Strahlenschutzkommission

Geschäftsstelle der
Strahlenschutzkommission
Postfach 12 06 29
D-53048 Bonn
Germany
http://www.ssk.de

Radiological protection principles to limit radiation exposure from radon and its decay products in buildings

Recommendation of the German Commission on Radiological Protection

Adopted at the 124th session of the Commission on Radiological Protection,
21/22 April, 1994

The German original of this English translation was published in 1994 by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety under the title:

Strahlenschutzgrundsätze zur Begrenzung der Strahlenexposition durch Radon und seine Zerfallsprodukte in Gebäuden

in the Bundesanzeiger No. 155 of 18 August, 1994.

In the event of any doubts about the meaning, the German original as published shall prevail.

Contents

1 Introduction

The Commission on Radiological Protection already recommended radiological protection principles to limit the radiation exposure of the population from radon and its decay products at its 84th meeting on 30 June 1988 [SSK 91]. In the last few years new findings have been produced by different international studies through epidemiological research, leading the International Commission on Radiological Protection (ICRP) to produce a report and recommendations on protection from radon 222 in homes and at work [IC 93]. For these reasons the Commission on Radiological Protection has been looking at the subject again. It regards it as appropriate and necessary, taking account of the current scientific and technical knowledge, to make a new assessment, which means the further development of the earlier recommendations.

2 Starting situation

The radioactive isotopes of the noble gas radon (Rn 222 and Rn 220) are natural substances from the uranium/radium and thorium decay series, which occur everywhere in the environment. Radon can get into the atmosphere from the ground, from building material in houses, and from water, and thus also get into the air in houses. Generally the concentration of radon in houses is higher than in the outside air. When radon decays, more radioactive decay products are produced, which, if inhaled, lead to radiation exposure of the respiratory tract including the lungs. As a result of this inhalation, the respiratory tract and the lungs receive the highest radiation exposure from natural sources. The short-living decay products of radon 222 make the biggest contribution to radiation exposure.

The indoor radon concentration varies considerably from area to area and from house to house. It also shows great temporal variations. As the relevant source is generally the radon that comes out of the ground under the house, in most cases the highest concentrations in houses generally occur in the basement and in ground floor apartments.

The decisive factor for the radiation exposure of the inhabitants is the longterm average value in the inhabitated area of the house. The long-term measurements of radon concentration in randomly selected houses throughout the Federal Republic of Germany in the last decade reveal a very asymmetrical distribution. The annual averages of radon concentrations in dwellings vary from a few Bq/m^3 to a few thousand Bq/m^3, and in extreme cases reach some tens of thousands Bq/m^3; the average being 50 Bq/m^3. In areas of rock with a high uranium or radium content, and under certain geological conditions, higher radon concentrations often occur. In addition special survey measurements have found single particularly high values, that were caused by former mining, for example by workings under the houses.

According to these measurements, among the roughly 15 million residential buildings in the Federal Republic of Germany, radon concentrations can occur of between 250-1,000 Bq/m^3 in approximately 1-1.5 % of the buildings, and radon concentrations above 1,000 Bq/m^3 in approximately 0.1-0.3 %.

3 Risk from radon and its decay products

3.1 Radon and lung cancer

The high mortality rate among miners in the Saxon and Bohemian mines was already reported in the Middle Ages. In the l9th century lung cancer was recognised as one of the main causes, and in around 1920 people began to hold radon responsible for the increased incidence.

In the past decades numerous uranium miners were exposed to high radon concentrations and additional influential factors such as arsenic and dust. In the following decades these miners demonstrated a significantly increased rate of lung cancer. This is to be attributed mainly to the alpha-radiation of radon and its decay products. Lung cancer is, however, also produced by other ionising radiation, as is shown by the data from the studies on the survivors of Hiroshima and Nagasaki.

The observations on miners who have been exposed to increased radon concentrations coincide with the assumption that the increase in the rate of lung cancer is proportional to the radon exposure, and that there is no threshold value for radon concentrations below which there is no additional risk of lung cancer. Since the average radon exposure of the population accumulated throughout life is only lower by roughly the factor 10 than the exposures of miners in whom it was already possible to establish an increase in the rate of lung cancer, it is to be assumed that radon and its decay products in homes also contribute to the lung cancer rate.

