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# REMOVAL OF RADON DAUGHTERS BY FILTRATION AND ELECTROSTATIC PLATEOUT

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## ABSTRACT

Since the health risk associated with being exposed to a radon containing atmosphere is primarily caused by the airborne decay products of radon, the so-called short lived radon daughters, it is in some situations more practical to remove the daughter products from the air, rather than to implement a radon suppressing or removing procedure.
In the paper the results of an investigation of a series of commercially available electrofilters and/or ionizing devices will be presented.
It is shown that it is practically possible in indoor locations to reduce the exposure from the airborne radon daughters measured as the potential alpha energy concentration (or equivalent equilibrium radon concentration) by a factor of 4 - 5 and the corresponding radiological dose by at least a factor of 2.

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## INTRODUCTION

The problems associated with radon and more specifically its short-lived airborne daughter products in the indoor air have over the last decade received a steady increasing attention, and many procedures have been suggested for reducing the related exposure of the public.
Although the hazard is primarily caused by inhalation of the daughter products rather than by the radon gas itself most mitigation efforts have been aimed at lowering the radon level either by reducing the radon entry or by diluting radon-rich indoor air with outdoor radon-free (or -poor) air.

Several of these methods require rather elaborate and/or expensive installations and may further have undesirable side effects, like introducing too cold (or warm) outdoor air or changing the humidity of the walls etc. (1).

Unfortunately there is no method by which radon in a practical way can be directly removed from the indoor air.
The radon daughters, however, being non-gaseous molecular clusters or particle-attached atoms can be collected by filtration, electro or mechanical, or be plated out by the action of an electric field and ionization system.
The effect of any radon daughter removing process can be expressed by the change in the individual daughter concentrations or by the change in the exposure rate or PAEC (potential alpha energy concentration) measured in $J/m^3$ or $Bq/m^3$ EER (equivalent equilibrium radon). In earlier days the unit WL (working level) was widely used.
Since, however, the exposure rate may also change because of changes in the radon concentration, it is more convenient to use the normalized PAEC, also called the equilibrium factor, $e_p$, which can be defined as the EER divided by the radon concentration.
The radiological impact of being exposed to a given atmosphere is only partly determined by the PAEC (and exposure time) but also by the likelihood of deposition of the inhaled activity at specific sites in the respiratory tract. Since the unattached radon daughters have much higher coefficients of diffusion than the particle-attached they have a greater tendency to deposit in the upper part of the respiratory tract where tumors are likely to develop. As a consequence, the dose corresponding to <u>a given exposure</u> will increase strongly with increasing unattached fraction of PAEC (2).

## FILTRATION

The effect of filtration on the daughter concentrations and on the PAEC (potential alpha energy concentration) is easily predicted, if it is assumed that the only effect is the direct removal of the daughter products when the air passes the filter.

For any likely radioactive composition of an atmosphere the theory predicts that filtration with a rate of, say, 3 $h^{-1}$ will lower the equilibrium factor to about 40 % of its value in unfiltered air (3).

In practice, however, the reduction is considerably larger. The reason for this is that the daughter products are not only removed from the air by radioactive decay (and filtration) but also by plateout on surfaces in the room. The rate of plateout depends strongly upon whether the daughter products are attached to aerosol particles or are unattached molecular clusters.
Since the filtration also removes aerosol particles a larger fraction of the daughter products will remain in the unattached state and the gross plateout rate will increase, thus making the (total) filtration process more effective as far as reduction of exposure is concerned.
Since the filtration may change the partitioning of the radon daughters between the attached and unattached state the reduction in dose will not follow the reduction in exposure but normally be considerably smaller.

IONIZATION AND ELECTRIC FIELDS.

It is well known that a part of the airborne radon daughters carry an electric charge. If therefore an electric field is established in a room with a radon atmosphere the charged radon daughters will move in the field and deposit on the field electrodes.
The easiest way to establish the field is to have one or more electrodes at the same voltage with respect to ground and let the walls, ceiling and floor of the room, which are all essentially at ground potential, act as the counter electrode.
Such a field, however, drops off rapidly in the immediate vicinity of the electrode(s) and therefore only acts effectively in a small volume.
If, on the other hand, the electrode is made to emit (unipolar) ions by a corona discharge, the ions will move away from the electrode, because of the field, and the space charge set up by the ions will modify the field from the electrode, and while the mean value is maintained over the whole room, the variation of the field strength with the distance from the electrode is changed in such a way that the field is higher near the boundaries of the room, whereby the total plateout is significantly increased (4).

While it is easy enough theoretically to predict the effect of a filtration system on the radon daughters, there is no simple way by which beforehand to estimate the corresponding effect of an ionization/electric field system.
Obviously, parameters like electrode voltage and shape, electrode/wall distance and corona current play an important role.

