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INVESTIGATION OF NATURAL RADIOACTIVITY LEVELS USING GAMMA DOSIMETRY OUTDOORS

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ABSTRACT

Radiometric studies have been increasingly needed as an alternative to evaluate possible effects of natural radioactivity in humans, considering that the responses to health problems, in the main, depart from the environment of individuals, survival practices and human development. The present study aimed at the realization of the outdoor radiometry in the municipality of Paraíba, Brazil, to determine a value that can express and guide a reference for radiometry local, making it possible to describe some impact on the health of the population. The results were obtained by "in situ" measurements using a gamma detector, calibrated to measure the dosimetric quantity of the effective environmental dose rate. Monitoring data ranged from 0.06 to 0.38 mSv/y, with a mean and deviation of 0.20 ± 0.04 mSv/y, whose trend measurement can be assumed to be representative of the effective dose rate of the environment outdoor, characterizing the area as low background radiation, whose parameter dosimetric and means evaluated, did not provide justification to impact on the increase in the occurrences of diseases in the local population.

1. INTRODUCTION

Radioecological studies have been providing conditions to more efficiently evaluate the environmental and social impacts of the exploitation of natural resources and to understand the behavior of radionuclides, whether anthropic or natural, establishing the conditions to comply with the principles of radiation protection [1].

In the analysis of anthropic radionuclides, the radiometric monitoring provides the certainty of the control of the nuclear applications in the planet. Whereas the evaluation of natural radionuclides leads to the identification of areas with high levels of primordial radionuclides.

Especially the minerals associated with uranium and thorium, their classifications, determination of the contents and possible characterization of deposits, necessary for the development of peaceful nuclear programs. In addition, these studies also allow observing the environmental impacts resulting from the exploitation of natural resources.

From the radioecological point of view, the natural radionuclides, especially primordial ones, have a stronger impact on external exposure due to gamma emissions, contributing with more than 70% of the environmental radiation dose.

The United Nations Scientific Committee on the Effects of Atomic Radiation establishes reference values for the evaluation of terrestrial radionuclides, with a global average effective dose rate of 2.4 mSv/y [2].

The value referenced by UNSCEAR [2] presents differentiated weights, depending on the evaluated environment, that is, outdoor environment or indoor environment. In the latter case, increasing the chances of incorporation of radionuclides by inhalation and ingestion. Showing that a radiometric evaluation of the environment should involve the analysis of several environmental matrices, differentiated compartments, external and internal dosimetry to the environment and to the organism, as well as, studies of possible transfer and incorporation routes.

In this sense, it is assumed as a starting point for radioecological evaluation, the monitoring and characterization of the external environment. As this type of study, besides defining radiometric characteristics of the environment, promotes well-defined actions for the planning of future studies, when determining any anomaly [3].

Based on the importance of radioecological studies, areas with different levels or possible influence of natural radionuclides should be monitored for explanations and models that define the behavior of radionuclides present. As well as possible interactions with the population, given the innumerable transfer routes in the different compartments of the environment.

The state of Paraíba is an interesting region for the development of environmental dosimetric studies, in order to present, specifically in the municipality of Espinharas, one of the main deposits of uranium in Brazil, currently under evaluation in its various environmental aspects by the Group of Radioecology of the Department of Nuclear Energy, Center of Technology and Geosciences of the Federal University of Pernambuco [4].

The presence of a uranium deposit in Paraíba justifies the development of environmental research in the adjacent municipalities in search of new discoveries and the understanding of the radiometric behavior of the region, which will make it possible to determine in the future a reference value for background radiation of these environments, which will serve as the basis for the identification of areas influenced by radioactive minerals.

The municipality of Triunfo in the state of Paraíba, although it is distant from the uranium deposit of Espinharas, was very interesting geologically and geographically, mainly due to the high incidence of cancer cases in the local population, as well as other health and environmental problems [5].

Based on this concern, the objective of the research was guided, which was to investigate the levels of outdoor radioactivity in the city of Triunfo in the state of Paraíba, using "in situ" research with the determination of the environmental effective dose.

2. MATERIAL END METHOD

2.1. Investigated Area

The area of study was the municipality of Triunfo, located in the state of Paraíba, Northeastern Brazil, situated at the 38°21'59" West longitude and 06°43'44" South latitude (Fig. 1).

