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ESTIMATING RADON LEVELS FROM Po-210 IN GLASS

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ABSTRACT

The α-decay of Po-210 may become a useful indicator of the radon exposure during the last decades. The uncertainties associated with this technique were studied both experimentally and theoretically.

The depth distribution of absorbed Pb-214 and Pb-210 in glass is calculated using the theory of Lindhard for low energy heavy ions. It is found that 29.8 % of the absorbed Po-214 reappears at the glass surface after α-decay. The surface layer in which the decay products are absorbed is less than 100 nm. Measurements of the α-activity of Po-214 show that cleaning the glass once removes 85% of the deposited activity.

Room model calculations indicate that the ratio of the Po-210 surface activity to the radon air activity is about equally dependent on the deposition constant of the unattached decay products and on the attachment rate. The presence of aerosol sources, for instance, lowers the surface activity by a factor of two. Experimental investigations prove this finding.

INTRODUCTION

Lively in 1987 (1) and Samuelsson in 1988 (2) put up the idea of using the α-activity of Po-210, absorbed in vitreous glass, to determine the long term radon exposure in the living environment. The technique may be used as a retrospective exposure measure, for instance, in epidemiological studies.

The parameters influencing the absorbed and deposited Po-210 activity are indicated in figure 1. A fraction of the airbone Po-218, Pb-214, Bi-214, Po-214 and Pb-210 deposits on macroscopic surfaces. Half of the deposited activity recoils into the surface, upon α-decay, forming a thin absorbed layer. Subsequent α-decay makes a fraction of the absorbed activity to reappear at the surface. Household cleaning largely wipes away

the deposited activity. The values of the transfer probabilities will be assessed in the next sections.

