RETROSPECTIVE DOSIMETRY OF RADON GAS BASED ON THE ACTIVITY OF ^{210}Po IN GLASS OBJECTS

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A study based on retrospective dosimetry of radon gas was conducted in Băiţa-Ştei radon-prone area, Bihor County (Romania). The activity of ^{210}Po in glass objects was assessed using the CR-LR technique in 16 dwellings. The two detectors were mounted in pairs (33), out of which 22 were fixed as duplicates on the same glass objects. These detectors were exposed for 50 days. The results indicate that the geometric mean for retrospective radon concentration is lower (273 Bq/m^3) than the contemporary one (649 Bq/m^3). Nevertheless, a moderate correlation ($r = 0.65$, 95% CI: 0.26 – 0.86, $p < 0.01$, $n=18$) was found between log of retrospective and contemporary radon concentrations.

Key words: retrospective measurements, polonium, glass objects.

1. INTRODUCTION

Radon gas is one of the most important sources of natural radiation and a high exposure can lead to lung cancer [1, 2]. The most common way to evaluate the indoor radon exposure is through long term methods using Solid State Nuclear Track Detectors (SSNTDs). Long-term measurements were held for various periods of time ranging from 3 to 12 months. Nevertheless, with this method it is difficult to include factors such as seasonal or annual variability of radon gas. Also, over time the indoor radon concentration can vary due to architectural changes made in the house structure or to the owner's behavior, like ventilation rate of the house. Taking this into consideration, it is hard to assess the "real" indoor radon exposure. A possible solution to this problem is the retrospective dosimetry based on implanted ^{210}Po activities in glass objects using the CR-LR difference technique [3]. This method assumes that two detectors (one CR-39 and one LR 115) are fixed, side by side, on a glass object [3–5]. One of the reasons for which they are used for retrospective dosimetry consists in their energy threshold. The LR 115 detector can detect alpha particles with energy less than 5 MeV, while the CR-39 detector is sensitive to alphas with energies from less than 1 MeV to greater than 20 MeV. Therefore, while the LR 115 will have tracks made from alpha particles present in the glass object, the CR-39 detector will show tracks due to the implanted ^{210}Po alpha emissions and from the bulk activity of the glass [5, 6]. Hence, it is possible to determine the activity of ^{210}Po implanted in the surface of a glass object and to estimate the retrospective indoor radon concentration.

The study conducted in Băița-Ştei aimed to assess the retrospective radon concentrations based on the activity of ^{210}Po in 16 dwellings in which there were selected glass objects with an age between 18 and 54 years.

2. MATERIALS AND METHODS

The glass objects were selected for this study after meeting a series of criteria: they needed to be at least 10 years old, had to be exposed in the present dwelling for the same amount of time and they had to be flat (mirrors, cabinet glasses or picture glasses). Twenty-two different glass objects were selected in the 18 non-smoky rooms of 16 dwellings from Băița, Cîmpani and Fînațe (Băița-Ştei radon-prone area, Bihor County, Romania). The CR-39 (poly-allyl-diglycol carbonate) detectors were acquired from RadoSys (Hungary). The size of each detector was 1×1 cm^2. The LR 115, Type II, non-strippable (cellulose nitrate) detectors were purchased from DOSIRAD (France). The size of the LR 115 detectors used in the present study was 4 x 2 cm^2. In order to assess the activity of ^{210}Po, the two types of detectors, CR-39 and LR 115, were fixed in pairs on the glass objects using adhesive band and were exposed for 50 days.

The etching process was carried out using the RadoBath etching unit (RadoSys), equipped with an automatic liquid stirring. CR-39 detectors were etched in a 6.25 M solution of NaOH, at a temperature of 90 ±1 ^{o}C for 3 hours and 40 minutes, washed with distilled water and wiped dry with alcohol. For the LR 115 detectors, the etching process was made in a 2.5 M solution of NaOH, at a temperature of 60 ±1 ^{o}C for 90 minutes. The track counting was done using an optical microscope (100 x magnification). For LR 115 detectors, only the fully perforated tracks were counted. Each detector was read 10 times by the same person. The detectors' thickness was measured before and after etching with a digital micrometer with an accuracy of ± 1 μm.

