Assessment of the Environmental Outdoor Gamma Radiation Levels in São Paulo City

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ABSTRACT

Dose values from natural radiation sources in several sites of São Paulo city were assessed from environmental outdoor gamma radiation levels, by using $CaSO_4$:Dy thermoluminescent dosimeters. Twelve monitoring stations were placed in different regions of the town including both urban (where building materials are present) and outskirts areas. Dosimetric methodology was based on $CaSO_4$:Dy and the measurements were carried out quarterly observing the four seasons of the year. The average annual effective dose was calculated according to the ICRP-60 procedures, and the gamma radiation levels determined by thermoluminescent dosimetry were 1.23 ± 0.19 mSv.y^{-1}. The result is of the same order of magnitude as the average annual background effective dose of 1.00 ± 0.18 mSv.y^{-1} obtained from the Environmental Monitoring Programme followed by the Instituto de Pesquisas Energéticas e Nucleares, IPEN – CNEN/SP, the largest institute in the nuclear research field in Brazil, with a large number of nuclear and radioactive facilities. This environmental outdoor average annual effective dose is also compared with the 0.9 mSv/y^{-1} value, estimated by UNSCEAR 2000 as the world average contribution from terrestrial and cosmic gamma rays.

Key Words: ***Thermoluminescent dosimetry, background radiation dose, natural radiation, radiological protection standards, environmental outdoor gamma radiation***.

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1. INTRODUCTION

The natural radioactivity is admittedly the main cause of exposition to the world-wide population. In this sense, the dose assessment from natural exposures has become very important. There are two main contributors to natural radiation exposure: high-energy cosmic ray particles that originated in the earth´s atmosphere and natural radioactive nuclides that originated in the earth´s crust and are present everywhere in the environment, including the human body itself. Both external and internal exposures to humans arise from these sources.

An estimated global average exposure can be evaluated from the composed contribution of cosmic rays, terrestrial gamma rays, inhalated and ingested radionuclides to natural radiation. Depending on the specific concentration of such radionuclides in the environment and in the body, also related to the latitude and altitude, among others factors, wide distributions of exposure are found as a result of the several possible combinations for the effective dose at each location. The total annual global *per caput* effective dose due to natural radiation sources is 2.4 mSv. A typical range of individual doses is accepted to be within 1–10 mSv. For major populations, about 65% is expected to receive annual effective doses between 1 and 3 mSv, while around 25% stay under 1 mSv, with the remaining 10% showing annual effective doses in excess of 3 mSv [1,2].

The most important task of the radiation protection is to demonstrate that workers and members of the public have been adequately protected by the current dose limits system [3,4]. Therefore, it may be considered important to assess the natural radiation doses imparted at specific locations in São Paulo city, which has a huge density of population [5].

The present study particularly emphasizes the contribution of terrestrial gamma rays and cosmic rays to the environmental exposure (external exposure) of Sao Paulo population, assessed with $CaSO_4$:Dy thermoluminescent dosimeters.

Monitoring stations with TLD were placed at 12 different regions of the town including both country and urban areas (where building materials are present) in order to measure the environmental outdoor gamma radiation levels. These results were used to assess the average annual effective dose, according to the ICRP-60 procedures [3].

The average annual effective dose results were compared with annual dose limits for general public as proposed by the radiological protection standards [3,4] and with the background radiation of the surrounding IPEN facilities. The Institute of Nuclear and Energetic Researches, IPEN (Instituto de Pesquisas Energéticas e Nucleares), at São Paulo city, Brazil, is the largest institute in the nuclear research field in Brazil and consists of a number of nuclear and radioactive facilities, like the IEA-R1 Swimming Pool Nuclear Research Reactor, two isochronal Ciclotrons, a Nuclear Fuel Center and a Radiopharmacy Center.

