

Radiation Exposures and Risks due to Airtightening of Homes in an Alpine Area with High Radon Emanation

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INTRODUCTION

Radon and its short-lived decay products in the indoor environment are the most important single source of exposure to ionizing radiation in Switzerland. Modifications in the construction of dwellings implemented to reduce energy consumption may change indoor pollutant levels and cause substantial long term hazards to the general public (1). The following estimate of additional exposure of humans to the ionizing radiation from radon and its short-lived progeny in the indoor air of energy efficient dwellings, i.e. homes showing low air exchange rates, is based on radon measurements in Swiss alpine regions with high terrestrial radiation. Differences in the indoor radon levels between new or retrofitted dwellings are derived from a matched pair study of single family homes in Switzerland (2).

Risk factors for lung cancer induction from radon exposure have to rely mostly on occupational exposures in mines. However, the integral dose over the human life span from radon and its progeny in the indoor air in high background areas may approach or even exceed the values of miner populations showing significant increases in the incidence of malignant lung diseases. Although confounding factors such as poor control of smoking habits and additional chemical toxicants in mine air do not permit a direct comparison of environmental and occupational exposure risks, both radiobiological considerations and the results from human epidemiology point to a linear dose-effect relationship. This is in clear contrast to the case of formaldehyde, where no human data exist and where nasal carcinomas in rats follow a non-linear dose-effect relationship.

EXPERIMENTAL METHODS

Radon was measured with passive track etch dosimeters. In most cases three detectors per dwelling were used: one each in the cellar for source strength, living room (generally on the ground floor) and a bedroom (mostly on the first floor), respectively.

Table 1: Mean values and upper 10 percentiles for indoor radon concentrations and resulting annual effective dose equivalents for a sample of 32 dwellings in Southeastern Graubünden.

	geometric mean	upper 10 percentile
RADON CONCENTRATIONS in Bq/m ³ (pCi/l)		
cellar	770 (20.7)	3'560
ground floor	260 (6.9)	830
first floor	180 (4.8)	470
ANNUAL DOSE in mSv (mrem)		
living room (a)	7.5 (750)	24
bedroom (b)	5.2 (520)	14
living area (a + b)/2	6.4 (640)	19

RESULTS

a) Radon Concentrations in a Region of South-eastern Switzerland

The dwellings were situated in the area around Sankt Moritz where crystalline basement rock with relatively high uranium and thorium content reaches the surface. Figure 1 shows the radon concentrations (cellar, ground floor and first floor) in 32 single family homes in this area on a log/probability graph. The marked decrease from cellar to first floor indicates the importance of soil gas radon as compared to emanation from building materials. The geometric mean of the radon concentrations in the living quarters i.e. living room and bedroom amounts to 255 Bq/m³ (6.9 pCi/l) and 176 Bq/m³ (4.8 pCi/l), respectively. This is about 4 times higher than in the average Swiss home. Table 1 shows the numerical values of concentrations and annual effective dose equivalents for the means as well as for the upper 10 percentiles. The dose commitments are calculated using UNSCEAR82 conversion factors and a radon daughter equilibrium factor of 0.5 (3).

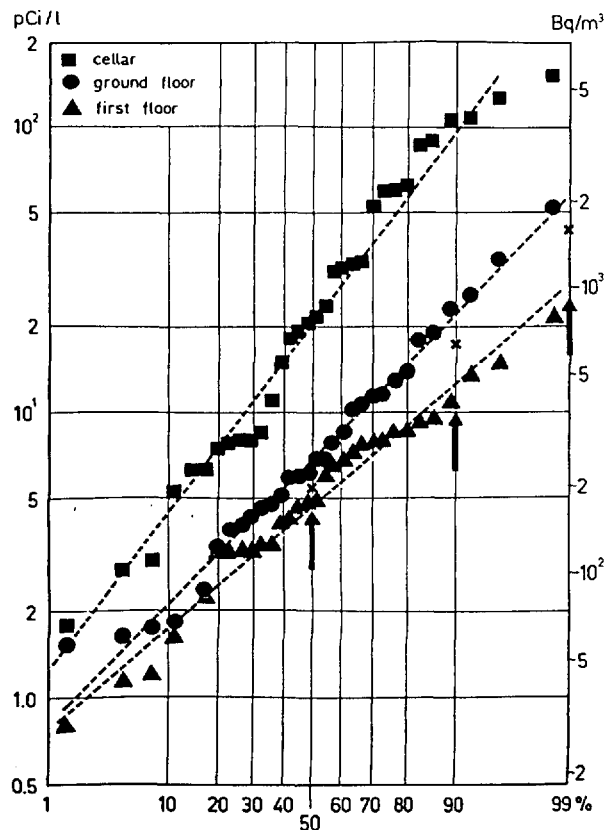


Figure 1: Distribution of the time averaged indoor radon concentrations during the winter of 1982/83 in a sample of 32 single family houses situated in three alpine valleys of Southeastern Graubünden.

b) Implications of Climate, Weatherstripping and New Building Technologies on the Radon Source Term

With the rare exception of direct radon emanation from walls in the living area, the radon source term, i.e. the amount of radon entering the indoor environment, is dependent on many and, in some cases, poorly understood parameters. Radon rich soil gas being the main source, radium concentration and permeability of the building grounds as well as cracks and conduits in the cellar floor and walls are recognized as important factors. In addition, the source strength may fluctuate considerably due to partially season dependent parameters such as water content of the subsoil, temperature differences indoor/outdoor (stack effect), wind speed and barometric pressure changes. The reduction of the air exchange rate and the tendency to use part of the cellar and the compulsory bomb shelter for indoor activities are bound to have a decisive influence on the amount of radon entering the living area.

