Comparing summer and winter indoor radon and radon daughters activity in Campinas, Brazil

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Abstract. We developed a technique — based on alpha particle track detection using CR-39 — where the activity originated from indoor radon can be potentially separated into three fraction: (i) radon in the air, (ii) radon daughters (RD), ^{218}Po and ^{214}Po, in the air and (iii) RD plated-out on the detector surface during exposure. In this work only a partial separation was carried out, then our results are limited to radon plus RD in the air and RD attached to detector surface. These activities can be separated if size and gray level of the round tracks are measured using an automatic optical microscopy system.Our group carried out an indoor radon and radon daughters (RD) survey in Campinas made up by a summer (November, 96 to May, 97) and a winter (May, 97 to November, 97) exposure, where the detectors were placed in the same rooms of the same dwellings (approximately 100) in both cases. Comparing winter and summer alpha activity for the detectors analyzed up to now, approximately 45 dwellings, we observed that: i) it seems that the source of radon is the material (brick and concrete mainly) making up walls, floor and ceiling of the dwellings, ii) there is no clear relationship between intensity of aeration and the activities measured in this work, and iii) the average ratio between winter and summer activity in the air (radon plus RD) is approximately equal to similar ratios observed in other countries, but for radon only.

Introduction

The radon gas has been intensively measured in the two last decades. Many experimental techniques have been employed [1], including etched track detectors [2]. One advantage of this technique is the long exposure, several months that is usually necessary. In this way, the tracks registered can be transformed in activity in the air that should be more realistic compared with the activity that people are actually submitted to.

We used in this work a well known track detector, CR-39, which is practically sensitive to all alpha particle´s energy range [3]. This sensitivity can be a problem if these particles cannot be separated concerning their energy and emission locus. We were able to carry out this separation, at least partially, as it is commented in the following. In this way, measurement results of the activity in the air, due to Rn-222 and RD, and due to the RD, plated-out on the detector surface during exposure are shown in the next sections, for a summer and winter survey (45 dwellings) performed in Campinas-Brazil.

The main goal of applying this technique in small a magnitude survey is to carry out a first evaluation of this new approach.

Methodology

Our group developed a technique where potentially the mean activity of Po-214 and Po-218, the RD that are alpha emitters, can be measured approximately free from the influence of environmental factors [4,6]. In this technique each assembly contains two CR-39 sheets: an internal detector used to measure radon and an external detector, exposed under a 2π geometry. The latter detector measures both the activity of radon plus RD in the air neighboring its surface and that one due to the RD plated-out on its surface during exposure. This work concerns only with the external detector. If only round tracks (eccentricity smaller than 1.10) are measured and if the gray level of each track is also measured — which implies the employment of an automatic microscopy system — the activity in the air due to radon plus RD can be separated from that due to RD plated-out on the detector surface [5, 6]. In the following sections the activity in the air is named Aw or As, where w and s mean winter and summer exposure, respectively, and the activity related to the plate-out of RD is named G_W or G_S.

Exposure

Detectors were exposed in dwellings selected by a weighted random process taking into account IBGE (Brazilian Institute of Geography and Statistics) annual income per capita. The unitary censual regions drawn in this way were constituted by approximately 200 families. To select a dwelling inside the unitary regions a new restriction was considered: the dwelling must be inhabited by a family where one of its members was professor or employee of UNICAMP (amounting approximately 16,000 families). Besides, the dwellings chosen had to present external aspects (building area, quality and conservation of the employed building material, etc.) similar to the neighboring houses. In the cases where this was not observed the dwellings were ruled out.

The advantage of this restriction was that we made a first contact with the chosen professors and employees at the Campus of our University, where the purposes of our research were explained and written texts about the matter were given to them. Usually some days after this first contact the correspondent dwelling was visited by members of our group and the exposure began. During this visit a questionnaire about characteristics of the dwelling (conditions of the floor, internal walls, ventilation, etc.) and some other useful information was filled and a plan of the dwelling was schematically drawn. It is worth to mention that detectors were exposed on a wall at the height of 2 m (to be out of the "children range") usually in one of the bedrooms of the dwelling. Using this procedure the agreement with exposure was greater than 95% and after its end the return of the detectors was approximately 90%.

Our survey at Campinas was divided in two steps. A first 100 dwellings exposure covered the months between November of 1996 to May of 1997 (summer exposition). A second exposure started in May of 1997 and ended in December of 1998 (winter exposition). It was carried out in 89 of the 100 dwellings of the first exposition. The purpose of repeating the dwellings was to study whether there are differences between winter and summer exposition, analyzing assemblies placed in the same rooms in the same dwellings.