3.2 Risk estimate

From the observations on mine-workers, the International Commission on Radiological Protection (ICRP) has estimated the risk of lung cancer in its report “Protection against radon 222 in homes and at work“ [IC 93]. For a male population of average age with average smoking habits, it deduces the mortality risk for lung cancer at 0.0003 (30 cases among 100,000 people) for a typical annual period of 7,000 hours in an air concentration of 250 Bq/m^3 radon[1]. Accumulated over 70 years of life, in a home with a radon concentration of 250 Bq/m^3, this produces an additional risk of lung cancer of 0.02, if the risk is transferred from the mines to the situation in the homes.

Since the dosimetric lung models for radon and its decay products are not yet certain enough, the ICRP assumes a risk estimate on the basis of the epidemiological data, and proposes as a convention, that the annual period spent in a home with a radon concentration of 250 Bq/m^3 is equivalent to an effective dose of 4 mSv/a from another radiation, as these two exposures lead to the same risk.

Since the estimate of the risk, i.e. of the probability with which a certain radon exposure causes lung cancer, is based on the observations on miners, the extrapolation to the different conditions and the lower radon concentrations in homes is naturally unsafe. The main uncertainty factors are differences in the breathing rates for underground work and in homes, and additional harmful influential factors - such as arsenic or dust - in mines, which can be responsible for some of the damage to health observed. Overall the risk values that have been

[1] With an equivalence factor of 0.4 between radon and its decay products.

deduced from the observations on miners (transfer of the exposure-dependent relative risk to other person groups) should represent a certain over-estimate if applied to radon in homes.

In epidemiological studies on a possible connection between increased radon concentrations in homes and the frequency of lung cancer, it has not yet been possible to recognise any clear connection. A new Swedish study [PER 94], however, demonstrates a connection and confirms the size of the above risk estimates. The general validity of these connections still has to be clarified. Like other countries (e.g. [TIR 93]), the Federal Republic of Germany is playing a part, through epidemiological studies, in improving knowledge of the actual risk.

3.3 Dependence on additional factors

There is no doubt that the risk of lung cancer is increased by smoking. There are indications that the additional risk from radon is increased by smoking. The Swedish study mentioned above shows that the additional risk for smokers from radon is not “additive“ (same increase in smokers and non-smokers), but rather “multiplicative“ (multiplication of the increase factors of radon and smoking). On the basis of the 1993 ICRP recommendation on radon [IC 93], this would mean that the risk of lung cancer from radon in smokers is roughly twice as high, and that in non-smokers roughly five times less, than the risk of lung cancer from radon for the average of the male population.

Finally, the risk estimates for lung cancer from radon are also to be viewed differently with regard to the dependence on the age at which exposure takes place. It is often assumed that radiation exposure at a young age means a greater overall risk of later damage, and in particular for radiation-induced cancers, than exposures at a later age. The observations on the survivors of the atomic bombs coincide with such an assumption. The research on the rate of lung cancer in miners after radon exposure, however, leads to the opposite conclusion: a certain exposure at a younger age, i. e. between 20 and 40, leads to significantly fewer cases of lung cancer than an exposure at a later age, i. e. between 40 and 60. It is true that a radon exposure at a young age causes a significantly higher relative risk for a few years, but only at a later age do the spontaneous rates of lung cancer rise to such high levels that an increased relative risk is also of significance for the absolute rates.

Since all observations of increased rates of lung cancer after radon exposure relate to miners or adult members of the population, no information is available relating directly to the radiation exposure of children. However, in all the research it has become clear that the main increases in the relative rates of lung cancer do not last more than about 20 years. Since, after exposure to radiation at a young age, even with high relative rates compared to the spontaneous risk of lung cancer, the absolute rates remain low during this period, children and young people are not a critical group with regard to radon exposure. The dose convention mentioned, i. e. the connection proposed by the ICRP between effective dose and radon exposure, is therefore conservative for children and young people.

4 Recommendations of the SSK

4.1 Homes

In its 1988 recommendation [SSK 91] the SSK suggested a value of 250 Bq/m^3 as the upper limit for the normal range of indoor Rn 222 concentrations. If higher radon concentrations are present, precautionary action should be considered to reduce the radon concentration. The period in which an improvement is to be made should be restricted so that the radon exposure accumulating over this period remains below a lifetime‘s exposure to the upper limit of the normal range of radon concentrations in houses, i. e. below 15,000 Bq a/m^3.