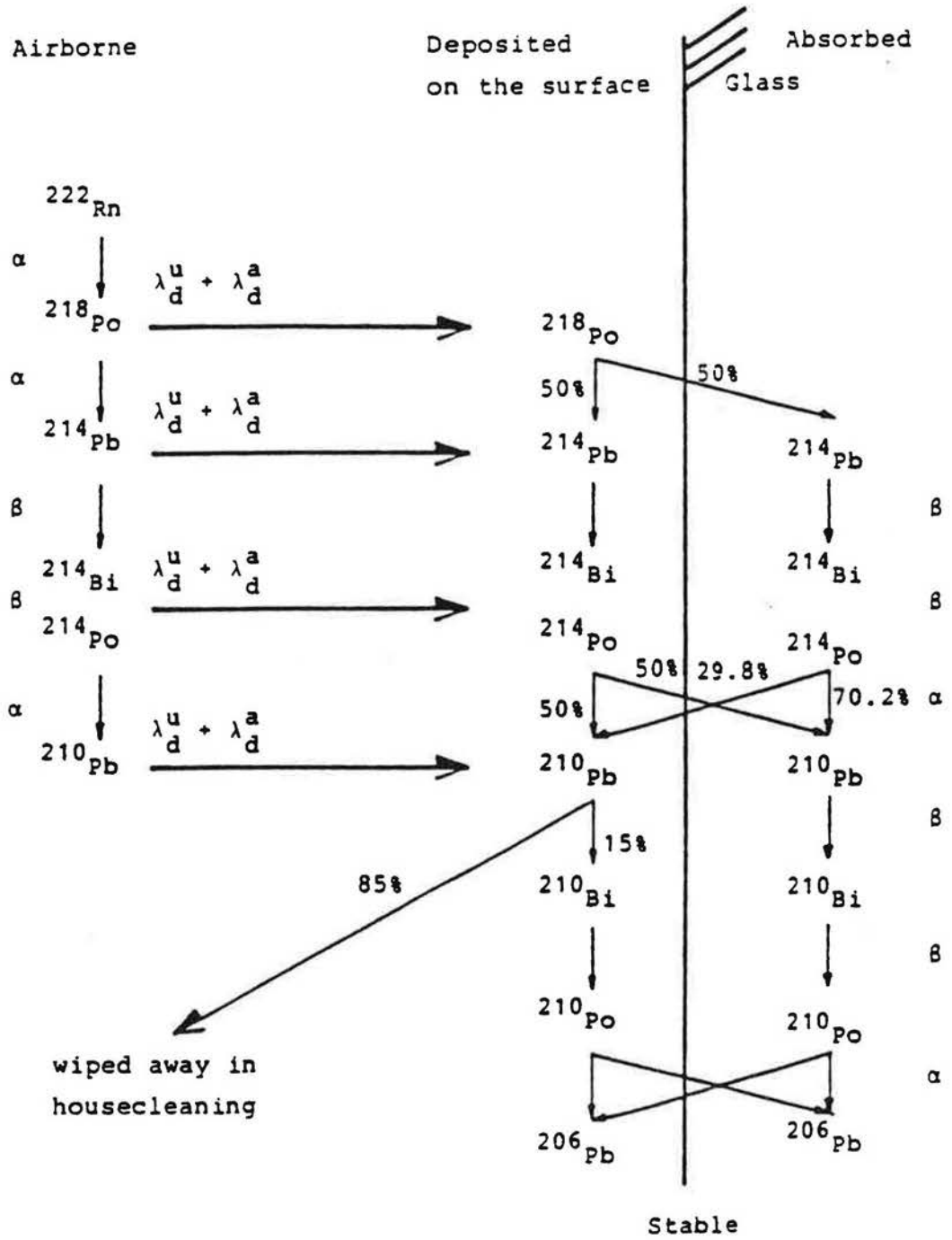

Figure 1. Decay-product deposition and absorption mechanisms and associated transfer probabilities.
λ_d^u is the deposition constant of the unattached decay products and λ_d^a is the deposition constant of the attached decay products.

DEPTH DISTRIBUTION OF Pb-214 AND Pb-210

The theory of Lindhard (3) provides a framework to determine the range of low energy heavy ions in amorphous media. Two recoil nuclei have to be considered, Pb-214 with a recoil energy of 112 keV and Pb-210 with a recoil energy of 146 keV. The details of the calculation are beyond the scope of this paper. They are published in dutch by Landsheere (4). A description in english is available on request.

The depth distributions of Pb-214 and Pb-210 are shown in figure 2. The full line and the broken line are calculated from Pb-214 and Pb-210 nuclei deposited on the surface of vitreous glass and recoiling into the glass.

The dot and dash line is the depth distribution of Pb-210 from Po-214 absorbed in the glass. The diffusion of the radon decay products in glass is negligable so that Pb-214 and Po-214 have the same distribution just as Pb-210 and Po-210. The depth distribution of Po-210 will always be a mixture of the two Pb-210 lines. The contribution of each line depends on the values of the transfer probabilities of the room model (see figure 2).