At IPEN, a regular environmental monitoring program is established since 1988 [6,7]. The external gamma radiation is determined with $CaSO_4$:Dy thermoluminescent dosimeters. Currently, holds 15 monitoring stations using thermoluminescent dosimeters - five of them at points of maximum predicted ground-level concentration, and the ten remaining ones in locations with no direct influence from the Institute facilities [6]. The background radiation of the surrounding IPEN facilities was determined considering the annual mean value of those 10 locations.

2. METHODOLOGY

2.1. Selection of the Monitoring stations at São Paulo city

Great São Paulo is the metropolitan region of São Paulo State, southeast Brazil, that includes the capital São Paulo itself and other 39 cities, an urban accumulation of 19 million inhabitants, whose population is distributed over an area of 7944km² (2469 hab./km²) [5].

For the sake of evaluating the environmental dose distribution in São Paulo, monitoring stations were placed at twelve different points, selected in order to cover a large and representative area of town, considering mainly the occupancy of each region (urban area), the absence of influences from man-made ionizing radiation sources and also safely recessed places. One of twelve points is situated in a county with low population density. A map of SP indicating the monitoring stations accounted is presented in Fig. 1, where most central monitoring station #9 ('Centro' according to Table 1) is located at latitude 23.547 S, longitude 46.643 W.

