BOUNDARY CONDITIONS AFFECTING RADON ESTIMATION BASED UPON DAUGHTER DEPOSITION

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ABSTRACT

The use of glass as a substrate for radon active product monitoring was previously suggested by Lively and Ney[1] and further discussed by Samuelsson [2] as a retrospective radon monitor. The deposition of active products on glass or other stable surfaces is partly accomplished by transport by aerosols and partly by unattached ions and atoms. The surface Pb^{210} activity has two components, the aerosol transported which can be wiped off, and the unattached atomic component which is embedded in the substrate. The unwashable part is believed to be associated with the carcinogenic component first postulated by Chamberlain and Dyson[3].

DISCUSSION

Lively and Ney (1987) published a report of work in which they measured the surface alpha activity on material from a cave where the average radon level was 230 pCi/l and a basement window from a room with a minimum radon level of 7 pCi/L. The surface activity was also compared with the quantity of ^{210}Po recovered chemically by removal of the surfaces of the rock and glass. The results indicated that either the surface alpha activity or the amount of ^{210}Po could be used to assess average long-term ^{222}Rn levels in rooms. Samuelsson (1988) has extended this idea and proposed using glass and ^{210}Po surface alpha activity as a retrospective radon exposure system, providing data on integrated radon levels in houses over the past several decades.

Recent results from continuing studies on the use of glass and other materials as integrating radon monitors indicate that several conditions must be understood before surface alpha activity can be used to determine indoor radon concentration and thus provide an estimate of long-term exposure to radon daughter products.

The principal substrate used in the previous and ongoing studies was glass. The results presented in this paper are based on measurements of surface alpha activity and ^{210}Po, by (1) gross alpha counting in situ with a 75 cm^2 alpha scintillation counter, (2) alpha spectroscopy of 4.9 cm^2 glass surfaces., and (3) removal of the glass surface with hydrofluoric acid and measuring the chemically recovered ^{210}Po with an alpha spectrometer. All of the methods agree within 10 percent.

The diffusion constant in glass is so low that very little displacement of the embedded recoil nucleus takes place in the period that the glass surface acts as a monitor. We have not measured the diffusion constant directly, but expect it to be less than 10^{-21} cm/sec, a diffusion distance of approximately one micron in 20 years. Samuelsson (1988) suggested that the alpha emitting daughter products are implanted by alpha recoil to a distance of 0.1 micron. The lack of significant diffusion and the small implantation distance produce an ideal thin source from which the ^{210}Po alpha particles can escape with very little energy loss. Alpha spectroscopy measurements on the glass surface showed that the full width at half intensity of the 5.30 Mev ^{210}Po spectrum is on the order of 1 percent, very near the theoretical resolution of the Ortec 576 alpha spectrometer system. The only peak observed between 4 to 8 Mev was that related to 5.30 Mev ^{210}Po.

Following up on the idea of implantation (Samuelsson, 1988)) which might prevent the daughter products from being wiped off, we find that on

our glass surfaces the surface alpha activity and the ^{210}Po consists of two components, one which can be wiped off the glass surface and one which is stably embedded. Table I shows the results of the gross alpha counts for a 75 cm^2 area of the exposed surface of the glass.

Table 1
Specimen G

Unwashed	73 + 1 Counts/hour
Washed Once	28 + 1 Counts/hour
Washed Twice	27 + 1 Counts/hour
Washed Three Times	25 + 1 Counts/hour
Background	3.9 + 0.8 Counts/hour

For this surface the ratio of the two components is (69.1/22.8)-1≈2. The washable (cleanable) fraction has twice the activity of the unwashable. Other samples on the same window have ratios that range between 1 to 2 for the same components. The ratio of removable to non-removable activity is supported by the alpha spectroscopy measurements on the glass surface and by the chemically recovered quantities of ^{210}Po from washed and unwashed surfaces.

The washed activity was associated with material which we have previously seen to be carbonaceous particulates. We believe that the washable component is transported to the window on aerosol particles, commonly referred to as attached daughter products. The unwashable component is assumed to be transported to the window surface as high-mobility, unattached daughter products. The alpha recoil process probably binds the attached daughter products to the aerosol grains in the same way that the unattached daughters are bound in the substrate.

It is of interest to note that since it is believed that the unattached active products represent a significant part of the carcinogenic component of the radon daughters (Chamberlain and Dyson, 1956), the unwashable component of the ^{210}Po alpha activity serves as a retrospective monitor for the species of interest for epidemiology. The portion of the radioactive deposit which cannot be removed by cleaning is the part that is most important in developing better lung cancer and exposure models.

In order to compare our values with Samuelsson's (see Figure 2, Samuelsson 1988), we need to determine our total radon exposure. We know the window has been in place for 33 years, and we believe it has been there since the house was constructed in 1905. If we assumed that it has been collecting active products for 83 years and that the room radon level has been 5 picocuries per liter, then the integrated ^{222}Rn corrected for decay is 5.5 kbq year/m^3 in the units used by Samuelsson.

From the average of six measurements of gross alpha activity, the unwashed surface gave 8.7 Bq/m^2 and the washed surface 4.4 Bq/m^2. Our value for the washed surface then plots on his figure in fair agreement with the line he has shown.

It must be emphasized that the method of using surface flux monitors such as glass to infer radon levels or radon daughter exposure requires a knowledge of the deposition velocity (defined as the ratio of wall flux of the daughter products to the ^{222}Rn volume density). Our agreement with the plot of Samuelsson (1988) may either be fortuitous or imply similar deposition velocities.

We also found that surfaces other than glass have similar collection properties. In a basement room adjacent to that in which the glass was measured there is a furnace with a baked enamel finish. We measured washed and unwashed activities from this surface in good agreement with those from the window. The exposure time for the furnace cover is well known (25 years). We suggest that other potential substrates include heating and ventilating pipes and the baked enamel surfaces of washing machines.

In summary, we believe that the monitoring of long-term radon levels and daughter product exposures by the use of ^{210}Pb ^{210}Po surface deposition has important applications, for example in epidemiology and models for exposure. It should be useful for times somewhat longer than 138 days (the half life of Po^{210}) and not much longer than 66 years (three half lives of Pb^{210}). Further research is necessary to establish an appropriate calibration and to determine the variability introduced by room geometry and ventilation. This variability will be largely contained in the range of values of the deposition velocity.

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