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ON THE BEHAVIOUR OF RADON DAUGHTERS IN INDOOR AIR

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Abstract – In the present work the effect of small aerosol particles and the effect of the air cleaning devices on the behaviour of the decay products have been studied. The long term measurements in a one-family house have shown that the behaviour of the decay products is strongly dependent on both the concentration of aerosol particles (i.e. attachment rate) and the ventilation system used. By recirculating the air through a mechanical filter it was possible to reach such low particle concentrations that the deposition of free decay products on the surfaces became important. In this case low concentrations of decay products in air were measured. When an electrostatic precipitator was used the concentration of small particles did not reach such low values as in the case of a mechanical filter. This is obviously due to the fine particle formation which is caused by corona discharge in the electrostatic precipitator. The concentration of these particles was high enough to significantly reduce the wall deposition effect. In this case the concentration of the decay products was higher than it was in the case of a conventional mechanical filter.

INTRODUCTION

The relatively high concentrations of radon in indoor air, especially in some one-family houses, have raised the question of the possible health effects caused by the decay products ^{218}Po, ^{214}Pb, ^{214}Bi and ^{214}Po. The decay products can be captured by aerosol particles or they can be deposited on the surfaces of the room. This is why the behaviour of radon daughters is complicated compared to the behaviour of radon itself. In contrast to radon, the decay products can be captured by air cleaning devices as well. In the present work the factors affecting the concentration of radon daughters have been studied experimentally in a one-family house equipped with an air recirculation system.

TEST HOUSE

The measurements have been carried out in a room of a relatively new one-family house. The house consists of four rooms, kitchen and sauna, all on the ground level. The total volume of the dwelling is approximately 250 m^3. The house is equipped with a ventilation system, the principle of which is shown in Figure 1. The indoor air is circulated at the rate of 1 to 2 air changes per hour through an air cleaning system containing both a low efficiency mechanical filter and an electrostatic precipitator. The infiltration rate of the house was below 0.1 air change per hour. Because of the low ventilation rate, relatively high radon concentrations were measured (~800 Bq.m^{-3}). During the day time the ventilation rate was higher due to human activity (e.g. doors were opened temporarily) and therefore the radon concentration decreased to near the outdoor level. The measurements were carried out in three different situations:

- recirculation off
- recirculation on, electrostatic precipitator off
- recirculation on, electrostatic precipitator on.

Most of the measurements took place during normal use of the house. The effect of the electrostatic precipitator was also studied in more controlled conditions. In these measurements the house was empty and the doors were kept closed during the measurement period.

METHODS

The concentration of radon and its decay products was measured for several weeks using an ionisation

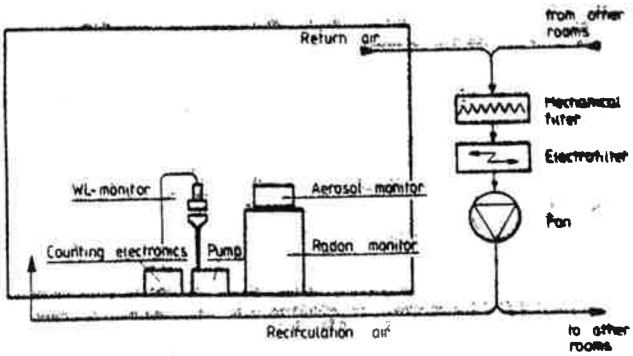

Figure 1. Experimental conditions in the one-family house.

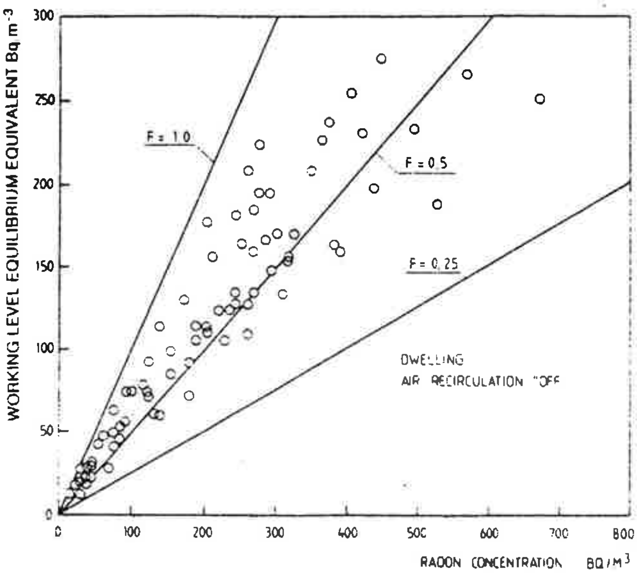

Figure 2. The relationship between WL value and radon concentration when the recirculation system was off. The natural ventilation rate was 0.1 air change per hour.