Experimental investigations (5,6,7), however, seem to indicate that the reductions in PAEC and dose by the use of ionization systems are comparable to those obtainable when using traditional filtration systems.
Both positive and negative ionization (positive and negative electrode voltage) will cause reductions in the daughter concentrations, but the effect of positive ionization is considerable greater than that of negative ionization.

In the following an overview will be given of the results of a series of investigations of both filtration and ionizing devices. The measurements were normally carried out in laboratory rooms but it has been attempted to make the experimental conditions as realistic and similar to living quarter conditions as possible.

## EXPERIMENTAL RESULTS

Most of the measurements were performed in a room with the volume 120 $m^3$. The radon concentration in the rooms could be varied in the range 50 - 6000 $Bq/m^3$ by the use of solid (RaCl) radon sources. The following quantities were measured: radon concentration, by grab sampling and counting in scintillation cells and/or recording on a radon monitor, individual radon daughter concentrations and unattached fractions, by alpha spectroscopy of membrane filters and wire screens, aerosol concentrations and AMD, by condensation nucleus counter and diffusion boxes, and, in some of the ionization measurements, corona current.
Between operation of the filters and/or ionization devices the natural, radioactive, untreated state of the air was determined regularly by 1-2 days measurements of the parameters mentioned above.

Below are given two examples of results of series of measurements.

Example 1.
June 27, 1988, room 001 (120 $m^3$), average of 7 set of measurements.
State of the air: no treatment.
Concentrations:
$^{222}Rn = 2905$, $^{218}Po = 2123$, $^{214}Pb = 1537$, $^{214}Bi = 1387$ $Bq/m^3$
unattached fractions 0.33 0.05 0.02
aerosol concentration about 30.000 $cm^{-3}$
From these figures the following quantities can be calculated:
total and unattached potential alpha energy concentration
PAEC = $8.6 \cdot 10^{-6}$ $J/m^3$ $PAEC_u = 0.7 \cdot 10^{-6}$ $J/m^3$
total dose 0.352 Gy/year, unattached dose = 0.209 Gy/year.

We see that while only about 8 % of the PAEC is in the unattached form, this fraction is responsible for about 60 % of the dose.

To make comparisons at different radon concentrations possible we

also calculate the relative and normalized parameters:
relative concentrations:
$^{222}Rn:^{218}Po:^{214}Pb:^{214}Bi = 1:0.73:0.53:0.48$
total and unattached equilibrium factor $e_p = 0.531$ $e_{pu} = 0.042$
normalized total dose $1.214 \cdot 10^{-4}$ (Gy/year)/(Bq/m$^3$)
normalized unattached dose $0.718 \cdot 10^{-4}$ "

Example 2
July 4, 1988, room 001, average of 11 set of measurements.
State of the air: Filtration with Filter A, high flow.
Concentrations
$^{222}Rn = 1989$, $^{218}Po = 1063$, $^{214}Pb = 331$, $^{214}Bi = 154$ Bq/m$^3$
unattached fractions 0.34 0.10 0.05
aerosol concentration about 50.000 cm$^{-3}$
total and unattached potential alpha energy concentration
PAEC = $1.9 \cdot 10^{-6}$ J/m$^3$ $PAEC_u = 0.3 \cdot 10^{-6}$ J/m$^3$
total dose 0.126 Gy/year, unattached dose 0.098 Gy/year
relative concentrations:
$^{222}Rn:^{218}Po:^{214}Pb:^{214}Bi = 1:0.53:0.17:0.08$
total and unattached equilibrium factor $e_p = 0.171$ $e_{pu} = 0.029$
normalized total dose $0.635 \cdot 10^{-4}$ (Gy/year)/(Bq/m$^3$)
normalized unattached dose $0.491 \cdot 10^{-4}$ "
When the filter is operated about 17 % of the remaining PAEC is in the unattached form contributing with about 77 % of the remaining dose.

Since the radon concentration had changed between the two series of measurements, it is not relevant to compare the absolute values of the PAEC or the doses.
We see, however, that the equilibrium factor by the operation of the filter is reduced from 0.531 to 0.171 and the normalized total dose from $1.214 \cdot 10^{-4}$ to $0.635 \cdot 10^{-4}$ (Gy/year)/(Bq/m$^3$), which means that independently of the radon concentration the filter will (in a room of this particular size) lower the exposure (PAEC) to about 32 % and the dose to about 52 % of the unfiltered value.

In Figure 1 are shown similar results for a series of electrofilters and in Figure 2 for various ionization devices and for combinations of ionizers and filters.

