BJRS

BRAZILIAN JOURNAL
OF
RADIATION SCIENCES
09-01A (2021) 01-18

SBPR
Sociedade Brasileira de Proteção Radiológica

Quantitative analysis of the natural ionizing radiation level in the city of Botucatu

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ABSTRACT

Radiation affecting the environment is divided into non-ionizing radiation (NIR) and ionizing radiation (IR). Natural radiation comes from radioisotopes present in the environment and cosmic rays and causes biochemical changes capable of inducing carcinogenic effects. In this work the levels of natural ionizing radiation in Botucatu-SP city were analyzed. Twenty-seven different points of measurement were determined in places of different altitudes in the city of Botucatu-SP. Two different Geiger-Muller (GM) detectors were used to carry out the measurements. The readings were performed on two different days spaced at fourteen months. The analyzes were also performed with a set of thermoluminescent dosimeters (TLDs) positioned at nineteen measurements points, and three TLDs were kept in a place not exposed to the external environment. The TLDs were positioned for forty-eight days. Two meteorological stations, Instrutemp (ITWH-1170) and Oregon Scientific (AWS888N) were used to verify the environmental variables: temperature, relative humidity (RH) and atmospheric pressure (PA). The altitude of the analysis points ranged from 757 m to 908 m and measured PA values ranged from 699.00 mmHg to 683.65 mmHg. The measured values for the PA presented an uncertainty of the order of 1.2% when compared with the values of PA calculated with Torricelli equation. The average reading of the GM detectors was 0.0183mR/h (± 0.07). The TLDs showed an average reading of 0.10 nC/h (± 0.03). Although the altitude of Botucatu city is larger than several cities of São Paulo, the background (BG) radiation level was like that observed in other regions.

Keywords: **background radiation, ionizing radiation, radiation detectors.**

ISSN: 2319-0612
Accepted: 2021-01-04

1. INTRODUCTION

Every day, the human being is inevitably exposed to natural radiations, also known as background radiation (BG). Radiation is defined as a moving energy form and can be distinguished in ionizing radiation (IR) and non-ionizing radiation (NIR). The major difference between them is the ability of IR to ionize, that is, to remove electrons from atoms and molecules because of their large amount of energy, a characteristic that NIR does not have. Both types of radiation can be beneficial and harmful. Moderate and cautious exposures to solar radiation, for example, aid in the synthesis of vitamin D, but in excess can lead to irreparable damage [1]. IRs may be artificial (found mainly in diagnostic and therapeutic medicine and obtained in particle accelerators, X-ray tubes and nuclear reactors) or natural (from radionuclides present in the environment or from cosmic rays) [2] and the ionizations caused by them can result in biochemical changes in the body [3] capable of induce tumors and, for this reason, this type of radiation is considered a carcinogenic agent [4].

Cancer is the accelerated and disorganized division of cells of the organism, forming a tumor in the affected region, a process called carcinogenesis [5] and which can be stimulated by external factors related to the environment (chemicals, irradiation and viruses) and internal, usually predetermined and linked to the body’s ability to defend itself against external aggressions (hormones, immunological conditions and genetic mutations) [6]. For the year 2019, are estimated 600 thousand new cases of cancer in Brazil, 70% of which are concentrated between the South and Southeast regions. Different types of cancer vary with the type of affected cell. For example, in the case of the skin, which is the largest organ in the human body, there are two main types of malignant tumors: melanoma and non-melanoma [7].

Non-melanoma skin cancer (NMSC) is the most frequent and does not present a high risk of metastasis [8]. On the other hand, tumors of the melanoma type have a lower incidence when compared to NMSC, but their metastasis capacity is higher, which characterizes it as more serious and with greater lethality [7].

Factors such as advanced age, fair skin and, especially, exaggerated exposure to sunlight are directly linked to the incidence of skin cancer [9]. Brazil is a tropical country and is in the

ISSN: 2319-0612
Accepted: 2021-01-04

intertropical zone, one of the areas with the highest solar incidence, therefore, the levels of exposure to solar radiation are high and constant during a large period of the year and in most of its territory [10].

Considered the largest worldwide, exposure to natural radiation varies by location [11]. The solar radiation index increases with altitude due to the lower presence of attenuating elements of this radiation. At sea level, the annual effective mean dose is approximately 0.3 mSv. However, for a height of 2000 m for example, the dose received is reasonably higher [2]. The city of Botucatu is located 786 m above sea level, considerably higher when compared to the altitude of nearby cities. In Araçatuba-SP, for example, which is 286 km from Botucatu, the average altitude is 355 m.

