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Optimization of methodology with solid state nuclear track detector (SSNTD)

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ABSTRACT

The present study aims to optimize the passive methodology with Solid state Nuclear Track Detector (SSNTD) called the sealed can technique in the physics laboratory of the Federal Institute of Paraná - Telêmaco Borba Campus. The work used a polycarbonate polymer as a detector because it is a polycarbonate of national manufacture and of low cost. A factorial design was carried out with three variables: first one with two levels, the second one with three levels, and the third one with four levels, totaling 24 experiments.

. The factors evaluated were the volume of the sealed can (1000 ml, 300 ml and 200 ml), chemical etching time (1 h, 2 h, 3 h and 4 h) and the chemical etching solution (solution A, *PEW-40* and solution B, *KOH- 70*). In all 24 experiments the can was sealed with aliquots of the same geological sample for 38 days before chemical etching and counting of the tracks. The results showed that solution B can be discarded due to the low concentration of tracks obtained in all 12 experiments performed with it. The results for solution A showed that the highest concentration of tracks is obtained for the chemical etching time of 3 h, regardless of volume, and that the volume of 300 ml is the best result. Thus the conclusion of the study is that solution A in the volume of 300 ml and with chemical etching time of 3 h is the optimal procedure for the development of the tracks.

Keywords: **SSNTD, methodology, sealed can technique.**

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1. INTRODUCTION

Natural radionuclides are present in almost all materials in the earth's crust, soil, air, water and even live organisms. These radionuclides emit radiations that pose a risk to human health depending on the intensity of the exposure, the type of radiation and the exposed tissue [1].

Radon is among the natural sources of radioactivity and as it is a noble gas, it can concentrate on air, mainly indoors (homes, schools, shops), thus contributing to the most of effective dose received by humans [2].

The radon isotopes, ^{222}Rn, ^{220}Rn, and ^{219}Rn, are radioactive and emitting alpha particles. Due to the short half-lives of ^{220}Rn (55.6 s) and ^{219}Rn (3.96 s), the greatest radiological concern is the ^{222}Rn with longer half-life (3.8 days), because after escaping the mineral grains in rocks and soils, by alpha decay, it has more time to diffuse through the material and it can be found concentrate in internal environments of human conviviality, for instance, residences [3-5].

For the detection of radon, a low cost technique is the one that uses solid detectors of nuclear tracks, also known by the acronym SSNTD (Solid State Nuclear Track Detector). SSNTDs can be organic or inorganic and have the property of permanently recording damage caused by nuclear radiation from heavy charged particles (alpha, protons, and fission fragments). When these radiations interact with these materials they deposit energy along their trajectories causing disarray in the structure of the material. From this, a suitable chemical treatment (etching) is necessary, so that these tracks become visible under the optical microscope, allowing the count of present tracks [6, 7].

This work consists in the optimization of the methodology for the determination of radon and its descendants through the technique of passive detection using SSNTD detectors, known as the Sealed can technique, [3-5], basically consisting of internally fixed SSNTD detectors on top of a sealed chamber (usually cylindrical).

The SSNTD detector used was a polycarbonate produced by Acrilicos Brasil SA [8]. A polycarbonate plate named by the compact polycarbonate by the company with dimensions of 1220 – 2440 mm with a thickness of 1 mm, and a density of 2.00 g.cm^{-3}, was acquired. it contains some desirable properties to be used as a radiation detector such as polished surfaces and partially transparent to visible light, exhibiting a transmittance of approximately 90%.

The aim of this work is the optimization of the integration procedure and development of solid nuclear tracks employing the Sealed can technique. This optimization will be performed based on three factors: chemical etching time, chemical etching solution, and volume of the sealed can.

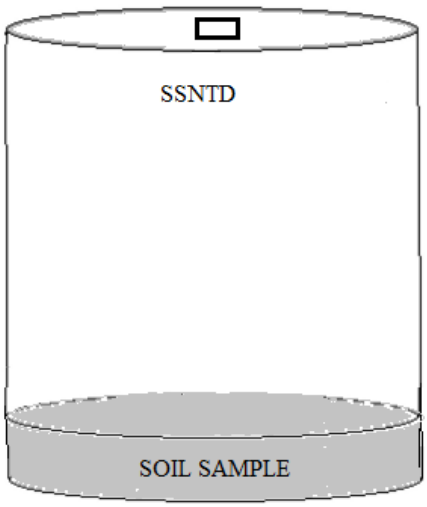
2. MATERIALS AND METHODS

A superficial soil sample collected in the city of Telêmaco Borba in August 2018 [9] was used as a source of radon.