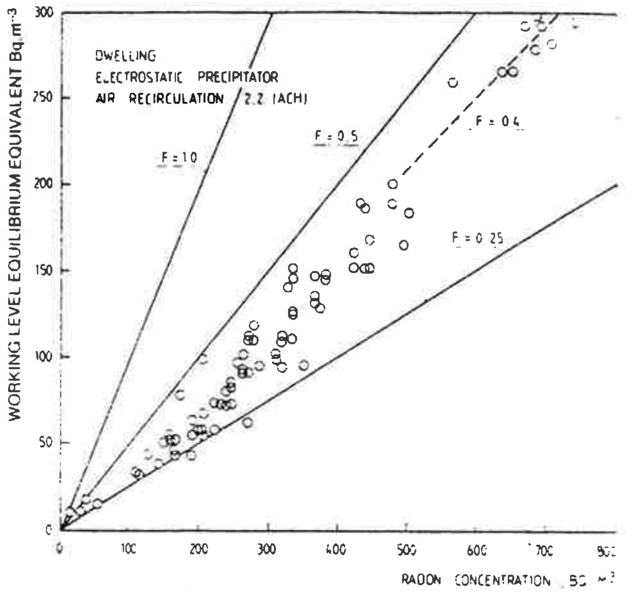

Figure 4. The relationship between WL value and radon concentration in the case of air recirculation (2.2 air changes per hour) through the mechanical filter.

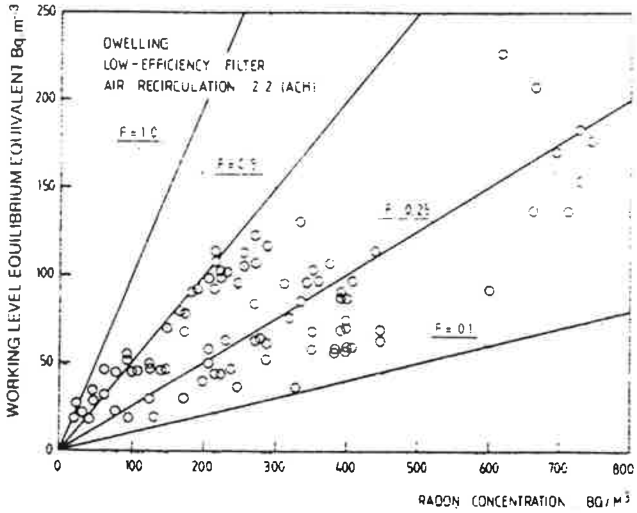

Figure 3. The relationship between WL value and radon concentration in the case of air recirculation (2.2 air changes per hour) through the electrostatic precipitator.

chamber[1,2] and a WL monitor. The WL value was determined by measuring the alpha activity of the decay products collected on a membrane filter. In most of the measurements the method used by Nazaroff[3] was used to calculate the WL value. Air was sampled every 3.5 hours for 10 minutes and the alpha activity was measured for 30 minutes starting 50 minutes after the end of each sample period.

In some experiments the air was continuously sampled and the alpha activity of the sample monitored. Also in some of these experiments a metal screen was used to collect only the unattached decay products. During these measurements the aerosol particles were measured with the aid of an electrical aerosol monitor[4]. The size dependency of the attachment probability of decay products to aerosol particles is roughly similar to the size dependency of the unipolar charging process. This is why the current measured by the electrical aerosol monitor can be regarded as a measure of the attachment rate of the decay products to aerosol particles. This approximation can be used in the particle size range from 0.05 μm to 1 μm.

RESULTS

The results of the measurements of the concentration of radon and the corresponding WL value are shown in Figures 2, 3 and 4. The Working Level (WL) is expressed as the equilibrium equivalent radon concentration. Figure 2 shows the relationship between the WL value and radon concentration when the recirculation was switched off. The equilibrium factor, F, (= WL/radon concentration) varies between 0.4 and 1.0 in this case. The corresponding results in the case when the recirculation system was switched on, are shown in Figure 3. The equilibrium factor now varies in a relatively wide range between approximately 0.15 and 0.5. When the electrostatic precipitator was used, the equilibrium factor was near to the value of 0.4. It may also be noticed that the variations in the equilibrium factor are now much smaller than was the case with air recirculation through the mechanical filter alone.

A possible explanation of the phenomena described above is the behaviour of submicron aerosol particles. When the low efficiency mechanical filter is used alone the concentration can vary over a relatively wide range. During periods with no unusual particle formation inside, the concentration reaches low values which leads to an increase in the attachment of free decay products to the surfaces of the room. In this case low values of the equilibrium factor can be observed. The situation is different when the electrostatic precipitator is used. The corona discharge used in the electrostatic precipitator seems to be one factor which can lead to the formation of small particles (condensation nuclei)[5]. However, it is interesting to note that the particle concentration immediately after the electrostatic precipitator is very low. This indicates that the particles are gradually formed in the room air. It is also possible that the particles are formed in the electrostatic precipitator but the size of the particles is extremely small. Consequently they are not detected until the particle size has grown, e.g. due to coagulation. Because of these small particles the wall deposition of radon daughters does not seem to be a significant factor.

