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Proposed method for studying radon exhalation

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1. Introduction

Natural radioactivity is responsible for approximately 80% of the average annual radiation dose received by human being. This is mainly due to natural radionuclides in the Earth's crust that are generally referred to as primordial radionuclides. Approximately 65% of the population is expected to receive annual doses between 1 and 3 mSv, 25% below 1 mSv, and 10% exceeding 3 mSv [1] Given the importance of Rn gas for the annual effective dose received by the human being and acknowledging geological factors' role in Rn emanation and exhalation, the World Health Organization (WHO) recommends that member countries implement national mapping programs to assess the increasing risk of Rn exposure based on geological and geographical studies [2]. Peake and Schumann (1993) state that the most common sources of radon in soil gases are granitic rocks and metamorphic rocks, black shales, phosphate rocks and some carbonate rocks. According to the authors, granitic rocks commonly concentrate uranium in specific minerals during their initial crystallization phase [3]. Considerable research has been presented on the gas transport process in the crust [4]. In fractured rock, radium decay is the main source of radon. radon transport can understood that most radon in buildings is generated by radium decay in nearby soil and rock. Radon then migrates through soil pores by gas-phase diffusion and advection to the interfacial region between the soil and the building. Radon enters buildings primarily by advective transport of air through openings in the substructural shell, including cracks and deliberate penetration [5]. Andrews and Wood [1972] and Bossus [1984] computed the escape probability for radon atoms generated within the recoil range of the surface of a spherical particle and obtained 23.5 and 25%, respectively. Porosity of a material allows radon to diffuse through it. Atmospheric 222Rn originates mainly from the decay of 226Ra atoms that are located in and on the surfaces of mineral grains in the uranium ore [6]. The main objective of the study was to test the methodology for different grain sizes of a granite rock.

2. Methodology

The Bahia street was chosen to be sampled, because in radiometric surveys carried out by the team at the natural radioactivity laboratory (LRN) of the nuclear technology development center (CDTN), a count greater than 400 counts per second (CPS) was noted nearby of the aforementioned street, which has a large flow of people, mainly tourists.

The study of radon by exhalation was performed in closed circuit (Fig. 1), where 1 is sample holder, 2 is the detector, 3 a pump e 4 flow measurements. The detector used was the AlphaGUARD® (AG) model PQ2000 PRO, manufactured by SAPHYMO GmbH, Germany, with an internal volume of 0.56 L and a potential of +750 V inside when turned on. The parameter of 10 minutes/flow was used to realize the 4 days count protocol. The total volume was 0,00502 m^3. The radon exhalation closed circuit method was used by Taveira et. al (2021), with solid samples.

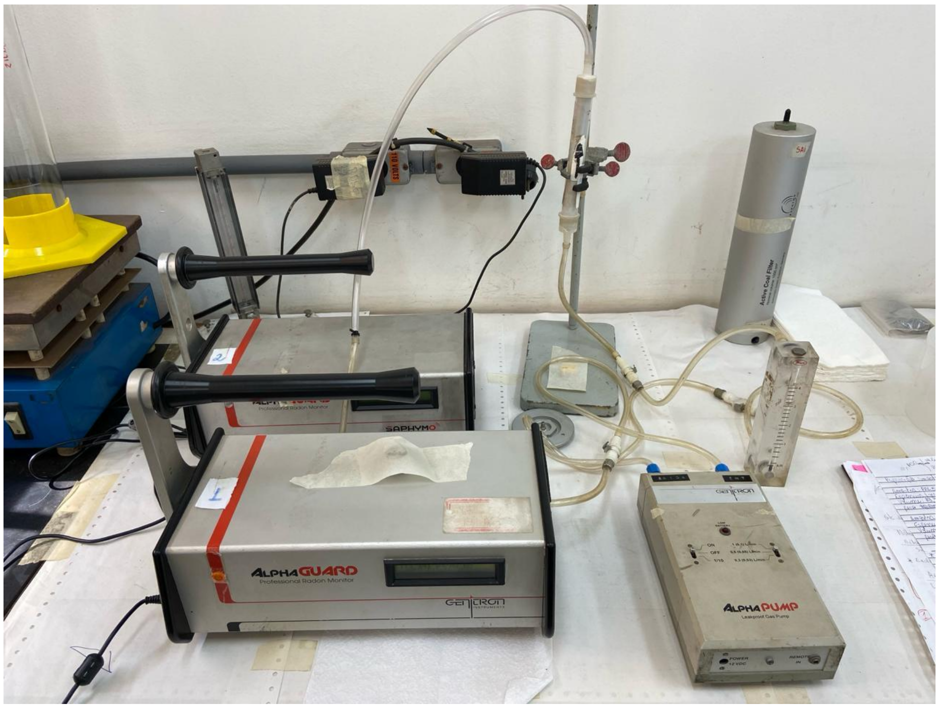

Figure 1: Exhalation radon study by closed circuit.

An aliquot of 60g was placed in a sample holder, awaiting an equilibrium time between Ra and Rn of 30 days. To test the idea, grain sizes from 1# to 350# (Fig. 2) were used, varying in 1#, 4#, 16# and 350#, of a granite from Rua da Bahia. Samples with different particle sizes were placed in tubes to be connected to the radon exhalation circuit.

Figure 2: Samples being prepared in different granulometry

After obtaining the radon concentrations by AG, an exhalation calculation was made according to the equation 1 below.

$$Ex = \frac{C \times V \times \lambda}{S} \qquad (1)$$

where Ex is the exhalation rate per unit area and time ($Bq.m^{-2}.s^{-1}$), C is the radon concentration, V is the volume of the system (0.00133 m3), λ is the radon decay constant (s^{-1}), and S is the exhalation surface area of the sample (m^2).

3. Results and Discussion

The preliminary results (Table 1) revealed a limitation of the method for granulometries below 350#. This limitation arises because the air flow passing through the tube displaces the sample column, reducing airflow at the ends (fluid pressure loss).

Table I: Radon concentrations and its exhalation

Sample	Granulometry	Rn Concentration (Bqm^{-3})	Rn exhalation ($Bqs^{-1}m^{-2}$)
1	1#	10899.5 ± 1500	$6,16E^{00}$
2	4#	6412.6 ± 130	$3.70E^{00}$
3	16#	8715.46 ± 250	$2.12E^{01}$
4	350 #	1426.17 ± 100	$2.46E^{03}$

Mean	-	6863.43	6.16

It is possible to notice that the smaller the granulometry, the higher the radon concentration and the lower the exhalation per unit of surface. The result is expected up to a particle size of 350#, for this purpose the air flow compresses the sample in the tube and prevents the air from being roasted.

Porosity of a material allows radon to diffuse through it. The thickness of the sample must be optimized to meet two conditions; it must be small compared with the radon diffusion length in the porous medium studied, and as large as possible to get a large source of radon, which reduces the uncertainty in the radon concentration measurement. Given the radon diffusion length in unweathered rock matrix, which is generally of the order of 1 cm (Amaral, 2011).

4. Conclusions

The studied method proved to be effective with particle sizes up to 16#. For very fine particle sizes, the air flow is hampered and therefore reduces the effectiveness of transporting the radon-filled gas. It is proposed for future work to try to reduce the pressure loss caused by the air flow from the pump in the sample column. The Computational Fluid Dynamics (CFD) simulations can help understand the limitations encountered.

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