2013 International Nuclear Atlantic Conference - INAC 2013
Recife, PE, Brazil, November 24-29, 2013
ASSOCIAÇÃO BRASILEIRA DE ENERGIA NUCLEAR - ABEN
ISBN: **978-85-99141-05-2**

RADIOLOGICAL ASSESSMENT OF BEACH SANDS OF MARATAÍZES, ESPÍRITO SANTO STATE, BRAZIL

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ABSTRACT

In this study samples of three major beaches of Marataízes (Centro Beach, Preta Beach and Cidade Nova Beach) were analyzed by high resolution gamma-spectrometry in order to determine the activity concentration of ^{226}Ra, ^{232}Th and ^{40}K, followed by the dosimetric index assessment. Samples were collected, dried at 80°C for 24h sealed in 100-mL HDPE flat-bottom cylindrical 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. The gamma-ray spectra were analyzed with the InterWinner software. The ^{226}Ra activity concentration was determined from the weighted average concentrations of ^{214}Pb and ^{214}Bi and the ^{232}Th activity concentration was determined from the weighted average concentrations of ^{228}Ac, ^{212}Pb and ^{212}Bi. The activity concentration of ^{40}K was determined by its single gamma transition of 1460 keV. The activity concentrations for the studied sites are in the range from 75 to 860 Bq.kg^{-1} for ^{226}Ra, from 990 to 2300 Bq·kg^{-1} for ^{232}Th and 30 to 270 Bq·kg^{-1} for ^{40}K. The radium equivalent activities concentration ranged from 300 to 4200 Bqkg^{-1}. The highest activity concentration has been determined for "Cidade Nova" beach. The measured values for the locality of Marataízes are higher than other locations previously investigated.

1. INTRODUCTION

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

Marataízes is a tourist city which occupies an area of 135,402 km², predominantly relief of plains, faraway around 127 km of the capital Vitória, located on the Atlantic coast in the south of Espírito Santo State, Brazil (Fig. 1), with about 37,000 inhabitants and approximately 25 km of beaches [2].

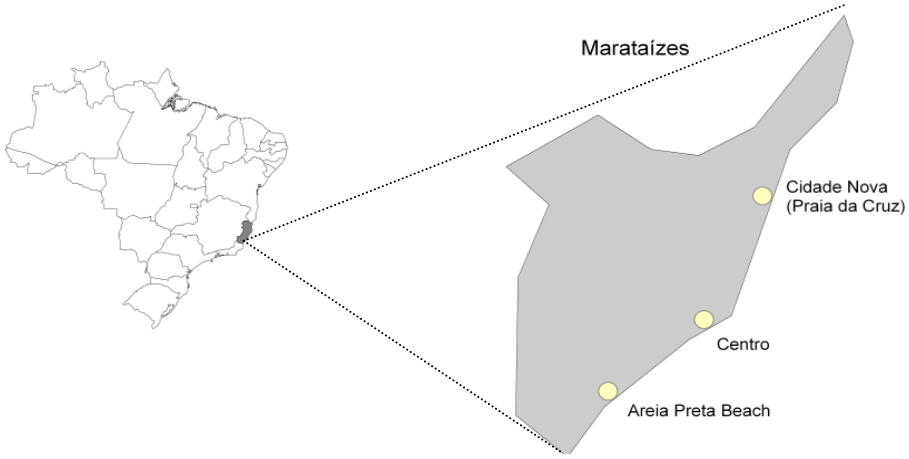

Figure 1: Marataízes beaches, with sampling locations.

Along the shore, it is possible to observe the black spots over the sand, in particularly for "Centro" Beach, "Preta" Beach and "Cidade Nova" Beach, similar to those found in the sands of 'Areia Preta" beach in Guarapari, which contain minerals such as ilmenite, monazite, rutile and zircon with well known high concentrations of ^{238}U, ^{232}Th and ^{40}K.

Whereas Maratízes beaches are frequented both locals as by tourists throughout the year, it is very important to know the radioactivity content of these sands, in order to evaluate the radiation hazard in these areas.