We see that all filters at high flow reduce the exposure to between 23 and 36 % and the dose to between 51 and 58 %. At the lower flow rates the effects on both exposure and dose are correspondingly smaller. All filters examined (A, B, C, and D) are relatively small units (from 0.05 to 0.150 m$^3$) with noise levels, which especially for the newer models like C and D, are very moderate.
In Figure 1 are also shown the results of measurements with a small ventilation system, mounted in a window. The system provides a balanced ventilation with radon-free outdoor air, which is passed through a mechanical filter and a heat-exchanger,

before it enters the room. At high flow, which is only about 100 $m^3/h$, the system reduces the exposure to 22 % and the dose to 18 % of the unventilated/unfiltered value.
The ionizers A and B are very small units (size like 3-4 cigarette packs). During the measurements they were mounted about 1 m below the ceiling.
It appears that these ionizers will reduce the exposure to about 50 % and the dose to about 50-60 %. The ionization/filtration unit is a commercial radon daughter removal unit, which simultaneously may (mechanically) filter and ionize the air and expose it to an electric field. When ionization alone or both ionization and filtration is applied the exposure is reduced to about 30 % and the dose to about 40 %.
The combination of filtration and ionization was also investigated with separate units. Filter B + Ionizer B will thus reduce the exposure to 14 % and the dose to 39 %, and Filter D + Ionizer A the exposure to 18 % and the dose to 46 %, while a combination of Filter B and four ionizing emitter needles at +25 kV (1 m below the ceiling) will reduce the exposure to 5 % and the dose to about 20 %.
Ionizers A and B were also tested in a smaller room with a volume of 40 $m^3$. The exposure was reduced to 24 % for both A and B and the doses to 50 and 54 % for A and B respectively. Ionizer A was further checked in combination with Filter D leading to a remaining exposure and dose of 9 and 33 %.

## GENERAL COMMENTS AND CONCLUSION

It appears from the measurements described above that it is possible, by the use of filtration or ionization devices of relatively small size, to reduce the exposure from radon daughters to, typically, about 20 - 40 % of the value in untreated air, and down to 10 - 20 % if a combination of the two methods is used. The reduction depends upon the filtration rate and ionization voltage, but it seems as if an increase of the filtration rate over 4 - 5 $h^{-1}$ and of the ionization voltage over 20 kV has very little effect.
The decrease in the radiological dose is, according to the dose model in most common use at the present, lower than the reduction in exposure, typically down to 50 - 60 % for one method and to 30 - 50 % when a combination of the methods were used.
The fact that the reduction in exposure and dose is different obviously makes a statement of the effect of an air treatment difficult.
It should, however, be kept in mind that while the determination of the exposure relies strictly on physical measurements, the determination of the dose is based on assumptions, which over the years have changed considerably, primarily in the weighting of the unattached daughters to the attached ones.
The measurements also demonstrate that diluting the indoor air with radon-free outdoor air can be a much more effective way of reducing exposure as well as dose.

In such situations, however, where the use of ventilation is unacceptable, and where only moderate reductions are needed, combinations of filtration and ionization seem to offer a practical possibility.

## ACKNOWLEDGMENT

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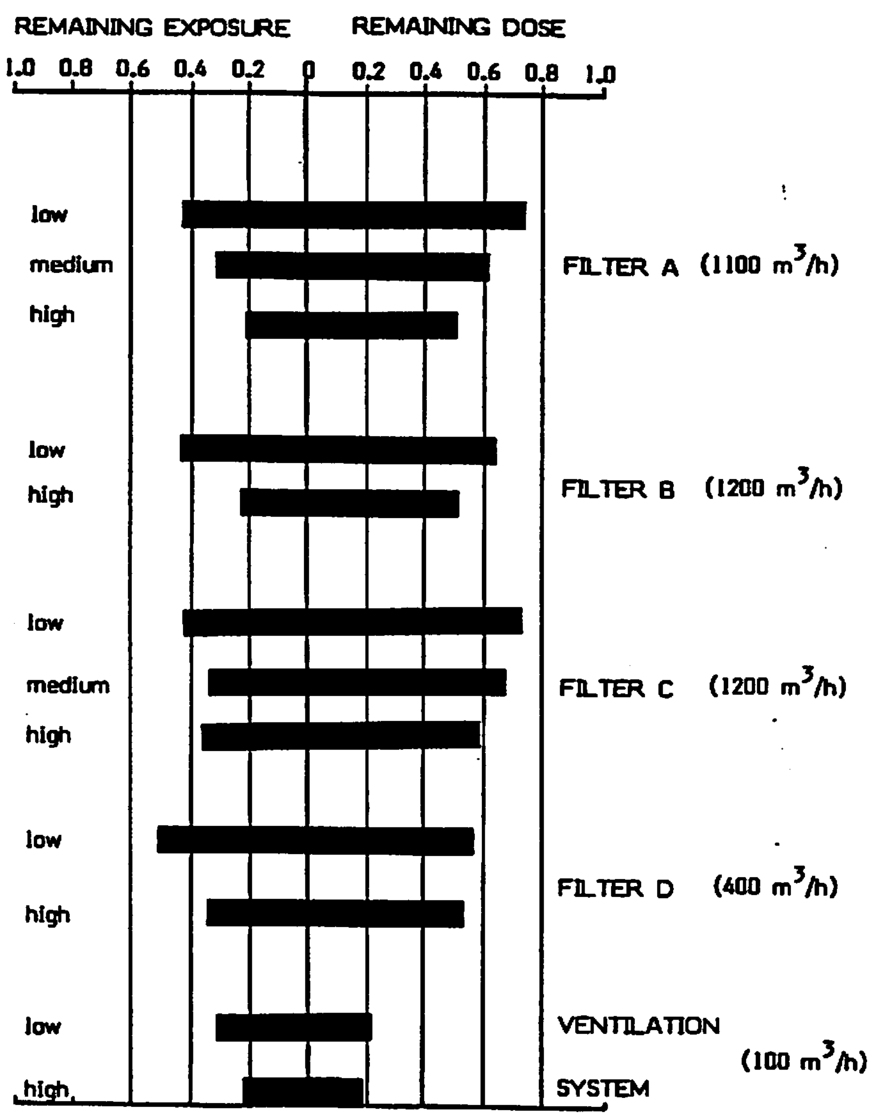


