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GAMMA RADIATION MEASUREMENTS IN SELECT SAND SAMPLES FROM CAMBURI BEACH-VITÓRIA, ESPÍRITO SANTO, BRAZIL: PRELIMINARY RESULTS

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ABSTRACT

The variation of natural radioactivity along the surface of the beach sands of Camburi, located in Vitória, capital of Espírito Santo, southeastern Brazil, was determined from the contents of ^{226}Ra, ^{232}Th and ^{40}K. Eleven collecting points was selected along all the 6 km extension of the Camburi beach. Sand samples collected from all established points on January 2011 were dried and sealed in standard 100 mL 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.. The ^{226}Ra concentration was determined from the weighted average concentrations of ^{214}Pb and ^{214}Bi. The ^{232}Th concentration was determined from the weighted average concentrations of ^{228}Ac, ^{212}Pb and ^{212}Bi and the ^{40}K from its single gamma transition. Preliminary results show activity concentrations varying from 5 Bq.kg^{-1} to 222 Bq.kg^{-1} for ^{226}Ra and from 14 Bq.kg^{-1} to 1074 Bq.kg^{-1} for ^{232}Th, both with the highest values for Camburi South and Central. For ^{40}K, the activity concentrations ranged from 14 Bq.kg^{-1} to 179 Bq.kg^{-1} and the highest values were obtained for Camburi South.

1. INTRODUCTION

The main external source of irradiation to the human body are the naturally occurring radioactive elements in the soils and rocks, namely ^{40}K and the primordial radionuclides ^{226}Ra and ^{232}Th, respectively from the ^{238}U and ^{232}Th series, originated in the earth crust and present mostly everywhere in the environment [1].

In Brazil, Guarapari beach, Espírito Santo State, is a well known place presenting high levels of NORM (Normally Occuring Radioactive Materials). In a previous work, Aquino [2] found that Camburi Beach also presented high levels of ^{226}Ra (near 700 Bq.kg^{-1}) and ^{232}Th (near 4000 Bq.kg^{-1}). As those results were obtained for a few samples collected in the summer, it is interesting to extend the study for samples covering all the year. Camburi Beach, with an extension of 6 km, located in Vitória, capital of Espírito Santo State, Brazil, a city with approximately 300 thousand inhabitants [3], is the only beach located in the mainland city. The geographic location of Camburi Beach is shown in Fig.1.

Camburi Beach comprehend three different regions, namely North, Central and South, with silica group sands (SiO_2) and also monazitic ($(Ce, La, Nd, Th)PO_4$) and ilmenitic ($FeTiO_3$) sands [4], shown in the Fig.2, well known for their high radiation content. As the weather in Vitória is warm and pleasant almost the entire year, these beaches are constantly frequented by the general public, and, until now, there is no assessment of the NORM effects of the Camburi sands. The aim of this work is to determine the seasonal variation of natural radioactivity along the extension of the Camburi Beach mainland.

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.

Figure 2. Central Camburi Beach, with visible speckle pattern in the sand, due to the presence of ilmenite and monazite, that extends right to the beach. Photo: Flávio Santos. [2]

2. MATERIALS AND METHODOLOGY

2.1. Samples Collection and Preparation

In the sampling process, the locations had been selected following the human concentration criterion and the mineral composition of the sands samples throughout the coast of Camburi Beach. Dark tonalities in sands were observed in regions of higher ilmenitic mineral concentrations. It was also observed that the monazitic sands present a variation of tonality between the colored and brown tones, not black as it is believed [4].

Superficial beach sand samples with a depth of about 2 cm were collected at a distance of 3 m of the sea line. 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 [5].

The Dante Michelini Avenue is the main street bordering the beach of Camburi and has the best hotel infrastructure of Vitória. The streets perpendicular to Dante Michelini Avenue were used as reference for the choice of landmarks sampling points. The sampling points, characterized by their landmarks, their reference perpendicular streets and reference numbers on the Dante Michelini Avenue are listed in Table 1. The samples locations are shown in Fig.3.

Table 1. Sampling points (landmarks), their reference streets and Dante Micheline Avenue reference numbers.