Considering that a large part of population is unprepared for the prevention of skin cancer and uninformed about effects of radiation on health, the subject is of extreme scientific importance for more information about the disease and its causes to be propagated. This work intends to quantify the level of natural ionizing radiation in the city of Botucatu-SP, simultaneously verifying environmental variables that may influence the values obtained.

2. MATERIALS AND METHODS

For the direct dosimetry of IR, two different Geiger Muller (GM) detectors were used. Both them are described according to Table 1 and illustrated by Figure 1.

Table 1: Description of the radiation detectors used

Technical characteristics	Detector 1	Detector 2
Brand	MRA	MRA
Model	G1-E	G1-E
Series	G1E-812	G1E-676
Scale	x100, x10, x1 (mR/h)	x100, x10, x1 (mR/h)
Probe type/series	External/SE-812	External/SE-676

ISSN: 2319-0612
Accepted: 2021-01-04

Figure 1: *Geiger-Müller detector.*

Source: MRA manufacturer's manual.

The readings were performed on two different days spaced at 14 months. Twenty-seven points of measurement were determined in places of different altitudes in the city of Botucatu-SP. Concomitantly, the values of temperature, atmospheric pressure (AP), and relative humidity (RH) of the air were measured at each of the geographic points analyzed using an Instrutemp weather station (ITWH-1170) and another Oregon Scientific (AWS888N).

The values obtained from AP by the meteorological stations were compared with those estimated mathematically with the Torricelli equation (Equation 1) [3]. The altitude measurements were previously obtained with GPS (Global Positioning System) equipment.

$$P = P_0 . e^{\frac{(-g.\mu_0.h)}{P_0}} \quad (1)$$

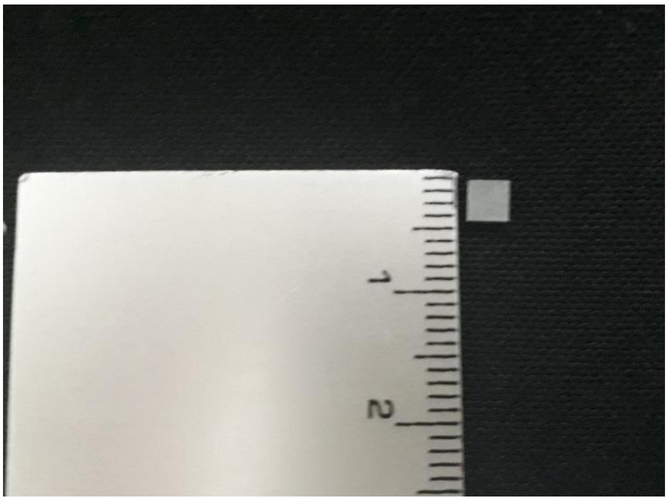
Where P_0 is the atmospheric pressure at sea level (P_0= 759,75 mmHg), g is the acceleration of gravity (g= 9,81 m/s²), μ_0 is the density of air at sea level (μ_0= 1,33 kg/m³) and h is the altitude of the local in meters.

A set of nineteen LiF7 (lithium fluoride) thermoluminescent dosimeters (TLDs) was used to indirectly survey of the natural radiation. Three of them were stored in a room of the Department

ISSN: 2319-0612
Accepted: 2021-01-04

of Dermatology and Radiotherapy of Botucatu Medical School, far from any incidence of radiation, so that they could be used as detectors of background radiation (BG). Figure 2 shows a TLD like those used in this work.

Figure 2: *Thermoluminescent dosimeter.*



Source: CIDRA - Centro de Instrumentação, Dosimetria e Radioproteção.

Of the twenty-seven points chosen for the direct survey, sixteen were determined so that the remaining dosimeters were installed by the city of Botucatu. Each TLD was introduced into a plastic so they were protected from conditions like rain and wind. The installation, which took place on 01/10/2019, counted on the use of adhesive tapes. The withdrawal occurred on 02/28/2019, totaling forty-eight days of dosimetry.

The readings were done on 04/03/2019 at the Nuclear Engineering Center (CEN) of the Nuclear and Energy Research Institute (IPEN).

ISSN: 2319-0612
Accepted: 2021-01-04

3. RESULTS AND DISCUSSION

Table 2 shows the results of measurements of natural IR levels and the environmental variables analyzed during the surveys, S1 and S2, for each of the twenty-seven analyzed points.

