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INDOOR RADON PROBLEM AND VENTILATION STRATEGIES

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ABSTRACT

All buildings, depending on their design and particularly on how they are vented, are polluted to some extent with radon. Radon and its daughters may be trapped within buildings and accumulate there, thus threatening the health of their dwellers. Radon is an inert radioactive gas whose emanation into the building can mostly come from the underlying soil and from the building materials. The unhealthy buildings risk starts to act with tendency of saving energy and the related limitation of room ventilation to minimum. From indoor radon concentration point of view the dilemma does exist between air exchange respecting hygienic standards and indoor radon respecting limitation requirement of standard level. In this paper the seasonal and annual indoor radon concentrations related to ventilation rate in Slovak dwellings are presented. The study is based on continuous weekly radon measurements over a period of 1 year.

KEYWORDS

Indoor radon, Standards levels, Screening measurements, Seasonal variation, Air change

INDOOR RADON

Radon emanation into the building can mostly come from the underlying soil and from the building materials. The principal isotope, ^{222}Rn decays to products which, if inhaled can result in exposure of respiratory tract. From the view-point of unfavourable effects on human health, it is necessary to remark that radon itself is substantially less harmful than its short-lived daughter or transformation products ^{218}Po, ^{214}Pb, ^{214}Bi, because these radionuclides unlike radon, inert gas, are absorbed on air particles.

While the decisive significance in assessment of indoor exposure under normal conditions has ^{222}Rn, the biggest influence on its content itself as well as on the content of short-lived products of the transformation in the air have two competitive processes. The first one is the exhalation of Rn which depends on specific activity of ^{226}Ra, emanation coefficient and on ambient meteorological factors. The great influence is the ventilation rate. After complete sealing of all the ventilation holes it takes several hours to reach the saturated value of radon, while after opening the windows this value falls drastically in several seconds. The resulting volumetric activity of indoor air radon is given by emanation and room ventilation rates. Then start to act simultaneously two circumstances which can extremely increase the risk. It is the tendency to save energy and the related limitation of room ventilation to minimum (Senitkova, 1993).

The radon content in indoor air may be increased by utilisation of new building materials, energy conserving measures and by the change of living conditions. This may lead in the future to an increase of indoor exposure of the population. The significance of radon for the human health is well known and thus the measurement of indoor radon is important for the evaluation of its impact in the public health field. There has been much of concern in recent years about health-related risks from high concentrations of indoor radon. Health effects are believed to be associated with periods of long-term exposure.

Standards Levels

Notice of Slovak Health Service Ministry Standard No 406/1992 referring to limitation requirements of radon and other natural radionuclides radiation states maximum allowable value of equivalent volume radon activity (EOAR) that is 100 $Bq.m^{-3}$ for new buildings and 200 $Bq.m^{-3}$ for existing buildings.

Indoor radon limiting values in other countries for new buildings are: 50 $Bq.m^{-3}$ in Latvia, 100 $Bq.m^{-3}$ in Czech Republic, 200 $Bq.m^{-3}$ in Finland, Poland, Sweden, United Kingdom, 250 $Bq.m^{-3}$ in Germany and 400 $Bq.m^{-3}$ in Austria, Switzerland, Belgium. It is necessary to say that limiting value need not be conceived as limit value, but as upper value of optimising alternatives, which should lead in practice to as low levels as possible.

METHODS AND MEASUREMENTS

All radon-control measures applied in existing buildings require: maximum effectiveness, simple realisation, minimum impact on environmental comfort, economic effectiveness at realisation as well as its realisation and minimum maintenance.

Screening Measurements

On the base of radon program, the indoor radon concentrations in residential buildings were studied by our department. The buildings were different by the building materials, type of windows, by heating system, and ventilation rate. Also indoor spaces were different by their distance from the soil. The screening measurements over a period of a year using CR - 39 system were done. The trace detectors which were located in various rooms of dwellings were used. The detectors were fastened on a string hanging about 40 cm from the ceiling and at least 20 cm from the wall opposite to the window. The detectors were hung for a 1 year period. After exposure the detectors were collected and assessed by Quantimet 520 Analyser.