Landmarks	Reference Perpendicular Street	Dante Michelini Avenue Reference Number
1	Anísio Fernandes Coelho Avenue	30
2	Adriano Fontana Street	435
3	Carlos Eduardo Monteiro Lemos Street	1564
4	Doutor Antonio Basílio Street	991
5	Aristóbulo Barbosa Leão Street	51
6	Antonio Borges Avenue	2097
7	Adalberto Simão Nader Avenue	2461
8	PIER 1	-
9	PIER 2	-
10	Carlos Martins Street	3957
11	Paschoal Del Maestro Street	465

As landmarks 8 and 9 are in front of a large field of Aeronautics, there is no reference number on the Dante Michelini Avenue. PIER 1 and PIER2 are walkways over the water that serve as a breakwater, so they are not streets, but serve as references.

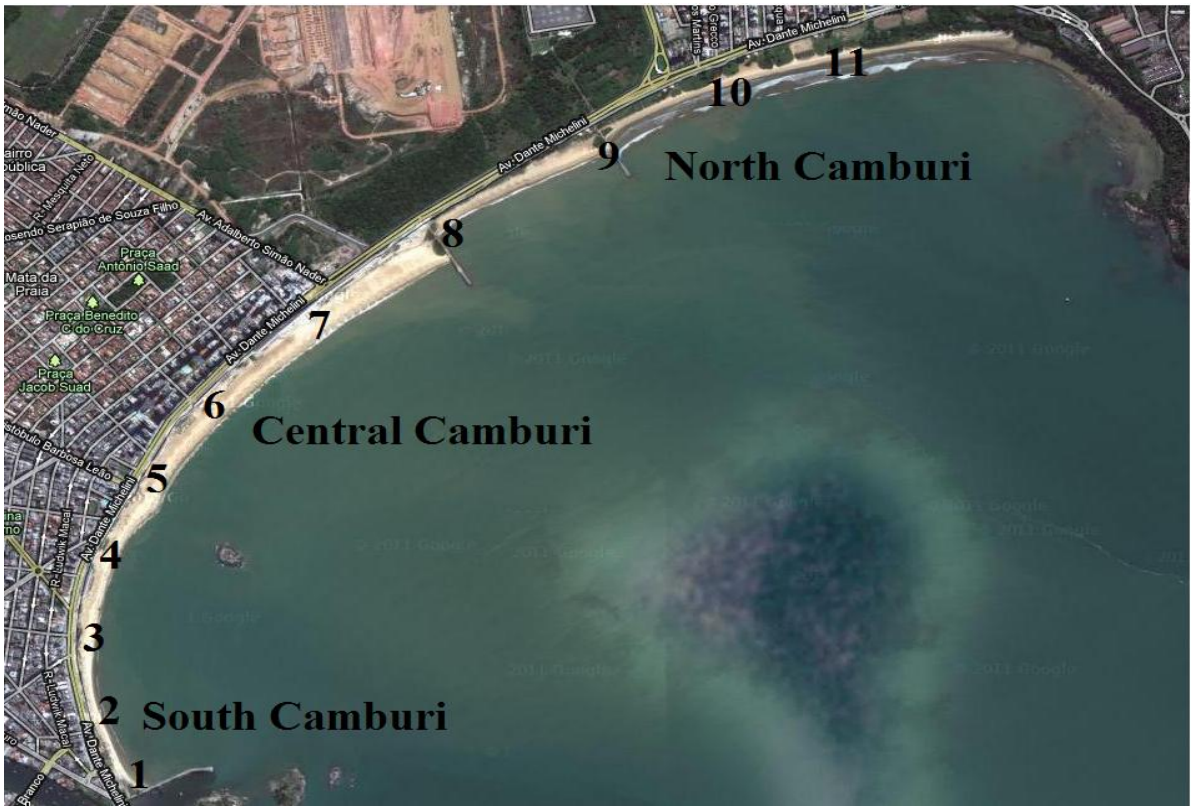

Figure 3. The numbers (1-11) represent the location of the collected samples.

2.2. 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. All spectra were analyzed with the WinnerGamma software [6], assuming an equivalent water density for all samples. 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.