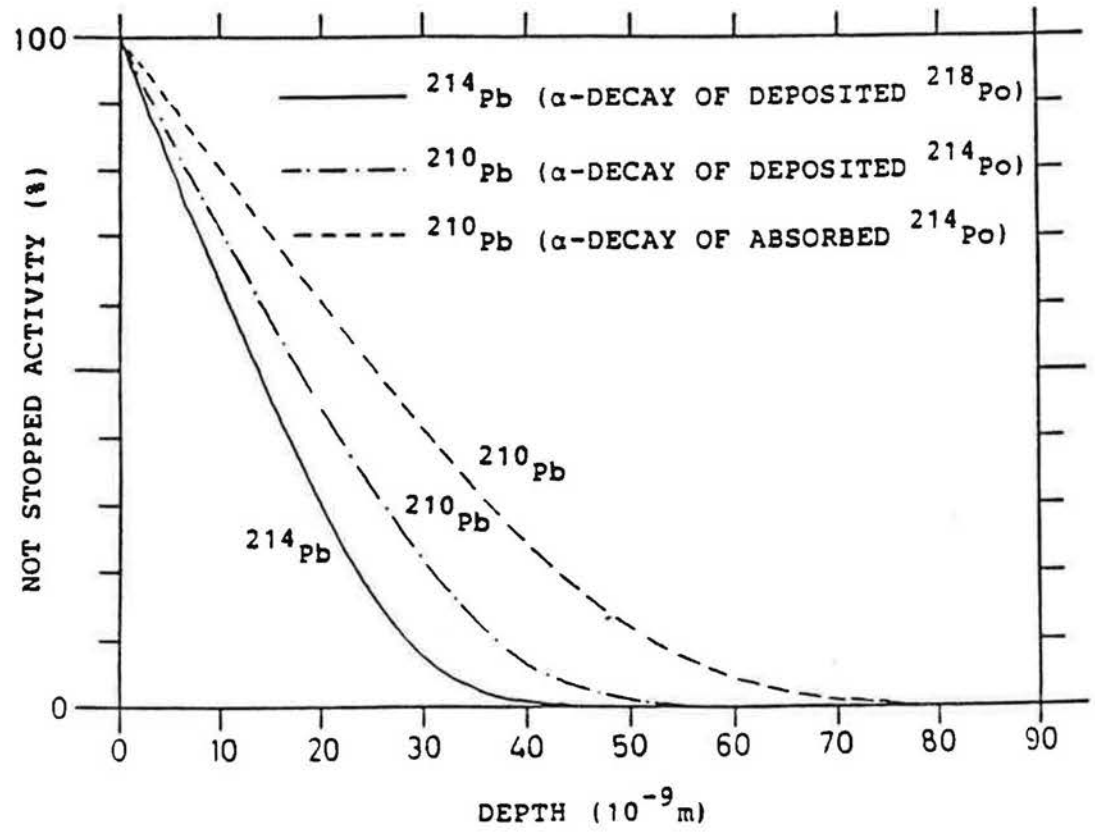

Figure 2. The penetration depth distributions of Pb-214 from decaying Po-218 deposited on the surface and of Pb-210 from deposited Po-214 and from absorbed Po-214.

The probability for recoiling Pb-210 to reappear at the surface of the glass is calculated from the depth distribution of absorbed Pb-214. The resulting probability is 29.8%.

CLEANING EFFECTS ON DEPOSITED DECAY PRODUCTS

An experimental arrangement was setup to investigate wether cleaning removes the deposited activity (see figure 3). A radon chamber of 1 m^3 was filled with radon laden air having a relative humidity of 50%. NaCl aerosol was produced with an atomiser and supplied to the chamber at least 4 hours before performing a measurement.