This sample was chosen due to the non-availability of a standard sample of radon source similar to the samples collected to be evaluated in the future by the technique. Moreover, for the present work, it is sufficient that the radon source standard/soil samples generate the same radon concentration in all experiments regardless of the value of this concentration. It is certainly expected that the soil used presents a concentration of natural radioactivity close to the media of the earth's crust [2], this fact confirmed by the results of the work of Rosa et. al. (2019) [9]. This characteristic is important to maintain the geometry of the experiments used in the optimization of the technique for the future use of the method, which will be applied to measure soils and sediments with natural concentrations of radioactivity.

The aliquots of the dried samples were weighed about 80 g in each can and filled to the vessel whose lids were with a fixed SSNTD detector. Afterward, the pots were hermetically sealed for 38 days (Figure 1) for later reading, after integration the etching was carried out in a water bath at 70 ºC.

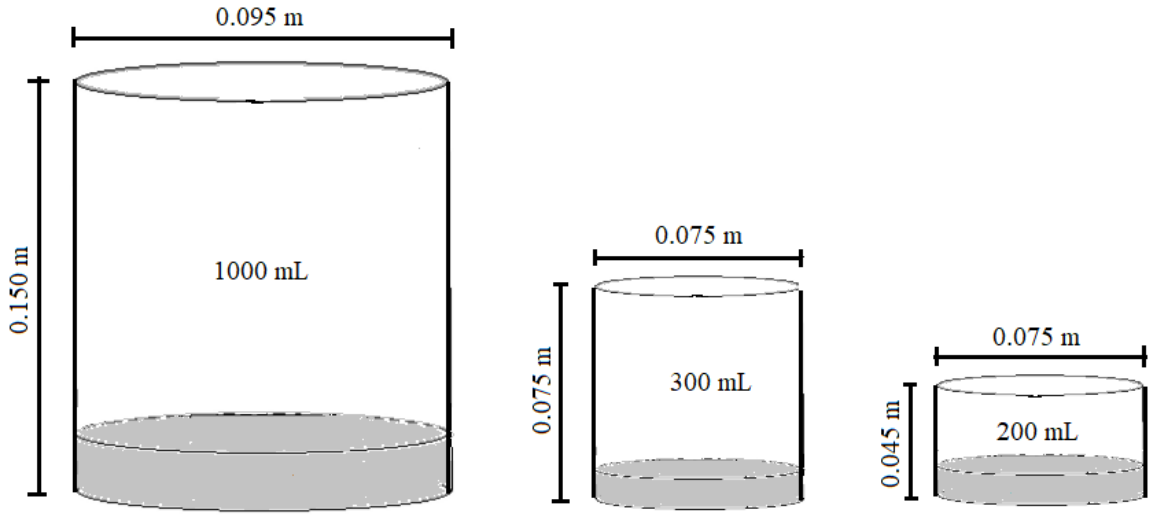
Figure 1: *Figure of the Sealed can technique.*



Source: The authors

The volumes of the sealed can studied were 1000 mL, 300 mL, and 200 mL (Figure 2). The chemical etching occurred at times of 1, 2, 3, and 4 hours. This experiment was performed for two different etching solutions, totaling 24 experiments (3 x 4 x 2), as shown in Table 1.

Figure 2: *Illustration, out of scale, of the dimensions of the containers used as sealed can.*



Source: The authors

Table 1: Experimental Design.

Volume	Etching time (h)	Etching Solution A	Etching Solution B
1000 mL	1	1.1	1.1-2
	2	1.2	1.2-2
	3	1.3	1.3-2
	4	1.4	1.4-2
300 mL	1	2.1	2.1-2
	2	2.2	2.2-2
	3	2.3	2.3-2
	4	2.4	2.4-2
200 mL	1	3.1	3.1-2
	2	3.2	3.2-2
	3	3.3	3.3-2
	4	3.4	3.4-2

The Etching Solution A is the PEW-40 solution, composed of 40% Absolute ethyl alcohol 99.8% P.A. (Ethanol E), 15% potassium hydroxide (KOH) (Potassium P) and 45% ultra pure water (water W). The Etching Solution B is KOH-70 composed of 30% KOH and 70% ultra pure water [10].