c) Assessment of Additional Exposure due to Weatherstripping

For existing building stock, airtightening is the most cost-effective measure to achieve energy savings at unchanged temperature settings. This can be achieved by means of caulking and weatherstripping to seal off airways along windows, doors and blinds. Although air exchange rates in occupied buildings are difficult to assess due to their dependence on a multitude of climatic and behavioural parameters, it is generally accepted that the introduction of central heating systems led to a strong reduction of air exchange rates over the last decades. If a constant source term for indoor radon is assumed, the indoor radon concentration will be inversely proportional to the air exchange rate. Therefore, weatherstripping may increase the risk from radon and its daughters considerably. The calculation of the additional exposures due to an increase in radon levels resulting from airtightening is depicted in table 2 for the alpine sample previously described. The difference in radon concentration between new or retrofitted energy-efficient buildings and conventional homes is based on a matched pair analysis in the same area (2). In this study, an increase by a factor of 1.5 of the radon levels in the airtight homes was found.

Table 2: Parameters assumed for the calculation of radon exposure due to airtightening.

	conventional	house airtight
Rn indoor conc. Bq/m ³	307	461
equilibrium factor		0.5
time spent indoors		80 %
Annual dose, He mSv/a	9.05	13.58
ADDITIONAL DOSE mSv/a (mrem/a)		4.53 (453)

d) Risk assessment

To assess the lung cancer risk from exposure to environmental levels of radon, several assumptions have to be made. Using UNSCEAR82 (3) conversion factors which are corrected for lower breathing rates and volumes in the indoor environment as compared to mining, the total exposures over a life time in single family dwellings in parts of the Alps approach or even exceed the exposures of groups of miners showing statistically significant increases in the lung cancer incidence. Figure 2 depicts exposure and annual lung cancer risk due to radon exposure for the many groups of miners studied. The arrow shows the 30 year exposure at an average indoor radon gas concentration of 370 Bq/m³ (10 pCi/l).

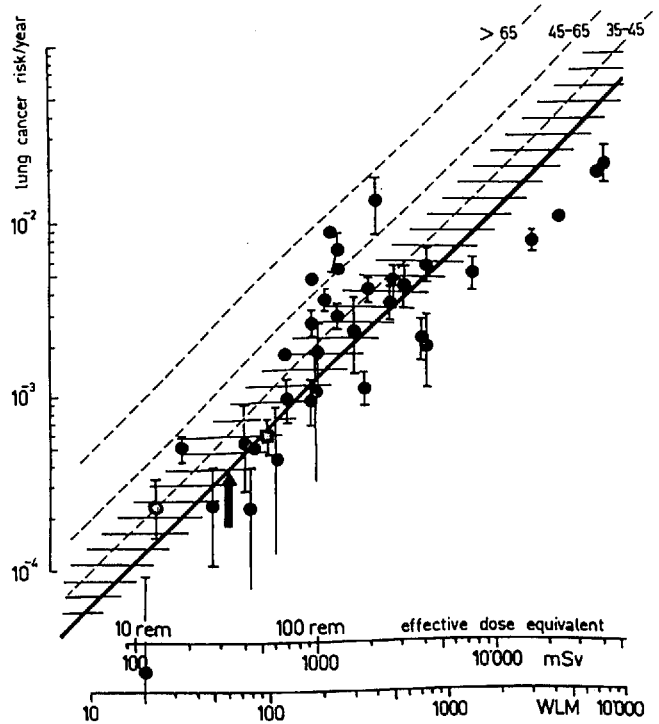


Figure 2: Human epidemiological data on radon induced lung cancer. Each point denotes a population of miners. Risk factors from A-bomb survivors (○) and from Ankylosing spondylitis patients (◐) are similar. Details and sources in (1).

DISCUSSION

In Switzerland, many inhabited areas in the crystalline Alps show high radon emanation into buildings from crystalline subsoil. In few cases, the lowering of the air exchange rates for the purpose of energy conservation and new building technologies may lead to annual effective dose equivalents in the range of the limits for occupational exposure or even surpass them. The concomitant risk for lung cancer from a lifetime exposure is estimated for the energy efficient home in table 2 as follows: a fifty year exposure at 16 mSv/a with a lung cancer risk factor of 2.4E-5 per mSv (total risk over 20 year expression period) yields a 2% chance of dying from lung cancer in a high risk area. However, in cases where weatherstripping will also influence the radon source strength, the above assessment may under- or overestimate the risk from energy conservation. Even in geological problem areas of Switzerland, the lung cancer risk to the population from indoor radon is a fraction of the risk from smoking. Therefore, an epidemiological approach to quantify effects from exposure to indoor radon will be difficult.

REFERENCES

- Burkart, W. and Chakraborty, S.: Possible Health Effects of Energy Conservation: Impairment of Indoor Air Quality due to Reduction of Ventilation Rate. *Env. International* 10, 455-461, 1984
- Burkart, W., Wernli, C., and Brunner, H.H.: Matched pair analysis of the influence of weatherstripping on radon concentration in Swiss dwellings. *Rad. Prot. Dos.* 7, 299-302, 1984
- UNSCEAR 82: Ionizing Radiation: Sources and Biological Effects. Report of the UN scientific committee on the effects of atomic radiation, United Nations, New York, 1982