THE SWISS RADON PROGRAMME

G. Piller, G.A. Roserens and W. Zeller

Swiss Federal Office of Public Health, Division of Radiation Protection, CH-3003 Bern
Tel: +41 31 324 10 41
Fax: +41 31 322 83 83
E-mail: georges.piller@bag.admin.ch
Web: www.admin.ch/bag

The very high indoor radon concentrations found in the western part of Switzerland in the early 80th were at the origin of an extended research programme between 1987 and 1991. The results obtained showed a real need for a further detailed radon programme. This should be based on the state of knowledge, take economical aspects into account and be practically orientated. The main aim is to deal with elevated concentrations. Thus three principal pillars were defined to achieve this goal: legislation, communication and formation.

In 1994, the Swiss Legislation on Radiological Protection fixed a limit value of 1000 Bq/m³ and a guideline value of 400 Bq/m³ for residential and recreational premises. After the investigation of about one half of the 3000 municipalities, areas with high concentrations were found principally in Alpine and Jura regions. But, values overcoming the limit were also found on the Swiss Plateau. In more than 90% of the measured houses, the radon concentration is situated below the guideline value, but in about one percent the radon concentration exceeds the limit. The arithmetic mean value is 75 Bq/m³ for inhabited rooms.

The communication with different target groups regarding radon and its harmful effects on health is very important too. House owners must be motivated to perform measurements and to carry out remedial work if necessary.

Finally, construction experts must know the different possibilities to reduce the radon gas concentrations in the residential and recreational premises. Therefore, an efficient collaboration with educational establishments and the different professional associations has to be realised.

INTRODUCTION

Measurements performed in the early 80th revealed indoor radon concentrations of up to several 10000 Bq/m³. A research programme was then initiated and co-ordinated by the Swiss Federal Office of Public Health (SFOPH). The results (SFOPH 1992, Surbeck 1992) indicated a real need for further investigations and the implementation of regulations on radon. The main aims were to avoid elevated concentrations for new constructions, take protective measures (for instance for tenants) and establish remedial programmes. This should be achieved mainly by measurement campaigns, communication with different target groups and formation of construction experts. The actual Swiss radon programme consists of the three principal pillars i.e. legislation, communication and formation. National and international experiences and recommendations are used for an objective and transparent information of local authorities, mass media and public at large.

LEGISLATION

In 1994, the Swiss Legislation on Radiological Protection fixed a limit value of 1000 Bq/m³ for inhabited rooms. If the limit is exceeded, persons concerned e.g. tenants, may request remedial measures. The house owner has to take necessary actions in order to reduce the radon concentration...
at one's own expense. For new and reconstructed buildings, a guideline value of 400 Bq/m³ shall apply.

The SFOPH co-ordinates all activities in the radon field, but certain tasks are delegated to the Cantons. Each Canton has a service which is responsible for radon. The Cantons shall ensure that a sufficient number of measurements are made throughout their territory, in order determine areas with elevated radon gas concentrations. The Cantons shall also take the necessary measures to ensure that new and reconstructed buildings are erected in such a way that the limit is not exceeded. They shall further ensure that suitable construction techniques are used to endeavour to keep the radon gas concentration below the reference value.

The priorities are set by the Radiological Protection Ordinance. So, the charts of areas with elevated radon gas concentrations shall be available for public consultation at the latest in 2004 and the remedial work shall be completed until 2014.

The radon gas concentration measurements must be performed by recognised laboratories. The measuring system has to meet the state of the art and must be linked to national or international comparison standards. The traceability is established by the Swiss National Institute for Metrology.

MEASUREMENTS OF RADON

In Switzerland, the geology changes on a very local scale and is not always well known. It was therefore decided to base the classification of radon areas mainly on measured radon gas concentrations in dwellings (Piller et al., 1998). The radon concentration is measured with integrating passive dosemeters over a recommended period of three month. Since the focus is set on houses with high concentrations, single family houses, farmhouses and older buildings preferably with natural soil in the basement are first chosen. This selection of houses, of course, leads to a biased distribution of radon concentrations.

