



Indoor radon survey in Visegrad countries

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HIGHLIGHTS

- Radon was measured in 123 houses and offices and 33 schools and kindergartens.
- Maximum values amounted to 843 Bq m⁻³ for houses and 875 Bq m⁻³ for schools.
- In 32% of schools the maximum indoor radon was reached in the summer months.

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ABSTRACT

The indoor radon measurements were carried out in 123 residential buildings and 33 schools in Visegrad countries (Slovakia, Hungary and Poland). In 13.2% of rooms radon concentration exceeded 300 Bq m⁻³, the reference value recommended in the Council Directive 2013/59/EURATOM. Indoor radon in houses shows the typical radon behavior, with a minimum in the summer and a maximum in the winter season, whereas in 32% of schools the maximum indoor radon was reached in the summer months.

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1. Introduction

The highest contribution to radiation exposure of the population is due to radon which may concentrate in dwellings. The main source of radon in the air of a dwelling is the ground under the building, which is responsible for 80% of the whole radon concentration inside a typical house. In particular, the building materials of houses, its design and ventilation systems strongly influence the levels of indoor radon and its decay products (UNSCEAR, 2000). Several national radon surveys were performed in Europe to assess the indoor radon levels (Barros-Dios et al., 2007; Cosma et al., 1996; Dubois et al., 2007; Minda et al., 2009; Zmazek et al., 2002; Žunic et al., 2007; Žunic et al., 2014). The report (Dubois, 2005) highlights that the national radon surveys carried out in European countries show significant differences.

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Determining the radon levels in residential buildings in Slovakia was conducted at the beginning of the 1990s using an integral method with track detectors of LR-115 and CR-39 type (Vičanová et al., 2006; Vičanová and Pinter, 2008). In total, 3657 houses were investigated, including 409 houses with indoor radon activity concentration higher than 500 Bq m⁻³. The maximum measured value was 3750 Bq m⁻³. This study showed a high variability in radon concentration among studied localities in Slovakia, in a dependence of radium content in the underlying rocks and the geological structure of a studied area. Significant differences in indoor radon concentration were found between houses and blocks of flats. In this research also the dependence of radon level on the year of the building's construction, the presence of a cellar and the floor on which the studied room was situated were analyzed. Generally, the indoor radon level in rooms above a cellar was half amount in comparison with rooms situated directly on the subsoil. The highest values were measured in old houses. This study concluded, that in Slovakia, approximately 8.25% of

inhabitants live in houses with radon activity concentration exceeding 500 Bq m^{-3} . Based on this research a map showing annual average effective dose for inhabitants to indoor exposure from radon and its decay products for the districts in Slovakia was constructed.

During the years 1992 and 1993, radon surveys in 645 kindergartens and primary schools were carried out in Slovakia (Ďurčák et al., 1997). The measurements were performed using solid state nuclear track detectors type LR-115 and CR-39. Equilibrium equivalent radon concentrations, which were up to the action level of 200 Bq m^{-3} , were found in 13 kindergartens and in 3 primary schools.

Continuous monitoring of indoor radon in a selected house in Slovakia from May 2007 till April 2008 showed the seasonal variation with a minimum in spring months (600 Bq m^{-3}) and a maximum in early autumn (1600 Bq m^{-3}) (Müllerová and Holý, 2008). The anti-correlation between the outdoor temperature and indoor radon activity concentration in this house was not observed. Radon activity concentration measured at the point of radon entry to the room was approximately ten times higher than in the center of the room. The radon activity concentration at this point was in a good anti-correlation with the outdoor temperature (Müllerová and Holý, 2007).

In recent years a radon survey was carried out in Poland with the use of CR-39 track detectors in 132 houses over a period of one year from March 2008 till February 2009 (Kozak et al., 2011). The houses studied included 113 detached houses, 5 terraced houses, 4 tenement houses and 10 blocks of flats. Radon activity concentration varied from 5 to 1769 Bq m^{-3} . The lowest mean monthly values were registered in the summer season (June–August) while the highest ones were in November. From the detailed analysis of the results a diversity of the mean monthly radon concentrations due to the location of monitored buildings in different parts of Poland is evident, depending on various geological structures, different thermal-precipitation regions and the presence or absence of a cellar under a building.

