HEALTH RISKS OF INDOOR RADON GAS

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A WHO Regional Office for Europe organized Working Group discussed radon at a meeting in Dubrovnik, Yugoslavia, in August 1985. In the light of the anticipated and observed health problems caused by radon, the Group was asked to review and evaluate the risks involved, and to recommend appropriate guidelines.

Much of the natural background radiation to which the general public is exposed comes from the decay of radium-226 which produces radon gas and other products. Because radium is a trace element in most rock and soil, indoor concentrations of radon can come from a wide variety of substances, such as building materials and the soil under building foundations. Tap water taken from wells or underground springs may be an additional source. Tests indicate that indoor concentrations of radon and its decay products are often higher than those outside. High indoor concentrations of radon are of concern due to the potential carcinogenicity of its decay products. (The US EPA has estimated that current exposure to radon gas could account for as much as 10% of all lung cancer deaths in the USA.)

OBSERVED LEVELS OF RADON AND RADON DAUGHTERS IN INDOOR AIR

The radon daughter concentration in indoor air is a function of the rate of entry into the building from the various sources, the effective ventilation rate removing radon from the building and the rate at which radon daughters settle or plate onto surfaces. A sizable number of buildings have been monitored, and the reports show that the range of mean concentrations is 10-50 Bq/m^3. However, in a number of countries some dwellings exceed even 400 Bq/m^3 equilibrium equivalent radon (EER) concentrations. It is also clear that a small fraction of dwellings in each country has concentrations exceeding 10 times the national average of that country. In general, the average level of radon daughters in buildings can be expected to be higher in a region with high terrestrial gamma flux as has been found for Finland [1], and as has also been found for Cornwall as compared to the whole of the United Kingdom [2].

EXPOSURE AND EFFECTS

The critical organ for exposure to radon daughters is the lung. The uptake of radon gas by all other routes is minor. Therefore, the air route is of the major concern. Upon being inhaled, the radon daughters will be carried into the bronchial region of the lungs and a substantial fraction will be deposited and remain there. The radioactive half-life of the radon daughters is of the order of 30 min, so that once deposited the alpha emissions will impact on the immediate region [3] and deliver a very densely concentrated ionization in that tissue. The amount of radon daughter intake depends on the breathing rate which affects both the total quantity inhaled per unit time and the pattern of deposition in the respiratory tract. The volume of air inhaled at rest is about 0.5 m^3/h; during physical activity this volume can reach 1.5 m^3/h or higher. The fraction of attached radon daughters inhaled which are deposited depends on the size of the particles and the breathing patterns but has been estimated as 30%.

A minimum and irreducible exposure to radon daughters of about 1.5 Bq/m^3 EER occurs outdoors. But most people spend 80-90% a day in residential and nonradiation-connected occupational environments, which constitute their major source of radon exposure. The concentrations of radon daughters in these environments are 10 to $10^4 Bq/m^3$ EER, and sometimes even higher.

UNSCEAR estimated a mean indoor concentration of 15 Bq/m^3 EER as an average for the total population of the world's temperate regions [4]. Hence, a mean dose equivalent of about 15 mSv/a to the bronchial and 2 mSv/a to the pulmonary region from indoor exposure to radon daughters should be expected, corresponding to an effective dose equivalent of 1 mSv/a. The indoor exposure at home accounts for 70-80 % of this dose. In population groups living in houses with strongly enhanced radon levels, considerably higher dose levels to the target tissues in the lung will occur.

Underground mine workers, and especially uranium mine workers, are exposed to substantial concentrations of radon daughters, equivalent to 5-days-a-week and 8-hours-a-day exposures of 1500 Bq/m^3 EER. For residential and non-occupational indoor exposures, this would correspond to about 430 Bq/m^3 for an exposure factor of 80% indoor occupancy. The increased lung cancer risk among miners, and especially uranium miners, has been well documented in several large epidemiological studies. Results from the follow-up of more than 25 000 radon-exposed miners have been summarized and reviewed [4,5,6,7]. The results are consistent with the conclusion that at least for the lower dose range, the relationship between cumulative exposure to radon daughters and excess frequency of lung cancer is linear. This conclusion is also supported by the results of animal exposure studies and human studies on the effects of densely ionizing radiation. Assuming an 80% occupancy of indoor environments, an annual incidence of 10-40 cases per million persons should be expected that is attributable to exposure to radon daughters. The model of relative risk leads to the conclusion that under these conditions, about 5-15 % of the observed frequency of lung cancer or of the lifetime risk may be attributable to radon daughters in the indoor environment. This relative risk is nearly equal for males and females, and for smokers and nonsmokers. The combined effect of exposure to radon daughters and tobacco smoke can thus approximately be described as multiplicative, and people exposed to radon daughters can especially reduce their risk of lung cancer by avoiding tobacco smoking.

CONCLUSIONS

1. Radon daughter concentrations in indoor environments are

considerably higher than outdoor concentrations which are of the order of 2-5 Bq/m^3 EER. Mean population averaged concentrations in houses have been found to range to 50 Bq/m^3 EER.

2. In any region, the range of indoor radon daughter concentrations is substantial, with an approximately log-normal distribution; a small number of buildings have values of 10 times the median concentrations or more.

3. The estimated risk of lung cancer attributable to inhaled radon daughter concentrations indoors is a significant fraction of the total lung cancer risk. It is estimated that at the observed mean levels indoors, about 10% of all lung cancer cases might be caused by radon daughters. Corresponding higher risk values should be expected in members of the public who are chronically exposed to higher indoor levels. At the high end of the concentration distribution, the risk is of the order of that caused by cigarette smoking.

4. Although radon daughter concentrations cannot be reduced to zero, it is possible to reduce them, especially the higher concentrations. In most existing buildings, the radon concentration can be reduced by a variety of measures. In new construction, this can be done even more effectively.

5. Reducing exposure to radon daughters is an effective approach to reduce lung cancer risks.

RECOMMENDATIONS

1. In general, buildings with radon daughter concentrations of more than 100 Bq/m^3 EER as an annual average should be considered for remedial actions to lower such concentrations, if simple measures are possible.

2. Remedial actions in buildings with a radon daughter concentration higher than 400 Bq/m^3 EER as an annual average should be considered without long delays (the total dose before remedial action should not be allowed to exceed 2000 $Bq.a/m^3$ EER).

3. Building codes should have sections designed to avoid levels exceeding 100 Bq/m^3 EER in new buildings and should prescribe appropriate practices.

4. All appropriate authorities should consider representative surveys of radon daughter concentrations in their building stock to identify areas that may have excessive levels.

5. Appropriate epidemiological studies should be conducted in regions of high and varied radon daughter concentrations, where cancer case registries can be used to estimate the relative and absolute risks of lung cancer related to different exposures. Specifically, countries in those regions, such as northern Europe, can separately or jointly perform case-control studies, with appropriate controls for age, sex, occupational exposure, site of exposure and tobacco smoking.

6. Appropriate animal and epidemiological studies are still required and should be conducted to develop exposure-response relationships.

7. Further studies should be conducted to investigate the dependence of indoor radon daughter concentrations on sources, ventilation rates and other factors to improve the basis for criteria to identify areas or houses with excessive concentrations and for measures to limit such concentrations.

8. Comparison and intercalibration exercises between organizations involved in the measurement of radon and its daughters should be organized at regular intervals.

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