2. MATERIALS AND METHODOLOGY

2.1. Sampling Collection and Preparation

In the sampling process, the location was selected considering the apparent tonality variation, which suggest concentration of black sands (ilmenitics mineral) and red to brown sands (monazitics sands).

Superficial black sands samples were collected with a 2 cm a depth on black spots (Figure 1). After manually removing macro-impurities (like shells, pebbles, food leftovers), the sands were dried at 80°C for 24h, and therefore sealed in 100-mL HDPE flat-bottom cylindrical 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 [3]. For each location, the samples were prepared in triplicate.

2.2. Measurements

All samples were measured by high resolution gamma spectrometry with a coaxial high-purity germanium detector (HPGe) of 15% relative efficiency with conventional electronics and a 919 ORTEC EG&G Spectrum Master 4k multichannel analyzer. The measured resolution for the ^{60}Co 1332.5 keV is 2.9 keV. The HPGe detector and the samples were placed inside a conventional lead shield, with 10 cm of thickness and the counting time for all samples was 1000 s. All spectra were analyzed with the WinnerGamma software [4].

The activity concentration of a single transition is classically calculated as in Eq. 1 [3]:

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

Where:
A(X) = activity of the considered gamma transition of the isotope X in the sample ($Bqkg^{-1}$);
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 background radiation was determined by measuring a high purity water sample in the same geometry as the sand samples.

The detector efficiency curve was determined with a standard multi-radionuclide aqueous solution in the same geometry as all measured samples. The high-resolution gamma spectrometry methodology and the detector efficiency curve are regularly verified through proficiency tests [5].

The ^{226}Ra activity concentration was determined from the weighted average concentrations of ^{214}Pb and ^{214}Bi and the ^{232}Th activity concentration was determined from the weighted average concentrations of ^{228}Ac, ^{212}Pb and ^{212}Bi.

All nuclides activities are given with uncertainty statistics at ±1σ confidence level. Detections limits are given at ±2σ confidence level with the GTN5 formulae.

2.3. Radium Equivalent Activity

The radium equivalent concept allows a single index or number to describe the gamma output from different mixtures of uranium (i.e., radium), thorium, and ^{40}K in a material. The radio equivalent activity (Ra_{eq}) is calculated from the ^{226}Ra, ^{232}Th and ^{40}K activities concentrations, (A_{Ra}, A_{Th} and A_K respectively), assuming that 370 $Bqkg^{-1}$ of ^{226}Ra, 259 $Bqkg^{-1}$ of ^{232}Th and 4810 $Bqkg^{-1}$ of ^{40}K will produce the same dose rate of gamma radiation (Eq. 2). [6]

$$Ra_{eq}=370\cdot\left(\frac{A_{Ra}}{370}+\frac{A_{Th}}{259}+\frac{A_K}{4810}\right) \quad (2)$$

It is well-known that the Ra_{eq} is an helpfull radiological index for assessing building materials and also that sea sand cannot used for construction. Also, sea beaches are protected by law as being permanent preservation areas. However, the colorfull sands from Marataízes beaches are frequently used as an indoor decorative material, even its removal being prohibited by law. So, the Ra_{eq} should be assessed, on order to estimate the risk for public health.

The OECD Ra_{eq} recommended value for safe use of building materials with natural radioactivity content is 370 $Bqkg^{-1}$[7].

3. RESULTS AND DISCUSSION

The average concentrations values of ^{40}K, ^{232}Th and ^{226}Ra, together with their standard deviations, are represented in Table 1.

Table 1: Activities concentrations and radio equivalent activity.

ID	Beach	^{226}Ra	^{232}Th	^{40}K	Ra_{eq}	References
1	Cidade Nova	860±70	2300±260	270±40	4200±300	Present work
2	Areia Preta	300±30	990±100	200±30	1800±100	
3	Centro	75±5	150±10	30±4	300±20	
Other locations						
	Guarapari	4320±570	37000±2600	4320±570	52280±2670	[8]
	Ilha do Boi	150±20	1100±80	150±20	1767±112	[8]
	Ilha do Frade	3220±200	19800±1300	2200±300	29600±1350	[9]
	World Average	35	30	400	452	[1]

* Measurements with 68% (± 1σ) confidence level, k=1

For easier understanding, the activities concentrations values measured at Marataízes beaches are plotted in Fig. 2.

