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DETERMINATION OF EFFECTIVE DOSE RATE REFERENCE VALUES IN SÃO JOSÉ DO SABUGI-PB, BRAZIL.

Nilson V. da S. Medeiros[1], José A. dos Santos Júnior[1], Patrícia B. da Silveira[2], Romilton dos S. Amaral[1], Josineide M. do N. Santos[1], Eduardo E. N. de Araújo[1], Otávio P. dos Santos Junior[1], Filipe L. de B. Correia[1], Lino A. V.Rojas[1,3] and Marvic O. Milán[4]

[1]Grupo de Radioecologia, Departamento de Energia Nuclear, Centro de Tecnologia e Geociências, Universidade Federal de Pernambuco. Avenida Professor Luiz Freire, 1000, Cidade Universitária, 50740-540, Recife/PE, Brasil.
nilson.medeiros@ufpe.br,jaraujo@ufpe.br,romilton@ufpe.br,josineide.santos@ufpe.br ,otavio.santos@vitoria.ifpe.edu.br,filipelbck@gmail.com

[2]Centro Regional de Ciências Nucleares CRCN-NE
Av. Prof. Luís Freire, 200 - Curado, - PE, 50730-120Recife/PE, Brasil
pbrandao@cnen.gov.br

[3]Centro de Aplicaciones Tecnológicas y Desarrollo Nuclear, Calle 30 # 502 entre 5ta y 7ma Ave., Playa, La Habana, Cuba.
linomarvic@gmail.com

[4]Instituto Superior de Tecnologías y Ciencias Aplicadas, Quinta de los Molinos, Ave. Salvador Allende # 1100 entre Infanta y Rancho Boyeros.
Plaza de la Revolución. La Habana.Cuba
marvic@instec.cu

ABSTRACT

Brazil has some areas with elevated concentration of uranium and/or thorium, such as Guarapari in the State of Espírito Santo, Poços de Caldas in Minas Gerais and regions between the States of Pernambuco and Paraíba.The Seridó region, in the State of Paraiba, consists of rocks classified as pegmatites, gneisses and feldspars, with high level of uranium ores. The high levels of primordial radionuclides have been the focus of the studies performed in the area, specifically in the uranium deposit of Espinharas and some adjacent municipalities. The aim of this work was to carry out "in situ" measurements in the city of São José do Sabugi, Paraíba. Measurements were done using a portable gamma discriminator with combined NaI (Tl) and BGO probe, coupled to a motor vehicle that allowed to monitor 520 points in the urban and rural areas of said municipality, obtaining effective dose rates ranging from 0.7 to 1.56 $mSv.y^{-1}$and averages of 0.26 mSv.y-^{1}and 0.87 $mSv.y^{-1}$, respectively. The results obtained for radiometry of this municipality allow to conclude that the urban and rural areas meet the criteria established by UNSCEAR for areas considered as low background radiation. With this work, reference parameters were established for radiometric characterization of the surrounding municipalities to the uranium deposit of Espinharas.

1. INTRODUCTION

Humans are constantly exposed to ionizing radiations, wich can be detected in several compartments of the ecosystem such as soils, rocks, water and vegetables. Environmental radioactivity is derived from natural radionuclides classified as primordial, present in the earth's crust since its formation, plus the contribution of cosmic rays and cosmogenic

radionuclides. Some artificial radionuclides, originated from human activity, also contribute to increase the levels of radiation in the environment [1].

The activity concentration of natural radionuclides in rocks and soils are usually low, however, in Brazil there are areas with high levels due to the presence of radionuclides derived from the ^{238}U and ^{232}Th series, as well as ^{40}K.One of the most known regions is located on the coast of the state of Espírito Santo, which presents monazite sands and the regions of alkaline intrusion in the state of Minas Gerais. It is also worth noting the sedimentary belt of the Northeast of Brazil, where radiometric surveys verified the existence of uranium [2].

Taking into account the exposure to natural radionuclides, new research are done to deepen the knowledge about the risks and effects caused by radiation to the population in regions with high levels of natural radioactivity [3]. According to UNSCEAR, the average annual effective dose from exposure to natural sources is 2.4 $mSv.y^{-1}$ [4] and potential doses above this value justify the radiometric monitoring to know the levels of environmental radioactivity in these areas, helping to establishing the radiometric profile and assess their probable impact on health´s population.

The city of São José de Espinharas, in the state of Paraíba, is located in an area known as the Borborema Plateau. high levels of natural radioactivity were detected, as results of a study carried out in an area near the city, due to a uranium deposit with an average content of 1,200 mg/kg of U_3O_8[5]. The city of São José do Sabugi PB-Brazil is important in the radiometric context because it is also included in this region, besides possessing a similar geology with the city of São José dos Espinharas.

Based on these occurrences and possible correlations with adjacent municipalities, the present study aimed to perform the radioecological monitoring, with the measurement of the effective dose rate in the open air in the municipality of São José do Sabugi.

