EVALUATION OF Ra, Th, K AND RADIUM EQUIVALENT ACTIVITY IN SAND SAMPLES FROM CAMBURI BEACH, VITÓRIA, ESPÍRITO SANTO, BRAZIL.

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ABSTRACT

Camburi beach, in the city of Vitória, Espírito Santo State, Brazil, is a naturally high background region in Brazil. The beach sands contain monazite, ilmenite and other accessory minerals rich in ^{226}Ra, ^{232}Th and ^{40}K. As these radionuclides are the main natural contributors to external exposure from gamma rays, the knowledge of the sands radioactivity content plays an important role in radiation protection. In this work, ^{226}Ra, ^{232}Th and ^{40}K activities concentrations, together with the radium equivalent activity, $Ra_{eq,}$ were determined in some selected sand samples from a single location at Camburi beach, known for the high level of radioactivity. The sand samples collected monthly from January to December 2011, were dried and sealed in standard 100 mL HPDE polyethylene flasks and measured by high resolution gamma-spectrometry after a 4 weeks ingrowth period, in order to allow the secular equilibrium in the ^{238}U and ^{232}Th series. Preliminary results, without considering samples self-attenuation, show activities concentrations in the range from 12 ± 1 Bq kg^{-1} to 1022 ± 30 Bq kg^{-1} for ^{226}Ra, 35 ± 1 Bq kg^{-1} to 5731 ± 134 Bq kg^{-1} for ^{232}Th and 18 ± 4 Bqkg^{-1} to 430 ± 21 Bq kg^{-1} for ^{40}K. The Ra_{eq} presented values ranging from 63 Bq kg^{-1} to 9250 Bq kg^{-1}.

1. INTRODUCTION

Natural sources as soils, rocks and sands may have high radioactivity levels and ^{226}Ra, ^{232}Th and ^{40}K radionuclides are the main natural contributors to external exposure from gamma rays [1]. Therefore, the knowledge of the radioactivity content plays an important role in radiation protection.

In previous works, Barros [2] and Aquino [3] show that the Camburi beach, Espírito Santo State, is a naturally high background region in Brazil, since the beach sands are rich in silica minerals (SiO_2) and also monazitic ((Ce, La, Nd, Th)PO_4) and ilmenitic ($FeTiO_3$) minerals[4]. These accessory minerals contain traces of radioactive elements as uranium and thorium and are deposited non-uniformly at the beaches by the actions of waves and currents. Added to this dynamic, the sand may have come to their place after transport by wind [5].

So, for a single location at the beach, the mineralogical composition may vary depending on climate dynamics. The aim of this work is to determine the seasonal variation of activities concentrations of natural radionuclides ^{226}Ra, ^{232}Th and ^{40}K and the related radium equivalent activities, Ra_{eq}, for a single location at the Camburi Beach from January to December 2011.

2. MATERIALS AND METHODOLOGY

2.1. Study Area

Camburi Beach (Fig. 1) is located in Vitória, capital of Espírito Santo State, Brazil, with an extension of 6 km. The city has approximately 300 thousand inhabitants [6] and Camburi is the only beach located in the mainland city.

Camburi Beach comprehend three different regions, namely North, Central and South, the weather is warm almost the entire year, so the beach is constantly frequented both by locals and tourists.

Figure 1. Map of Espírito Santo State and geographic location of Camburi Beach (North, Central and South Camburi) on the coast of Espírito Santo State, Brazil. [2]

2.2. Samples Collection and Preparation

The location had been selected following the mineral composition and the geographical coordinate of the collecting point is 20º16'57.35"S 40º17'19.38"W (Fig. 2). A speckle pattern is more intense in the region of Central Camburi, due to the presence of ilmenite and monazite. (Fig. 3). The sand samples were collected almost at the beach surface, within a depth of about 2 cm.

Each sample was sealed in a standard 100 ml polyethylene flask and stored for approximately 4 weeks before counting, in order to allow the reaching of secular equilibrium in the ^{238}U and ^{232}Th series [7]