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

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

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 ^{232}Th concentration was determined from the average concentrations of ^{228}Ac, ^{212}Pb and ^{212}Bi. The ^{226}Ra concentration was determined from the average concentrations of ^{214}Pb and ^{214}Bi and the concentration of ^{40}K is determined directly by its gamma transition.

For each sample, the activity of ^{40}K was calculated through its single gamma transition, the activity of ^{226}Ra by the weighted mean of the ^{214}Pb and ^{214}Bi gamma ray transitions and the activity of ^{232}Th by the weighted mean of the ^{212}Pb, ^{212}Bi and ^{228}Ac gamma ray transitions, all chosen by their highest intensities, as showed in Table 2.

Table 2. Gamma transitions used for determination of the activities concentrations of ^{226}Ra, ^{232}Th and^{40}K.

Radionuclide	Progeny	Gamma energy (keV) [6]	Gamma intensity(%)[6]
^{226}Ra	^{214}Pb	295.21 351.92	18.7 35.8
	^{214}Bi	609.32	45
^{232}Th	^{212}Pb	238.63 300.09	43.5 3.25
	^{212}Bi	727.33	6.64
	^{228}Ac	911.07 968.90	27.8 16.74
^{40}K	^{40}K	1460.83	10.67

3. RESULTS AND DISCUSSION

3.1. Activity Concentration in Camburi Sands

The activities concentrations values of ^{232}Th, ^{226}Ra and^{40}K found in this work and by Aquino [2] are presented in Table 3.

Table 3. Activities concentrations values of ^{232}Th, ^{226}Ra and ^{40}K.
(in brackets the uncertainty, with a confidence level of 68 %, (± 1 σ), k=1)

Landmark	^{232}Th (Bq.kg^{-1})		^{226}Ra(Bq.kg^{-1})		^{40}K(Bq.kg^{-1})	
	This work	[2]	This work	[2]	This work	[2]
1	25(5)		8(1)		179(12)	
2	968(79)	1462(93)	170(12)	259(14)	159(22)	139(11)
3	26(4)		8(1)		26(7)	
4	92(9)		29(2)		ND	
5	1074(78)	4170(262)	222(13)	738(38)	82(11)	367(19)
6	116(10)		28(2)		14(7)	
7	107(10)		29(2)		23(7)	
8	67(8)		17(2)		23(7)	
9	116(10)		28(2)		14(7)	
10	15(3)	17(4)	5(1)	6(1)	ND	44(8)
11	14(4)		ND		27(6)	

ND = Non Determined

The results of Table 3 are plotted in Fig. 4.