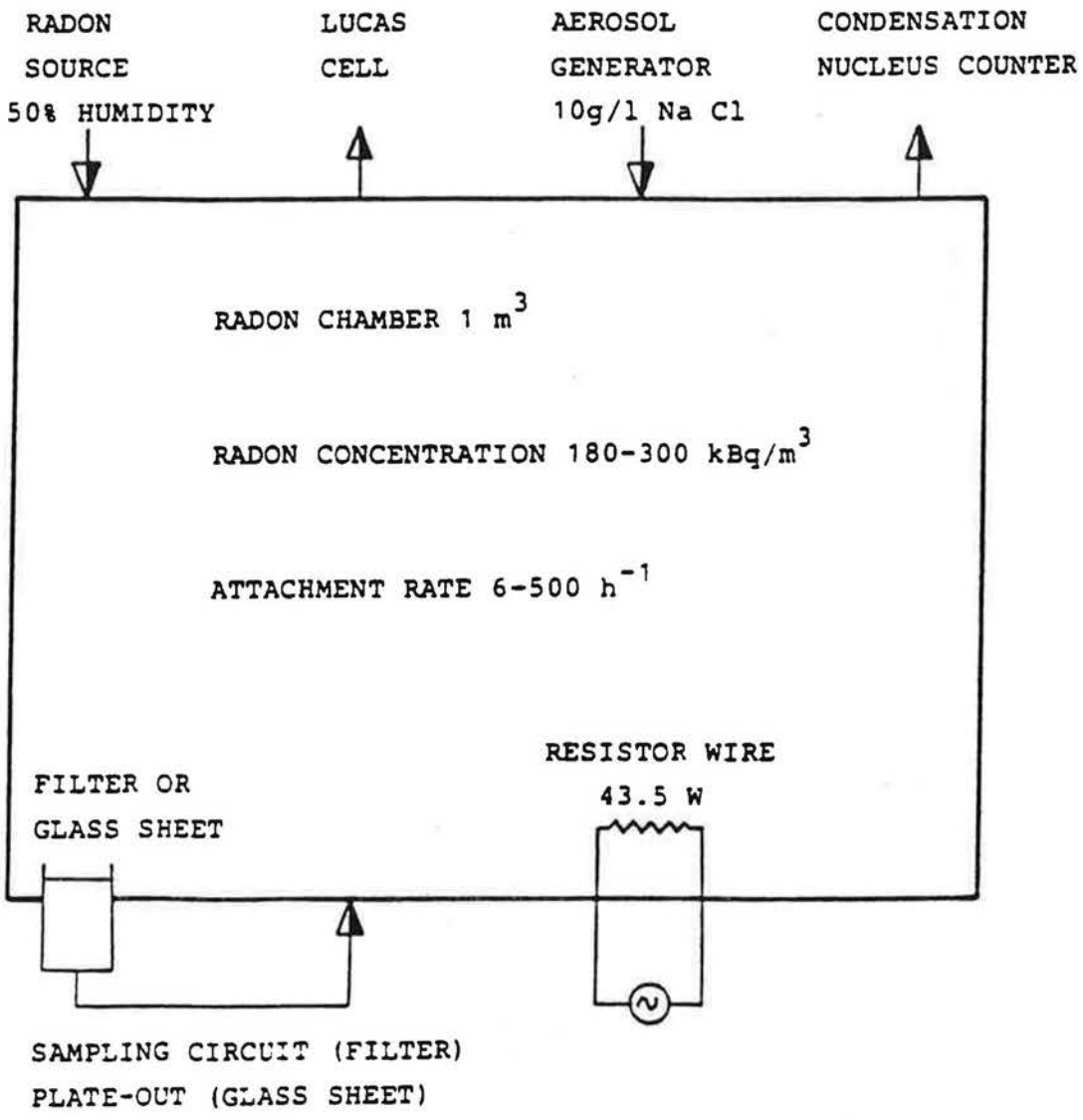

Figure 3. Experimental setup.

The aerosol concentration was measured with a condensation nucleus counter. Turbulence was standardised with a resistor wire dissipating continuously 43.5 W in the radon chamber. A glass sheet was exposed until steady state activities for the shortlived decay products were reached. The Po-218 and Po-214 α-activity of the glass sheet was measured outside the radon chamber for 20 min. Then the glass was cleaned with a cloth containing alcohol and the remaining Po-214 was registered.

Cleaning removes activity from the glass. The number of counts if no cleaning would have taken place was obtained from a filter measurement. The details of the procedure are given by Cornelis (5). The non-wiped fraction is shown in figure 4 as a function of the attachment rate. The indicated error is one standard deviation. The attachment rate was calculated from the particle concentration using the formula of Bricard (6). The diameter distribution was measured a few times with an electrostatic classifier. About 35% of the activity remains on the glass after cleaning. The scatter at high attachment rates is due to counting statistics caused by low plate-out. The lines are the calculated ratios of the absorbed activity to the total activity (absorbed + deposited). They are assessed from the room model using two sets of deposition constants for the unattached decay products. The dashed line was calculated with the same value for the three shortlived decay products (11 1/h, 11 1/h, 11 1/h). Recent experiments (7) indicate that the unattached deposition constant of Po-218 has a higher value than the one of Pb-214. Different values were taken to calculate the full line (11 1/h, 5.5 1/h, 5.5 1/h). A higher deposition constant for Po-218 gives less deviation between theory and experiment (see figure 4).

Cleaning the glass once doesn't remove all of the deposited activity. From the difference between the experimental and the theoretical values (see figure 4) it is concluded that about 15% of the deposited activity remains on the glass.

CALCULATION OF THE Po-210 SURFACE ACTIVITY

The fraction of the Po-210 activity remaining on vitreous glass depends on the values of the parameters of the room model. Most of the variability is due to the deposition constant of the unattached decay products and due to the attachment rate. The surface activity of Po-210 is given in table 1 assuming a radon air activity of 1 Bq/m^3 during 50 years. During this period the following conditions are assumed to be present on an average.

- Ventilation rate 1.0 1/h.
- Surface to volume ratio 3 1/m (a typical value for a furnished room).
- 15% of the deposited activity is not cleaned away.
- Deposition constant of the unattached decay products 10 1/h or 20 1/h or 30 1/h. The same value is taken for all of the decay products.
- Deposition constant of the attached decay products is 1/100 of the deposition constant of the unattached decay products.
- Attachment rate 20 1/h or 40 1/h or 100 1/h.