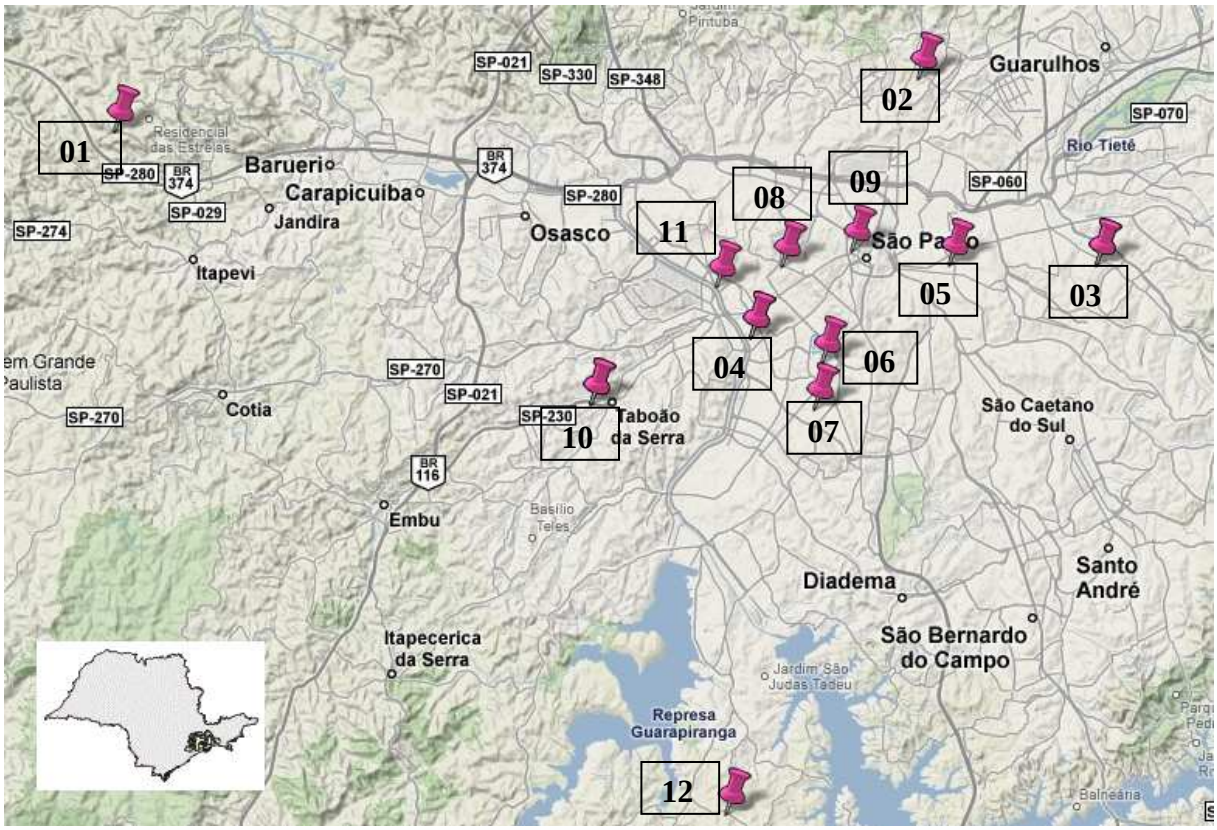

Figure 1. Map of SP showing 12 monitoring stations numbered according to Table 1

2.2. Measurement of external gamma radiation

The measurement of the environmental outdoor gamma radiation levels (direct radiation from the environment) was carried out by using $CaSO_4$:Dy thermoluminescent dosimeters [8].

The arrangement uses one dosimeter protected by a PVC plastic envelope, placed atop a 2 ½ inches diameter PVC pole, 1m above the soil surface and buried 400mm into ground.

The standard procedure for placement and subsequent quarterly substitution requires two dosimeters for each point: the field dosimeter, and a control dosimeter which is kept inside a thick lead shielded container, except when accompanying the field dosimeter during transportation, or waiting for readout. The control dosimeter serves as dual purpose: for subtracting both background and noise

reading, including any incidental undesired transportation dose [1,2]. Due to the considerably low expected values, a portable shielding was exceptionally used during transportation for this study.

The stack pole arrangement used as holder for single dosimeter 1m above ground is illustrated in the Figure 2.

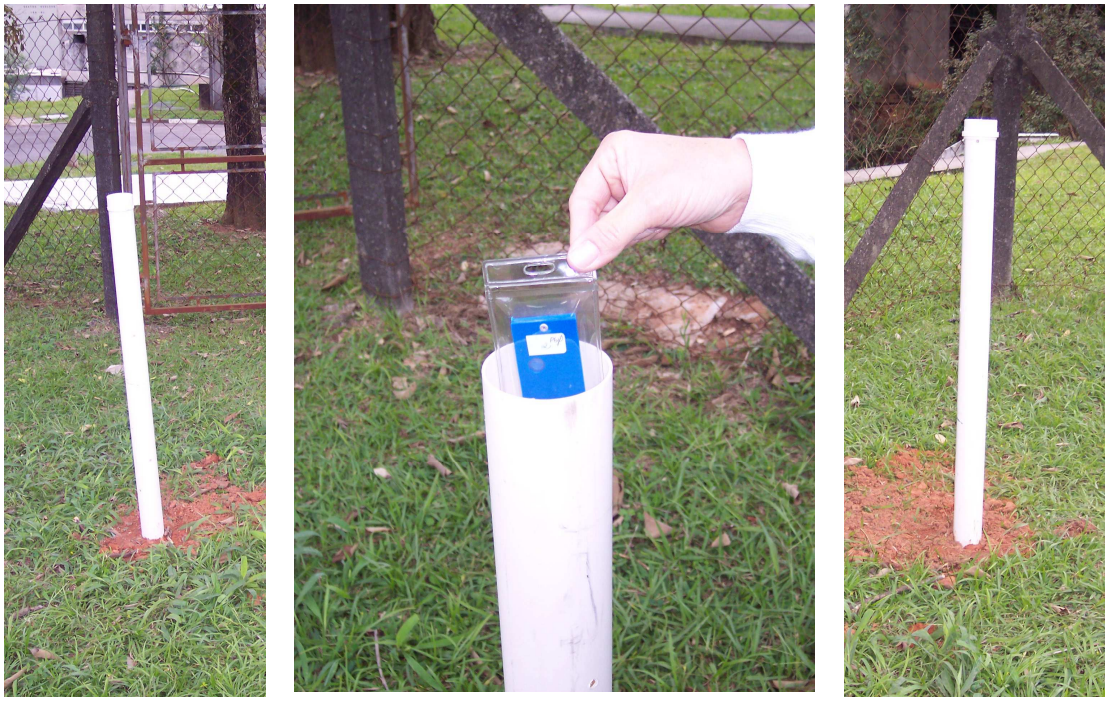

Figure 2. Illustration of the stack pole arrangement used as holder for single dosimeter 1m above ground.

