 ORIGINAL PAPER

Radon and thoron parallel measurements in dwellings nearby a closed Hungarian uranium mine

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Abstract. Integrated measurements of radon (^{222}Rn) and thoron (^{220}Rn) were executed in a Hungarian village, located in the vicinity of an abandoned uranium mine. The applied passive radon and thoron monitor was the RADUET which is based on a CR-39 track detector. The investigated 35 houses were one storey buildings made of bricks. The rock under the village is a gray-sandstone with an average of 136 and 77 Bq·kg^{-1} uranium and thorium, respectively. The detectors were mostly placed in the inhabited areas of the houses, such as bedrooms and living-rooms, at a height of 1–1.5 m close to the wall. The measurement periods were between December 2006 and May 2007 and between May 2007 and February 2008. Annual averages of radon concentrations were calculated applying seasonal correction factors to the results of the two measurement periods. The results show that the radon concentrations in the case of considerable part of the investigated dwellings seems to be significantly higher than the Hungarian averages for ground-floor houses (152 Bq·m^{-3}). The thoron concentrations in some cases are also not negligible indicating that radon measurements which are sensitive to thoron can be misleading. Additionally, thoron can also be a contributor of extra dose.

Key words: radon • thoron • dwelling

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Introduction

As it is known, the radon (^{222}Rn) gas and its progenies are considered to be the major contributors to human exposure from natural radiation sources [1]. Several surveys seem to have concluded that the radon in the living environment implies an increased health risk [3, 9, 18]. This is the reason why national authorities and international organizations issues guidelines concerning radon levels in homes.

Although radon has the main concern among the health physicists, thoron also needs attention. Previous studies have shown that thoron (^{220}Rn) was find in a not negligible extent in traditional Japanese houses [5, 10, 15], in dwellings of Mexico City [11] and it has gained an important part in surveys in India [12] and China [7, 13].

The presence of thoron can have an effect on accurate radon measurement [14] and thoron itself might result in radiation exposures comparable to those due to radon [2]. The measurement of thoron is usually more complicated than radon measurement. Thoron concentration is highly inhomogeneous with a strong dependence on the distance from the source [6].

In this paper a radon survey executed in a Hungarian village, located in the vicinity of an abandoned uranium mine are described. Seasonal correction factors were applied to the lesser-than-one-year measurements in order to calculate the annual averages of radon concentrations.

Radon measurements executed earlier in this village showed higher levels here than the characteristic one for Hungarian villages [16]. Our former investigations also indicated elevated radon levels in this village [8].

Methods and measurements

The applied passive alpha track etch detector was the RADUET. The RADUET is a twin detector containing a plastic container with a CR-39 polycarbonate plate inside only for radon detection and an almost identical another container enhancing its air change for detecting both radon and thoron. The two parts of the twin detector are implanted in a cardboard holder which helps to keep the appropriate distances from the wall (95 mm between the wall and the center of the container). These detectors were developed in a collaboration of the National Institute of Radiological Sciences (NIRS), Chiba, Japan and a Hungarian factory, RADOSYS. The detectors were sent to NIRS for evaluation.

The village chosen for this study was Kővágószőlős with 1200 inhabitants. It is located in the Mecsek Mountains in the south part of Hungary. There is an abandoned uranium mine in the vicinity of the village and some tunnels are located under the dwellings. The investigated houses were one storey buildings made of bricks.

The bedrock in that region is a gray-sandstone. The analysis of the drill cores taken from a depth of 1–2 m in the soil of the village showed that the average content of uranium and thorium were 136 and 77 $Bq \cdot kg^{-1}$, respectively. These values exceed the world averages [17] (33 and 45 $Bq \cdot kg^{-1}$).

The detectors were placed mostly in the inhabited areas of the houses, such as bedrooms and living-rooms, at a height of 1–1.5 m in a way that the cardboard holder is situated close to the nearest wall for keeping the appropriate distance. This was important for the thoron measurement.

The measurement periods were between December 2006 and May 2007 and between May 2007 and February 2008. The number of the investigated dwellings was 43, but in 8 cases one of the detectors was lost or damaged, therefore, only in 35 cases the authors got information for both measurement periods.

Annual averages of radon concentration were calculated applying seasonal correction factors to the results of the two measurement periods. Radon levels in the domestic built environment are assumed to vary systematically during the year, being generally higher in winter than in summer. The seasonal correction factors comprise a series of numerical multipliers, which convert a 1- or 3-month radon concentration measurement, commencing in any month of the year, to an effective annual mean radon concentration [4]. In this case seasonal correction factors for 1-month exposures suggested by Woods *et al.* [19] were used to calculate the appropriate factors to the measurement periods. Table 1 shows the above-mentioned seasonal correction factors for 1-month exposures suggested by Woods *et al.* [19]. These seasonal factors were normalized to 12 months. This means that the sum of the 12 monthly factors equals 13.4. 12 divided by 13.4 resulting in "normalized" factor equals 0.89. Each monthly factor was multiplied by the normalized factor providing the "normalized" values for each month. As correction factors, the authors have applied the arithmetical mean (AM) of the normalized seasonal correction factors for 1-month exposures taking into consideration the given months. Consequently, the multiplying factor for the measurement period of December–April was 0.71. The AM of the five appropriate values are from Table 1 (0.70; 0.61; 0.64; 0.72; 0.89). Using the same method, the applied multiplying factor for the period of May–February was calculated as 1.04. We are aware that these seasonal correction factors may not fit perfectly to our case, however, the inaccuracy can be acceptable.