After the chemical etching, the wash was performed with 15% nitric acid (HNO_3) and ultra pure water, and the counts were performed manually under a Motic brand optical microscope. Basicament was fixed as counting area the field of view of the microscope with an increase of twenty times (20X) and for each detector 4 fields of view were counted, so the result of the density of tracks is the average of these four counts, divided by the area of the field of view.

3. RESULTS AND DISCUSSION

The results of the mean values of the four counts for each detector of the determinations performed are shown in Table 2. The standard deviation of these averages ranged from 5% to 10%. It was evident that Etching Solution A presented a density higher than solution B, considering that all experiments were exposed to the same source of radiation and at the same time.

In Table 2 for solution B, we can observe that, for the volume of 1000 mL, the density of tracks decreases as the etching time increases, indicating that for longer etching times the detector is corroded until erasing a greater number of tracks. This result is even more evident for the volume of 300 mL where, for the etching times of 3h and 4h, all tracks were corroded (washed out). For the volume of 200 mL this trend is not evident, in this case, the number of tracks is practically constant regardless of the etching time, which seems to indicate that the tracks have a larger and more uniform range in the detector. This may have occurred because, for this volume, with a height of 0.045 m, the SSNTD detectors are closer to the source compared to the other two volumes with heights of 0.15 m and 0.074 m Figure 2.

For solution A, it is possible to verify that the density of tracks increases up to the 3h etching time in the three geometries and decreases to etching time of 4 h, indicating that most tracks concentrate to such depth in the detector and that for longer times of etching than 3h these tracks begin to be washed out. It was verified again that the smallest amplitude of variation of track density was observed for the geometry of lower height 200 mL, the same result that was found for solution B.

For Etching Solution A, it is also possible to observe a higher track density for the etching time of 3 h, for the three geometries, with values of 1484 tracks.cm^{-2}, 3516 tracks.cm^{-2}, and 2710 tracks.cm^{-2} for the geometries of 1000 mL, 300 mL and 200 mL, respectively. This shows that regardless of the geometry used for Etching Solution A, the time of 3 h is the one with the greatest efficiency in the etching of the tracks (Table 2).

Regarding the studied geometries, it is possible to verify that the average densities of tracks obtained from the four times were higher for the geometries of 300 mL and 200 mL with values of 2016 tracks.cm^{-2} and 2012 tracks.cm^{-2}, respectively, compared to the 1000 mL geometry with an average value for the four times of 1089 tracks.cm^{-2} (Table 2).

Table 2: Results.

Volume	Etching Time (h)	Etching Solution A	Track Density (tracks.cm^{-2})	Etching Solution B	Track Density (tracks.cm^{-2})
1000 mL	1	1.1	581	1.1-2	226
	2	1.2	1097	1.2-2	258
	3	1.3	1484	1.3-2	145
	4	1.4	1194	1.4-2	97
300 mL	1	2.1	1290	2.1-2	258
	2	2.2	1742	2.2-2	290
	3	2.3	3516	2.3-4	0
	4	2.4	1516	2.4-4	0
200 mL	1	3.1	1226	3.1-2	161
	2	3.2	1677	3.2-2	242
	3	3.3	2710	3.3-2	129
	4	3.4	2435	3.4-3	161

Among all the 200 mL and 300 mL geometries, the 3 h etching time in the 300 mL geometry was the most efficient with a result of 3516 tracks.cm^{-2} (Table 2).

4. CONCLUSION

In this study, three factors were evaluated in the process of track etching using a national polycabonate as SSNTD detector. The factors evaluated were the Geometry, the Etching time, and the Etching Solution. In all, 24 experiments were carried out and the results showed that the Etching Solution A, for the 3 h etching time, is the one with the best efficiency.

For the geometry, it was emphasized that the geometries of 300 mL and 200 mL are more efficient than the geometry of 1000 mL. There is a small advantage to the volume of 300 mL in the time of 3 h.

As a suggestion for future works, it would be important to verify the influence of temperature on the etching process with at least three levels and the influence of integration time with at least three levels.

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