Measurements

Using an automatic microscopy system under a nominal magnification 10×63 (each observation field — the image sent by a CCD camera to the screen of the coupled TV monitor — has an area of 1.628×10^{-4} cm^2) the tracks contained in 1,600 observation fields were counted, for each detector. As quoted above only the tracks with eccentricity smaller than 1.10 — the round tracks — should be measured. To select them we employed the CRTRAN soft (developed in our laboratory) that measures, for each track, the major and minor diameters, the gray level of the track and of its neighboring area and calculates its eccentricity, product of the diameters and relative gray level.

Table 1. Data from the analyzed dwellings. Painting ages are expressed in years (a)

Dwelling	Aeration	Painting	A_S (Bq m^{-3})	A_W (Bq m^{-3})	G_S (Bq m^{-2})	G_W (Bq m^{-2})
2	Yes	Latex – 5 a	38.24 ± 7.68	53.75 ± 9.65	2.96 ± 0.45	2.27 ± 0.40
3	Yes	Latex – 2 a	87.21 ±	80.02 ±	5.97 ± 0.70	6.69 ± 0.76
4	Yes	Acrílic	24.72 ± 6.02	53.75 ± 9.65	2.09 ± 0.38	4.66 ± 0.61
5	Yes	Latex – 1 a	194.28 ±	117.05 ±	14.18 ± 1.30	8.36 ± 0.89
6	No	Latex – 10 a	45.95 ± 8.87	188.83 ±	2.30 ± 0.40	5.23 ± 0.65
8	Yes	Latex – new	33.91 ± 7.29	175.78 ±	2.37 ± 0.41	3.74 ± 0.53
11	Yes	Latex – new	96.75 ±	83.61 ±	8.84 ± 0.92	11.05 ± 1.08
12	-	Yes	88.38 ±	119.44 ±	8.00 ± 0.86	9.91 ± 1.00
13	Yes	Latex – 4 a	160.05 ±	163.63 ±	17.14 ± 1.49	14.39 ± 1.31
14	yes	Latex – 2 a	31.21 ± 6.87	38.22 ± 7.76	3.48 ± 0.51	4.60 ± 0.60
15	Yes	Latex – 5 a	20.41 ± 5.35	26.28 ± 6.19	1.38 ± 0.30	1.55 ± 0.32
16	Yes	Latex – 1 a	254.51 ±	152.88 ±	11.95 ± 1.14	11.76 ± 1.13
17	Yes	Latex – 3 a	127.25 ±	81.22 ±	6.18 ± 0.73	4.78 ± 0.62
18	Yes	Latex – 3 a	51.62 ± 9.41	45.39 ± 8.65	2.82 ± 0.45	3.52 ± 0.51
19	No	No	96.02 ±	151.16 ±	10.46 ± 1.04	10.03 ± 1.01
23	Yes	No	150.84 ±	193.94 ±	20.53 ± 1.73	13.32 ± 1.23
24	Yes	Latex – 2 a	48.97 ± 9.08	70.47 ±	4.12 ± 0.56	3.46 ± 0.51
25	Yes	Latex – new	113.47 ±	77.64 ±	11.82 ± 1.13	6.69 ± 0.76
26	Yes	Latex – 2 a	52.92 ± 9.19	83.61 ±	3.64 ± 0.53	3.34 ± 0.50
28	little	Latex – 4 a	31.37 ± 6.97	66.23 ± 9.82	3.04 ± 0.47	2.35 ± 0.41
31	yes	Latex – 2 a	224.14 ±	70.47 ±	6.79 ± 0.78	5.79 ± 0.70
33	yes	Latex – 7 a	70.60 ±	76.44 ±	9.41 ± 0.97	6.87 ± 0.78
35	yes	Latex – 3 a	49.54 ± 9.27	76.44 ±	5.64 ± 0.69	5.73 ± 0.69
36	yes	Latex – 2 a	170.93 ±	93.16 ±	4.83 ± 0.63	4.66 ± 0.61
37	yes	Latex – 1 a	84.23 ±	111.08 ±	5.76 ± 0.70	5.20 ± 0.65
38	yes	Latex – 2 a	115.80 ±	125.41 ±	12.76 ± 1.21	12.78 ± 1.20
39	no	Latex – 0.17	68.64 ±	82.84 ±	7.05 ± 0.80	5.52 ± 0.68
41	yes	Latex – 0.25	53.87 ± 9.19	80.22 ±	3.99 ± 0.56	5.67 ± 0.69
46	yes	Latex – 1 a	49.43 ± 8.87	77.95 ±	5.67 ± 0.70	4.72 ± 0.61
48	yes	Wall paper	172.43 ±	66.03 ±	3.71 ± 0.54	4.38 ± 0.58
49	yes	Latex – 0.5 a	124.60 ±	50.16 ± 9.22	4.59 ± 0.61	5.85 ± 0.70
50	yes	Latex – new	39.02 ± 8.02	47.78 ± 8.94	2.64 ± 0.44	4.00 ± 0.55
51	no	Latex – 4 a	42.79 ± 8.50	67.73 ±	4.28 ± 0.59	3.51 ± 0.51
56	no	Latex – bad	54.19 ± 9.82	105.49 ±	2.71 ± 0.45	4.04 ± 0.55
58	yes	Latex – 2 a	32.64 ± 7.29	82.20 ±	1.64 ± 0.34	3.15 ± 0.48
66	yes	Latex – 3 a	32.63 ± 7.29	35.83 ± 7.46	2.69 ± 0.45	1.85 ± 0.35
67	little	Latex – 3 a	39.93 ± 7.92	81.12 ±	3.17 ± 0.50	2.21 ± 0.39
74	yes	Latex – 5 a	28.14 ± 6.63	36.02 ± 7.50	2.49 ± 0.43	2.04 ± 0.37
80	yes	Latex – 2 a	33.26 ± 7.32	39.62 ± 7.95	1.92 ± 0.37	3.06 ± 0.47
82	yes	Latex – 1 a	53.62 ± 9.94	63.30 ±	4.58 ± 0.62	4.42 ± 0.59
84	little	Latex – 0.25	38.03 ± 7.61	34.64 ± 7.31	2.57 ± 0.44	2.57 ± 0.42
86	yes	Latex – 2 a	42.46 ± 8.24	96.02 ±	6.56 ± 0.78	2.28 ± 0.44
96	yes	Latex – 0.33	54.41 ± 9.92	69.63 ±	4.30 ± 0.59	6.66 ± 0.76
122	yes	Latex – 0.75	67.66 ±	64.50 ±	6.02 ± 0.75	5.32 ± 0.66
124	yes	Latex – 10 a	54.76 ±	72.86 ±	4.18 ± 0.60	4.66 ± 0.61

