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Residential, soil and water radon surveys in north-western part of Romania

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ABSTRACT

The exposure to radon and radon decay products in homes and at workplaces represents the greatest risk from natural ionizing radiation. The present study brings forward the residential, soil and water radon surveys in 5 counties of Romania. Indoor radon measurements were performed by using CR-39 track detectors exposed for 3 months on ground-floor level of dwellings, according to the NRPB Measurements Protocol. Radon concentrations in soil and water were measured using the LUK3C device. The indoor radon concentrations ranged from 5 to 2592 $Bq\cdot m^{-3}$ with an updated preliminary arithmetic mean of 133 $Bq\cdot m^{-3}$, and a geometric mean of 90 $Bq\cdot m^{-3}$. In about 6% of the investigated grid cells the indoor radon concentrations exceed the threshold of 300 $Bq\cdot m^{-3}$. The soil gas radon concentration varies from 0.8 to 169 $kBq\cdot m^{-3}$, with a geometric mean of 28.4 $kBq\cdot m^{-3}$. For water samples, the results show radon concentrations within the range of 0.3–352 $kBq\cdot m^{-3}$ with a geometric mean of 7.7 $Bq\cdot L^{-1}$. The indoor radon map was plotted on a reference grid developed by JRC with the resolution 10×10 km^2.

1. Introduction

Exposure to radon in homes and workplaces is now recognized as the most important natural factor in causing lung cancer (UNSCEAR, 2000; Darby et al., 2006; Field et al., 2006; WHO, 2009; ICRP, 2010; Council Directive 2013/59/Euratom European Council, 2014). The main source of radon in homes is usually the soil under the construction, whose content in radon ranges from a few $kBq\cdot m^{-3}$ up to hundreds of $kBq\cdot m^{-3}$. Besides the concentration of radon in soil, soil permeability can also vary in a wide range (Cosma et al., 2013a). When there are high concentrations of radon in soil near a house, there should also be high radon content in nearby well waters (Moldovan et al., 2014). Therefore, measurements of radon in soil and water can provide valuable indicators of radon potential of an area (Cosma et al., 2013a). A second cause of indoor radon, especially in the rooms upstairs, is linked to radon emanation from building materials (Cosma et al., 2013a).

Given the important role (second after smoking) played by radon in triggering lung cancer (Darby et al., 2006; Field et al., 2006), authorities and national organizations with responsibilities in the field of radiation protection and public health have initiated research studies focused on monitoring this gas (UNSCEAR, 2000; WHO, 2009; ICRP, 2010; Tollefsen et al., 2014) and established methods to reduce and prevent its entry indoors (Holmgren et al., 2013; Cosma et al., 2013b, 2015). The international organizations which aim at protecting the public and the environment from exposure to radiation (UNSCEAR, WHO, IAEA, IRPA, ICRP) are recently paying an increased interest to radon exposure and radiation protection measures (Bochicchio, 2011; Council Directive 2013/59/Euratom European Council, 2014). The Joint Research Centre of the European Commission started an initiative to develop a map of exposure to natural radiation for the European population (European Atlas of Natural Radiation), in which the map of residential radon exposure holds a very important role and it is presently in full progress (Tollefsen et al., 2014). Across all participating European countries, 30% of the cells present arithmetic mean higher than 100 $Bq\cdot m^{-3}$ and 4.2% higher than 300 $Bq\cdot m^{-3}$. The highest values were identified for the Czech Republic, with 90% of cells exceeding 100 $Bq\cdot m^{-3}$. The high percentage obtained for Estonia is associated with measurements carried out mainly in areas with increased risk of radon. The lowest exposure risk was

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found at cells with data reported by the Netherlands which do not show arithmetic means exceeding the reference level (Tollefsen et al., 2014).

This European Indoor Radon Map strongly demonstrates how differently European countries are affected by the problem of radon. On this chart, from 24 European countries participating in the mapping initiated by the European Commission (at May 2014), Romania is ranked 4th on the risk of exposure to radon, with 65% of cells showing mean concentrations of radon exceeding 100 Bq·m^{-3} and 10% higher than the action level of 300 Bq·m^{-3}, giving a strong indicator of how serious is the problem of residential radon in our country (Tollefsen et al., 2014).

The radon studies in Romania had an early start. Systematic measurements of residential radon began around 2000 with the acquisition of Radosys 2000 equipment (Hungary). The first regions targeted for research were in the Băiţa-Ştei radon prone area and in Someş Valley due to the increased radioactivity (Cosma et al., 2009a,b). Preliminary results obtained during 2000–2010 for different areas of Transylvania were already published (Cosma et al., 2009a) and included in the 2012 European Indoor Radon map (Cosma et al., 2013b). Based on these measurements a pilot European program was funded to mitigate a selected lot of houses in the Băiţa-Ştei area (Cucoş et al., 2012; Cosma et al., 2013a; 2015). Measurements of radon in schools and kindergartens were also conducted (Szacsvai et al., 2013).