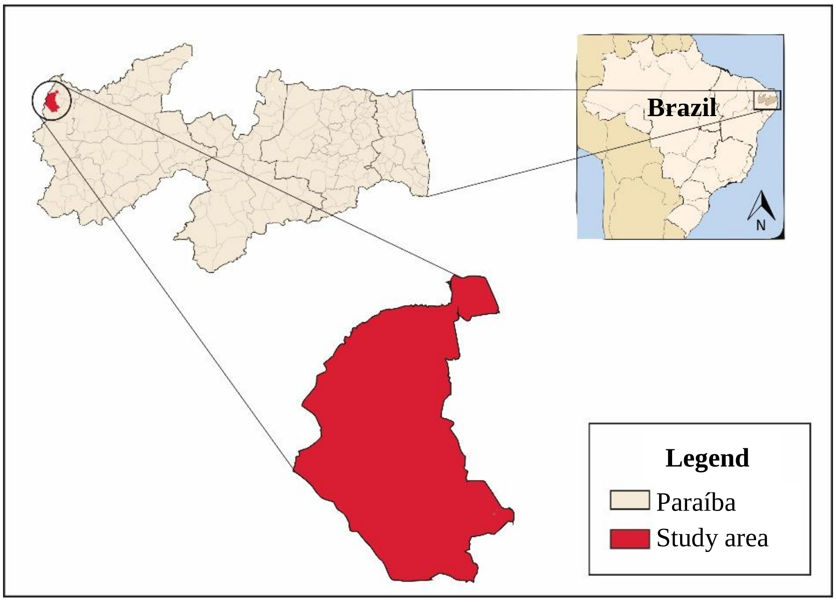

Figure 1: Map of Paraíba with emphasis on study area.
Source: adapted from [6].

The municipality has a territorial area of approximately 239 km². It has a total population of 9,447 inhabitants, being 46.7% resident in the urban area [7].

The economy of Triunfo is based on agricultural, industry and services activities. Regarding climatological aspects, it has a semi-arid climate, hot and dry, with daily temperature variations between 23 to 30°C, depending on the time of year.

The rainfall is low, with annual averages around 778 mm of irregular distribution [8]. The soils of the region are mostly of the Ultisol type, of loamy texture, locally combined with patches of oxisols and entisols. The drainage network is intermittent, with a dendritic pattern, where the relief is included in the "Sertaneja Plain," highlighting the elongated and aligned residual elevations of the regional geological structure.

2.2. System of Measures

The measurement system used in the research consists of a control unit and combined NaI (Tl) and BGO probe, composing the discriminator detector, brand: GF Instruments®, model: Gamma Surveyour®.

The equipment has several operational advantages such as: easy handling, robustness, portable, which provides on-site monitoring. It allows several types of instrumental measures, necessary to define radiological protection criteria. It has the function of searching for natural radioactive sources, determination of primordial radionuclide contents and calculation of absorbed and effective dose rates, used to guide deterministic parameters in radioecology, which are guided by TECDOC 1363 [9].

In terms of the absorbed dose rate, the equipment has a minimum detection limit of the order of nGy/h, which allows background measurements in areas with low environmental ionizing radiation. In addition, it has a scale for registers of counting rates of up to 250,000 pulses per second and an internal source of ^{137}Cs for stabilizing the measurement system, making it possible to trace the radiometric profile of areas influenced by Naturally Occurring Radioactive Materials (NORM).

2.3. Experimental Arrangement

The experimental arrangement used in radiometric monitoring was based on the recommendations of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), which considers the calculation of the effective equivalent dosimetry by the dosimetric magnitude of the effective environmental dose, inferred for outdoors environments, 1.0 m from the earth's surface [2], which provided conditions for modeling the radiometric map of the municipality under evaluation.

In order to make the results closer to the local reality, the measurements were carried out "in situ", with detector coupled to a motor vehicle and gamma acquisitions held continuously, covering all area of the municipality of Triunfo in the state of Paraíba. The map of Fig. 2 shows the areas radiometrically investigated. In the figure are highlighted the map of Paraíba and the municipality of Triunfo, whose territory of the topographic image, was carefully monitored by the specified experimental arrangement.

Some parameters were standardized in the radioecological investigation, such as: (a) average speed of the motor vehicle at 20 km/h; (b) continuous measurements with records in terms of absorbed dose rate and unit in nGy/h; (c) mean detector distance to the surface of approximately 0.8 m, corrected to 1.0 m; (d) time of acquisition and recording of the pulses referenced in the empirical measures of 10 seconds; (e) occupancy factor for outdoor dosimetry (outdoor dose) standardized at 0.2; (f) the maximum annual occupancy time established as 8,766 hours; (g) absorbed dose rate conversion factor for the environmental effect was 0.7 Sv/Gy and (h) the radiation weighting factor was 1.0.

The environments that could not be accessed by vehicle were monitored on footpaths, obeying the same standardization specified above, except speed.

Figure 2: Map of Paraíba with highlight to the municipality of Triunfo.