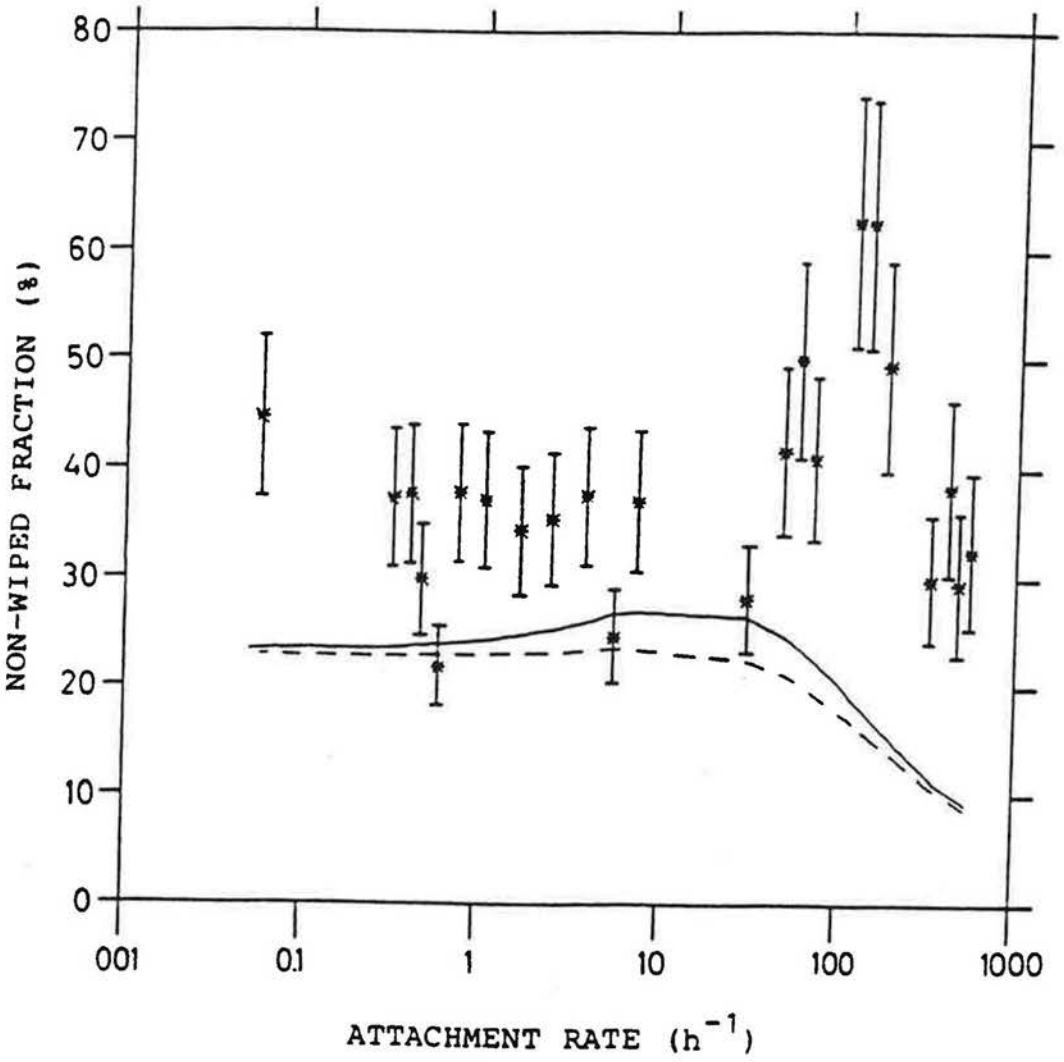

Figure 4. The remaining Po-214 activity after cleaning the glass sheet with a cloth containing alcohol versus the attachment rate. The lines are calculated from the room model using two sets of deposition constants for the unattached decay products. Only the absorbed fraction is assumed to withstand cleaning.

