INDOOR RADON CONCENTRATIONS AND BUILDING MATERIALS
CONTROL OF AIRBORNE RADIOACTIVITY

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ABSTRACT

The contribution to the airborne radioactivity from the building materials can be predicted by measurements of exhalation rates of samples placed in closed containers. The effect of sample dimensions, porosity and dead space on the back diffusion is discussed, and it is shown that the back diffusion will usually not change the measured exhalation rates with more than 10-15%.

Efforts on reducing ventilation rates in order to save energy can lead to unacceptable high levels of radon and radon daughters in the indoor environment.

The major radon source for indoor air is often the soil, from which radon can diffuse through the base of the house. The possibility of reducing the diffusion rate by proper composition of the floor and base material is mentioned.

Finally the results of an investigation on reducing the radon daughter concentrations by circulation and filtration are reported. It is shown that a passage of the air through an ordinary filter with a rate of 1-2 h^{-1} may reduce the radon daughter level with a factor of 5-10.

KEYWORDS

Radon; building materials and radon; radon daughters; control of airborne radioactivity.

INTRODUCTION

About sixty years ago it was established that ionizing radiation originating from uranium ore was a major cause of the high incidence of lung cancer among workers in underground mines. In 1924 it was shown that the radiation was associated with the inert gas radon, which is the first daughter product of radium, but it lasted almost another 30 years before it was demonstrated (Harley, 1952), that the airborne short-lived daughter products of radon rather than the mother product were the real source of the major part of the radiation dose.

This figure, however, will be lower than the free exhalation rate E corresponding to exhalation into an empty space, or into an ordinary room.
The difference is caused by the so-called back diffusion, which will slow down the exhalation rate from the material as the activity (concentration) in the container grows.
The magnitude of the difference depends upon a) the dimensions of the sample relative to the diffusion length of the material, and b) the ratio between the dead volume of the container and the void volume of the sample, i.e. the product of the porosity and the sample volume. If the dead space is chosen as approximately twice the sample volume, then for most building materials with porosities below 0.5 the exhalation value determined from eq. (2) will not differ from the free exhalation value by more than 10-15% at the most.
In the first column of Table 1 are shown the results of measurements of exhalation rates from a series of commonly used building materials

TABLE 1 Exhalation rates and contributions to radon concentrations for various building materials

Material	Exhalation rate $\frac{atoms}{m^2 s}$	Exhalation rate $\frac{pCi}{m^2 s}$	Radon concentration R_0 $\frac{pCi}{\ell}$	Radon concentration $R_{0.5}$ $\frac{pCi}{\ell}$
chipboard fiberboard gypsum board (nat. gypsum)	<1	$<5 \cdot 10^{-5}$	$<5 \cdot 10^{-2}$	$<8 \cdot 10^{-4}$
rockwool bricks	2	$1.1 \cdot 10^{-4}$	$1 \cdot 10^{-1}$	$1.6 \cdot 10^{-3}$
light weight concretes (dan. origin)	20-30	$1.1\text{-}1.7 \cdot 10^{-3}$	1-1.5	$1.6\text{-}2.4 \cdot 10^{-2}$
ordinary concretes (danish dep.)	130-180	$7\text{-}10 \cdot 10^{-3}$	7-10	$1.1\text{-}1.5 \cdot 10^{-1}$
gypsum tiles (chemogyps.)	800	$4.5 \cdot 10^{-2}$	43	$6.4 \cdot 10^{-1}$
alum shale light weight concrete	1400-4000	$8\text{-}22 \cdot 10^{-2}$	76-200	1.1-3.2

If a material with the exhalation rate E is being used in a room the contribution to the radon concentration from the material is given by

$$R_n = \frac{\lambda}{\lambda + n} \cdot \frac{S}{V} \cdot E \qquad (3)$$

where S is the exhaling area, V the volume of the room, n the ventilation rate and λ the decay constant of radon.
If all surfaces of a room are covered with the exhaling material, then $\frac{S}{V} \sim 2\ m^{-1}$.
The corresponding radon concentrations R_o for an unventilated room and $R_{0.5}$ for a room with a ventilation rate of 0.5 h^{-1} are shown in the second column in the Table.

Radon itself is known to be adsorbed by the surface of materials like active charcoal, but the adsorption efficiency is rather low at room temperature.
In order to produce a significant drop in the radon level by passing the air through uncooled charcoal filters, it is therefore necessary to use very bulky and impractical filter arrangements. It is, however, possible that even a moderate lowering of the filter temperature may increase the adsorption efficiency to practical levels. This possibility has, to the knowledge of the author, not yet been investigated.
The daughter products of radon on the other hand have a high probability of being retained by filters or adhering to surfaces by contact. In order to investigate the possibilities of removing the radon daughters by a mechanical treatment of the air a series of experiments were performed at the Technical University of Denmark. The room used for the measurements is a basement room with walls, floor and ceiling made of concrete. The average exhalation rate of radon is 380 atoms/$m^2 \cdot s$, the volume of the room is 324 m^3 and the surface area is 360 m^2 (McLaughlin and Jonassen, 1978). The natural air exchange rate of the room is about 0.2 per day (corresponding to radon free air). The long term average radon activity is about 5-10 pCi/ℓ.
Simultaneous measurements of the activity of radon and its daughter products were done in the period Sep.-Nov. 1979. Atmospheric pressure, temperature, relative humidity and condensation nucleus concentration were also determined (Jonassen, 1980).
Measurements were taken in different states or during different treatments of the air: 1) undisturbed or static air, 2) air passing through a fan system with no direct filtration at a flow rate of 1200 m^3/h (or an exchange rate for the room of $\sim 10 \cdot 10^{-4} s^{-1}$) and 3) air filtered at 400 m^3/h ($\sim 3 \cdot 10^{-4} s^{-1}$) and 1200 m^3/h ($\sim 10 \cdot 10^{-4} s^{-1}$).