The then proposed value of 250 Bq/m^3 coincides well with the range of 200-600 Bq/m^3 recently proposed by the ICRP [IC 93], within which a national standard value for the upper limit of the normal range should lie. In line with these new recommendations of the ICRP, the SSK makes the following recommendations for the annual average of representative values of radon concentration in homes:

1. 250 Bq/m^3 continues to apply as the upper limit of the normal range of radon concentrations in residential buildings in the Federal Republic of Germany. Action is thought to be unnecessary for values in the normal range.

2. The range between 250 and 1,000 Bq/m^3 is regarded as the discretion range for simple action to reduce exposure from radon. The possible action depends heavily on the entrance points and the distribution of the radon in the building, i. e also on the type of construction, the condition of the building, and the habits of the inhabitants. Depending on the situation, the following can be appropriate simple actions:

   – action to be taken by the inhabitant himself:

     • change of the use of the rooms depending on the radon concentration and the times spent in the individual rooms,
     • more frequent or more intensive ventilation,
     • sealing of obvious entrance points for radon (cracks, gaps, places where pipes come through etc),

   – action to be taken after specialist advice:

     • change of the pressure and circulation conditions in the building (for example by creating natural ventilation openings in appropriate places or by using small ventilators to maintain excess or low pressure),
     • application of radon-preventive coatings.

3. The range above 1,000 Bq/m^3 is regarded as the remedial action range, in which the radon concentration should be reduced, even if more expensive action is required. A suitable method can only be selected after the matter has been investigated. The remedial measures – generally constructional and ventilation measures – should be carried out in an appropriate period that is determined, amongst other things, by the level of the radon concentration. For concentrations above 15,000 Bq/m^3, however, it is recommended that a remedial measure is carried out as soon as possible, within one year at the most.

4. For radon measurements in existing buildings, care must be taken that the radon concentration shows both periodic day/night values and a variation over the year due to the ventilation pattern and climatic conditions. Action should only be proposed on the basis of representative annual average values. An alternative in urgent cases is to replace the whole year‘s value by a 3-monthly average value from Spring or Autumn.

5. When new buildings are being constructed, those responsible should try to make sure that the normal range of radon concentration is not exceeded.

6. There are areas in which increased radon concentrations in buildings occur particularly frequently. This depends firstly on natural geological conditions, in particular the radon

concentration of the ground air and the permeability of the ground – which may have been increased by mining in these areas –, and secondly on the construction method used in the buildings. It is recommended that in the Federal Republic of Germany such areas are gradually recorded in detail, taking into account both the geological conditions and the results of radon measurement programmes in existing buildings. In these areas with increased occurrence of radon, priority should be given to radon protective constructions. Practical experience on suitable building materials and building methods is already available.

4.2 Workplaces

When increased radon concentrations occur in workplaces within buildings, it is to be taken into account that less time is spent at work than at homes. Correspondingly higher radon concentrations may therefore be allowed before action is to be considered.

5 References

[IC 93] International Commission on Radiological Protection, protection against radon 222 at home and at work; ICRP Publication 65, Annals of the ICRP, Vol. 23, No. 2, 1993

[PER 94] Pershagen, G.; Akerblom, G.; Axerlson, O.; Clavenejo, B.; Damber, L.; Desai, G.; Enflo, A.; Lagarde, F.; Mellander, H.; Svartengren, M.; Swedjemark, G.A.: Residential Radon Exposure and Lung Cancer in Sweden. N. Engl. J. Med 330, 159-164, 1994

[SSK 91] Strahlenschutzgrundsätze zur Begrenzung der Strahlenexposition der Bevölkerung durch Radon und seine Zerfallsprodukte. Empfehlungen der Strahlenschutz-kommission 1988/1989, Gustav Fischer Verlag, Stuttgart/New York, 1991

[TIR 93] Tirmarche, M.; Raphalen, A.; Allin, I.; Chameaud, J.; Bredon, P.: Mortality of a cohort of French uranium miners exposed to relatively low radon concentrations. Br. J. Cancer 67, 1090-1097, 1993