Figure 1. Effect of filtration on the exposure and dose from airborne radon daughters.

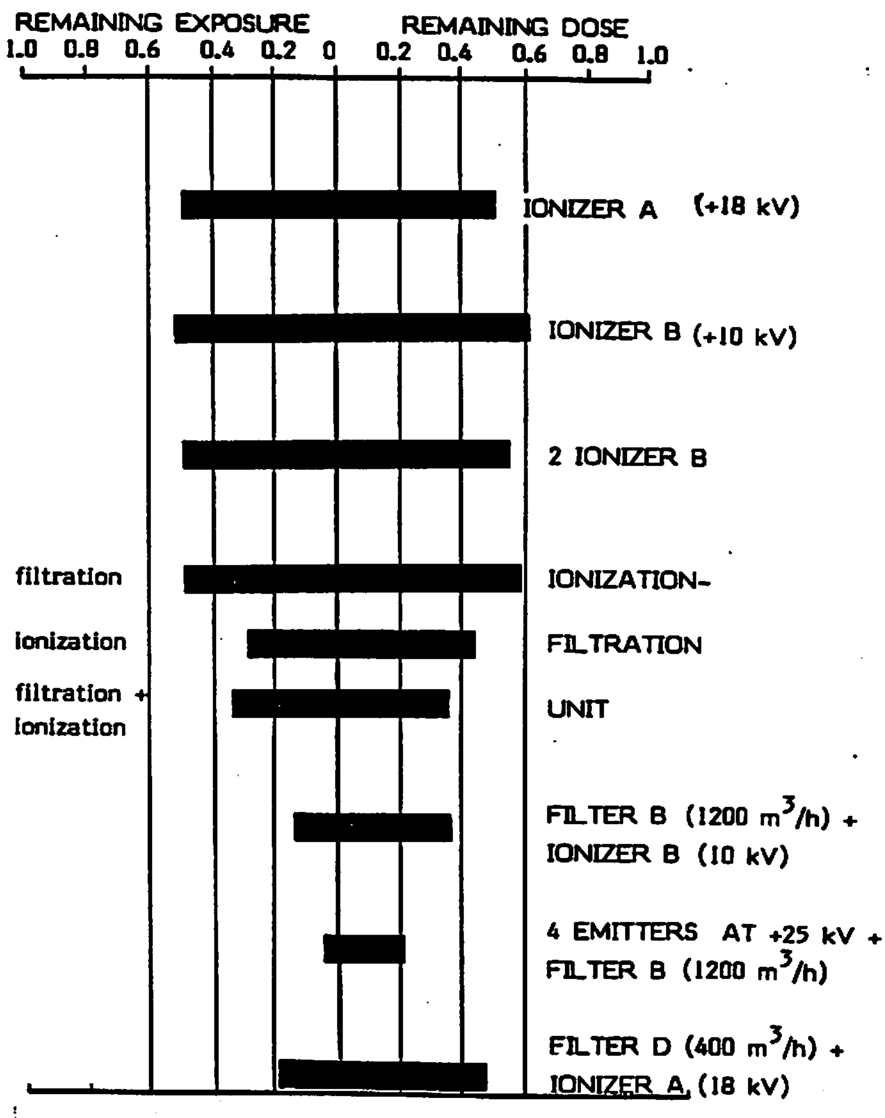


Figure 2. Effect of ionization and/or filtration on the exposure and dose from airborne radon daughters.