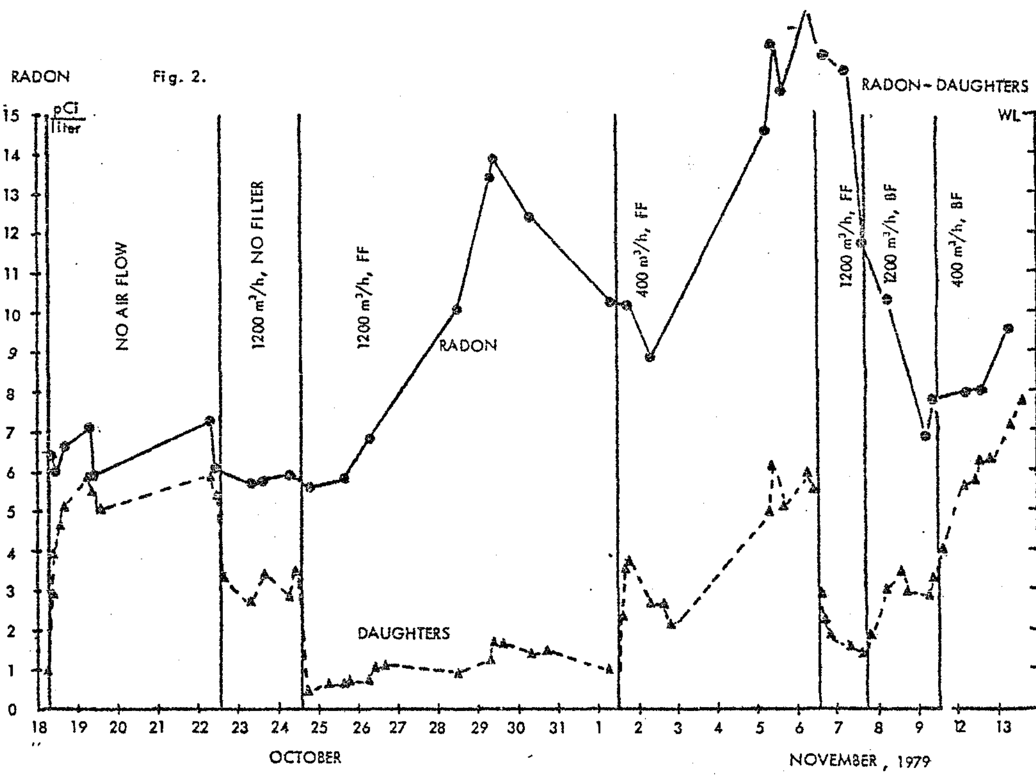

Fig. 1. Radon concentration and working level for various treatment of the air.

rather close to the filtration rate, while the removal rate of RaA is many times higher. This is undoubtedly due to an increase in the unattached fraction of RaA caused by the large decrease in the nucleus concentration. The results reported here are to be considered as preliminary. On one hand it appears that a circulation or filtration with a moderate rate may cause a significant decrease in the working level in a room. On the other hand a filtration will increase the unatteched fraction of the radon daughters, and thus changing the radiational impact of the inhaled air on the respiratory tract.

In the investigation reported above no attempts were made to measure the unattached fraction of the radon daughters. Such measurements are, however, necessary in order to give a complete characterization of the radiological properties of the air and will be part of the future work on control of airborne radioactivity.

REFERENCES

Cliff, K.D. (1978), Assessment of airborne radon daughter concentrations in dwellings in Great Britain, Phys. Med. Biol.,(23), 4, 696.

Culot, M.V.J., H.G. Olson, and K.J. Schiager (1978), Field applications of a radon barrier to reduce airborne radon progeny, Health Phys., 34, no 5, 499.

Harley, J.H. (1952), A study of airborne daughter products of radon and thoron, Ph. D. Thesis, New York, Rensselaar Polytechnical Institute.

Jonassen, N. (1975), On the effect of pressure variations on the radon 222 concentration in unventilated rooms, Health Phys. 29, 216.

Jonassen, N. (1980), Removal of radon daughters from indoor air by mechanical methods, Nat. Rad. in our Envir., Nord. Soc. Rad. Prot., Geilo, Norway, Jan 1980.

Jonassen, N., and J.P. McLaughlin (1978), Exhalation of radon 222 from building materials and walls, Proceedings Nat. Rad. Envir. III, Houston, Tx.

McLaughlin, J.P., and N. Jonassen (1978), The effect of pressure drops on radon exhalation from walls, Proceedings Nat. Rad. Envir. III, Houston, Tx.

Swedjemark, G.A. (1977), The ionizing radiation in dwellings related to the building materials, Nat. Inst. Rad. Prot., Stockholm, SSI: 1977-004.