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Construction of Radon Exposure Maps on Beaches in HBRA Areas: A Proposition

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1. Introduction

Brazil has an extensive anomalous area that extends from the Rio de Janeiro state coast to the Bahia state coast, with a high concentration of the rare earth elements, in addition to thorium. One of those responsible for this condition is the presence of the mineral monazite [1]. In this strip of territory, there are some areas that are considered HBRA (High Background Radiation Areas), such as Guarapari-ES municipality [2].

Among the radionuclides, the most responsible for exposure to natural radiation and a major cause of problems to human health is radon, which is the decay product of radium 226 (^{226}Ra) and radium 228 (^{228}Ra). Inhalation of radon represents 47.6% of the average annual effective dose due to natural radionuclides [2].

The gamma spectrometry technique is a good alternative for the analysis of radionuclides in environmental samples, as it is a fast, a multi-elemental, and a non-destructive analysis method without the need for chemical pre-treatment. This radioanalytical technique is very widespread and is used by most laboratories that work with determination of radionuclide concentration in different types of samples [3].

The aim of this study is to discuss a feasibility plan for the construction of a radon exposure map in HBRA areas. This mapping can be of distinguish help with Public Health and Governance issues related to lung cancer case studies and in discussions of radiological protection aspects.

2. Methodology

A random sample was collected at Praia da Areia Preta (position UTM zone 24: 343866.843; 7713137.642), in Guarapari-ES municipality, Brazil, at a depth of 10 cm. The sample was sealed in a 120 ml polyethylene pot for 30 days to reach the secular equilibrium condition. The counting time was 12000s. In addition to this sample, literature reports on the levels of radioactivity in sand in this region will be used.

For sample analysis, the detection system installed at the LMN (Nuclear Measurement Laboratory/Argonauta/IEN/CNEN) was used. This system consists of a high-resolution spectrometer, which is a semiconductor hyperpure germanium (HPGe) detector, with 20% relative efficiency, model GEM-F5930, and lead shielding, both from ORTEC.

Activity concentration and uncertainty were determined according to data provided by Maestro software, version 7.01. Equation 1 was used to measure activity concentration based on the Currie derivation [4]. The error associated with the activity concentration measurement was calculated by calculating the error propagation (Equation 1).

$$Aesp = \frac{N_L}{\varepsilon * m(kg) * t(s) * P\gamma} \tag{1}$$

Where $Aesp$ is the activity concentration measured in Bq/kg, N_L is the net area under the photopeak, *m* is the sample mass in kilograms, ε is counting efficiency for a specific energy (γ), $P\gamma$ is the probability of emission of the measured gamma ray (γ) and *t* is the counting time in seconds.

To measure the activity concentrations of ^{226}Ra and ^{228}Ra, the energies of 609.3 keV of the gamma radiation emitted by ^{214}Bi (bismuth 214) and of 911.1 keV emitted by ^{228}Ac (actinium 228) were measured, respectively. The measured activities of ^{226}Ra and ^{228}Ra were converted into doses by applying the factors 0.462 and 0.604, respectively [2,5]. These factors were used to calculate the gamma dose rate absorbed into air at 1 meter above ground level by using Equation 2:

$$D = 0{,}462 C_{Ra_{226}} + 0{,}604 C_{Ra_{228}} \tag{2}$$

Where D is the absorbed dose, measured in nGy/h, and $C_{Ra_{226}}$ and $C_{Ra_{228}}$ are the activity concentrations in Bq/kg of the radionuclides. The annual effective dose estimate is given by expression 3:

$$E = D * Exp * f \tag{3}$$

Where *E* is the annual effective dose given in Sv/year, *Exp* is the term referring to the exposure time, in hours/year, and *f* is the conversion factor from Sv/Gy to the absorbed dose in air, which is estimated at 0.7 [2].

3. Results and Discussion

Table 1 shows the results with the sand sample collected at Praia da Areia Preta, in addition to the results of other researchers covering the same range of the country analyzed. The first and second columns present the range of values, minimum and maximum, of activity concentration found, with the exception of the present study that used only one sample. In this work, the found concentration of Ra-228 is much higher than the concentration of Ra-226, which diverges from most of the works addressed in the literature [2]. The third column shows the annual effective dose considering the exposure time of 100 hours, which is equivalent to a total time of just over 4 days on the beach in these regions.

Table 1 – Activity concentration (Bq/Kg) and annual effective dose (μSv/year), with 100 hours of exposure of sand samples at an HBRA.

^{228}Ra (Bq/kg)	^{226}Ra (Bq/kg)	Effective Dose (μSv/year)	Researchers
7 - 7422	3 – 738	0.39 – 337.7	[6]
2.5 - 1256	5.7 – 117.5	0.3 – 56.9	[7]
36070 ± 1418	2617±135	1609.7	Present Study
77 - 55537	34 – 4043	4.4 – 2478.9	[8]
20 - 57037	6 – 4059	1.04 – 2542.8	[9]

The observed differences in Table 1 can be explained by the variety of sample collection locations: In Aquino's research [6], he analyzed surface sands at 16 collection points in 4 municipalities in Greater Vitória (Serra, Vitória, Vila Velha and Guarapari). Malanca *et al.* [7] and Veiga *et al.* [9] analyzed beach sands in Guarapari. Vasconcelos *et al.* [8] analyzed beach sand in 4 states: São Paulo, Rio de Janeiro, Espírito Santo, and Bahia.

Moreover, the third column (Table 1) shows that, for individuals with an exposure of 100 hours, in specific places on certain beaches, the annual effective dose exceeds the limit of 1 mSv/year stablished for individuals in the public. In addition, for the exposure time of 1000 hours on some beaches an annual effective dose exceeds the limit of 20 mSv/year for occupationally exposed individuals according to Standard CNEN – NN – 3.01 of 03/13/2014 "Basic Radiological Protection Guidelines". It is important to highlight that in certain places, with only 100 hours of exposure, the value of the world average effective dose of natural radiation of 2.24 mSv/year is already surpassed [2].

This discussion must consider many variables as, for example, whether the person is standing at the same point or walking along the beach, what makes the field of exposure change, whether it is windy or not, what makes the radon gas be displaced by the action of the wind. However, the obtained and reported values are impactful enough to exposure, in simple scenarios, the individual to a dose higher than that one allowed for an occupationally exposed worker. This result justifies and enables the implementation of research on exposure to radon gas in HBRA areas and in common areas.

4. Conclusions

The study demonstrated through the data that it is feasible and justifiable to carry out research to characterize and build radon gas exposure maps in HBRA areas.

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