2. MATERIALS AND METHODS

2.1. Study area.

The study area was the municipality of São José do Sabugi, in Paraíba, located at an average altitude of 335 meters and coordinates S 06º 46 '30, 9 "; W 36º 47' 55, 7". It has an area of 215.4 km^2 [6], with a population of 4,010 inhabitants, of which 2,579 inhabitants reside in the urban area and 1,431 in the rural area. The population density is 18.61 inhabitants per km².

The area includes several geological formations of the Seridó Group, constituted by biotite, biotite shale, amphibians, paragnaisses, calcium silicate stones and skarns, micaxies, quartzites, iron formations, muscovite and metaconglomerates. I also includes the folded belt of Seridó, which houses a wide variety of granite rocks and pegmatic rocks, usually related to large masses of plutonic rocks[7].

The climate of this region presents intense semi-arid characteristics, with average temperature varying between 23 to 30ºC and annual precipitation estimated around 530 millimeters. The economy is based on the extraction of minerals, agriculture and livestock[8].

2.2.Experimental setup.

A portable gamma detector, model Gamma Surveyor from GF Instruments, was used for field measurements. The equipment is classified as discriminator type and includes control unit and combined probe with NaI (Tl) and BGO scintillators. A Garmin GPS was used for the georeferencing of measured points.

The detection system uses an algorithm to perform the measurements, based on the recommendations of the IAEA-1363 technical document prepared by the International Atomic Energy Agency [9].

The calibration of the detector was performed at the Metrology Laboratory of Ionizing Radiation (LMRI) of the Department of Nuclear Energy (DEN) of UFPE, using a ^{137}Cs source with certified activity. Calibration was done by correlating the dose rate with the source-detector distance, with values between 0.18 and 20.0 $\mu Gy.h^{-1}$. The calibration geometry adopted was of the longitudinal axis type, with the detector perpendicular to the radiation beam, having as reference point the geometric center of the sensitive volume of the detector.

2.3Radiometric measurements.

To carry out the measures "in situ", the measurement system was coupled to a motor vehicle, keeping the detector separated one meter from the ground. The average speed of the vehicle during the radiometric sweep was 20 km / h, being realized acquisitions every 10 seconds. The monitoring was done taking following a route describing of net, investigating all the streets of the urban area, besides the rural area.

The calculation of the outdoor effective dose rate was performed using the parameters recommended by the International Atomic Energy Agency (IAEA), described in the guide for the mapping of natural radionuclides, geological mapping and mineral exploration by gamma ray spectrometry, TECDOC-1363 [9].

The results were estimated for an annual period, taking into account the occupancy factor of 0.2 for external environments (Equation 1).

$$\dot{H}_E = 2{,}35992\,\dot{D} - 1{,}75560 \qquad (1)$$

where, $\dot{H}_E$ is the outdoors effective dose rate, in mSv.y-^{1}and $\dot{D}$ is the absorbed dose rate(μGy.h^{-1}).

3. RESULTS AND DISCUSSION

Environmental radiometric monitoring in the city of São José de Sabugi in Paraíba resulted in outdoor effective dose rates at 382 points in the urban area and 138 in the rural area. Analyzing the behavior of the values obtained for the studied areas (Table 1), it was verified the occurrence of heterogeneity for the data collected in the rural and urban regions. The dispersion of the data is evidenced by the high values of the coefficient of variation. The t-student test was used to evaluate if there were significant differences between the means of the two data groups (rural and urban areas).

Table 1: Descriptive statistics of results obtained in the urban and rural area of São José do Sabugi-PB, Brazil.

Parameter	Urban area	Rural area
Sample Numbers	382	138
Minimum dose (mSv/y)	0.07	0.13
Maximum dose (mSv/y)	0.40	1.56
Total Amplitude	0.33	1.43
Coefficient Variation (%)	21.9	65.2
Median (mSv/y)	0.27	0.27
Mode	0.25	0.26
Arithmetic Mean	0.26	0.33
Standarddeviation	0.06	0.22
Variance	1.03	0.047

The test result indicated the rejection of the null hypothesis highlighting the existence of significant differences between the means of the data sets. This behavior can be justified by some higher values of the effective dose rate, measured in the rural area, which exceed the average obtained in this study.

Figure 1 shows the distribution of the set of measures, being possible to observe the differentiated values for some effective doses obtained in the rural area. The highest values were obtained on a farm in the rural area of São José do Sabugi, whose measurements were carried out on land with outcropping rocks.