Since 2013, in the frame on an ongoing project, comprehensive surveys of radon in homes, soil and water for roughly 40% of the Romanian territory (16 counties out of 42) have been begun with the aim to create a radon database. This paper presents the results of radon measurements in homes, soil and water in 5 of those 16 counties. The main purpose of our survey is to complete the preliminary Romanian Indoor Radon Map with 5000 additional indoor radon data, and respectively 3000 radon measurements in soil and water.

2. Materials and methods

The study area was divided into cells of 10 × 10 km^2, according to grid defined for the European Indoor Radon Map. Measurements of indoor radon and soil nearby were carried out in each inhabited cell during 2013–2016, as well as water samples (well or spring) for radon in water. The working protocol followed the JRC recommendations (Tollefsen et al., 2014). The average number of indoor radon measurements per cell was 4 ± 2, and an average number of 3 radon measurements per cell, in soil and water. According to the population density, the number of the indoor radon measurements varied from 3 to 15 measurements per cell, except the Băiţa-Ştei, a radon prone area, where 428 measurements per cell were made.

2.1. Indoor radon measurements

For indoor radon measurements solid-state nuclear track detectors based on CR-39 (RSKS type, RadoSys, Hungary) were used and the tracks were later processed in our laboratory following the manufacturer protocol. The detectors were exposed indoors for periods between 3 and 6 months. The annual concentration was calculated using the methodology already described (Cosma et al., 2009a; Cucoş et al., 2012).

To date, approximately 5000 detectors were placed, from which 1000 are in processing stage. Together with the detectors, radon measurements in soil and water were performed, using the LUK 3C device and LUK 3C with Luk-VR scrubber, respectively (Cosma et al., 2008). For the selected dwellings within each cell (village, town, city), we had the support of local authorities (mayors, professors, medical personnel or local authorities). Each detector deployed was accompanied by a questionnaire about the owner's identification, geographical coordinates, construction material information, construction year, existence of basement, placement of detector (bedroom or living room) and the source of drinking water.

After completion of exposure, all detectors were brought to the laboratory, etched and read 3 times each. The etching process is based on the protocol presented in our earlier surveys (Sainz et al., 2009; Cucoş et al., 2012).

To ensure the accuracy of results, the correction factors for the seasonal measurements (Cosma et al., 2009a) and also for the storage of detectors recommended by the manufacturer were applied.

A requisite program for quality assurance of data obtained by passive detectors was continuously applied through participation in intercomparison exercises carried out in Japan (Janik et al., 2009; Janik and Yonehara, 2015), Spain (Gutiérrez-Villanueva et al., 2011; Burghele and Cosma, 2013; Papp et al., 2013), Czech Republic (Jílek and Marušiakova, 2011) or Germany. Additional testing was carried out in our own laboratory during the FERAS Symposium of 2012 (Papp et al., 2016).

2.2. Radon in soil measurements

The measurements of radon in soil were carried out with the LUK3C radon device by applying the Neznal method which is widely described in (Cosma et al., 2013a). Radon gas was collected from a depth of 60–80 cm.

The metrological control of instruments was regularly implemented in our laboratory by attending international intercomparisons carried out in Czech Republic (2010, 2012, 2014), Spain (2012) and Serbia (2014) (Papp et al., 2013).

2.3. Radon in water measurements

Radon in water measurements were performed by using the above mentioned LUK 3C instrument with the Luk-VR scrubber as the principal accessory. The method is previously described in (Cosma et al., 2008; Moldovan et al., 2014). Quality assurance was achieved through participation at the intercomparison exercise carried out in Spain in 2012 (Papp et al., 2013).

2.4. Statistical analysis

The statistical distribution of the log-transformed data was tested by Shapiro-Wilk test. The Spearman correlation coefficient was calculated in order to evaluate the relationship between the measured parameters. The comparison between samples was made with non-parametric Kruskal-Wallis test. The significance level was chosen at $\alpha = 0.05$. The data analysis was conducted by using Minitab 16.

3. Results and discussion

This paper presents the results (residential radon, radon in soil and water) for 5 counties of Romania (Alba, Arad, Bihor, Cluj and Hunedoara) out of the 16 counties which will be completed by the end of 2016. We mention that the analysed 5 counties (during 2013–2016) comprised 492 grid cells of 10 × 10 km^2, of which 415 inhabited cells and 77 without any localities. In the empty cells, radon measurements were not performed.

As the most valuable indicator of the project, a representative database was created, which contain the obtained results for residential radon, together with the geographic coordinates, values of radon concentration in soil and in water, as well as those on structural characteristics of the targeted dwellings.

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