In order to further study the effect of the electrostatic precipitator, some measurements were carried out in relatively well controlled conditions without indoor particle sources. In these experiments the alpha activity was measured during the continuous sampling. At the same time the aerosol particles were monitored with the aid of an electrical aerosol monitor. The recirculation system was operating continuously but the electrostatic precipitator was automatically switched on/off every twelve hours. Figure 5 (upper part) shows the behaviour of small aerosol particles. Because there were no indoor particle sources the concentration of particles decreases slowly during the air recirculation through the mechanical filter. Switching the electrostatic precipitator on causes a rapid increase in the reading of the aerosol monitor. After the electrostatic precipitator is switched off the reading starts to decrease again due to the mechanical filtration.

The corresponding behaviour of the alpha activity of the decay products collected on the filter is shown in Figure 5 (middle part). As one can see the increase in the attachment rate caused by the electrostatic precipitator leads to an increase in the concentration of the decay products. The corresponding results for the unattached products are shown in Figure 5 (lower part). In these measurements a fine copper screen was used instead of membrane filter. The wire diameter of the screen was approximately 0.004 cm, the mesh number 120 per cm and the face velocity of air approximately 10 cm.s^{-1}. The purpose of this measurement was to demonstrate the variations in the concentration of the free radon daughters.

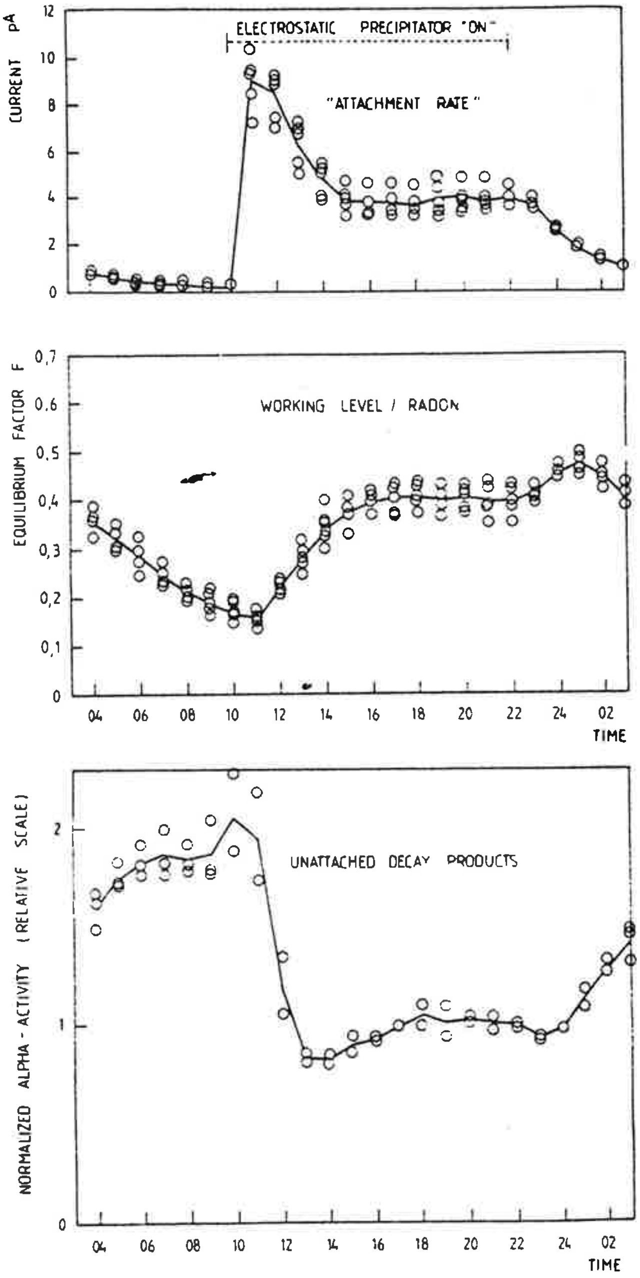

Figure 5. In the upper part the reading of an aerosol monitor is shown. In the middle part the equilibrium factor and below it the normalised concentration of unattached decay products is shown during the same period.

Therefore only the relative values of alpha decay frequency divided by the radon concentration are shown. The results indicate that the relative concentration of free decay products is remarkably lower during the use of the electrostatic precipitator.

CONCLUSIONS

The experiments carried out in a one-family house indicate that the equilibrium factor for radon daughters can vary over a relatively wide range depending on the ventilation system used. The low ventilation rates (without air recirculation) seem to lead not only to high radon concentrations but also to high equilibrium factors. The results also indicate that the concentration of radon daughters can be affected by the air recirculation through air cleaning devices. The effect of an electrostatic precipitator is somewhat different compared to the effect of a mechanical filter. This is probably due to the ultrafine particles generated by the corona discharge in the electrostatic precipitator.

ACKNOWLEDGEMENT

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