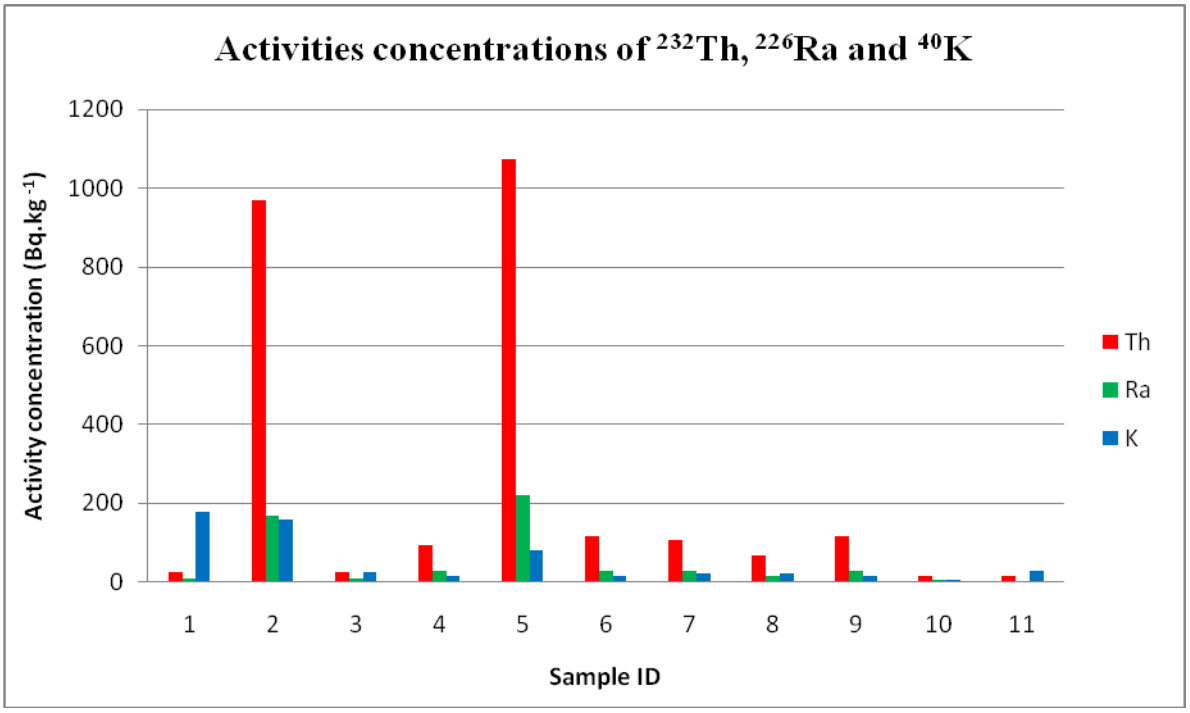

Figure 4. Activities concentrations of ^{232}Th, ^{226}Ra and ^{40}K in sands from Camburi Beach, ES, Brazil.

These results show concentrations varying from 5 $Bq.kg^{-1}$ to 222 $Bq.kg^{-1}$ for ^{226}Ra and from 14 $Bq.kg^{-1}$ to 1074 $Bq.kg^{-1}$ for ^{232}Th, both with the highest values for Camburi South and Central (landmarks 2 and 5). For ^{40}K, the results ranged from 14 $Bq.kg^{-1}$ to 179 $Bq.kg^{-1}$, with the highest value for Camburi South (landmarks 1 and 2). Previous results from Aquino [2] are comparable with the present work results, even if the location of the sampling points is lightly different.

4. CONCLUSIONS

Activities concentrations of ^{226}Ra, ^{232}Th and ^{40}K in sands collected in January 2011 from eleven sampling points covering the Camburi beach extension show sharply that the higher activities are in the Camburi South and Central beaches, as pointed out also by Aquino [2] in a single run sampling.

The results of the present work represent the January 2011 sampling. Monthly sampling will be done until the end of 2011, covering the four season of the year, and all samples will be measured in triplicates. As the sand samples have apparent densities around 1.7 $g.cm^{-3}$, attenuation factors for all samples will be further determined. Also, the results will be related with the tides of Camburi beach along the year.

The complete assessment of the natural radioactivity in the Camburi beach sands will be ended with the calculus of both radium equivalent activity and external hazard index.

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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. AQUINO, R. R. ***Avaliação da radioatividade natural em areias das Praias da Grande Vitória - Espírito Santo.*** 2010. Thesis (Master Degree) - Instituto de Pesquisas Energéticas e Nucleares- IPEN-CNEN/SP, São Paulo, 2010. 79 p. Available at: <http://www.teses.usp.br>.
3. "IBGE: Instituto Brasileiro de Geografia e Estatística. Censo 2010," Available at: <http://www.ibge.gov.br/censo2010> (2010) Accessed in 23/02/2011.
4. F.B. Machado, C.A. Moreira, A. Zanardo, A.C. Andre, A.M. Godoy ; J.A. Ferreira, T.Galembeck, A.J.R. Nardy, A.C. Artur, M.A.F de Oliveira, *Enciclopédia Multimídia de Minerais*,. Available at: <http://www.rc.unesp.br/museudpm> (2008) Accessed in 12/07/2009.
5. Knoll,Glenn F., *Radiation Detection and Measurement*, Third Printing, New York, United States (1999).

6. ORTEC, *InterWinnerTM6.0 MCA Emulation, Data Acquisition and Analysis Software For Gamma and Alpha Spectroscopy*, TOMCOM Software Ltd., (2004).