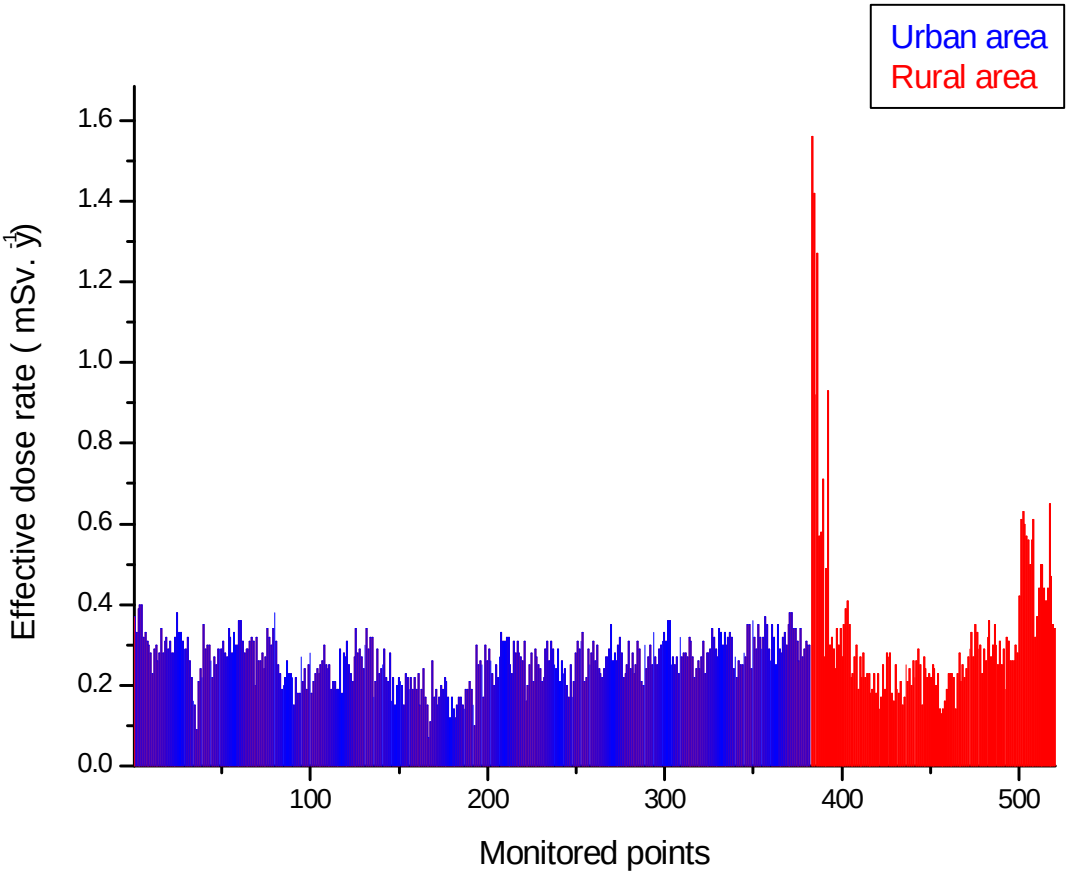

Figure 1: Radiometry of urban and rural areas of São José do Sabugi city ï PB

Table 2 shows the results of the radiometric analysis considering all the data obtained for the municipality in terms of effective dose rate, with values between 0.07 and 1.56 $mSv.y^{-1}$ and a mean of 0.28 $mSv.y^{-1}$.

Table 2: Descriptive statistics in São José do Sabugi city- PB, Brazil.

Parameter	Effective dose rate $mSv.\ y^{-1}$
SampleNumbers	520
Minimum dose	0.07
Maximum dose	1.56
Total Amplitude	1.49
Coefficient Variation	44.43%
Median	0.27
Mode	0.28
Arithmetic Mean	0.28
Standard deviation	0.12
Variance	0.02

The analysis of the whole data set obtained for the municipality made it possible to identify that the values of the three parameters of central tendency are very similar, suggesting a normal distribution of the data. To evaluate the hypothesis of normal data distribution, the non-parametric Kolmogorov-Smirnov test was applied and the results are presented in Table 3.

Table 3:Results of the Kolmogorov-Smirnov Test.

Values	Observed	Tabuled	Ho
Criticalvalue (0.05)	0.0596	0.0598	Accept
Criticalvalue (0.01)	0.0715	0.0716	Accept

It is observed that the null hypothesis was confirmed for both confidence levels. Thus, the mean of the data set obtained for the municipality of São José do Sabugi, can be used as the reference value for radiometry in this municipality.

The comparisons of the value obtained in this study with effective dose rate values reported in the literature are presented in Table 4. The reported values of studies performed in other parts of Brazil and the global mean value, estimated by UNSCEAR, were used.

Table 4: Values of outdoor dose ratein several localities in Brazil.

STUDY	YEAR	DOSE RATE $mSv.y^{-1}$
Present study	2017	0.28
Global mean[1].	2000	2.4
Outdoor world average[4]	2008	0,46
Ribeirão Preto- SP [13]	2011	0.034
São Paulo-Brazil[12]	2015	1.40
Triunfo-PB[11]	2017	0.23

The value found for the city of Triunfo-PB [11] is similar to the one obtained in that study, both cities being in the same State. In both cases, the dose rate value is lower than the world average of 2.4 $mSv.y^{-1}$. Another study [12] presented a value well above the average found for São José do Sabugi, a fact explained by the difference between the levels of the primordial radionuclides associated to each study area.

4. CONCLUSIONS

The results obtained for the city of São José do Sabugi, represents a first study to characterize the radiometry of the municipality, ensuring that the outdoor doses, due to the presence of natural radionuclides, are within the levels for areas considered as low background radiation.

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