The ^{210}Po activity implanted in glass was calculated using the following equation [7, 8]:

$$A_{210Po} = \frac{CR - B \times LR}{T \times K} \qquad (1)$$

where CR is the net number of tracks per cm^2 on the CR-39 detector, LR is the net number of tracks per cm^2 on the LR 115 detector, B is the ratio number of track densities recorded on a CR-39 detector to that of a LR 115 detector (unexposed glass), K is the sensitivity factor of CR-39 detector to ^{210}Po activity and T is the period of time (h) for which the two detectors were mounted on the glass surface. The values of B and K parameters depend on the etching conditions [5]. Taking into account the thickness of the active layer after the etching process of the detectors, according to the Monte Carlo simulations elaborated by Nikezic *et al.* (2006), the B was set to 2.2 and k to 0.102 [5].

Based on implanted ^{210}Po activity and the age of the glass objects, the retrospective radon concentration was estimated by [9]:

$$C_{Rn} = \frac{245 * A210Po}{1 - e^{-\lambda_{210Pb} * T}} \tag{2}$$

where C_{Rn} is the retrospective radon concentration, A_{210Po} is the ^{210}Po activity (mBq/cm^2), λ_{210Pb} is the decay constant for ^{210}Pb and T is the age of the glass object (years).

The contemporary indoor radon measurements were carried out in the same rooms for 6 months using CR-39 detectors (RSKS type, provided by RadoSys), during the IRART project [10, 11].

The statistical analysis has been performed using GraphPad Prism 5. The comparison between two paired samples was made with paired t-test, for the log-transformed data, if the normal distribution was confirmed by D'Agostino-Pearson test. The correlation analysis was performed using Pearson coefficient. The significance level was chosen at $\alpha = 0.05$.

3. RESULTS AND DISCUSSIONS

In 11 of the 22 selected glass objects, the CR-LR detectors were placed as duplicates. Therefore, from the total number of 33 pairs of CR-LR detectors, 16 were placed on cabinet glasses, 8 pairs were mounted on picture glasses and 9 pairs were fixed on mirrors. Regarding the age of the objects, the average was 37 years and 55 % of them are more than 35 years old. The results for all the 33 pairs are presented in Table 1. The average for track density on the CR-39 detectors was 1720 tracks/cm^2 and 255 tracks/cm^2 for LR 115 detectors.

The ^{210}Po activity was found to vary from 1.8 to 42.9 Bq/m^2, with an average of 14.2 Bq/m^2. The parametric paired t test was used to evaluate a possible difference between the ^{210}Po activities means calculated for the 22 glass objects where the detectors were placed as duplicates. No statistically significant difference was obtained between the means of two pairs of detectors ($p = 0.55$), which shows a high precision of the measurements. The dependence of the surface ^{210}Po activity in the glass objects and the age of the objects were also studied. After applying the Pearson analyses, the value obtained ($r = 0.08$) was not statistically significant ($p = 0.73$, $n = 21$).

Table 1

Track densities registered on the CR-39 and LR 115 detectors mounted on the glass objects

Code	Type of glass object	Age (years)	Track density CR-39 /cm^2	Track density LR115 /cm^2
B11	Picture glass	40	1140 ± 20	241 ± 38
B12	Picture glass	40	987 ± 23	203 ± 15
B21	Picture glass	54	1093 ± 83	233 ± 59
B22	Picture glass	30	5080 ± 106	236 ± 21
B23	Picture glass	54	1100 ± 53	226 ± 35
B41	Picture glass	50	3053 ± 220	270 ± 56
B42	Picture glass	50	2474 ± 76	230 ± 46
B51	Cabinet glass	38	2180 ± 178	190 ± 44
B52	Cabinet glass	38	1813 ± 61	323 ± 64
B61	Cabinet glass	40	1567 ± 200	240 ± 26
B62	Cabinet glass	40	1467 ± 145	216 ± 12
B71	Cabinet glass	39	833 ± 81	213 ± 45
B72	Cabinet glass	39	953 ± 42	280 ± 36
B73	Mirror	39	1493 ± 336	173 ± 31
B74	Mirror	39	1720 ± 53	220 ± 20
B81	Cabinet glass	20	1740 ± 262	243 ± 42
B91	Mirror	35	1053 ± 95	113 ± 23
B92	Mirror	35	1333 ± 95	170 ± 10
B101	Mirror	35	3340 ± 408	206 ± 12
B102	Mirror	35	5900 ± 436	303 ± 55
C11	Cabinet glass	44	1233 ± 250	273 ± 23
C12	Cabinet glass	44	1800 ± 35	266 ± 55
C21	Cabinet glass	35	947 ± 81	330 ± 81
C22	Mirror	35	813 ± 31	253 ± 60
F21	Cabinet glass	20	1333 ± 12	513 ± 136
F22	Cabinet glass	20	873 ± 189	460 ± 72
F31	Cabinet glass	35	2287 ± 364	283 ± 107
F32	Cabinet glass	30	2367 ± 230	263 ± 75
F41	Cabinet glass	18	1427 ± 270	390 ± 26
F51	Cabinet glass	25	1073 ± 31	233 ± 21
F52	Picture glass	40	760 ± 87	240 ± 17
P11	Mirror	30	800 ± 53	186 ± 45
P12	Mirror	40	733 ± 129	183 ± 55