Table 2: Averages of the values obtained for each point in the two surveys

Point	IR (mR/h)		Temperature (ºC)		RH (%)		AP (mmHg)		Altitude (m)
	S1	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	
1	0.02	0.02	27.45	18.10	35	59	693.35	710.40	835
2	0.02	0.01	27.35	18.15	36	60	691.40	710.40	846
3	0.01	0.01	28.25	17.50	36	60	690.60	710.40	859
4	0.01	0.01	28.80	17.45	35	60	691.60	710.05	833
5	0.02	0.02	29.65	17.70	31	63	690.55	710.55	866
6	0,02	0.02	29.65	17.00	31	68	690.20	710.10	869
7	0.01	0.01	29.80	16.75	32	68	690.90	709.94	859
8	0.02	0.02	31.15	17.45	31	70	688.35	710.75	873
9	0.02	0.01	31.35	17.15	30	70	690.50	710.80	869
10	0.02	0.02	31.80	16.35	32	72	693.10	710.95	823
11	0.03	0.03	32.40	17.85	33	69	693.75	711.10	823
12	0.02	0.02	32.15	18.05	31	67	695.90	711.10	802
13	0.02	0.02	32.05	18.05	32	67	696.00	711.40	815
14	0.02	0.01	32.05	18.35	31	68	691.75	711.75	853
15	0.02	0.02	32.25	18.80	31	66	691.65	711.90	772
16	0.01	0.01	33.30	19.01	31	65	697.00	712.00	783
17	0.01	0.01	33.10	19.07	32	64	699.00	711.75	784
18	0.01	0.01	33.65	20.30	30	58	691.85	711.40	757
19	0.01	0.01	33.35	20.55	30	58	691.45	711.80	833
20	0.01	0.01	33.40	20.95	30	60	693.65	712.00	817
21	0.01	0.01	33.45	21.45	30	57	693.45	710.90	822
22	0.02	0.01	32.05	22.70	32	53	685.95	710.50	891
23	0.03	0.02	32.05	23.65	33	53	685.55	710.10	900
24	0.01	0.01	34.15	22.75	26	50	683.65	709.90	908
25	0.01	0.02	33.20	23.95	29	47	685.95	709.41	892
26	0.03	0.02	32.45	24.90	30	46	687.70	709.25	887
27	0.02	0.01	30.95	25.75	37	40	686.45	709.25	898

Although the average altitude of the city of Botucatu (786 m) is larger than many cities in the

ISSN: 2319-0612
Accepted: 2021-01-04

interior of São Paulo, the levels of IR incidence measured in the first stage of work were lower than the average of readings shown by researchers in other cities of the same state, such as Araçatuba, which presented a mean natural RI value of 0.02 mR/h [3].

The readings obtained by the TLDs are shown in Table 3 in unit of electric charge (nC) and electric charge per hour (nC/h). The points represented are the same as those indicated in Table 2, except for dosimeters H (Treatment Room of the Department of Dermatology and Radiotherapy of Botucatu Medical School), Q, R and S (Standard detectors 1, 2 and 3 respectively).

Table 3: Exposure time and reading of TLDs

TLD	Point	Exposure time (hour)	TLDs reading (nC)	TLDs reading (nC/h)
A	19	1.125,38	99,060	0,080
B	20	-	-	-
C	16	1.133,21	51,210	0,040
D	1	1.133,53	30,600	0,027
E	6	1.134,04	123,400	0,100
F	7	-	-	-
G	25	1.135,31	235,900	0,002
H	Linear accelerator room	1.135,46	591,000	0,207
I	22	1.135,64	158,500	0,130
J	23	1.135,45	93,220	0,080
K	26	1.081,08	170,900	0,158
L	27	-	-	-
M	24	1.135,68	122,200	0,107
N	24	1.135,75	123,700	0,109
O	17	-	-	-
P	18	-	-	-
Q	Standard detector 1	2.016	141,100	0,066
R	Standard detector 2	2.016	102,100	0,047
S	Standard detector 3	2.016	100,800	0,047

"-" = There are no registered readings for the dosimeters B, F, L, O and P.

The higher-reading H dosimeter was installed inside the linear accelerator room of the HC-FMB, where it received exposure of scattered beams during the entire period of use of the teletherapy equipment, therefore, it does not represent the reading of natural ionizing radiation. We

ISSN: 2319-0612
Accepted: 2021-01-04

use this point only to verify the dose-response effectiveness of TLDs in different situations of exposure to ionizing radiations. Dosimeters B, F, L, O, and P were not located after 48 days of exposure.

The mean value of the readings obtained with the TLDs was 0.07 ± 0.04 nC/h (excluding the reading of the "H" TLD installed inside the HC-FMB teletherapy room). The mean value of the readings of the GM detectors was 0.0178 ± 0.0055 mR/hr. As it was not possible to obtain a calibration curve of the TLDs, the measurements of the two different types of detectors cannot be correlated. However, the obtained results show that the accomplishment of the radiometric survey can be practicable with the methodology illustrated in this research.

