Indoor radon in Lithuania: sources, doses, peculiarities

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Abstract. Indoor radon is the most important source of exposure of Lithuanian population asa whole. It has been determined during national indoor radon survey then measurements of indoor radon concentrations in randomly selected detached houses were carried out. The results of this survey and measurements of concentrations of natural radionuclides in construction materials indicate that the main source of indoor radon is soil. In particular cases construction materials might be also a significant source of exposure. Indoor radon concentrations depend on location of house, its age, some other peculiarities. On the basis of results of national indoor radon survey the regions with higher indoor radon potential were identified and more detailed measurements were started. The results of these measurements show that in some cases indoor radon can cause a significant exposure and remedial measures are to be considered.

Introduction

Indoor radon is one of the most important sources of exposure, and in many cases it might prove to be the most important one [1]. In deciding if remedial measures have to be taken and where these measures should be taken the wide indoor radon survey is to be carried. For selection of optimum remedial measures it is very important to identify sources of radon indoors and understand relationships between indoor radon concentrations and the factors, such as geology of site where the building under investigation is located or peculiarities of construction of building. On the other hand, concentrations and sources of indoor radon are important for understanding of magnitude of exposures from different sources. It is well known, that man-made sources such as nuclear energy production or nuclear accidents are considered as much more important than medical or natural source. Precise enough assessment of doses caused by indoor radon might help to achieve more objectivity in evaluation of the general exposure-related situation.

Materials and methods

Lithuanian indoor radon situation was completely unknown until 1995 when the first measurements of indoor radon concentrations were started with the help of the Swedish Radiation Protection Institute. Measurements of indoor radon concentrations were performed in 400 randomly selected living houses (out of 440 thousand all around Lithuania). When selecting houses their densities in different administrative units were taken into account. It helped to calculate the population weighed average concentration of indoor radon.

E-PERM^{TM} electrets [2] were used for measurements. Measurements were performed in two permanently used rooms closest to the ground surface. It gave some conservatism in assessment of doses, however it was acceptable due to the fact that the largest part (350) of investigated houses contained only one floor. On the other hand, it helped to "feel" better the influence of soil, which, as it was found, is the most important source of radon in Lithuanian detached houses.

Duration of measurement in any house was not less than 3 weeks. Such a duration was selected after long term continuous measurements performed with radon monitor Alpha Guard [3]. Selection of such duration was also supported by the fact that the measurements in randomly selected houses were performed during heating season (November-April). It also added to conservatyvism of assessment of the whole situation, but it should pointed out that at least in the karst region no statistically significant changes between summer and winher concentrations were observed.

Such parameters as the main construction material, number of floors, absence or presence of basement and water supply, year of construction, etc., were recorded during measurements. Dose rate indoors was recorded in the beginning and at the end of each measurement. It helped to evaluate an influence of gamma radiation on drop of potential of electrets.

Since construction materials can be a potential source of exposure – both external and internal – they are also investigated by means of gamma spectrometry. Standard HPGe spectometers are used for it. Ra-226, Th-232 and K-40 are radionuclides of interest during such investigations.

For evaluation of suitability of construction material from the point of view of radiation protection the activity index is calculated by dividing concentrations of Ra-226, Th-232 and K-40 (in Bq/kg) by 300, 200 and 3000, respectively, and summing the calculated ratios. If the sum does not exceed 1, the material can be used without any restrictions. In the opposite case the doses caused by use of this material are to assessed and decision made on the basis of principle of optimization of radiation protection. If the material is intended to be used for other purposes, i.e., construction of roads or pavements, or landscaping other coefficients are used for calculation of activity index.

Results and discussion

Measurements of indoor radon concentrations in randomly selected detached houses showed that the average indoor radon concentration in these houses is (55±5) Bq/m^3 (hereinafter error is given for 95% confidence). t-Test (a paired two-sample Student's t-test to determine whether a samples' means are distinct) revealed that the averages of concentrations of indoor radon in 5 regions differ from the average of concentrations in the remaining area. Higher indoor radon concentrations may be connected with lithological characteristics of these regions. For example, eskers of permeable gravel are frequent in the eastern region. Such eskers usually have very good conditions for intensive intake of ground air, containing radon, into buildings.

Higher indoor radon concentrations - (98±16) Bq/m^3 - were found also in the karst region. It should be pointed out, that this fact during measurements in the randomly selected houses has not been detected. Additional set of measurements has been performed in the karst region because there were suspicions that this region can yield higher indoor radon concentrations.

Additional more detailed measurements were performed in 552 houses of karst region in 2001-2002 [4]. The average indoor radon concentration in these houses was (88±7) Bq/m^3. It also differs statistically significantly from the average of concentrations in randomly selected detached houses.

It indicates that lithological characteristics, mainly permeability of soil, play an important role in indoor radon situation.

No differences between indoor radon concentrations were found in randomly selected urban houses and rural ones in series of measurements in 1995-1998.

Construction materials do no play an observable role. t-Test shows that houses constructed of concrete have statistically significant lower indoor radon concentrations in comparison with houses of other construction materials. However, concrete can not be the direct cause for it, when keeping in mind the fact that such materials as wood or white bricks have lower content of natural radionuclides. Concrete houses are newer that other ones, and the difference in their ages is statistically significant. Up to now the only plausible explanation is the fact that new houses have a tighter engineering barrier which prevents entry of soil gas containing radon into the house.