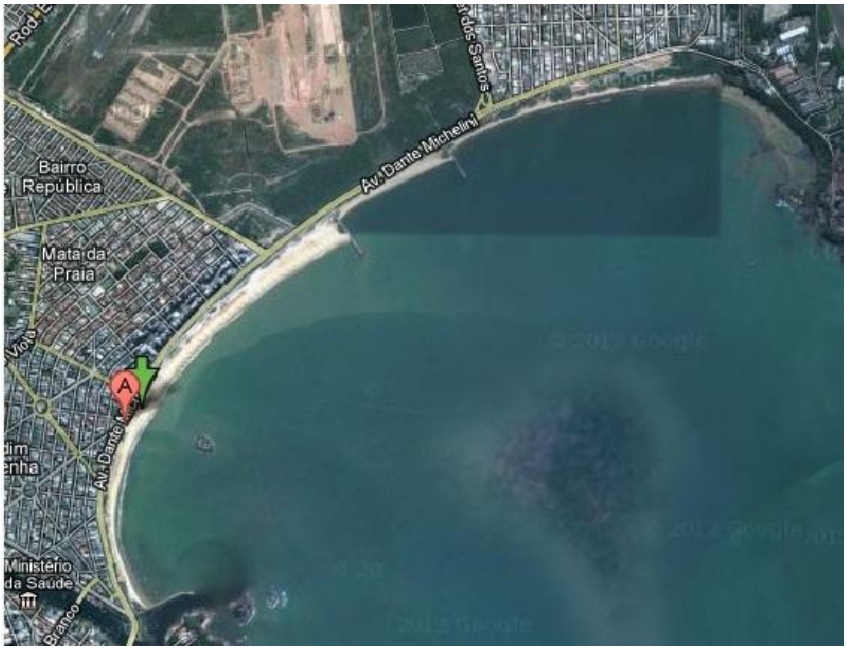

Figure 2. Camburi Beach. "A" red bubble shows the Dante Micheline Avenue and the green arrow indicates the location of the collection point.

Figure 3. Central Camburi Beach, with visible speckle pattern in the sand, due to the presence of ilmenite and monazite. Photo: Personal archive.

2.3 Measurements

The samples were measured by high resolution gamma spectrometry with a 15% HPGe ORTEC EG&G detector with conventional electronics and a 919 ORTEC EG&G Spectrum Master 4k multichannel analyzer. The resolution for the ^{60}Co 1332 keV energy is 2.8 keV.

The efficiency calibration curve used for the activities calculations was obtained with an aqueous standard multi-radionuclides solution in the same sample geometry. The background radiation was obtained with a 100-mL HDPE flat-bottom cylindrical flask with screw cap and bubble spigot filled with ultrapure water.

All spectra were analyzed with the WinnerGamma software [8], assuming an equivalent water density for all samples.

The activity concentration of a single transition was calculated as [2]:

$$A(X) = \frac{C(E)}{P_\gamma(E).\varepsilon(E).m.t} \quad (1)$$

Where:
A(X) = activity of the considered gamma transition of the isotope X in the sample (Bq.kg^{-1});
C(E) = net number of counts obtained for the gamma transition with energy (E) emitted by X;
Pγ(E) = probability of emission of the gamma transition with energy (E);
ε(E) = detector efficiency for the considered gamma transition;
m = sample mass (kg);
t = counting time (s).

The activity of ^{40}K was calculated through its single gamma transition of 1460.83 keV. The activity of ^{226}Ra was determined by the weighted mean of the ^{214}Pb (295.21 keV and 351.92 keV) and ^{214}Bi (609.32 keV) gamma transitions and the activity of ^{232}Th by the weighted mean of the ^{212}Pb (238.63keV and 300.09 keV), ^{212}Bi (727.33 keV) and ^{228}Ac (911.07 keV and 968.90 keV) gamma ray transitions.

2.4. Calculation of Radium equivalent activity (Ra_{eq})

The distribution of radioactivity in natural samples is not uniform. In order to assess the health effects from the natural radioactivity, the activity of ^{226}Ra, ^{232}Th and ^{40}K is converted into a single quantity termed Ra_{eq}, assuming that 370 Bq kg^{-1} de ^{226}Ra, 259 Bq kg^{-1} de ^{232}Th e 4810 Bq kg^{-1} de ^{40}K produce an equal gamma ray dose rate [9].

The radium equivalent activity index may be calculated using the formula [10]:

$$Ra_{eq} = A_{Ra} + 1.43A_{Th} + 0.077A_K \quad (2)$$

where A_{Ra}, A_{Th} and A_K are the activities concentrations of ^{226}Ra, ^{232}Th and ^{40}K, respectively. The Ra_{eq} is a useful guide in assessing the safety standards of radiation protection for individuals of the public residing in buildings. It is recommended for safe use in construction materials that the value of Ra_{eq} does not exceed the limit of 370 $Bq.kg^{-1}$ [11].