Through Equation 1, the theoretical AP values were calculated for each of the twenty-seven points analyzed. Such data were then compared to the measured values of the AP in the first survey and set out in Table 4.

ISSN: 2319-0612
Accepted: 2021-01-04

Table 4: Comparison between measured and calculated values of AP

Altitude (m)	Measured AP (mmHg)	Calculated AP (mmHg)	Error (%)
835	693,35	682,34	1,6
846	691,40	681,23	1,4
859	690,60	680,23	1,5
833	691,60	682,51	1,3
866	690,55	679,61	1,6
869	690,20	679,35	1,5
859	690,90	680,23	1,5
873	688,35	679,00	1,3
869	690,50	679,35	1,5
823	693,10	683,39	1,4
823	693,75	683,39	1,4
802	695,90	685,24	1,5
815	696,00	684,09	1,7
853	691,75	680,75	1,6
772	697,65	687,89	1,4
783	697,00	686,92	1,4
784	699,00	686,83	1,7
757	691,85	689,22	0,3
833	691,45	682,51	1,3
817	693,65	683,92	1,4
822	693,45	683,48	1,4
891	685,95	677,43	1,2
900	685,55	676,64	1,3
908	683,65	675,95	1,1
892	685,95	677,34	1,2
887	687,700	677,78	1,4
898	686,45	676,82	1,4

The measurements for atmospheric pressure agree with those estimated with the Torriceli equation, with mean error of ± 1.2%.

4. CONCLUSION

The Torriceli equation can be used to obtain the local AP in cases where it is not feasible to use

ISSN: 2319-0612
Accepted: 2021-01-04

a barometer or a weather station. In addition, natural IR was like that observed in other cities near Botucatu-SP, therefore, it is not possible to affirm that the high altitude of the city leads to a higher incidence of BG in it. It is suggested to calibrate the set of dosimeters for new measurements and to apply statistical tests to the results for a better analysis of them.

ISSN: 2319-0612
Accepted: 2021-01-04

REFERENCES

[1] OLIVEIRA, M. M. F. Radiação ultravioleta/Índice ultravioleta e câncer de pele no Brasil: Condições ambientais e vulnerabilidades sociais. **Revista Brasileira de Climatologia,** v. 13, p. 60-73, 2016.

[2] UNEP - United Nations Environment Programme. **Radiation: effects and sources**, 2016. 68p.

[3] FERNANDES, M. A. R.; NAGAMATSU, R. Y.; CASTELLI, N. C.; NASCIMENTO, M. V.; LIMA, F. M.; FLÁVIS, J. M. ; VALADÃO, B.; VIEIRA, S. R.; KADRI, N. G. Avaliação do índice de radiação ionizante natural e exposição solar na região de Araçatuba-SP. **Universitas**, v. 1, p. 151-166, 2011.

[4] OKUNO, E.; YOSHIMURA, E. **Física das Radiações**. São Paulo: Oficina de Textos, 2010.

[5] MOURA, P. F.; OLIVEIRA, C. S. P.; OLIVEIRA, C. F.; MIGUEL, M. D. Câncer de pele: Uma questão de saúde pública. **Visão Acadêmica**, v. 17, p. 36-42, 2016.

[6] VIEGAS, C. C. D. **Dosimetria in vivo com uso de detectores semicondutores e termoluminescentes aplicada ao tratamento de cancer de cabeça e pescoço**, Tese (Mestrado em Engenharia Nuclear). Rio de Janeiro: Universidade Federal do Rio de Janeiro, 2003.

[7] INCA – Instituto Nacional de Câncer José Alencar Gomes da Silva. **Estimativa 2018: Incidência de cancer no Brasil**. Rio de Janeiro: INCA, 2017. 130p.

[8] GUTJAHR, G. M.; ALMEIDA, T. S.; BASTIANI, E. S.; TEJADA, V. F. S.; RODRIGUES, O. Câncer de pele não melanoma - Análise de 293 casos diagnosticados em um hospital universitário no extremo Sul do Brasil. **Vitalle - Revista de Ciências da Saúde**, v. 22, p. 63-72, 2011.

[9] COELHO, J. C.; RIBAR, J.; SCHWARTSMAN, G. Câncer de pele. In: HELLER, N. **Cirurgia plástica para o leigo**, 2nd ed., Porto Alegre: Editora Conceito, 2016.

[10] MENDONÇA, F.; OLIVEIRA, I. M. D. **Climatologia: noções básicas e climas do Brasil**. São Paulo: Oficina do Texto, 2007.

[11] SCAFF, L. **Física na radioterapia: a base analógica de uma era digital**. São Paulo: Projeto Saber, 2010.

ISSN: 2319-0612
Accepted: 2021-01-04