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Comparison of radon doses based on different radon monitoring approaches

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A B S T R A C T

In 43 places (23 schools, 3 kindergartens, 16 offices and one dwelling), indoor radon has been monitored as an intercomparison experiment, using α-scintillation cells (SC – Jožef Stefan Institute, Slovenia), various kinds of solid state nuclear track detectors (KfK – Karlsruhe Institute of Technology, Germany; UFO – National Institute of Radiological Sciences, Chiba, Japan; RET – University College Dublin, Ireland) and active electronic devices (EQF, Sarad, Germany). At the same place, the radon levels and, consequently, the effective doses obtained with different radon devices differed substantially (by a factor of 2 or more), and no regularity was observed as regards which detector would show a higher or lower dose.

1. Introduction

In the Slovenian national radon programme, in the last two decades radon (^{222}Rn) has been surveyed in approximate 1400 homes and 1700 public buildings (Vaupotič, 2003). Radon concentrations exceeding the national limit of 400 Bq m^{-3} (ULRS, 2004) have been found in approximate 8% of buildings, mostly situated on highly porous and permeable carbonate bedrock (Popit and Vaupotič, 2002).

Various measurement techniques and protocols have been used, primarily depending on the equipment currently available and financial support. In all the 730 kindergartens (Vaupotič et al., 1994a) and all the 890 schools (Vaupotič et al., 2000), and about hundred other public buildings (spas, hospitals, wineries, offices) (Vaupotič, 2003), radon screening was performed using Lucas type α-scintillation cells (Vaupotič et al., 1992). The screening was followed by additional thorough measurements in places of more than 1000 Bq m^{-3}, and then of more than 400 Bq m^{-3}, aimed at assessing radon doses, as the criterion on which to decide whether a place needs mitigation or not. For that purpose, solid state nuclear track detectors, mostly provided from the Karlsruhe Institute of Technology (Urban and Schmitz, 1993), were exposed for defined periods of time. During these periods, also short-term continuous radon monitoring was carried out using AlphaGuard (at that time Genitron, Germany), and EQF and Radon Scout devices (both Sarad, Germany).

In the first campaign in dwellings, solid state nuclear track detectors, manufactured at the Jožef Stefan Institute (Šutej et al., 1988) were exposed for three winter months in the living rooms of about a thousand randomly selected dwellings in houses and blocks of flats all over the country, regardless of which floor (Humar et al., 1992). In the second, recent radon campaign (Vaupotič et al., 2013), radon was measured in 400 dwellings by exposing solid state nuclear track detectors twice a year for six months, in living rooms in the ground floor. Detectors were provided from the Landauer Nordic, Sweden.

In comparison to radon, the thoron (^{220}Rn) survey has been rather modest and not systematics, comprising only 12 homes, 6 kindergartens, 42 schools and 22 other public buildings (Vaupotič et al., 2008, 2012; Vaupotič and Kávási, 2010). For that purpose, the UFO (National Institute of Radiological Protection, Japan) and

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Raduet (Radosys, Hungary) solid state nuclear track detectors have been used. Thoron levels have always been lower than those of radon, with the ratio amounting to 0.03–0.83.

The present work has been designed as an intercomparison experiment for several of radon devices used in our previous radon surveys. The retro detectors were added to the choice, as a potential technique to be used in our future work to assess the exposure of residents during their year-long stay in dwellings subject to past reconstructions. For the experiment, 43 buildings were chosen of already known elevated radon levels, comprising 23 schools, 3 kindergartens, 16 offices and a dwelling. Based on the obtained radon activity concentrations, effective doses have been calculated and their comparison discussed. The obtained results are a solid basis to critically assess the effective doses shown by different radon measuring techniques and consider them on a common scale.

2. Experimental

2.1. Selected places

For this work, 49 rooms in 43 buildings were chosen as a result of their elevated radon levels. They are in villages mostly in the karstic west-southern part of the country (Fig. 1), where the majority of high radon spots had been found in previous surveys (Vaupotič, 2003). The choice comprised 23 schools, 3 kindergartens, 16 offices and one dwelling. Radon was measured in only one room in each kindergarten. Only one room was considered also in the majority of schools, except in two schools where 2 rooms were surveyed and in another two schools with 4 rooms surveyed. In each of the four offices, 3, 4 or 6 rooms were considered. In kindergartens, mostly playrooms were surveyed, in schools, classrooms, and in offices, the working rooms. The buildings varied in age, size, type and quality of construction and are only naturally ventilated. The dwelling building is in the karst region and is connected to a small karst cave. Measurements were carried out in the kitchen, living room, bedroom, garage, workroom and the nearby karts cave. Although in buildings, a room on the ground floor was primarily preferred, measurements have also been carried out on the first floor or basement (Table 1).