Discussion

Considering the measurements carried out on 45 dwellings (see Table 1 and Figure 1) the following results should be pointed out:

(a) The mean values for the ratios between the air (A_W/A_S) and selfplated-out (G_W/G_S) activities are different: 1.39 and 1.07, respectively. These results can be explained taking into account the fact that the main source of radon are the materials (floor, walls and ceiling) enveloping the indoor environments under measurement. The approximately unitary mean value of the G_W/G_S ratio is probably due to the short half-life of the radon daughters (mainly ^{214}Po), which suffer a weak influence from aeration and a strong influence from the "radon source" (the same in both exposures). In the case of the air activity, the long half-life of radon makes this ratio to be more influenced by aeration (certainly greater in the summer exposure). Consequently radon, that is homogeneously distributed through the air, can be partially carry out to outdoor by aeration.

(b) Dwellings without internal painting (detectors 19 and 23) presented activities (A_I, A_V, G_I and G_V) greater than the corresponding mean values. Only one dwelling was internally painted with acrylic paint (detector 4); it presented the lowest activities (A's and G's) among all the dwellings analyzed in this work.

(c) Analyzing 8 residences (detectors 6, 19, 28, 39, 51, 56, 67, 84) where aeration was practically absent or very weak – in accordance with information given by the dwellers — one observes that only detectors 19 for summer exposure and 6, 19 and 56 for winter exposure presented A's greater than the corresponding mean values ($\bar{A}_S$ and $\bar{A}_W$, respectively). Concerning the G's, only detectors 19 (summer) and 19 and 36 (winter) presented superficial densities greater than the corresponding mean values ($\bar{G}_S$ and $\bar{G}_W$, respectively).

(d) Four flats were analyzed (detectors 28, 66, 74 e 86). With the exception of detector 86, the other three presented A's and G's quite smaller than the corresponding average values. It is important to mention that in the case of flat 86 exposure took place in a room presenting an apparent concrete ceiling.

(e) In figures 1.1 and 1.2 one can see a roughly linear relationship between the G's and A's. This result is expected as the greater is the number of radon and RD in the air the greater also is the probability that RD can attach to the material surfaces making up a room (including the detector surface, also). Atypical results, residences presenting great activities in the air and low RD superficial activities, appear both in figure 1.1 (detectors 6 and 8) and 1.2 (16, 31, 36, 48 and 49). These results can be a consequence of a fall in the probability that RD become attached to the walls where these detectors were exposed due to the turbulence caused by air currents in these residences.
It is suggestive that detectors showing great G's and low A's are not observed in figure 1.1 and 1.2. If a result of this kind was observed the most part of the radon atoms penetrating the indoor air (from the floor/soil, walls and ceiling) should decay quickly and, then, close to the walls, what would lead to an increase in the G value. However, as mentioned above, the long half-life of radon makes very probable that before their radioactive decay occur the radon atoms have enough time to spread uniformly through the room.