Fonte: adapted from [10]

To place the equipment, the vehicle's bucket remained open and the detector positioned so that the combined probes were facing the ground, minimizing the possible effects of interference from the car's structure. For positioning geometry of the detector, it is observed that it was positioned approximately 0.8 m from the surface, and corrections were made to meet the criteria established above.

2.4. Algorithm for Calculating the Effective Environmental Dose

In order to determine the algorithm that was used in the calculations of the effective environmental dose rates of the study region, the measurement system calibration was carried out at the Laboratory of Metrology of Ionizing Radiations (LMRI) of Nuclear Energy Department (DEN) of the Federal University of Pernambuco (UFPE), as standardized by the arrangement of Fig. 3.

The model adopted for this calibration used a source of ^{137}Cs, physical half-life of approximately 30 years, with certified activity. To increase the points of the calibration curve and to better verify the detector response to the reference values, the distance - dose relationship and the interposition of barriers (lead shields) were adopted.

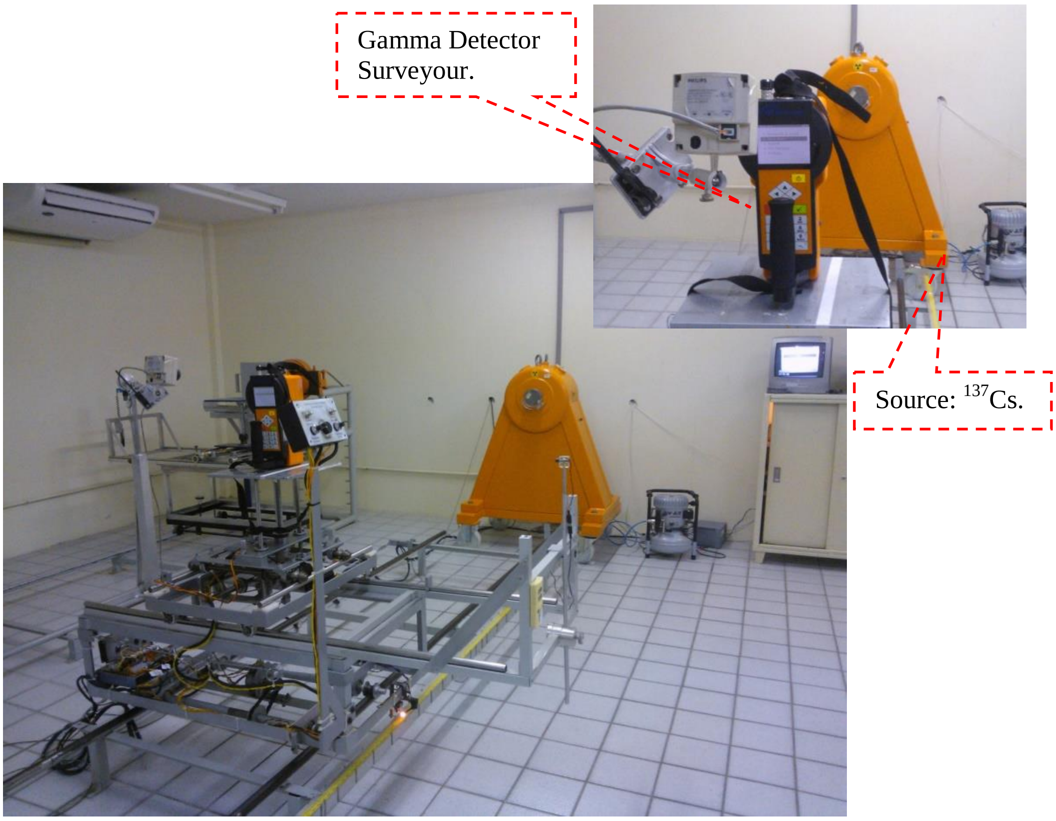

Figure 3: Arrangement to be adopted for gamma detector calibration.

The calibration geometry adopted was of the longitudinal axis type, with detector perpendicular to the radiation beam. The reference point is the geometric center of its sensitive volume, with doses varying from 0.18 μGy/h to 20.00 μGy/h. Statistical confidence fluctuates between 1σ and 2σ, with σ representing the mean standard deviation.

The final mathematical model considered, in addition to the cited parameters, the factors established in the experimental arrangement, providing the radiometric response to the city of Triunfo-PB.

The adjustment equation presents as the lower dose limit the value of approximately 0.18 μGy/h, which did not represent any limitation for the application of said model, since all adjusted results gave dose rates above this limit.