According to the 1992 Slovak Standard for indoor radon, the value of 100 $Bq.m^{-3}$ was exceeded in 57 % indoor spaces. Maximum level of 981 $Bq.m^{-3}$ and the average radon activity of 95 $Bq.m^{-3}$ were measured. The information about the results of the measurements is given in the Table 1. On the other side the level of 200 $Bq.m^{-3}$ was exceeded only in 10 %. The radon concentration in atmospheric air was between 5 - 15 $Bq.m^{-3}$. These screening measurements are consistent with the results previously obtained (Senitkova,1997,1999).

TABLE 1
INDOOR RADON CONCENTRATION

Number [%]	Level [Bq.m^{-3}]
1,74	< 20
41,36	20 - 99
47,29	100 - 199
8,56	200 - 599
1,05	600 -999

Seasonal Variation

The information about the concentration of radon, in most cases is based on a single short-terms measurement. Because of the temporal variations in indoor radon concentrations, such a measurements may not accurately represent the value that would have been obtained from measurements made over a longer period.

The weekly radon concentrations in the room situated in the lower ground floor were measured using the Radon Progeny Monitor - system RPM-256. The lower ground floor was a controlled space for experimental and study work. The test spaces had an area of approximately 50 - 100 m^2. There was no air-conditioning system present in any of the measured rooms. As well, each room was equipped with central heating system. The data were collected and the mean radon concentration and mean standard deviation were estimated. It is evident that we need to search for factors that dominantly influence indoor radon concentration, that s why intensity of air change was also measured. The seasonal variation of the radon concentrations is described in the Table 2.

TABLE 2
SEASONAL VARIATION OF THE RADON CONCENTRATIONS

Season	Mean Radon Concentration [Bq.m^{-3}]	Mean Standard Deviation [Bq.m^{-3}]	Mean Air Change [n.h^{-1}]
Winter	152,8	6.4	0,3 - 0,5
Spring	146,0	6.5	0,3 - 0,5
Summer	58,2	4.7	0,7 - 0,9
Autumn	54,6	3.8	0,7 - 0,9

Statistical analysis of the results shows that the probability that a weekly measurement represents the yearly radon concentration is more than 0,5 only during winter and spring period. Overall the results indicate that short-term radon measurements appear to represent the year long average only if the measurements are made during winter and spring.

Indoor Radon and Air Change

As the influence of air change rate was identified, the indoor radon problem is to be watched and solved mainly regarding to ventilation rate. In conformity with above mentioned, the measurements were realised in winter and spring period. Intensities of air change by infiltration were influenced by individual properties of building construction especially windows and meteorological conditions and was estimated on the base of NO_x concentration differences. Indoor radon exposures depend in a complex way on the characteristics of the soil, the type and details of the building structure, meteorology, the design of air-change, and occupant behaviour. On the base of these facts the dependence of indoor radon concentration level and infiltration air change was watched.

There also has been hygienic standard established for minimal air change for indoor spaces in Slovakia that is currently 0,5 h^{-1}. The results of measurements are presented in the Figure 1 for the buildings with underground floor as well as in the Figure 2 for the buildings without underground floor. The presented results of indoor radon concentration related to Slovak standard limit value for indoor radon and limit value for hygienic air change can be discussed.

Buildings with underground level and buildings without underground level were divided and subsequently followed in the first and second group, respectively. In the first group 100% effectiveness in reaching safe radon concentrations (100 $Bq.m^{-3}$ or lower) was attained by n = 0,9 h^{-1} air change intensity. Since this situation clearly suggests increased energetic requirements, it is necessary to establish a proper strategy of ventilation. It appears very convenient to install HVAC system that will assure necessary hygienic air change intensity. In the second group of building the situation was a bit better. Air change n = 0,7 h^{-1} air change was necessary for every building being under 100 $Bq.m^{-3}$. Still, energetic requirement for such air change intensity is high. Similar strategy could be implied. In buildings it is low ventilation rate that mostly contribute to radon high levels. Increasing the ventilation rate - preferably with systems that do not decrease the interior pressure - can help reduce radon concentrations. This approach may be most needed where the infiltration rates are very low.

