

THREE YEARS OF SEASONAL DOSE ASSESSMENT FROM OUTDOORS GAMMA EXPOSURE IN SAO PAULO CITY, BRAZIL

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ABSTRACT

Measurements of external (outdoors) gamma exposure from natural background radiation have been used to estimate the average annual doses in Sao Paulo city. Twelve monitoring stations were placed in different regions of the town including both urban (where building materials are present) and outskirts areas. Seasonally surveys observing the four seasons from 2008 to 2010 have been carried out. The data were drawn from a 3-month sampling using the thermoluminescent dosimetry. The effective doses values are quite similar (slightly higher during the winter), so it can be considered that these results are not under significant influence (or variability) of seasonal environmental conditions like temperature, wind or rain. Dose values over the three years period, from Vila Carrão district, exclusively an urban location with mostly no green areas, present the highest values, while the lower values were always obtained for Tucuruvi district, near the biggest urban forest, *Parque Estadual da Cantareira*. Over the assessed period, the mean of the average annual effective doses was $1.3 \pm 0.1 \text{ mSv.y}^{-1}$. For the same period, the average annual background from nuclear and radioactive facility at IPEN was $0.75 \pm 0.12 \text{ mSv.y}^{-1}$.

1. INTRODUCTION

Human exposure to natural radiation sources has always existed. The earth has always been bombarded by high-energy particles originating in outer space that generate secondary particle showers in the lower atmosphere. Additionally, the earth's crust contains radionuclides. For most individuals, exposure to natural background radiation is the most significant part of their total exposure to radiation [1].

An estimated global average exposure can be evaluated from the composed contribution of cosmic rays, terrestrial gamma rays, inhaled 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 [2].

The main factors that determine the exposure rate to a particular individual are the concentration of radionuclides in the soil, the time spent outdoors, and the shielding by

buildings. However, as the materials of which most buildings of the outdoors radiation field is often more than offset by the presence of additional radionuclides in the building materials.

The main objective of this work is to verify a potential seasonal influence (the variability takes into account seasonal patterns) in the annual averages dose to the general public, assessed during 2008 to 2010, considering only the gamma rays from natural radiation sources.

Besides that, the present study compares the contribution of natural background radiation to the annual effective dose at different monitoring sites on São Paulo city with the background from of the Instituto de Pesquisas Energéticas e Nucleares, IPEN, (Nuclear and Energy Research Institute) at São Paulo city, Brazil. The major nuclear and radioactive facilities at IPEN, which contribute to the background, are the IEA-R1 Swimming Pool Nuclear Research Reactor, two isochronal Cyclotrons, a Nuclear Fuel Center and a Radiopharmacy Center.

2. METHOD

2.1 Measurement of External Gamma Radiation

The measurement of the environmental outdoor gamma radiation levels (direct radiation in the environment) was carried out by using $\text{CaSO}_4:\text{Dy}$ thermoluminescent dosimeters (TLD) and the data were drawn from a 3-month sampling period.

The arrangement uses one dosimeter protected by a PVC plastic envelope, placed atop a 2 ½ inches PVC pole, 1m above the soil surface and buried 400mm into ground. The standard procedure for placement and subsequent quarterly substitutions 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 [3, 4].

The measurements were carried out quarterly on each monitoring station over the evaluation period, from 23/10/2007 until 08/11/2010. The monitoring period accounted for 12 consecutive quarters, observing the four seasons for São Paulo state.

2.2 Dose Assessment

The evaluation of the external exposure from naturally occurring radionuclides was carried out directly measured external gamma dose rates in air outdoors.

The average annual effective dose results were compared with annual dose limits for general public as proposed by the radiological protection standards [5-7] and with the background radiation results obtained for the surrounding IPEN facilities [8].

In order to evaluate the annual effective doses, the absorbed dose in air was converted into effective dose by the use of a suitable conversion coefficient [7].

2.2.1 Monitoring stations at São Paulo city

Great São Paulo is the metropolitan region of São Paulo State, southeast Brazil, which 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) [9].

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.

The choice was made considering mainly the occupancy factor of each region (urban area), the absence of influences from man-made ionizing radiation sources and also safely recessed places. One of the twelve points is situated in a county (Aldeia da Serra) with low population density and being the higher of them (altitude=1100 m); the surveyed area ('Centro') is located at latitude and longitude of 23.547 S and 46.643 W, respectively and 792.06 meters of altitude.

