CLEANERS IN REDUCING THE HAZARDS OF INDOOR RADON DECAY PRODUCTS

N. Montassier, P.K. Hopke, Y. Shi and P. Wasiolek
Department of Chemistry, Clarkson University, Potsdam, N.Y., 13699-5810, USA

and B. McCallum
Atomic Energy of Canada, Ltd, Ottawa, Ontario, Canada

ABSTRACT

The objective of this study was to evaluate the influence of three types of air cleaner on the concentration and size distribution of radon progeny in a normally occupied house. Using an automated, semi-continuous, graded-screen array system and a radon monitor, the activity size distribution and radon concentration was measured and the exposure of the occupants of the home to radon could be assessed. The dose model developed as part of the recently released U.S. National Academy of Sciences report was used to relate the exposure to deposited dose in the tissue of the bronchial epithelium. Thus, the effectiveness of the air cleaners in reducing both exposure and dose were evaluated.

INTRODUCTION

A critical factor for the effectiveness of radon decay products in providing dose to the human respiratory tract is the size of the particle to which the decay product is attached. Air cleaners can effectively remove most particles and radon decay products from indoor air. The rmoval of the particles results in the increase of the "unattached" fraction, that can deposit more effectively its dose of radiation to the lung tissue. In fact, the increased dose per unit exposure means that the dose reduction will be lower than the reduction of the radioactive concentration. Thus, the exact dose impacts of air cleaners are uncertain, and studies are needed to measure the concentration and size distributions of the radon progeny activities in real living conditions where air cleaners are being employed.

HOUSE CHARACTERISTICS AND INSTRUMENTATIONS

Experimental data used in this study were collected in a one-story, ranch home in Arnprior, Ontario. This house has a basement with an approximate area of $200m^2$ while the first floor has an area of about $210m^2$. The house was occupied by three people none of whom smoke. Measurements were made from May to July 1991. No heating or air conditioning was used during this period. The sampler and air cleaner were placed at the dining room end of the kitchen/dining area ($23m^2$).

Three types of air cleaner were investigated, a ionization, filtration and air circulation system (NO-RAD), an Electronic Air Cleaner (EAC) with fan, and a multi-stage filter with fan (Pureflow).

Measurements of radon progeny size distributions were made using the Automatic Semi-Continuous Graded Screen Array (ASC-GSA) described in detail by Ramamurthi and Hopke (1991). The ASC-GSA system is a fully automatic device capable of measuring the activity-weighted size distribution of each individual short-lived radon decay product. It uses wire screens for particle segregation and alpha spectrometry for alpha particle detection. The measurements were made over a week long period with alternatively no air cleaner and air cleaner running (Table 1).

Exp.	Sampling period	Number of samples	Conditions

1	May 13-21	77	Background
2	May 21-28	50	NO-RAD on
3	May 28-June 3	54	Background
4	June 3-10	77	EAC on
5	June 10-17	69	Background
6	June 30-July 5	52	Pureflow on
7	July 5-6	11	Background

Table 1: Experiments conditions

Continuous measurements of radon gas were done using a passsive radon detector.

RESULT AND DISCUSSION

Mean values plus standard deviation of radon concentration, PAEC and equilibrium factor are presented in Table 2. As expected, radon concentration was not affected by the air cleaners and the values were almost the same for every experiment with a mean of 1.1pCi/l (41 Bqm^{-3}). However, we observed a reduction of PAEC and a significant decrease of the equilibrium factor when the air cleaners were running.

Exp.	Mean pCi/l	Radon std	Mean mWL	PAEC std	Equilibrium mean	factor std
1	1.2	0.5	5.8	2.0	0.50	0.13
2	0.8	0.5	2.2	1.1	0.31	0.14
3	0.7	0.4	2.6	2.0	0.41	0.22
4	1.1	0.6	2.1	1.6	0.18	0.12
5	1.7	1.2	7.5	6.2	0.43	0.19
6	1.1	0.7	1.6	1.1	0.15	0.08
7	1.1	0.4	5.0	2.1	0.45	0.13

Table 2: Measurements summary

From the equilibrium factor, one can observe that at fixed radon concentration, the NO-RAD reduced the mean PAEC by 38% while the EAC provided 56% and the Pureflow 65% of reduction.

Changes in size distributions (Fig.1) of the radon progeny as well as PAEC was also observed when the air cleaners were working. A peak in the size range of 1.5 to 5nm was induced when the NO-RAD was running. The EAC caused an increase in the activity fraction of the small particles with a distinct peak in the smallest particle size. Meanwhile, the activity fraction of particles greater than 15nm decreased. The Pureflow system did not seem to change the shape of the size distribution significantly. Those differences can be due to the way air cleaners remove particles. With its HEPA filter, the Pureflow system eliminate particles of all sizes with almost the same efficiency. This is not the case for the other devices whose removal mechanism can have a greater effect on the largest particles.