The retrospective radon concentration was assessed based on the activity of ^{210}Po using the equation (2) and showed a geometric mean of 273 Bq/m^3 (Table 2). The contemporary radon concentration measured by Cucoş *et al.* (2012) in the selected dwellings ranged from 142 to 1404 Bq/m^3, with a geometric mean of 649 Bq/m^3 [10]. The distribution of the contemporary or retrospective indoor radon concentration was lognormal. Unlike other studies [5, 12, 13], here, the geometric mean of retrospective radon concentration is about 2.4 lower than the contemporary one. After applying the paired t test, a statistically significant difference between the means of the two samples (log of retrospective *vs.* contemporary radon concentrations) was found ($p < 0.01$, $n = 18$).

Table 2

Descriptive statistics for retrospective and contemporary radon concentration in 16 dwellings from Băița-Ștei radon-prone area

Radon concentration	**Min (Bq/m^3)**	**Max (Bq/m^3)**	**Median (Bq/m^3)**	**AM (Bq/m^3)**	**SD (Bq/m^3)**	**GM (Bq/m^3)**	**GSD (Bq/m^3)**
Retrospective	97	1509	277	386	389	273	2.3
Contemporary	142	1404	705	754	375	649	1.8

There are two possible explanations for this result. The first, which is also the main constraint of the study, pertain to the etching process of LR 115 using RadoBath without any previous calibration, namely the lack of accuracy in determining the thickness of the active layer by the micrometer. A second reason could be the presence of double-glazed windows in each investigated room. A previous study [14] showed a 25% increase in indoor radon concentrations if the windows were double-glazed and not simple. Consequently, the replacement of simple windows with double-glazed windows that occurred within the last 10 years could induce an increase radon concentration better detected by the contemporary measurements as opposite to the retrospective ones, taking into consideration the age of the studied glass objects.

A moderate correlation ($r = 0.65$, 95% CI: 0.26 – 0.86, $p < 0.01$, $n = 18$) was found between the log of retrospective and contemporary radon concentrations (Figure 1).

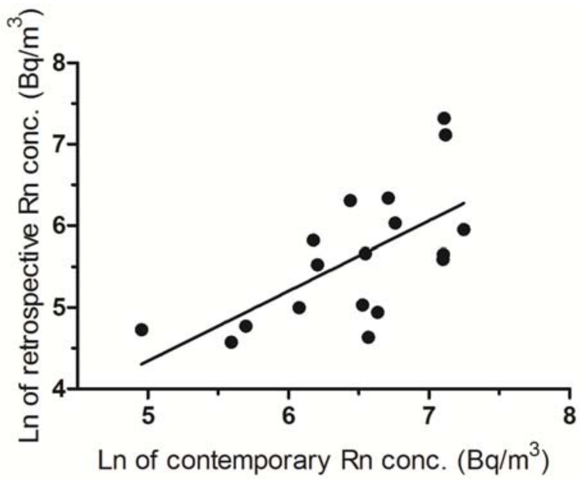

Fig. 1 – Comparison between log of contemporary and retrospective radon concentration.

This result is similar to that obtained in other studies: Zunic *et al.* (2007) found a good correlation ($r = 0.73$) between the log of retrospective and contemporary radon concentrations in 46 rooms from Niska Banja (Serbia) [13]; a very good correlation coefficient (r = 0.83) was also obtained by Bochicchio *et al.* (2003) between retrospective and contemporary radon concentrations for 21 objects in non-smoky dwellings [15]. Despite this, in some studies, a weak or no correlation was reported between ^{210}Po activity and contemporary radon concentration [6, 12, 16].

4. CONCLUSION

This study showed a moderate correlation between the contemporary and retrospective radon concentration. Nevertheless, the geometric mean of retrospective radon concentration is about 2.4 lower than the contemporary one. The slope factor (0.86) obtained using the regression analysis for the log of concentrations indicated the presence of some discrepancies in the assessment of indoor radon gas by two methods. It is highly recommended to further investigate and elaborate a specific protocol for etching LR 115 detectors using a type of etching unit such as RadoBath.

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