2.2.2 Background radiation of IPEN/SP

The Institute was founded in 1956 with the main purpose of doing research and development in the fields of nuclear energy and its applications. It is located at the campus of University of São Paulo – USP, at São Paulo city, in an area of nearly 500,000 m².

At IPEN, a regular environmental monitoring program is established since 1988. The external gamma radiation is determined also with TLD. Currently, holds 15 monitoring stations using TLDs - 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. The background radiation of the surrounding IPEN facilities was determined considering the annual mean value of those 10 locations [8].

For illustration and location, the Figure 1 shows the map of Brazil highlighting the Sao Paulo state, its geographic subdivisions and the area corresponding to the IPEN.

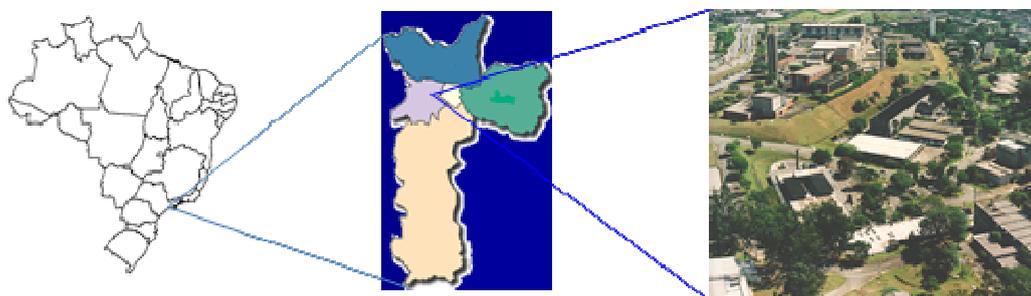


Figure 1. Map of Brazil highlighting the Sao Paulo state, its geographic subdivisions and the area corresponding to the IPEN.

3. RESULTS AND DISCUSSION

In Table 1 the average annual effective dose results from 12 monitoring stations are shown. The annual external exposure for each monitoring point was obtained by integrating the data along the three years evaluating, from 23/10/2007 to 08/11/2010. In this Table also is presented the regions selected that showed prominence in demographic and urban terms.

Table 1. Average annual effective dose from 12 locations of São Paulo over three years

Location	* Population Density	Annual Effective Dose 2008	Annual Effective Dose 2009	Annual Effective Dose 2010
		mSv	mSv	mSv
Aldeia da Serra	low	1.21	1.40	1.25
Tucuruvi	medium	0.93	1.23	1.01
Vila Carrão	medium	1.53	1.87	1.55
Jardim Europa	medium	1.26	1.48	1.22
Mooca	medium	1.27	1.47	1.32
Ibirapuera	medium	1.08	1.16	1.14
Congonhas	medium	1.24	1.54	1.30
Cerqueira César	medium	1.26	1.48	1.25
Centro/Pça da República	high	1.22	1.37	1.34
Taboão da Serra	high	1.36	1.51	1.42
Pinheiros	medium	1.03	1.32	1.15
Parelheiros	low	1.35	1.54	1.35

*Demographic density (hab/km²) to 5.000: low; >5000-11.500: medium; >11.500 high [9, 10]

According to the results of Table 1 and illustrated in Fig.2, the annual effective doses of the locations studied ranged from 0.93 mSv, minimum value (Tucuruvi station) to 1.87 mSv maximum value (Vila Carrão station).

The 0.2 mSv/month TLD method sensitivity is enough to conclude that the annual average doses in Tucuruvi and Vila Carrão are substantially different. However, the same value is not sufficient to detect a dose difference that could be attributed to the different stations of the year [5].

