HAZARDS OF RADON DAUGHTERS TO THE GENERAL PUBLIC

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Recent data from various countries in northern latitudes suggest that the most important source of public exposures to ionizing radiation may well be the inhalation of radon daughters which accumulate inside buildings; these exposures result in appreciable radiation doses to the bronchial epithelium and smaller doses to the pulmonary region of the lung, with little increment in radiation dose to other organs of the body (1).

The incidence of lung cancer resulting from inhalation of radon daughters by the general public is not known. Considerations based on vital statistics suggest that appropriate risk estimates for the general public probably lie in the range 0 to 200 fatal lung cancer per million working level months (WLM) (2,3). Risk estimates can be derived from analyses of data on excess lung cancer incidence observed in uranium miners who were in the past exposed to high concentrations of radon daughters. These data can be fitted by linear dose-response models, by "quasi-threshold" models involving, for example, a probit response on log dose (3) or by curvilinear relationships which exhibit a decreasing response per unit dose with increasing dose (4). The available data are not precise enough to distinguish between linear and "quasi- threshold" models as representing the most probable fit, but do indicate that the curvilinear relationship (4) is statistically much less probable than either of the first two models (3).

Assuming a linear dose-response relationship, and assuming that most of the fatal lung cancers induced in uranium miners occur between 10 and 25 years after the initial exposure to radon daughters (5), the available data from the U.S.A. and Czechoslovakia indicate about 100 fatal lung cancers per million·WLM in uranium miners, with a range from 50 to 200 in these estimates (3). The more limited data available from other countries including Canada (6) are not incompatible with this estimate.

If this risk estimate is directly applicable to the general public, and assuming that average public exposures due to accumulation of radon daughters in buildings are in the region of 0.08-0.16 WLM per year (1,7), then inhalation of radon daughters by the general public would be responsible for 8-16 lung cancers per million persons per year. This is equivalent to 3-6% of all lung cancers or about 0.8% of all fatal cancers in Canada in recent years. Other published risk estimates (1,4,7) would yield percentages which are considerably higher. However, even the lower numbers suggested above indicate that the public health hazards due to radon daughters are greater than those due to 0.1 rem whole body radiation per year either from natural background radiation (approximately 0.3-0.5% of all fatal cancers, based on the absolute risk model) or from medical diagnostic procedures. This conclusion remains the same whether absolute or relative risk models should prove to be most appropriate. All of the percentages are increased 2-3 fold when the relative risk model is used (7,8), even though the loss of life expectancy is essentially the same with the absolute or relative risk models (7,9).

The concentrations of radon daughters in open air, inside buildings and in air entrapped in soil are usually in the region of 0.0006, 0.003-0.005 and 0.3-10 WL respectively (1,7,10). The primary sources of radon and thus of radon daughters inside buildings are the building materials themselves and radon which enters the building from the soil through various openings in the building foundations; dissolved radon in water from wells may also form an appreciable source in some cases. The concentration of radon daughters inside buildings is strongly influenced by the ventilation rate (2). The possible health hazards of decreased ventilation in buildings and the cost of heating the air required to provide extra ventilation during winter months in a cold climate have been calculated on the basis of the following assumptions: (a) An average of 100 cubic metres of enclosed building space per person. (b) Approximately 5,000°C-days of heating required, primarily over six months of the year, as is true for the Ottawa region in Canada. (c) Approximately $120 (U.S.) per person required at current 1979 prices to heat 100 cubic metre of air at a ventilation rate of one change of air per hour over 5,000°C-days. (d) An average exposure of 0.14 WLM per year at one change of air per hour (2), assuming that 80% of a person's time is spent inside the building. (e) An increase in radon daughter concentrations at decreased ventilation rates in proportion to the values calculated by Cliff (2). (f) A risk of 100 fatal lung cancers per million WLM. The results of this calculation are shown in Table 1.

Current ventilation rates in Canadian homes during winter months are estimated to be about 0.3 to 0.5 air changes per hour (11,12). The cost of heating air to provide extra ventilation during the winter months is in the region of one to ten million dollars (U.S.) per fatal lung cancer avoided (Table 1) based on the assumptions listed above. Factors that would affect this result are:

a) If a heat exchange unit were installed between the outgoing warm air and incoming cold air in a forced ventilation system, costs of heating this air could be reduced by 30 to 40 percent. Offsetting this saving would be the cost of the heat exchange unit.
b) The actual radon daughter concentration in a house with a "forced air" central heating system, common to many Canadian homes, could be much less than taken from Cliff (2) for the same radon output. The rapid mixing of air in such a forced air system would result in increased plate-out of radon daughters onto the walls of the heating ducts and the coarse filters in the system. Wrenn *et al.* (13) have shown that this effect can reduce the concentrations in air by up to a factor of 10 under appropriate conditions.
c) The assumption that a linear exposure response relationship will extend from the high exposures accumulated by miners down to the exposure and exposure rate applicable in most buildings may overestimate the actual risks. There is some evidence to suggest that very low concentrations of alpha-emitters may not produce cancers within the normal life-span (14).

TABLE 1. Estimated benefits and costs of increased ventilation in buildings

(i) Increase in ventilation rate (changes of air per hour).	(ii) Decrease in exposure to radon daughters (WLM) for the six month heating period	(iii) Fatal lung cancers avoided (per million persons).	(iv) Cost of heating air to provide increased ventilation (millions of dollars per million persons).	(iv/iii) Cost/benefit (millions of dollars per lung cancer avoided).
from 0.1 to 0.2	from 0.94 to 0.46	48	12	0.25
from 0.2 to 0.5	from 0.46 to 0.16	30	36	1.2
from 0.5 to 1.0	from 0.16 to 0.07	9	60	6.7
from 1.0 to 2.0	from 0.07 to 0.032	4	120	30.

d) Risk estimates derived from studies of uranium miners may not be valid for the general population due to differences in smoking habits, age distribution, and exposure to dust and other factors.

This paper has attempted to quantify the cost-benefit relationship for decreasing radon daughter exposures in Canadian homes by increasing ventilation rates. It has identified the main components in this relationship and pointed out the uncertainties associated with some of them. The uncertainties in the calculated values appear to be related primarily to the most appropriate risk estimates for inhalation of radon daughters and to actual radon daughter concentrations inside buildings at various ventilation rates.

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