Based on the adjustment equation for the empirical measurements, determined by the calibration, and considering the parameters established by UNSCEAR (2000), that is, the maximum annual exposure time of 8,766 hours; factor of conversion of dosimetric quantities of 0.7 Sv/Gy, permanence factor for outdoor environments of 0.2 and necessary adjustments for multiples and submultiples of units, Equation 1 was obtained.

$$\dot{H}_E = 2{,}35992\,x\dot{D} - 1{,}75602 \qquad (1)$$

This equation allowed to calculate the effective dose rate outdoors in mSv/y, $\dot{H}_E$, as a function of the absorbed dose rate, $\dot{D}$, determined empirically with the Gamma Surveyour detector in µGy/h for each monitored point.

3. RESULTS AND DISCUSSIONS

Fig. 4 (A) allows observing the radiometric behavior in terms of effective dose rates measured outdoors in the city of Triunfo - PB, which ranged from 0.06 to 0.38 mSv/y, with arithmetic means, median and mode presenting statistically the same value, 0.20 mSv/y.

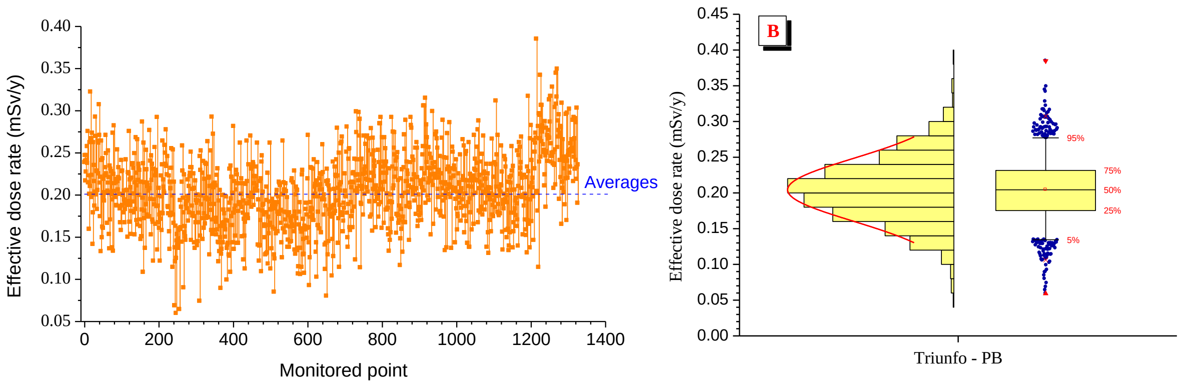

Figure 4: Effective dose rate behavior in the study area.

Figure 4 (B) presents the distribution by frequency range, with representation for median, quartiles and arithmetic mean, where close and higher frequencies are observed around these means.

It is evident the tendency for an uniform distribution of results around the data obtained for the municipality, which obeys, almost symmetrically, the behavior of the normal distribution, whose small extreme values are not representative for heterogeneity configuration.

In order to confirm the type of distribution of the study carried out in the city, the non - parametric statistical test of Kolmogorov - Smirnov was used. The results are presented in Table 1 for the 95% confidence levels ($\alpha = 0.05$) and 99% ($\alpha = 0.01$).

Table 1. Kolmogorov – Smirnov test.

STUDY	n	D_α		D_n		HYPOTHESIS
		0.05	**0.01**	**0.05**	**0.01**	**H_0**
Triunfo-PB	1,327	0.0373	0.0448	0.0335	0.0417	Accept

N: number of data; D_α: critical values (tabulated); D_n: empirical values (calculated); H_0: null hypothesis.

Analyzing the test results, it is observed that, for all confidence levels considered, the critical values (D_α) are higher than the values obtained empirically (D_n), characterizing that there is no evidence to reject the null hypothesis (H_0) that confers normalized data, that is, the most divergent extreme values obtained in a few points of the study are not representative in the general context, justifying that the arithmetic mean itself represents, very well, the reference value for outdoor dose rate in the analyzed municipality, which can characterize the reference measure for effective outdoor dose rate (environmental radiometry).

UNSCEAR (2008) estimated as the global mean value of the effective outdoor dose rate as 0.46 mSv/y for each individual, due to the contribution of gamma emissions of primordial radionuclides and cosmic radiation, whose value, in the first moment, served as a comparative parameter for this study.

It is observed that the maximum value for effective dose rate determined in the present study, which was 0.38 mSv/y, is lower than that estimated by the United Nations Scientific Committee on the Effects of Atomic Radiation, with an average of 2.3 times lower, which characterizes that the area in question presents background radioactivity within what is expected for low background regions.

4. CONCLUSIONS

The results obtained in the study evidenced the characterization of the area as being of low radioactive background, not providing any external radiometric environmental condition that could, in the first study, characterize deterministic effects and, consequently, contribute to cancer increase in the studied region.

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