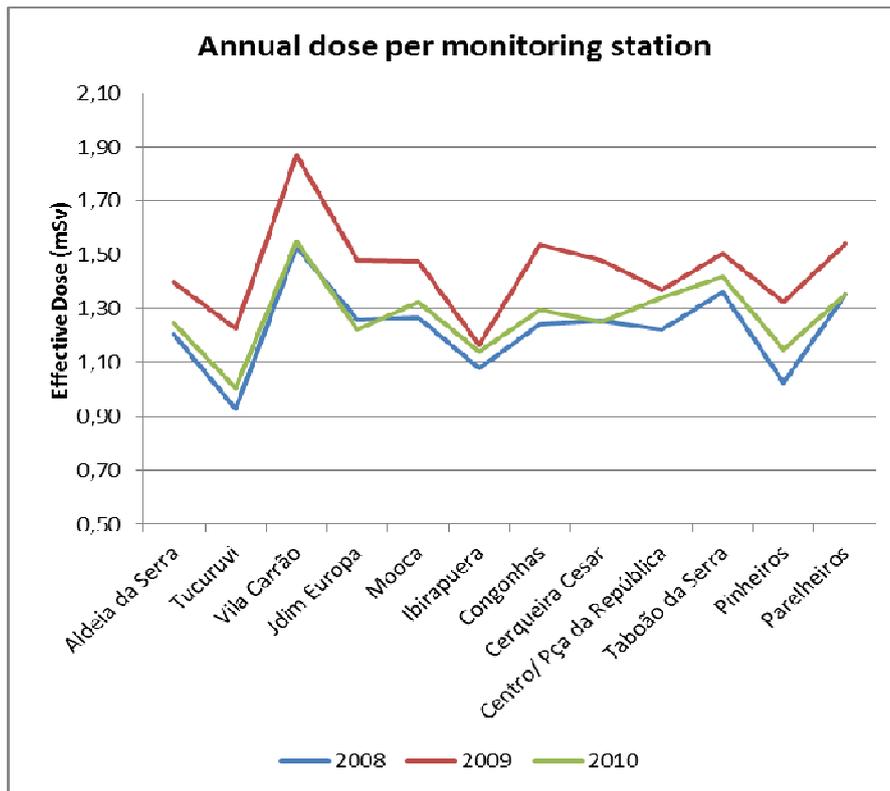


Figure 2. External dose (mSv) findings along different stations

In Fig. 3 are shown the dose values obtained quarterly during the monitoring period.

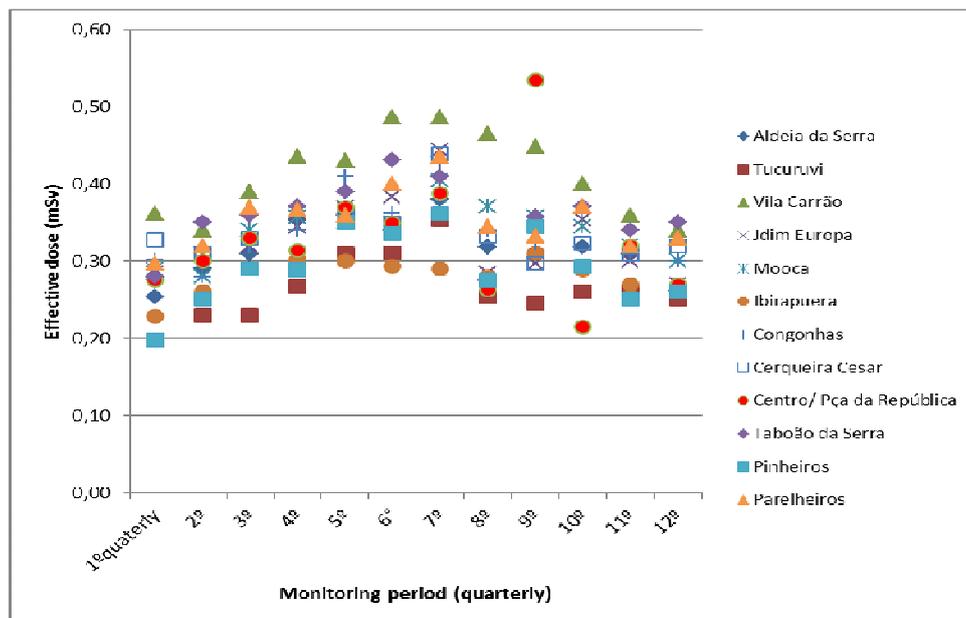


Figure 3. Results of quarterly monitoring period over 2008-2010

The results of average effective dose for each season of the year, along 3-years survey in Sao Paulo, Brazil are summarized in Fig 4.

