

# Follow up of the natural radiation exposure from gamma rays in the city of São Paulo, Brazil

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## ABSTRACT

The effective doses received by the general population from the natural radioactivity in the city of São Paulo, Brazil, were assessed since 2007, over a period of 05 years, as, apart from the variation from place to place, the background gamma levels in air are not constant in time. The outdoor gamma radiation levels were carried out with thermoluminescent dosimeters, TL, quarterly exposed, using twelve monitoring stations, covering both places frequented daily by people with emphasis in the most populated districts and safely recessed places, with no influences from man-made ionizing radiation sources. The average annual effective dose in the city of São Paulo, found as  $1.3 \pm 0.1$  mSv, is below the annual global *per caput* effective dose due to natural radiation sources of 2.4 mSv and within the annual effective doses range of 1 to 3 mSv, expected to be received by 65% of major population.

*Keywords:* gamma radiation levels, natural radiation sources, effective dose, city of São Paulo, thermoluminescent dosimetry

## **1. Introduction**

The exposure of mankind to ionizing radiation from natural sources is a continuing and inescapable feature of life on the earth, considering the low levels exposures to radiations and its possible biological effects in the human population, which are still not properly quantified or clarified.

The identification of radiation levels in the environment, in a particular place, is important to carry out potential implementations of the protection measures. Furthermore, it is possible to obtain an average exposure value from the natural gamma radiation outdoors, to which the population as a whole, is submitted.

This study was aimed to estimate the dose received by the population in the city of São Paulo from environmental outdoor gamma radiation levels, since 2007, over a period of five years.

## **2. Methodology**

The outdoor gamma radiation levels were carried out on the basis of direct environmental radiation measurements with TL dosimeters, considering both the cosmogenic radiations and the gamma rays contributions to the dose arising from soil and building materials.

### **2.1 The city of São Paulo – selection of the monitoring stations**

Great São Paulo is the metropolitan region of São Paulo State, southeast of Brazil with an urban accumulation of 19 million inhabitants, whose population is distributed over an area of 7944 km<sup>2</sup> (IBGE, 2010; Prefeitura de São Paulo, 2010).

In order to cover a large and representative area of the town, twelve monitoring locations were selected, considering mainly the occupancy of each region (urban area), the daily people frequency, the absence of influences from man-made ionizing radiation sources and also safely recessed places.

## 2.2 Dose assessment – effective dose

The absorbed dose in air (kerma) was evaluated through the outdoor direct gamma radiation carried out quarterly, for all monitoring stations (Carneiro et al., 2008, 2010). In order to evaluate the annual effective doses, kerma in air was converted into effective dose by use of a suitable conversion coefficient [ICRP 74, 1996; CNEN NN 3.01, 2011]. The annual effective doses were calculated from the sum of all quarterly values for each considered year.

The average annual effective dose in the city of São Paulo is the mean value of the twelve annual effective doses.

## 3. Results e Discussion

### 3.1 Public exposure to natural radiation – Annual effective dose

The annual effective dose for each of the 12 studied regions of São Paulo city and the annual average effective doses with the standard deviations for the whole city, covering the evaluated period, are shown in Table 1 and Fig. 1.

The observed deviations between the average doses observed in the same year have less than 2% of discrepancy.

The results obtained of the environmental outdoor gamma radiation in terms of external exposure ranging from 0.93 mSv/y (Tucuruvi) to 1.87 mSv/y (Vila Carrão); net values obtained after subtracting of the control dosimeter.