Political municipality borders are used to separate areas. The SFOPH recommends to classify a municipality as radon area if a sufficient number of measurements shows that the arithmetic mean for residential premises is higher than 200 Bq/m³ or if the maximum value is higher than 1000 Bq/m³. If more than of 20 houses are measured per municipality there is little probability for misclassification (Piller et al., 1998). For municipalities with less than 400 houses, the sample size may be reduced. This means that over 50000 permanently occupied houses should be analysed in Switzerland. Regions with high concentrations were found mainly in the Alpine and Jura regions (Fig. 1). But values overcoming the limit were also found on the Swiss Plateau. The geometric mean or the percentage of houses with concentrations over some reference level could also be used for the classification of radon areas. But, since these criteria are correlated (Piller et al., 1998), essentially the same findings will result. For future radon charts spatial correlation and risk mapping methods will be used. The applicability of these methods for the radon data has been investigated. The result is encouraging and it will become possible to estimate the spatial probability of having more than some given radon concentration.

Nowadays, about 35000 houses have been investigated in Switzerland. The mean value is approximately 75 Bq/m³ for residential premises. The distribution of radon concentrations is
approximately log-normal (Fig. 2). An adjustment for bias of distribution, floor dependence and regional population can be applied.

The corresponding cumulative distribution (Fig. 3) indicates that more than 98 % of the population in Switzerland lives in houses with radon concentrations below 400 Bq/m$^3$, but 0.3 % live in concentrations of more than 1000 Bq/m$^3$.

**REMEDIAL MEASURES**

Before remedial measures are taken, a control measurement is always recommended. Mitigation is mostly performed in several steps. First simple measures are tested. If the reduction is not satisfactory further actions are initiated. Different radon reduction methods are known and applied in practice. Several examples are shown here:

One simple method was applied in a Kindergarten where concentrations over 1000 Bq/m$^3$ were found. Chipboards were placed on part of the floor surface with some air space in between (Fig. 4). The whole surface was then sealed with a plastic material. The air from the intermediate space is exhausted by a fan. As can be seen from Fig. 5, the radon concentration is reduced to about 150 Bq/m$^3$.

In another Kindergarten the radon concentration was between 1000 and 2500 Bq/m$^3$. Two holes were drilled trough the concrete foundation. The air containing radon is sucked trough tubes by a ventilator which is installed in the loft. The tubes could be hidden inside cupboard units. The radon reduction is very significant and the resulting concentrations are below 200 Bq/m$^3$ in all rooms (Fig. 6).

In several parts of Switzerland drainage-tubes are laid around the building at the depth of the foundation. If the radon concentration inside is too high, an attempt can be made to ventilate this system. This can lead to a reduction of the radon as indicated in Fig. 7. But there is a lack a experience with respect to this and it is possible that the drainage-tube system by itself helps to keep radon concentration relatively low.

**CONCLUSIONS**

The Swiss radon programme is based on legislation, communication and formation. The legislation became effective in 1994, whereas communication and formation started later. The collaboration between federal and local authorities based on objective and transparent information is well established. It is of fundamental importance for dealing with radon and its health effects.

The Cantons are performing the necessary measuring campaigns to elaborate the charts of areas with elevated radon concentrations. The political borders of municipalities are considered until now, but spatial correlation and risk mapping will be used in the future.

Special information should be given to the population of areas with high indoor radon concentrations. The effects of implemented actions has to be evaluated regularly in order to recognise faults and ineffective measures and to take the necessary corrective measures.
Different remedial measures are known and applied in practice. Some methods have to be simplified because of too high expenses. Construction experts must be aware of the different possibilities helping to lower the radon gas concentrations. This means that an efficient collaboration with educational establishments and different professional associations has to be institutionalised.

However, most important is that preventive measures are taken in areas with elevated radon concentrations. Suitable construction techniques are known and must be applied in order to avoid new buildings with elevated radon concentrations. Some Cantons have already introduced adequate dispositions in their building regulations.

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REFERENCES

Figure 1: Radon-map of Switzerland, novembre 1998, L+T, Geostat 1990
Figure 2: Probability density distribution of radon concentrations for inhabited rooms.
Figure 3: Cumulative distribution of radon concentrations for inhabited rooms.
Figure 4: Sucking of radon containing air out of the space in between.
Figure 5: Radon concentrations in two rooms of Kindergarten B before and after mitigation.

Figure 6: Radon concentrations in different rooms of Kindergarten A before and after mitigation.
Figure 7: Mean radon concentrations measured in basement with (grey background) and without fan.