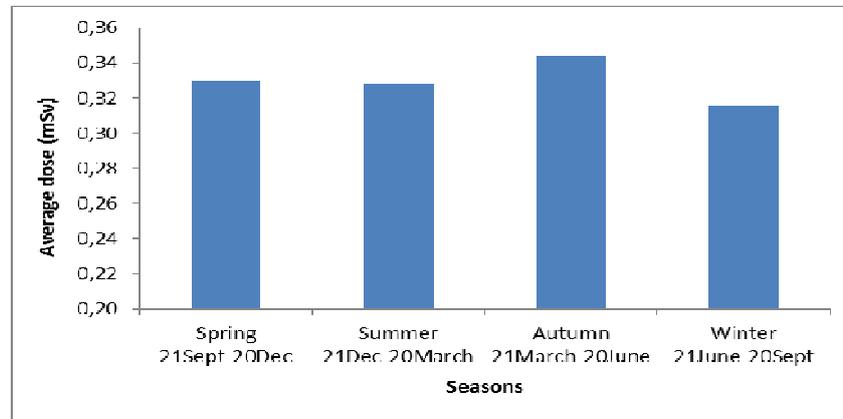


Figure 4. Average dose variation (mSv) for 12 stations per year

The estimated effective dose in different seasons is found to be slightly higher during the autumn and lower in winter.

The climate in São Paulo city is characterized by a rainy and a wet season, the results of this study suggest the existence of four distributions, each associated to one of the four seasons but no significant variability among the seasons.

The present study has showed that the natural background of São Paulo city, represented by 12 monitoring stations, was estimated to be 1.42 ± 0.11 mSv. This data was compared with the background from IPEN.

The temperature and atmospheric precipitation data for São Paulo city, in the studied period are from CIIAGRO/IAC (Centro Integrado de Informações Agrometeorológicas do Instituto Agrônomo de Campinas) [11]. Those data were evaluated together with the average doses obtained from the survey period and presented in Fig.5.

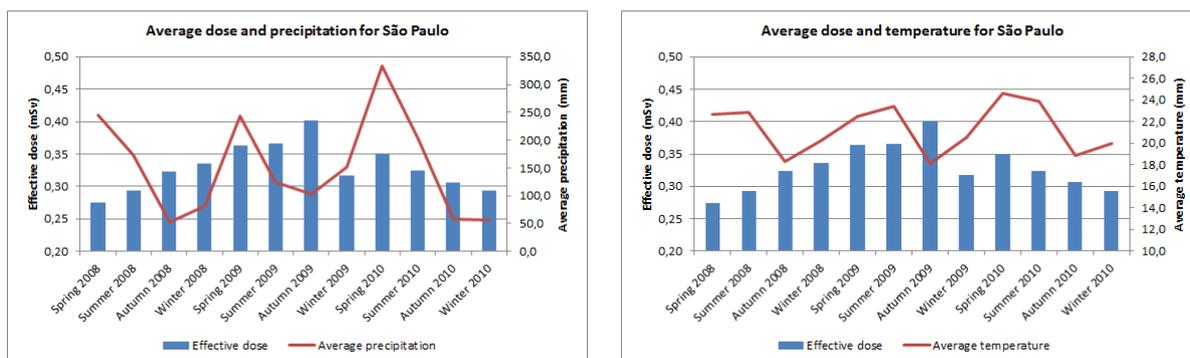


Figure 5. Evaluation of average dose with temperature and atmospheric precipitation in Sao Paulo city

According to Fig.5, it seems that the temperature and atmospheric precipitation show a minor influence on the average doses.

3. CONCLUSIONS

The effective doses values obtained are quite similar and can be considered that these results have not been influenced by the variability seasonal or by others factors as the presence of buildings (presence of additional radionuclides) nearby in urban and outskirts areas as well in the surroundings of the nuclear and radioactive facilities.

The effective doses values are similar (slightly higher during the autumn), so it can be considered that these results are not under significant influence (or variability) of seasonal environmental conditions like temperature or rain.

Dose values over the three years period, from Vila Carrão district, exclusively an urban location with mostly no green areas, present the highest values, while the lower values were always obtained for Tucuruvi district, near the biggest urban forest, *Parque Estadual da Cantareira*. These results show that the radiation levels are strongly dependent on the presence of buildings and vegetation density.

Over the three years, from 2008 to 2010, the mean of the average annual effective doses was $1.42 \pm 0.11 \text{ mSv.y}^{-1}$. For the same period, the average annual background from nuclear and radioactive facility at IPEN was $0.75 \pm 0.12 \text{ mSv.y}^{-1}$.

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