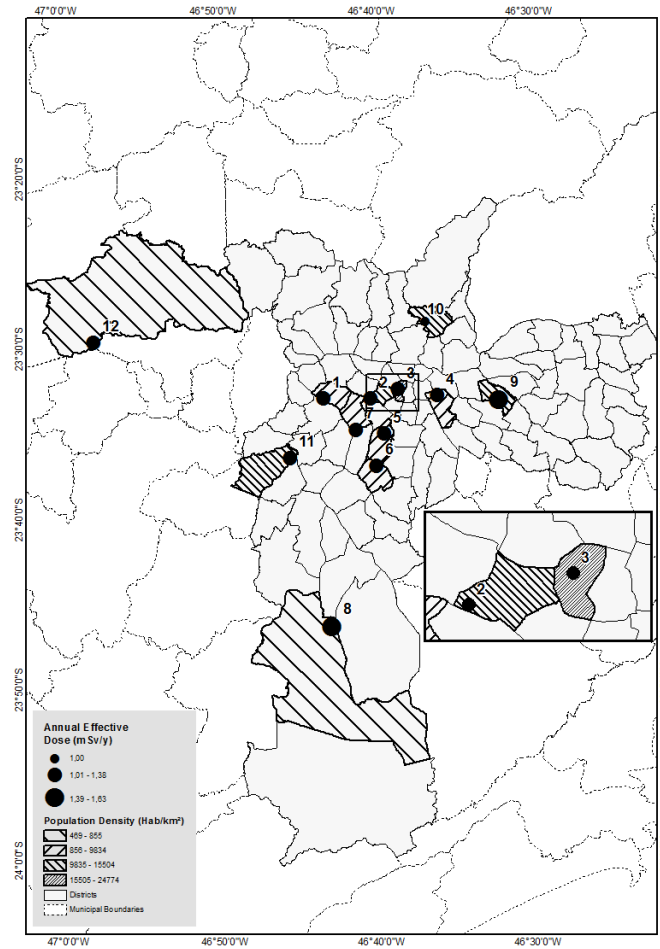
**Table 1** Annual effective dose for each of the 12 studied regions of São Paulo city and annual average effective dose for the whole city, from 2007 to 2012.

Region/District	Hab/km <sup>2</sup>	Annual effective dose (mSv/y)				
		2007-2008	2009	2010	2011	2012
1.Alto de Pinheiros	5,600	1.03	1.32	1.15	1.02	1.54
2.Consolação	15,504	1.26	1.48	1.25	1.05	1.53
3.Pça da República	24774	1.22	1.37	1.34	1.09	1.52
4.Móoca	9,834	1.27	1.47	1.32	1.07	1.19
5.Pq Ibirapuera	9,263	1.08	1.16	1.14	1.13	1.55
6.Campo Belo	7,472	1.24	1.54	1.3	1.19	1.4
7.Pinheiros	8,171	1.26	1.48	1.22	1.09	1.31
8.Parelheiros	855	1.35	1.54	1.35	1.51	1.51
9.Carrão	11,104	1.53	<b>1.87</b>	1.55	1.41	1.81
10.Tucuruvi	10,938	<b>0.93</b>	1.23	1.01	0.87	0.95
11.Taboão da Serra	11,949	1.36	1.51	1.42	1.25	1.38
12.Aldeia da Serra	469	1.21	1.4	1.25	1.03	1.32
Average annual±SD		1.23± 0.16	1.45±0.18	1.28±0.15	1.14±0.18	1.42±0.22

SD – Standard Deviation

This study showed that the dose distributions results for the São Paulo population during the considered five years remained in that range, but the typical range for total external terrestrial radiation is 0.3-1.0 mSv (UNSCEAR 2008). However, UNSCEAR 2000, 2008 Reports estimates that about 65% of individuals have exposure between 1 and 3 mSv, so, the values from Table 1 are consistent.

The Fig. 1 shows a map of São Paulo city, with the annual effective doses and the population density for the twelve assessed regions.



**Fig. 1.** Map of São Paulo city, with the annual effective doses and the population density for the twelve assessed regions, according to Table 1 (ArcGIS software).

#### 4. Conclusions

The effective dose (natural background exposure) showed relatively small variations among the twelve monitoring stations representing the city of São Paulo city over five years. 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.

In terms of effective dose the contribution of outdoor gamma radiation to the annual effective dose in São Paulo city is about  $(1.30 \pm 0.13)$  mSv. The value of the estimated

average exposure should not be taken to be too precise, since broad averaging is involved.

### **Acknowledgments**

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