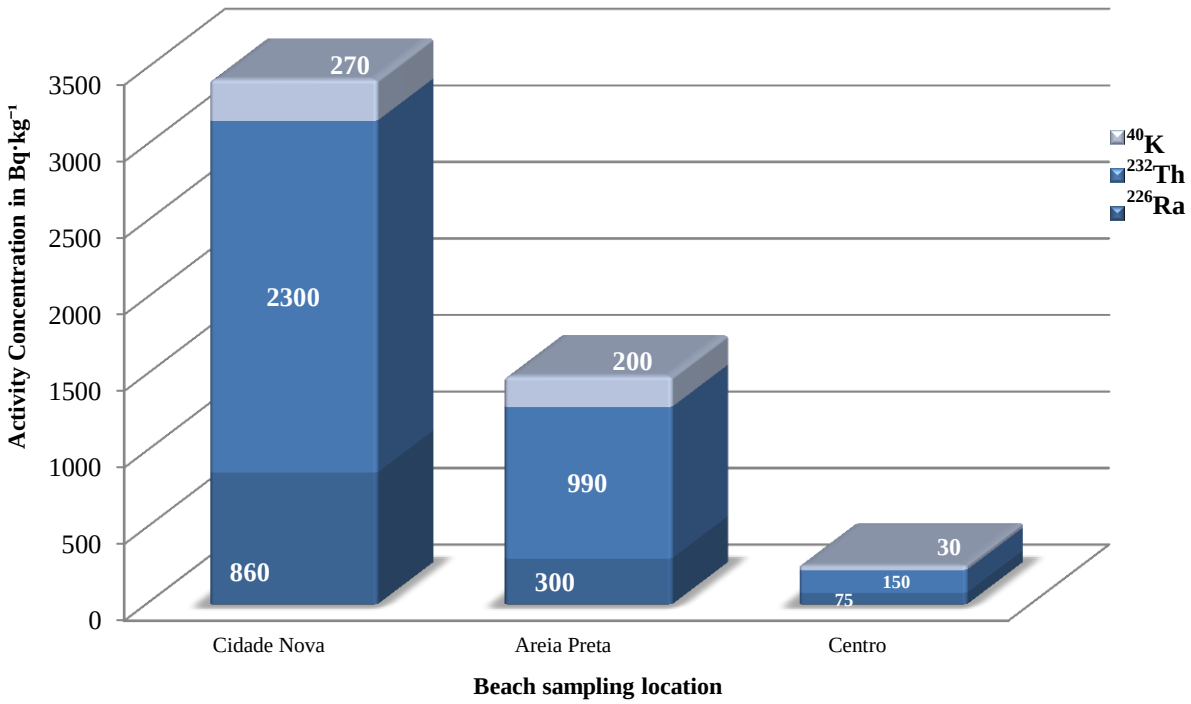

Figure 2: ^{226}Ra, ^{232}Th and ^{40}K activities concentrations in Marataízes Beaches Samples.

4. CONCLUSIONS

The activities concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Marataízes, Espirito Santo state, southeast of Brazil, were evaluated by high resolution gamma-ray spectrometry, together with the radiological index Ra_{eq}.

The lower values were obtained for “Centro” Beach, even when comparing with nearby Marataízes beaches.

The highest activity concentration has been observed for "Cidade Nova" Beach. The measured values for Marataízes location are high considering the world average values [1].

The radium equivalent activities varied from 300 up to 4200 $Bqkg^{-1}$. For all locations but “Centro” Beach, the Ra_{eq} is higher than the recommended limit of 370 $Bqkg^{-1}$ [7] and four up to 9 times greater than the world average, allowing to conclude that the use of these beach sands for indoor decorative must be avoided.

ACKNOWLEDGMENTS

This work was conducted at the Environmental Radiometric Laboratory at the Nuclear and Energy Research Institute (IPEN).

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