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ASSESSMENT OF EFFECTIVE DOSES FROM RADON LEVELS FOR TOUR GUIDES AT SEVERAL GALLERIES OF SANTANA CAVE, SOUTHERN BRAZIL, WITH CR-39 DETECTORS: PRELIMINARY RESULTS

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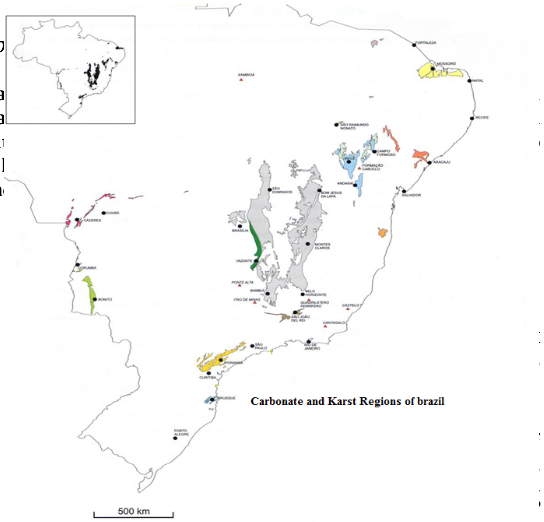
Indoor radon concentrations have been measured in the Sa
Ribeira River Tourist State Park), situated southern of Sao Pa
CR-39 detectors installed in four of the most frequently visi
June 2010 show radon concentrations varying from 1.9 ± 0.1
galleries was 3.33 mSv.y^{-1}. The complete evaluation will be con



INTRODUCTION

Radon and radon progeny are the greatest sources of natural radioactivity. It has been estimated that inhalation of short-lived radon progeny accounts for more than half of the effective dose from natural sources(1). Prolonged exposure to radon may cause a negative effect on our health, causing lung cancer and bronchial tissue damage. Exposure to radon is considered the second most important cause of lung cancer, after smoking. Radon and their progeny are always present in the open atmosphere, only in lower levels because the continued dispersion, but are found in higher concentrations in confined atmospheres of underground workplaces like natural caves, where tour guides are exposed to these radionuclides. Concentrations of indoor radon and its progeny in caves vary from levels hardly higher to levels several thousand times higher than outdoor air concentrations. Radon monitoring at highly radioactive locations such caves or underground mines is important in order to assess the radiological hazards to occupational workers like tour guides. Previous studies concerning radon levels in caves around the world show that their concentration can pose health risks to the people exposed to them (2,3,4).

Brazil is a country with a great speleological potential and presently, there are 4000 registered caves(5), but, so far, little information is available about their radiation levels and the effective doses at which the tour guides are exposed.

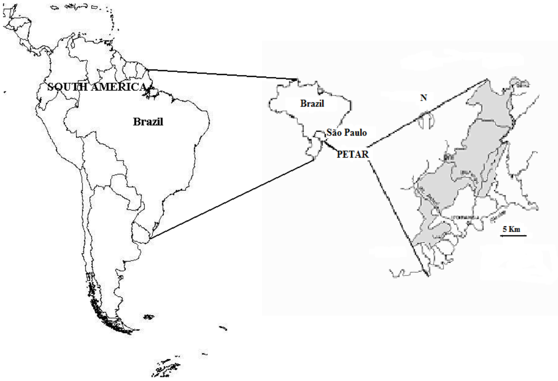


Figure 1. PETAR location.

Santana cave has

The radon concentrations activities were measured in the Santana cave, the most frequented cave of PETAR with CR-39 Solid State Nuclear Track Detectors.

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METHODS

The measurements were performed at galleries far away from the entrance, with poor ventilation, as follows: Disco saloon, São Paulo saloon and two intermediate saloons). The monitoring locations are indicated in Figure 2.

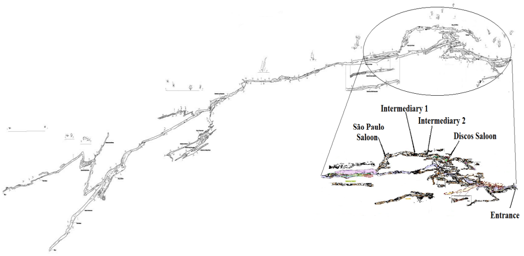

Figure 2. Santana Cave and monitoring points.