Knowing the PAEC concentration and its activity fraction, the annual average exposure E_p and the dose to the bronchial epithelium can be calculated (Table 3). An occupancy factor of 0.68 (ICRP, 1987) was used to estimate E_p. The dose per unit exposure, for a male adult at a mean breathing rate of 0.74 m^3h^{-1}, was calculated using the most recent dosimetric model (NRC, 1991 model modified by James et al., 1991). In the current model the dose to basal and secretory cells is evaluated taking account of the calculated deposition of activity as a function of particle size and breathing rate. As expected, the dose per unit exposure (D/E_p) was similar for the "backgrounds" (between 31 and 36 mGy/WLM). For the Pureflow the dose per unit exposure stayed at the same level; however this value increased to 44mGy/WLM for the NO-RAD and up to 48mGy/WLM for the EAC. This implies that the reduction of exposure by both the NO-RAD and the EAC was much higher than the dose reduction. In fact, comparing the experiments

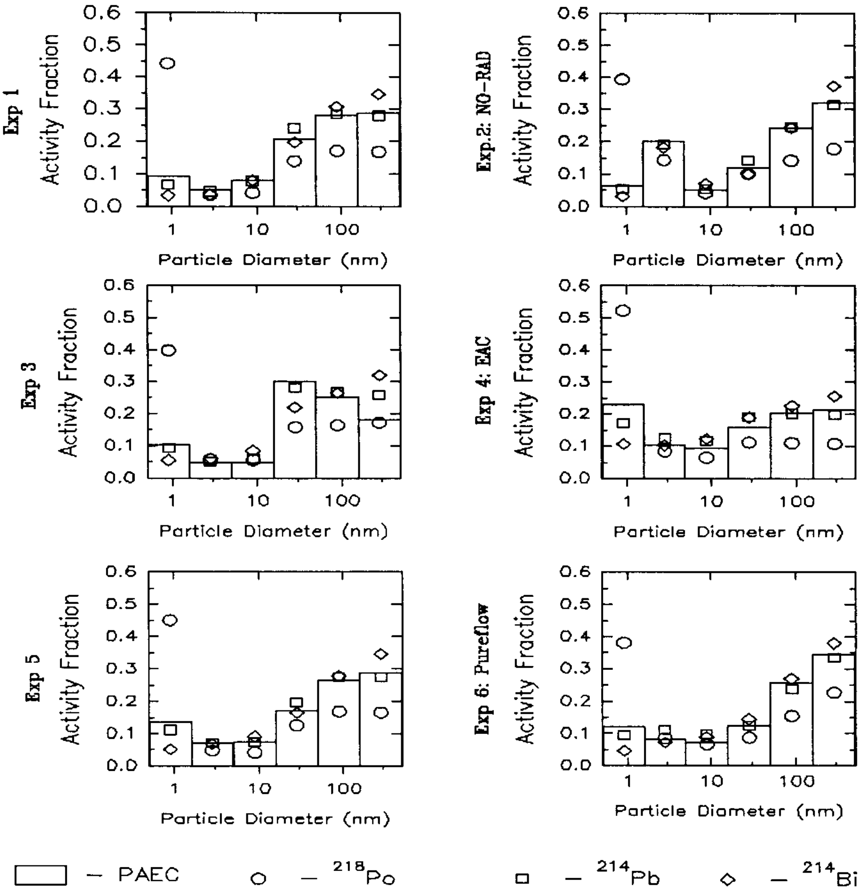

Figure 1: Size distributions

2, 3 and 4 when air cleaners were running with the experiments 1, 3 and 7 respectively, one finds that the exposure reduction per unit radon was 47% for the NO-RAD while the reduction of the doses per unit radon were 27%. The EAC diminished the exposure by 50% and the dose by 33%. A decrease of 67% was observed on both exposure and dose, for the Pureflow system.

Exp.	E_p WLM/y	E_p/Rn WLMl/ypCi	Secretory D/E_p mGy/WLM	Cells D/Rn	Basal D/E_p mGy/WLM	Cells D/Rn
1	0.20	0.17	33	5.6	16	2.6
2	0.08	0.09	44	4.1	20	1.9
3	0.09	0.14	34	4.6	16	2.2
4	0.07	0.07	48	3.1	22	1.5
5	0.26	0.15	36	5.6	17	2.6
6	0.06	0.05	35	1.8	16	0.9
7	0.17	0.16	31	4.9	15	2.3

Table 3: Dose exposure

SUMMARY

The effect of three types of air cleaner installed in a single family house in Arnprior, Ottawa, was investigated in a series of measurements. Each device decreased the concentration of the decay products and reduced the equilibrium factor as well as the exposure. On the other hand, air cleaners producing a shift of the size distribution towards smaller particles, where the dose rate per unit exposure are substantially larger, induce a much lower reduction on the dose. Thus, dose impact of air cleaners depends strongly on the way particles are removed.

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