

Contribution of Natural Background Radiation to Annual Effective Dose in Different Areas of Sao Paulo City – Preliminary assessment

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Natural background radiation doses received from some locations in Sao Paulo city, Brazil, were calculated through external gamma radiation levels determined with thermoluminescent dosimeters, assessed quarterly and seasonal during one year. Monitoring stations were placed in 12 different regions of town including both country and urban areas (where building materials are present) and also in the surroundings of the nuclear and radioactive facilities at the Instituto de Pesquisas Energéticas e Nucleares, IPEN. The external exposure due to six months of environmental outdoor gamma radiation levels were compared to the average annual background radiation of IPEN and also with the annual dose limits as proposed by the radiological protection standards.

KEYWORDS: *Natural radioactivity, external radiation, effective dose, thermoluminescent dosimeters.*

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1. Introduction

The United Nations Scientific Committee on the Effects of Ionizing Radiation, UNSCEAR, periodically undertakes a broad review of ionizing radiation sources and their effects. Data compilations by the Committee have been used by the International Commission on Radiological Protection, ICRP, to assess the risks associated to ionizing radiation and their dose limiting criteria.

A significant fraction of external radiation exposure is associated to radionuclides either naturally present in the natural environment or released from either standard practices or unexpected events. Whole body radiation exposure may result from the gamma radiation arising from the decay of externally located radionuclides.

The composed contribution of cosmic rays, terrestrial gamma rays, inhaled and ingested radionuclides to natural radiation has been evaluated to provide an estimated global average exposure. 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]. However, it should be noted that such doses include no contribution from the natural background radiation, despite of their measurable risks to health which are related to their magnitude. 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.

A compendium of some of the natural as well as man-made worldwide average annual effective doses taken from the various sources of radiation is summarized in Table 1.

Table 1: Worldwide average annual effective doses at year 2000 from natural and man-made sources of radiation (mSv), according to the UNSCEAR Report 2000 [3].

Source of radiation	Dose (mSv)
Natural background (total, all sources)	2.4
Inhalation (mainly radon)	1.2
Terrestrial gamma rays	0.5
Cosmic rays	0.4
Ingestion	0.3
Diagnostic medical examinations	0.4
Atmospheric nuclear testing	0.005
Chernobyl accident	0.002
Nuclear power production	0.002

Many radionuclides are found in natural terrestrial soils and rocks, and also in building materials derived from them. By decaying, those radionuclides produce an external radiation field to which all human beings will be subjected. In terms of dose, the chief primordial radionuclides are those from the natural series of ^{232}Th and ^{238}U (both with half-lives comparable to the age of the earth), which contribute significant human exposures [1,2].

The decay of naturally occurring radionuclides in soil produces a beta-gamma radiation field that travels through the soil-air interface leading to human exposition. The determinant factors for the exposure rate are: the concentrations of radionuclides in the soil, the time spent outdoors, and the shielding by buildings. However, as constituents of most buildings also contain radionuclides, the

outdoor radiation shielding effect by building walls is often more than offset by the contribution of radionuclides present in those walls.

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 thermoluminescent dosimeters. (Outdoor gamma contribution includes both cosmic and terrestrial radiation).

Monitoring stations were placed on 12 different regions of town including both country and urban areas (where building materials are present), and also in the surroundings of the nuclear and radioactive facilities at the Instituto de Pesquisas Energéticas e Nucleares, IPEN which plays a major role in several fields of Brazilian nuclear activities.

At IPEN, a regular environmental monitoring program was established since 1988 [4,5]. The external gamma radiation is determined with $\text{CaSO}_4:\text{Dy}$ thermoluminescent dosimeters.

IPEN 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 [5].

The main objective of this work is to measure the background radiation dose in different sites of Sao Paulo city, with the goal of estimating the dose values from natural radiation sources and comparing them with annual dose limits for public as proposed by the radiological protection standards [6,7] and also with the background radiation of the surrounding IPEN facilities.

2. Materials and 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 [8].

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. 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 1.

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



2.2 Monitoring stations at São Paulo city

The Paulo city composes with others 38 cities the São Paulo Metropolitan Region, an urban accumulation of 19 million inhabitants, whose population is distributed in an area of 1.509 km².

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 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.

The measurements were carried out quarterly and seasonal beginning October 2007.

2.3 Effective dose

In order to evaluate the annual effective doses, absorbed dose in air was converted into effective dose by the use of a suitable conversion coefficient [6,7].

3. Results and Discussion

In Table 2 the preliminary effective dose results from the 12 monitoring sites are shown. As can be seen, for each one of the monitoring sites, the values for the two assessed periods are similar, so the mean value of these periods can be assumed as a quarter of one year value. The average annual effective dose was estimated as four times the mean value. In Table 2, it is presented the regions selected that showed prominence in demographic and urban terms [9].

Table 2: Preliminary results from monitoring sites after first six months.

Location	Population Density	Effective Dose Nov-07 to Jan-08	Effective Dose Feb-08 to Apr-08	Annual Effective Dose
		mSv	mSv	mSv
Aldeia da Serra	low	0,25	0,29	1.08
Tucuruvi	high	0,20	0,23	0.86
Vila Carrão	medium	0,36	0,34	1.40
Jardim Europa	medium	0,28	0,31	1.18
Mooca	high	0,29	0,29	1.16
Ibirapuera	high	0,23	0,26	0.98
Congonhas	medium	0,30	0,28	1.16
Cerqueira César	medium	0,33	0,31	1.28
Centro	high	0,28	0,30	1.16
Taboão da Serra	high	0,28	0,35	1.26
Pinheiros	medium	0,20	0,25	0.90
Parelheiros	low	0,30	0,32	1.24

In this study, the contribution of natural background radiation to annual effective dose in different places of the IPEN as in the others monitoring points of São Paulo city were compared.

The average annual IPEN background equivalent dose, by TLD for the period 1993-2007 was around of 1.0 mSv.y^{-1} [10]. This value obtained from Environmental Monitoring Programme of IPEN is in agreement with ICRP 60 and national regulations dose limit for general public [6,7].

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 points was converted to effective dose according to ICRP 60 and national standard [6,7].

The rates of effective dose (mSv.y^{-1}) varied from 0.86 to 1.40 mSv.y^{-1} , net values obtained after subtracting of the control dosimeter. The standard deviation was 0.16 mSv.y^{-1} for an average of the 12 points of Sao Paulo city.

The annual average effective dose for the Sao Paulo city, 1.14 mSv.y^{-1} was also compared to the value available from literature, measured by the same methods. It could be noticed that the annual average of effective dose are of the same order to external exposures in accordance with others studies for Sao Paulo city and 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 [1,11].

UNSCEAR (1) has used a coefficient of 0.7 Sv Gy^{-1} to convert absorbed dose in air to effective dose equivalent and effective dose. Regarding this coefficient the annual average effective dose is $0,7 \text{ mSv.y}^{-1}$ [1].

As can be seen, the effective dose presents some variations from place to place. However, for a possible correlation between dose levels and environmental conditions or weather peculiarities, more information regarding the remaining quarter's values is being, processed by now.

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