Table 1. Seasonal correction factors for 1-month exposures [19] and the normalized values

Month	Correction factors	Normalized factors
January	0.68	0.61
February	0.72	0.64
March	0.81	0.72
April	1.00	0.89
May	1.18	1.05
June	1.39	1.24
July	2.00	1.79
August	1.65	1.47
September	1.30	1.16
October	1.04	0.93
November	0.88	0.79
December	0.78	0.70

Results and discussion

The annual radon concentrations in the 35 dwellings calculated from the data coming from the two measurement periods can be seen in Fig. 1. The values coming from the 10 months long measurements are systematically higher than the other ones provided by the 5-months long measurements. The reason can be the yearly variations and – more probably – the inaccuracy of the applied correction method.

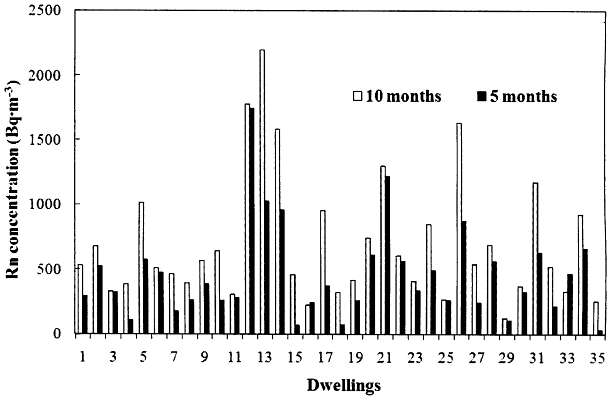

Fig. 1. The annual radon concentrations in the 35 examined dwellings.

Table 2. The number of dwellings characterized by radon concentration level above 200, 400, 600 and 1000 Bq·m^{-3}

Annual average Rn concentration (Bq·m^{-3})	Number of dwellings (%)	
	10-months survey	5-months survey
> 200	34 (97%)	29 (83%)
> 400	26 (74%)	15 (43%)
> 600	15 (43%)	7 (20%)
> 1000	7 (20%)	3 (8.5%)

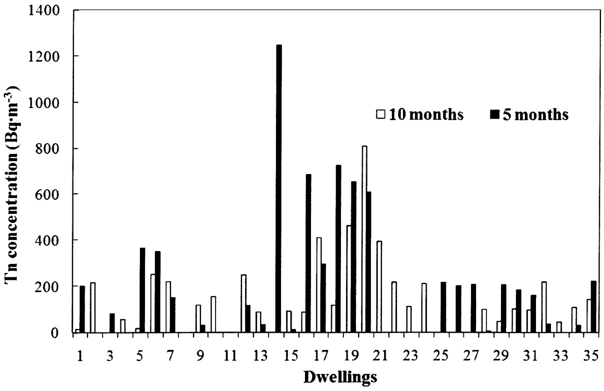

Fig. 2. The measured thoron concentrations.

The average radon concentrations in the two survey (10 months and the 5 months) are 700 (122–2195) and 458 (37–1445) Bq·m^{-3}, respectively.

The number of dwellings characterized by radon concentration level above 200, 400, 600 and 1000 Bq·m^{-3} can be seen in Table 2.

The results show that the radon concentrations in the case of considerable part of the investigated dwellings seems to be significantly higher than the Hungarian averages for ground-floor houses (152 Bq·m^{-3}). The thresholds in the first column of Table 2 correspond to different values advised by international and national guidelines. In Hungary, at this moment, there is no official limit for radon concentration in houses.

The results of the thoron measurements can be seen in Fig. 2.

The presence of thoron in some cases seemed to be not negligible. However, a considerable part of the data provided by the detectors were unusable or unrealistic; therefore, they are not presented in Fig. 2. The reason of this unreliability needs further examinations. The restricted number of results is not enough to be a basis of an accurate estimation of dose due to the thoron, or to calculate an average for thoron concentration in the investigated dwellings. Because the applied radon detector is not sensitive to thoron, these results are not considerably influenced by radon detection.

Conclusion

Integrated radon measurements were executed in a Hungarian village, located in the vicinity of an abandoned uranium mine. The applied detector was the RADUET, which is constructed to measure thoron parallel with radon. The detectors were placed in two periods – a 5- and a 10-months long. The number of the investigated dwellings was 35. Annual averages of radon concentrations were calculated applying seasonal correction factors. The results show that the radon concentrations in the case of considerable part of the investigated dwellings seems to be significantly higher – with calculated yearly averages of 700 (122–2195) and 458 (37–1445) Bq·m^{-3} according to the two surveys – than the Hungarian averages for ground-floor houses (152 Bq·m^{-3}).

The thoron concentrations in some cases are also not negligible, indicating that radon measurements, which are sensitive to thoron, can be misleading.

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