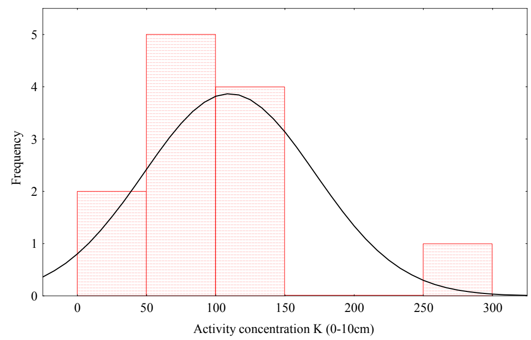


Figure 3 (g)

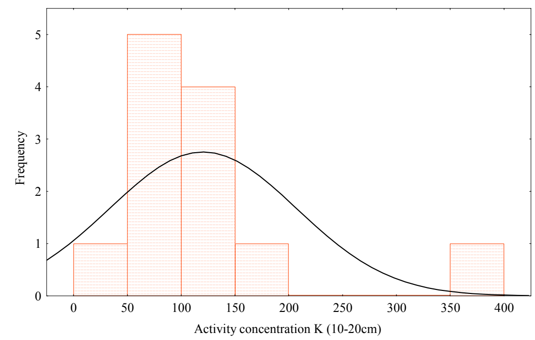


Figure 3 (h)

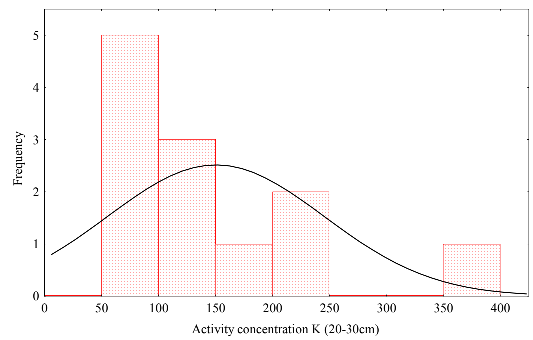


Figure 3 (i)

Figure 3: Frequency distributions from the activities concentration of $^{232}$Th (a-b-c), $^{238}$U (d-e-f) and $^{40}$K (g-h-i) in 0-10cm, 10-20cm and 20-30cm sand profiles.

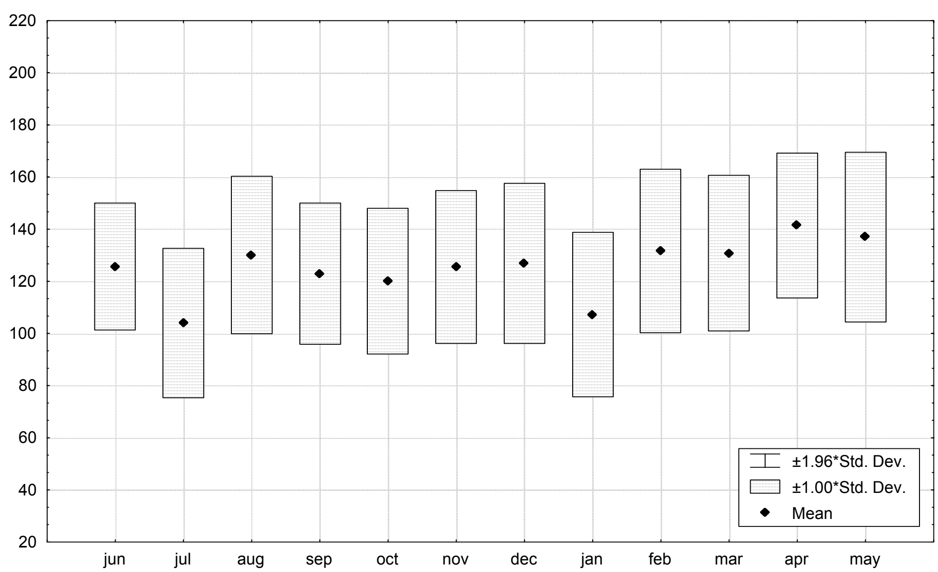


Figure 4: Variation in the gamma dose rate measured at Preta Beach, during the studied period.