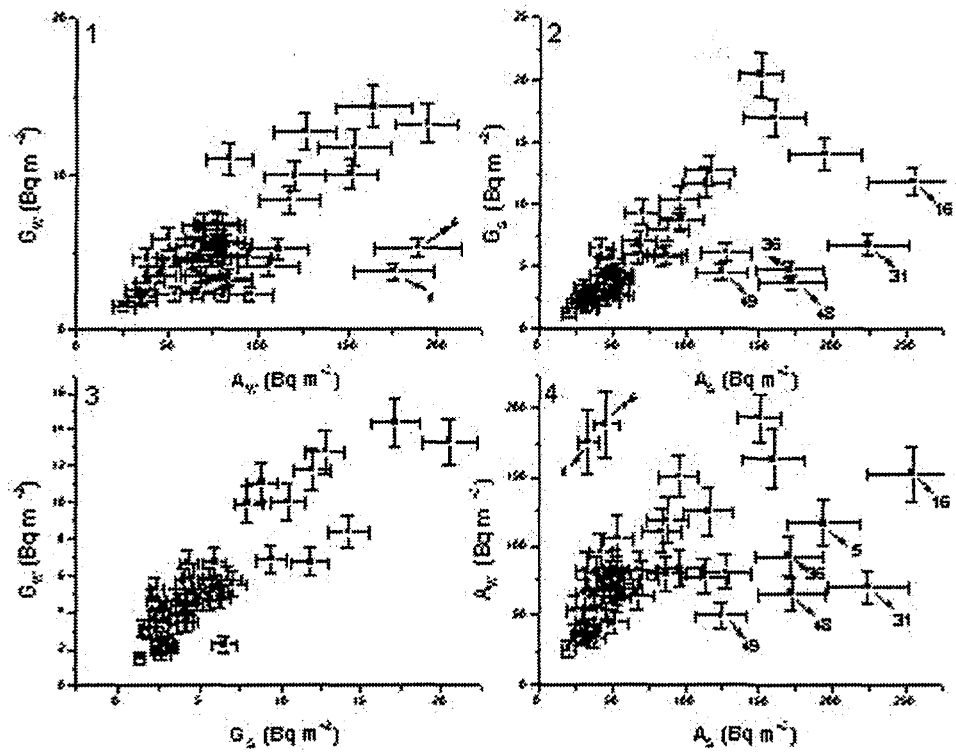

Figure 1. The activities of ^{222}Rn, ^{218}Po and ^{214}Po in the air for summer (A_S) and winter (A_W) exposures and of ^{218}Po and ^{214}Po plated-out on the detector surface, also for summer(G_S) and winter (G_W) exposures, were employed to build four plots: G versus A for winter and summer and G_W versus G_S and A_W versus A_S.

(f) In figure 1.3, one observes a clear linear dependence between G_W and G_S. The greater is G_W the greater is G_S for the corresponding residence. This indicates that the main factors determining the magnitude of the RD deposition rate should be associated with characteristics of the residences and not with factors that changed from the summer to the winter exposure, like the average temperature, ventilation rate, etc.

(g) In figure 1.4, if the points corresponding to the atypical residences (identified in figure 1.1, 1.2 and in this figure) are not considered, there is also a linear relationship between A_W and A_S, indicating again that the activity in the air is mostly influenced by the radon source, i. e. the residence.

Conclusions

Some results described in the previous section present coherence. Items a, b, c (observation about flat 86), f and g indicate that the "source of radon" comes from the material (brick and concrete are by far the most important materials used to build residences in Campinas) making up walls, floor/soil and ceiling of the dwellings. This is a partial result; only a half of our detectors were analyzed up to now. However, its confirmation can have an important consequence: indoor radon mitigation can be succeeded employing a proper internal wall painting. However, nowadays we can not go beyond this gross and generic statement. Our data are unclear if we search for more direct and detailed information at this respect. We did not found a relationship between age and conservation of the internal paintings usually utilized (latex) and a decrease of the measured activities. Only in one case (detector 4), this kind of decrease could be associated with the internal paint (acrylic). What means a proper internal painting (or even covering) is a matter that needs further investigation.

Our statistics concerning flats is very low: only four were analyzed. Then, it is difficult to state whether the low activities observed in these cases are due to their great distance to the soil, certainly also a source of radon, or to the lower amount of material — compared with houses — that is usually employed to build flats.

Our results (item c) also suggest that the activities measured in this work are not influenced by intensity of aeration. Although this intensity is only a rough and qualitative information given by the dweller owners.

The average A_W/A_S ratio found here is similar to winter to summer ratios carried out in other countries, but for radon only [7].

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