When analyzing differences of indoor radon concentrations in houses of different age (all the houses were grouped within intervals of 10 years) it was found that houses of 25 years and newer houses have statistically significant lower indoor radon concentrations than older ones. In very many old houses no basement or crawl space exists – the wooden floor is directly over the surface of soil. Due to such a construction peculiarity radon from soil can get into the house more easily.

Lower indoor radon concentrations are found in wooden houses with a layer of bricks outside. It might be explained by presumption that air gap between wooden wall and brick layer modifies flows of soil gas.

The highest indoor radon concentrations were detected in the cinder houses. Cinder contains high contents of Ra-226 – an average absorbed dose rate in the cinder houses was (179±17) $nGy \cdot h^{-1}$ (an average of all the investigated houses is (127±2) $nGy \cdot h^{-1}$). However, a number of investigated houses built of cinder is small, hence no common conclusions about influence of cinder on indoor radon concentrations can be made. On the other hand, this construction material is not widely used in Lithuania, therefore its significance in total is not important. However, an additional attention is already paid to cinder when investigating content of natural radionuclides in construction materials.

Number of floors does not have an influence on indoor radon concentrations. Instead, influence of soil as an indoor radon source is indicated by differences of indoor radon concentrations in the rooms on the different floors. The average concentration on the ground floor was (55±4) $Bq \cdot m^{-3}$, on the first floor – (15±11) $Bq \cdot m^{-3}$. The difference is statistically significant.

The average of indoor radon concentration in the houses with water supply was statistically significantly lower than the average in houses without it. It is evident, that water can not be a significant source of radon. Houses with water supply are newer, than ones without it, and this difference of ages is statistically significant.

Differences of indoor radon concentrations in the kitchens with tap water and without it are also statistically significant with lower concentrations in kitchens with water supply. Tap water is supplied to the kitchens, which are in the newer houses.

Differences in indoor radon concentrations in the separate rooms of the same house are on the average 20%. Measurements of indoor radon concentrations in the karst region performed in summer and in winter showed that these differences were higher in summer (up to 45%). This may be caused by differences in conditions of radon intake into separate rooms and air exchange rates in the different rooms. For this reason measurements shall be performed at least in couple of rooms.

Distribution of absorbed dose rate is log - normal. There is no relationship between indoor radon concentrations and absorbed dose rate - the coefficient of correlation is 0.07. The reason for it might the fact, that influence of radon daughters on absorbed dose rate is not significant in comparison with influence of ^{40}K and other natural radionuclides in the building constructions. On the other hand, source of radon (soil) is rather far from the point of the measurement (room).

Results of measurements of concentrations of natural radionuclides in some construction materials are given in Table.

Table. Activity indexes of natural radionuclides in some construction materials

Material	Activity index	Material	Activity index

chalk	0.005-0.11	white brick	0.11-0.27
marble	0.01-0.14	sand	0.12-0.48
quartz sand	0.02-0.06	granite	0.13-1.09
gypsum	0.02-0.09	gravel	0.21-0.60
dolomite	0.02-0.17	clay	0.23-1.36
wool	0.04-0.06	cinder	0.50-1.42
cement	0.06-2.64	ceramic till	0.71-0.16
plasterboard	0.07-0.11	expanded clay	0.75-1.10
lime	0.07-0.28		

As can be seen from the Table, the concentrations of natural radionuclides in construction materials may be in rather wide ranges. Such widely used materials as cement, sand, gravel are very different from the point of view of natural radioactivity. Some construction materials, e.g., cinder, ceramics, expanded clay can contain rather high concentrations of natural radionuclides. A special attention should be given to identification of such materials.

Construction materials made of by-products of industry should be considered a potential for higher exposure. It is particularly worth consideration because new types of construction material are introduced.

Recently more detailed investigations of indoor radon concentrations in identified areas are conducted. The aim of these investigations is identification of houses with indoor radon concentrations higher than action levels, identification of areas with the highest indoor radon potential, public information on radon and natural exposure related matters.

Average of doses due to indoor radon to inhabitants in detached houses is (0.97±0.07) Bq/m^3 per year. However, in some houses these doses can be higher than 10 mSv. Remedial measures should be considered in some cases.

External dose rates indoors (due to construction materials) were estimated on the basis of results of dose rate measurements indoors and taking into account cosmic radiation and shielding factors. They appear to be 106 nGy/h (the range is (65-146) nGy)). It shows that construction materials in some case might be rather significant source of exposure.

Attempts are made for identification of construction materials with higher content of natural radionuclides. It might help to find ways how to optimize radiation protection in this case – natural radionuclides in construction materials is one of the most important sources of exposure.

Conclusions

Natural radioactivity is the most important source of exposure in Lithuania. Indoor radon which mainly comes from soil is the largest among other natural sources, despite the fact that sedimentary rocks are prevailing in Lithuania. Areas with higher indoor radon potential were identified. However, construction materials may pose also a radiological risk. Their influence on exposure still needs a closer investigation.

References

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