The Solid State Nuclear Track Detectors used in this study is the CR-39. Each detector is a small plastic of 1,7 cm^2 of area, loaded into a diffusion chamber type NRPB/SSI detector(6), installed in the selected caves, at least 1 m away from the nearest roof, as in Figure 3. The exposure period was, at least, 2 months.

Figure 3. Santana Cave with diffusion chamber and CR-39 inside.

After exposure, the detectors were retrieved to the Environmental Radiometric Division, IPEN and processed. The CR-39 detectors were etched for 5,5 hours with a KOH solution in a temperature-stabilized water-bath and mild stirring, at 80°C(6). The track densities were read under a Zeiss/Axiolab optical microscope connected to a video camera and a personal computer. Radon concentrations were determined considering the track densities, the exposure period and a conversion factor of track density to radon concentration of 2.8 ± 0.2 $(track.m^3)/(cm^2.kBq.h)$(6) through the following equation(7):

$$C_{Rn} = D/k.t \qquad (1)$$

where:
C_{Rn} is the radon concentration ($kBq.m^{-3}$)
D is the track density ($track.cm^{-2}$)
k is the conversion factor $(track.m^3)/(cm^2.kBq.h)$
t is the exposure period (h)

The effective dose depends on the exposure period. For the calculation, considering the park limited visit hours and that the number of visitors is higher during the weekends, it was assumed a total of 40 work hours per year in each gallery. The effective doses due to exposure radon and decay products for the tour guides were calculated through(8,9) equation 2:

$$E = C_{Rn}.F.t.d.u \qquad (2)$$

where:
E is the effective dose ($mSv.y^{-1}$)
C_{Rn} is the radon concentration ($Bq.m^{-3}$)
F is the average equilibrium factor between radon and decay products
t is the time spend inside the cave ($h.y^{-1}$)
d is the dose conversion factor of 1.4 $mSv/mj.h.m^{-3}$ for workers(12)
u is the unit factor of 5.6 x $10^{-6}mj.m^{-3}/Bq.m^{-3}$(10)

RESULTS AND DISCUSSION

The radon concentrations are presented in Table 1. The radon concentrations lay in a range from 1.9 $Bq.m^{-3}$ to 8.4 $Bq.m^{-3}$. The calculated effective doses, ranging from 0.78 $mSv.y^{-1}$ to 0.93 $mSv.y^{-1}$ in Table 2.

The highest radon levels correspond to the gallery far-away from the Santana cave entrances, which is also observed in others studies all over the world(11). The highest value was obtained at the gallery Sao Paulo, that is, farther from the gallery of the cave entrance, where there is probably poor ventilation. The radon concentrations variations in karstic systems depend on a complex interrelation of different factors, both external and internal: outside-inside temperature differences, wind velocity, atmospheric pressure variations, humidity, karstic geomorphology and porosity and radium content of the sediments and rocks(12). For the worst scenario, considering that the tour guides take people to visit all four galleries the same day, the results show that the total effective dose is 3.33 $mSv.y^{-1}$ not exceedingly the occupational dose limit of 20 mSv.y$^{-1(13)}$. The last CR-39 detectors will be collected by September 2010, allowing to assess an one year period of surveillance.

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Table 1. Radon Concentration at Santana Cave.

Radon Concentration (kBq.m^{-3})			
Saloons	**11/24/09-01/23/09 60 days**	**01/23/10-03/19/10 55 days**	**03/19/10-06/26/10 99 days**
Discos	6.4 ± 0.4	5.8 ± 0.4	2.8 ± 0.2
Intermediary 1	6.9 ± 0.5	6.2 ± 0.4	1.9 ± 0.1
Intermediary 2	6.4 ±0.5	6.5 ± 0.5	2.9 ± 0.2
São Paulo	8.4 ± 0.6	6.7 ± 0.5	2.6 ± 0.2

Table 2. Effective dose for tour guides at Santana Cave.

	Effective Dose	
Cave	**Saloons**	***E(mSv.y^{-1})***
Santana	**Discos**	0.78
	Intermediary 1	0.78
	Intermediary 2	0.83
	São Paulo	0.93