2.2. Radon measuring devices

The devices (though not all) were included in the experiment as were mostly used in our previous radon surveys.

In a selected room of all the 43 buildings, the air was sampled into Lukas type α-scintillation cells (SC) (Vaupotič et al., 1992), in the morning hours during normal working time. Activities were measured in the laboratory in a PRM-145 α-counter (Ames, Ljubljana, Slovenia) and instantaneous radon activity concentrations obtained. Measurements were carried out in the period of October 8–22, 2004.

In 18 rooms, in which SC had shown the highest instantaneous radon activity concentrations, the solid state nuclear track detectors, purchased from the Karlsruhe Institute of Technology (KfK) (Urban and Schmitz, 1993), were exposed in the period from October 22 to November 24, 2004, to obtain average radon activity concentrations; they were placed on a wooden shelf or cupboard, 1–1.5 m above the floor and 0.4–0.5 m from any wall.

In 14 of the above 18 rooms, the UFO solid state nuclear track detectors (UFO) were exposed in the period from October 26 to November 24, 2004, in order to find both radon (^{222}Rn) and thoron (^{220}Rn) activity concentrations. The detectors used, were developed at the National Institute of Radiological Sciences, Inage, Japan (Doi and Kobayashi, 1994) and donated to the Vinča Institute of Nuclear Sciences, Belgrade, Serbia (Žunić et al., 2003). They were placed close to the KfK detectors.

Table 1
Number and percentage of measurements in each building category by floor.

Building	Cellar	Ground floor	First floor
Schools	9 (39%)	14 (61%)	0 (0%)
Kindergartens	1 (33%)	2 (67%)	0 (0%)
Offices	0 (0%)	14 (87.5%)	2 (12.5%)
Home	3 (43%)	3 (43%)	1 (14%)

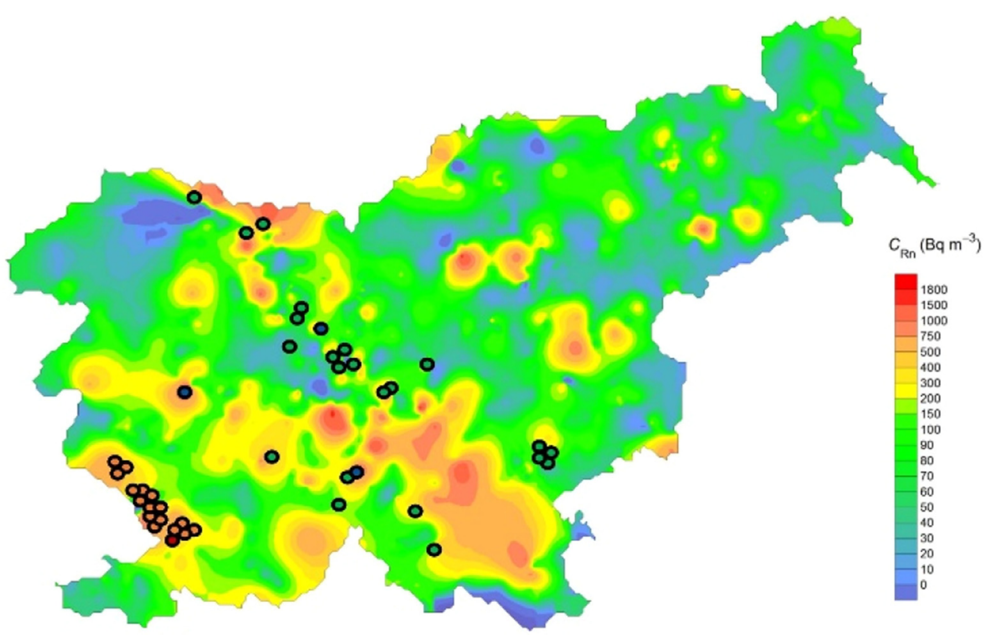

Fig. 1. Locations of measurement sites of the present study, shown by dots in the Radon map for Slovenian kindergartens and schools (Vaupotič et al., 2013). (schools, kindergartens, offices, home).