3. RESULTS AND DISCUSSION

3.1. Activity Concentration and Radium Equivalent Activity in Camburi Sands

The activities concentrations values of ^{232}Th, ^{226}Ra and ^{40}K and the Radium equivalent (Ra_{eq}) found in this work are presented in Fig. 4:

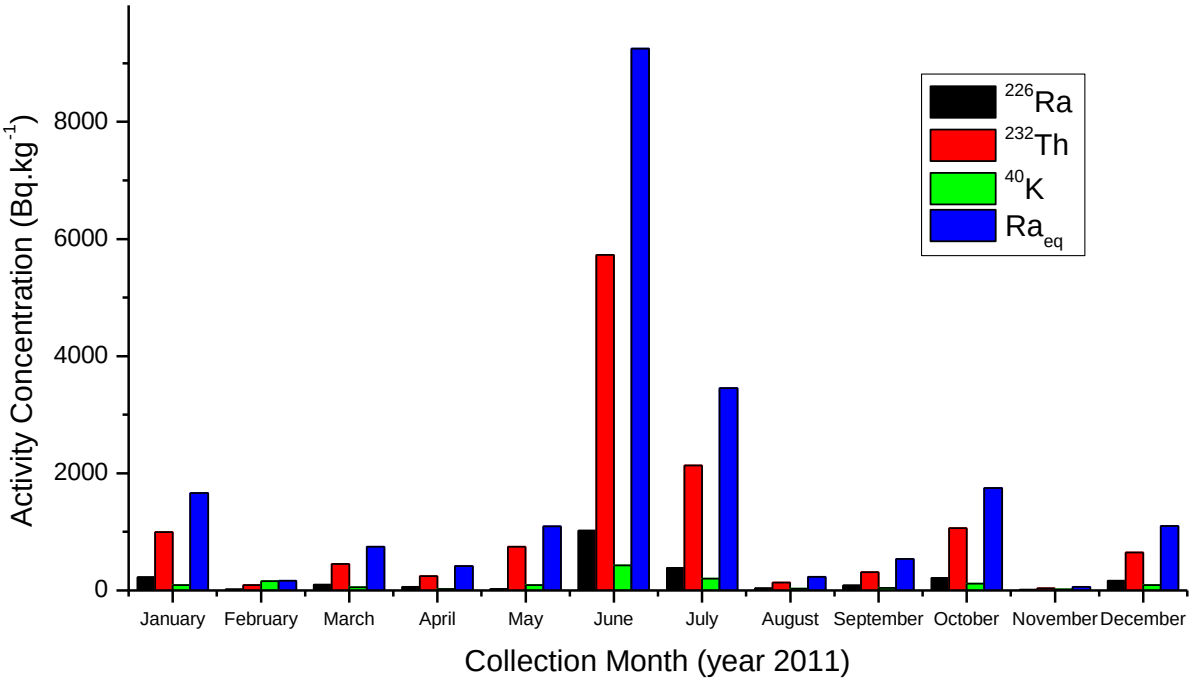

Figure 4. Activities concentrations of ^{226}Ra, ^{232}Th, ^{40}K and Ra_{eq} in sands samples from Camburi Beach, ES, Brazil for the collection months of the year 2011.

The results, with no self-attenuation correction, show activities concentrations in the range from 12 ± 1 Bq kg^{-1} to 1022 ± 30 Bq kg^{-1} for ^{226}Ra, 35 ± 1 Bq kg^{-1} to 5731 ± 134 Bq kg^{-1} for

^{232}Th and 18 ± 4 Bq kg^{-1} to 430 ± 21 Bq kg^{-1} for ^{40}K. The Ra_{eq} presented values ranging from 63 Bq kg^{-1} to 9250 Bq kg^{-1}.

The higher activities concentrations of ^{226}Ra, ^{232}Th and ^{40}K and higher radium equivalent activity (Ra_{eq}) were obtained for the month of June 2011. The value of Ra_{eq} is lower than the upper limit of 370 Bq.kg^{-1} [10] only for the months of February, August and November 2011.

Aquino [3] show activities concentrations from Camburi beach in the range from 6 Bq kg^{-1} to 755 Bq kg^{-1} for ^{226}Ra, 16 Bq kg^{-1} to 4155 Bq kg^{-1} for ^{232}Th and 29 Bq kg^{-1} to 377 Bq kg^{-1} for ^{40}K.

Veiga [12] show activities concentrations of ^{226}Ra, ^{232}Th and ^{40}K from Meaipe beach, located in Espírito Santo State, Brazil, respectively as 1001 ± 260 Bq kg^{-1}, 6422 ± 2040 Bq kg^{-1} and 127± 63 Bq kg^{-1}.

Sowmya [13] show activities concentrations from Kalpakkam beach, located in India, in the range from 9,6 Bq kg^{-1} to 53 Bq kg^{-1}for ^{226}Ra, 37 Bq kg^{-1} to 163 Bq kg^{-1} for ^{232}Th and 210 Bq kg^{-1} to 607 Bq kg^{-1} for ^{40}K.