The dependence of indoor radon measured in 129 buildings in Poland in relation to the geological setting of their foundation was studied (Przylibski et al., 2011). The comparison of mean annual indoor radon concentration in the tectonic units with buildings founded on igneous, metamorphic or sedimentary rocks indicated that the highest values were connected with igneous rocks. Lower values were characteristic when the bedrock was built from metamorphic rocks; however, these were only slightly higher than those for sedimentary rocks. The results also proved that in all of the tectonic units in Poland one can expect the existence of buildings with a mean annual ^{222}Rn concentration higher than 200 Bq m^{-3} .

In Hungary several radon surveys were performed to identify radon-prone areas. In these surveys indoor radon activity concentration was measured using closed CR-39 track detectors ($1 \text{ cm}^2 \times 1 \text{ cm}$), the detector container being a plastic cylinder. Between 1995 and 1999 the radon levels of 325 rooms situated on upper floors were measured. Radon levels of 15,277 first-floor rooms were investigated during the time interval 1994–2004. The measured radon data for bathrooms, kitchens, pantries, and garages as well as for public buildings (kindergartens, schools, libraries, temples), and different workplaces has been omitted from the present database. The maximum measured value was 5800 Bq m^{-3} , while the minimum was 10 Bq m^{-3} (Hátori et al., 2006). The action level for workplaces in Hungary is an average radon concentration 1000 Bq m^{-3} (Hungarian Regulation, 2000). However, in the case of the dwellings there is no legislation as yet.

In the survey performed between 2011 and 2012 73 houses and 7 workplaces in total were selected for the monitoring purposes. Radon concentration was measured with 4 different types of

SSNTD. The average indoor radon concentration was 79 Bq m^{-3} . In 58 measurement points radon concentration was below 100 Bq m^{-3} and in only one dwelling exceeded 200 Bq m^{-3} . The differences among the results obtained by the different types of the SSNTD were within 10% (Szeiler et al., 2012).

In the framework of the Visegrad Fund a standard project entitled “Harmonization of determining the radiation dose of the population originating from radon” was carried out from 2012 to 2013. Within the project a common questionnaire and a measurement protocol of the Visegrad countries for the measuring of indoor radon concentration was elaborated. The obtained results, which are presented in this paper, widened the countries' database on indoor radon and can also provide further information on improvement and completing the European Radon Map.

2. Materials and methods

Raduet type detectors (Radosys Ltd., Hungary) were used for integrating measurement in indoor air. Allyl diglycol carbonate (CR-39) plate is placed at the bottom of the chamber with sticky clays to detect the alpha particles emitted from radon and thoron as well as their progenies. The measurement method is also suitable for a discriminative measurement of radon and thoron simultaneously. Therefore, the results gained during the survey will also be beneficial for an indoor thoron level survey. Radon gas diffuses into the chamber through an invisible air gap between the lid and the bottom of the chamber. Since this air gap is a high diffusion barrier, little thoron enters the chamber due to its very short half-life (55.6 s), compared with that of radon (3.82 d). In order to detect thoron more effectively, six holes 6 mm in diameter are open at the side of the other chamber and are covered with an electroconductive sponge (Tokonami et al., 2005).

During the year-long survey four sets of detectors were used in each country, sets were changed after three months of exposure to compare the changes of radon activities during the year. The first period (spring) lasted from March to May 2012, the second (summer) from June to August 2012, the third (autumn) from September to November 2012 and the last (winter) from December 2012 to February 2013. Due to thoron measurement the detectors were uniformly placed at a distance of 15–20 cm from the wall.

Before starting to measure indoor radon a unified measurement protocol (placement of detectors, type of detectors and questionnaires) was jointly elaborated, thus providing comparable results. Information about the building material, window tightness, intensity of the ventilation, year of construction and reconstruction, number of inhabitants and time spent in the monitored room were obtained using the questionnaire. The pattern of a questionnaire is shown in Appendix A. The flyer informing about radon and radon survey was distributed to the inhabitants (Appendix B and Appendix C), motivated by the Czech radon survey (www.suro).

Each participant in the project chose the three areas in their country (in Hungary: Veszprém, Komárom-Esztergom and Somogy; in Poland: Łódź, Lublin and Kraków; in Slovakia: Bratislava, Mochovce and Ružomberok), where indoor radon concentration was possibly higher than average. Geological settings were one of the main reasons for the indoor radon survey in studied localities. The uranium and thorium content in soil and the information about soil radon activity concentration were also relevant.

In this paper only houses where radon was measured during the whole year are included. Information obtained by the questionnaire enabled us to discuss the result of the survey in relation to the type of the building, building material and other parameters which influence indoor radon level.

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