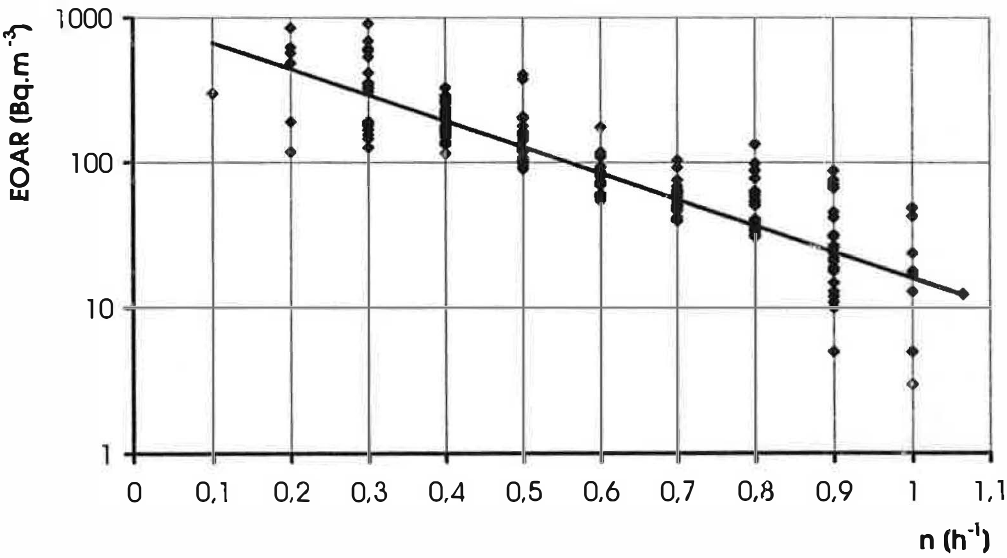

Figure 1. Indoor radon and air change in the buildings with underground floor

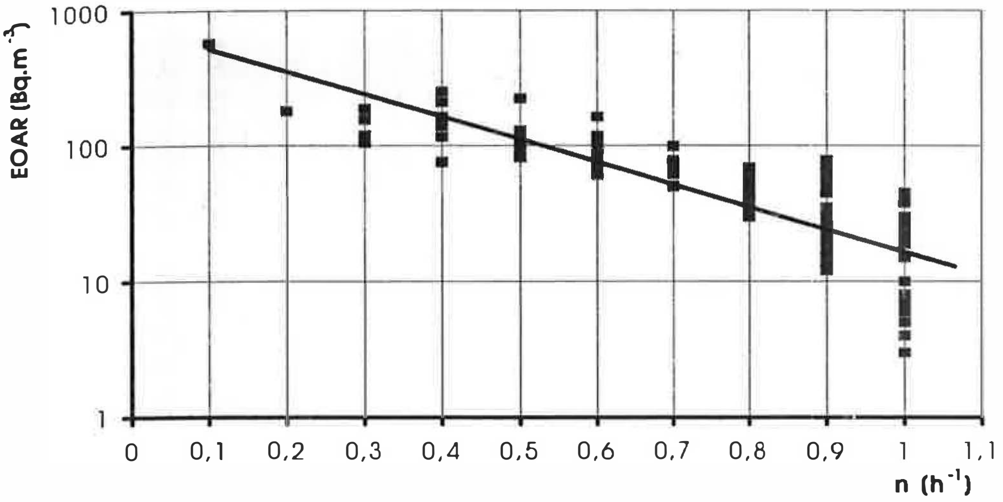

Figure 2: Indoor radon and air change in the buildings without underground floor

CONCLUSION

Generally, indoor radon concentration can be decreased using the suitable ventilation strategy. Finally the radon problem is influenced by ecological and economical aspects. It is necessary to emphasise that the HVAC system designs responsibility for the future indoor radon concentration. Since each building is characterised by its underlying soil-geological composition of soil layers, applied construction materials, building purpose, its exploitation and maintenance; technical radon-control measures have to be designed and solved individually. Civil engineering can, by suitable adjustments decrease significantly radiation risk.

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