All results of this work are within the range of literature values for similar sands of regions with high natural background radiation level.

4. CONCLUSIONS

This study intends to bring out the background radiation levels in the Camburi Beach through various radioactivity measurements. As expected, due to the strong presence of monazite, the the concentration of ^{232}Th is higher than the concentration of ^{226}Ra and ^{40}K.

The results of the present work are related to a single location at Camburi beach. Monthly samplings were done in 2011, covering all extension of the Camburi Beach mainland, with 11 samples locations. The activities concentrations values of ^{226}Ra, ^{232}Th and ^{40}K and Radium equivalent activities are in the final stage of assessment for all samples collected.

As the sand samples have apparent densities around 1.8 g.cm^{-3} and the efficiency calibration curve used was obtained with an aqueous standard multi-radionuclides solution, attenuation factors for all samples will be further determined [14].

As next step, is to relate the activities concentrations values of ^{226}Ra, ^{232}Th and ^{40}K will be correlated both with weather conditions such as wind and/or rain and behavior of tides, waves and ocean streams.

The complete assessment of the natural radioactivity in the Camburi beach sands will be concluded with the calculus of radiological hazard index, I_γ and H_{ex} [10].

ACKNOWLEDGMENTS

The authors will like to thank the Institute for Energetic and Nuclear Researches (IPEN/SP) for the Master Degree opportunity and the Environmental Radiometric Laboratory of IPEN for the use of the facilities.

One of the authors (Lívia F. Barros) would like to thank to Mateus F. Barros, Elany Soraia F. Barros and Leonardo F. Santos for their assistance in sample collection.

REFERENCES

1. UNSCEAR, *Sources and effects of ionizing radiation*, United Nations Scientific Committee on the Effects of Atomic Radiation, United Nations, New York (2000).
2. Barros, L. F., et al, "Gamma radiation measurements in select sand samples from Camburi Beach - Vitória, Espírito Santo, Brazil: Preliminary results." *2011 International Nuclear Atlantic Conference*, Belo Horizonte, October 24-28 (2011).
3. Aquino, R. R. "Avaliação da radioatividade natural em areias das Praias da Grande Vitória - Espírito Santo". Thesis (Master Degree) - Instituto de Pesquisas Energéticas e Nucleares- IPEN-CNEN/SP, São Paulo, 2010. 79 p. http://www.teses.usp.br (2010)
4. Machado, F. B., et al., *Enciclopédia Multimídia de Minerais*. ISBN: 85-89082-11-3, http://www.rc.unesp.br/museudpm (2012).
5. Eissa, H. S., et al, "Radiation Dose Estimation of sand samples collected from different Egyptian beaches", *Radiation Protection Dosimetry*, **Vol. 147**, pp.533-540 (2010).
6. "IBGE: Instituto Brasileiro de Geografia e Estatística. Censo 2010", http://www.ibge.gov.br/censo2010 (2012).
7. Knoll,Glenn F., *Radiation Detection and Measurement*, Third Printing, New York, United States (1999).
8. ORTEC, *InterWinnerTM6.0 MCA Emulation, Data Acquisition and Analysis Software For Gamma and Alpha Spectroscopy*, TOMCOM Software Ltd., (2004).
9. Stranden, E. "Some aspects on radioactivity of building materials". *Physica Norvegica.*, **Vol. 8**, pp. 167 (1976).
10. Beretka, J., Mathew, P. J. "Natural Radioactivity of Australian Building Materials, Industrial Wastes and By-products." *Health Physics*., **Vol. 48(1)**, pp.87-95 (1985).
11. OECD, 1979. Organization for Economic Cooperation and Development. *Exposure to radiation from natural radioactivity in building materials*. Report by Group of Experts of the OECD Nuclear Energy Agency, OECD, Paris (1979).
12. Veiga, R., et al, "Measurement of natural radioactivity in Brazilian beach sands", *Radiation Measurements*, **Vol. 41**, pp.189–196 (2006).
13. Sowmya M., et al, "Some natural radioactivity and associated dose rates in soil samples from Kalpakkam, South India." *Radiation Protection Dosimetry*, **Vol.141**, pp. 239-247 (2010).
14. Barros, L. F. and Pecequilo, B. R. S., "Self-Attenuation Factors in gamma-ray spectrometry of select sand samples from Camburi Beach, Vitória, Espírito Santo, Brazil.," *Radiation Physics and Chemistry*, http://dx.doi.org/10.1016/j.radphyschem.2012.12.031 (2013).