The surface activity of Po-210 is only 3 to 13% of the radon air activity. The attachment rate and the deposition constant are about equally important. The lower and the higher values of the attachment rate are typical for rooms without and with aerosol sources. The surface activity is about a factor of two lower if aerosol sources are present in the room. Turbulence influences the deposition constant. The presence of a convection heater near the vitreous glass, for instance, will enhance the surface deposition.

These considerations indicate that an accurate determination of the cumulated radon activity involves an estimation of the time averaged attachment rate and of the time averaged deposition constant of the unattached decay products.

TABLE 1. THE DEPOSITED AND ABSORBED SURFACE ACTIVITIES OF Po-214 AND Po-210 ASSUMING A RADON AIR CONCENTRATION OF 1 Bq/m^3 DURING 50 YEARS

X	λ_u	λ_d	Deposited Po-214	Absorbed Po-214	Without cleaning Deposited Po-210	Without cleaning Absorbed Po-210	With regular cleaning Absorbed + 15% deposited Po-210
l/h	l/h		Bq/m^2	Bq/m^2	Bq/m^2	Bq/m^2	Bq/m^2
20	10		0.12	0.04	0.07	0.07	0.08
20	20		0.16	0.06	0.09	0.10	0.11
20	30		0.18	0.08	0.10	0.11	0.13
40	10		0.08	0.03	0.05	0.05	0.06
40	20		0.13	0.05	0.08	0.08	0.09
40	30		0.15	0.06	0.09	0.09	0.10
100	10		0.05	0.01	0.04	0.03	0.03
100	20		0.09	0.03	0.06	0.05	0.06
100	30		0.11	0.04	0.07	0.06	0.07

DISCUSSION

The depth distributions of Pb-214 and Pb-210 in glass were calculated from recoiling surface activity and from recoiling Pb-210 already absorbed in the glass, using the theory of Lindhard (3) (see figure 2). Diffusion of the radon decay products in glass is negligable so that Pb-210 and Po-210 have the same distribution. In practice the depth distribution of Po-210 is composed of the two Pb-210 distributions. The importance of each distribution depends mainly on the aerosol and plate-out conditions in the room.
The probability for absorbed Po-214 to reappear at the surface of the glass upon α-decay is 29.8%.

The absorbed decay products are found in a thin layer of less than 100 nm, see figure 2. It should be investigated if decades of household cleaning doesn't remove this layer.
Another problem arises when the vitreous glass is not regularly cleaned. Dust will cover the glass so that a fraction of the recoil nuclei will be stopped in the dust and will be wiped away when the glass is eventually cleaned.
These considerations indicate the need for some tedious experimental work.

Experimental investigations indicate that 15% of the deposited activity remains on the surface of vitreous glass when cleaned once with a cloth containing alcohol. This may be due to radon decay products forming chemical bonds to the glass or to deposition of the decay products into microcracks present on the surface of glass.

ACKNOWLEDGMENT

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REFERENCES

1. Lively, R.S. and Ney, E.P. Surface radioactivity resulting from the deposition of Rn-222 daughter products. Health Phys. 52 : 411-415, 1987.

2. Samuelsson, C. Retrospective determination of radon in houses. Nature. 334 : 338-340, 1988.

3. Lindhard, J., Nielsen, V. and Scharff, M. Approximation method in classical scattering by screened coulomb fields. Mat. Fys. Medd. Dan. Vid. Selsk. 36 : 10, 1968.

4. Landsheere, C. Experimentele en theoretische studie van de fraktie van de Po-210 aktiviteit geabsorbeerd in glas. Student thesis, State Univ. Gent, Nucl. Phys. Lab., 1989.

5. Cornelis, J. Experimentele studie van de invloed van aerosolen op de in glas geabsorbeerde fractie van de Po-210 activiteit. Student thesis, State Univ. Gent, Nucl. Phys. Lab., 1990.

6. Bricard, J. Physique des aérosols II, nucléation, condensation, ions, électrisation, propriétés optiques. Report Commisariat à l'Energie Atomique, R-4831, 1977.

7. Vanmarcke, H., Landsheere, C., Van Dingenen, R. and Poffijn, A. Influence of turbulence on the deposition rate constant of the unattached radon decay products. Accepted for publication in Aer. Science and Techn. 14, 1991.