The measurements were carried out quarterly on each season during a whole year beginning in October 2007 until November 2008.

2.3 Effective dose

In order to evaluate the annual effective doses, Kerma in air was converted into effective dose (E) by the use of a suitable conversion coefficient [4,9], according to equation 1:

$$E = 1.14 * K_{air} \quad (1)$$

3. RESULTS AND DISCUSSION

In Table 1 the effective dose results from the 12 monitoring sites are shown. The annual external exposure for each monitoring point was obtained by integrating the data along the four seasons of the year.

Table 1 also presents the selected regions showing prominence in demographic and urban terms [10].

Table 1. Monitoring sites results for all seasons of the year.

	Location	Population Density	Effective Dose Nov-07 to Jan-08	Effective Dose Feb-08 to Apr-08	Effective Dose May-08 to Jul-08	Effective Dose Aug-08 to Nov-08	Annual Effective Dose
			mSv	mSv	mSv	mSv	mSv
1	Aldeia da Serra	low	0.25	0.29	0.31	0.35	1.20
2	Tucuruvi	high	0.20	0.23	0.23	0.27	0.93
3	Vila Carrão	medium	0.36	0.34	0.39	0.44	1.53
4	Jardim Europa	medium	0.28	0.31	0.32	0.34	1.26
5	Mooca	high	0.29	0.28	0.34	0.36	1.27
6	Ibirapuera	high	0.23	0.26	0.29	0.30	1.08
7	Congonhas	medium	0.30	0.28	0.32	0.34	1.24
8	Cerqueira César	medium	0.33	0.31	0.33	0.29	1.26
9	Centro	high	0.28	0.30	0.33	0.31	1.22
10	Taboão da Serra	high	0.28	0.35	0.36	0.37	1.36
11	Pinheiros	medium	0.20	0.25	0.29	0.29	1.03
12	Parelheiros	low	0.30	0.32	0.37	0.37	1.35

The present study compares the contribution of natural background radiation to the annual effective dose at different places of IPEN as well as other monitoring sites on São Paulo city.

The average annual IPEN background equivalent dose, by TLD for the period 1993-2008 was 1.00 ± 0.18 mSv.y^{-1} [11]. This value obtained from Environmental Monitoring Programme of IPEN is in agreement with ICRP 60 and national regulations dose limit for general public [3,4].

The results obtained of the environmental outdoor gamma radiation in terms of external exposure were compared to the average annual background radiation for IPEN. The values obtained and the mean value obtained from 12 stations was converted into effective dose according to ICRP 60 and national standard [3,4].

The rates of annual effective dose (mSv.y^{-1}) ranged from 0.93 to 1.53 mSv.y^{-1} net values obtained after subtracting of the control dosimeter.

The annual effective dose obtained for the Sao Paulo city was 1.23 ± 0.19 mSv.y^{-1} for an average of the 12 locations. This dose value was also compared to the value available from literature, measured by the same methods. It can be noticed that the annual average of effective dose is similar to external exposures in good agreement with others studies for Sao Paulo city, but slightly higher when compared to the estimated world average of 0,9 mSv (contribution from terrestrial gamma rays and cosmic rays), as released by UNSCEAR 2000 [1,2,12].

As can be seen, the effective dose (natural background exposure) shows relatively small variations among the 12 monitoring stations. However, for a possible correlation between dose levels and various components that should increase exposures such as environmental conditions or weather peculiarities, altitudes and latitudes and population density, more efforts will be required to detail the dose distribution among population groups. It is important to remember that the data presented here represent average outdoor dose values for the São Paulo Metropolitan Region population. The limited

number of measurements available is probably more influent on the uncertainties associated with the external outdoor dose assessment from natural radiation sources than the complexity of the dosimetric system itself.

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