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Research article

Indoor radon and thoron concentrations in some towns of central and South Serbia

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ABSTRACT

This study presents the results of indoor radon and thoron activity concentrations of some municipalities in central and south part of Serbia: Krusevac, Brus, Blace and Kursumlija. Measurements were carried out in 60 dwellings during the winter season. Passive discriminative radon-thoron detectors known as UFO detectors were used. The mean values of indoor radon and thoron concentrations were 82 Bq m^{-3} and 42 Bq m^{-3}, respectively. Population-weighted mean values were 76 Bq m^{-3} and 40 Bq m^{-3}, respectively. 26.7% of dwellings had radon concentration higher than 100 Bq m^{-3} (one location had even more than 300 Bq m^{-3}). There are no statistically significant correlations of indoor radon and thoron concentrations neither with the period of house construction, nor with the existence of a basement. The results of this study represent the first step of investigating radon and thoron levels in these parts of Serbia and therefore could be the basis for creating a radon map.

1. Introduction

Radioactive gases, radon (^{222}Rn) with half-life of 3.824 days and thoron (^{220}Rn) with relatively short half-life of 55.6 s are present in the indoor environment since their parent nuclei ^{226}Ra and ^{232}Th are present in building materials and soil. The contribution of radon to radiation dose was recognized long time ago while the significance of thoron has recently been established. At some locations thoron concentration can be comparable or even higher than that of radon (Tokonami et al., 2004; Janik et al., 2010).

After smoking, residential radon is the second leading cause of lung cancer and the first in non smokers (Field, 2011; ICRP, 1987; UNSCEAR, 2000; Zeeb and Shannoun, 2009; Al-Zoughool and Krewski, 2009). Lung cancer has the highest mortality rate of all cancers (National Cancer Institute, 2007) and it is the second most commonly diagnosed cancer. Inhalation is the primary route of radon entry into the body. A man spends about 80% of time indoors so it is important to determine indoor radon concentrations.

Radon and its progenies distribute homogeneously in indoor air while it does not apply to the short-living thoron and its progenies. Thoron concentration is highly inhomogeneous with a strong dependence on the distance from the source. It is known that thoron concentration decrease with increasing of distance from wall surfaces. On the other hand, thoron progenies are sufficiently long lived, so that motion and turbulent mixing can be assumed to lead to an approximately uniform distribution in a room, but very sensitive to air exchange (Cliff et al., 1992; Meisenberg and Tschiersch, 2011; Mishra et al., 2014).

The objective of this study was to carry out simultaneous measurements of radon and thoron in dwellings of some municipalities in central and south part of Serbia: Krusevac, Brus, Blace and Kursumlija. It was the first step of investigating radon and thoron levels in these areas.

2. Investigated area

The study included 60 houses located in the municipalities of Krusevac (44 houses), Brus (4 houses), Blace (2 houses) and Kursumlija (10 houses). Fig. 1 presents a map of the investigated areas.

Krusevac (43°35′N, 21°19′E) is located in the central part of Serbia. According to official census, the city has a population of

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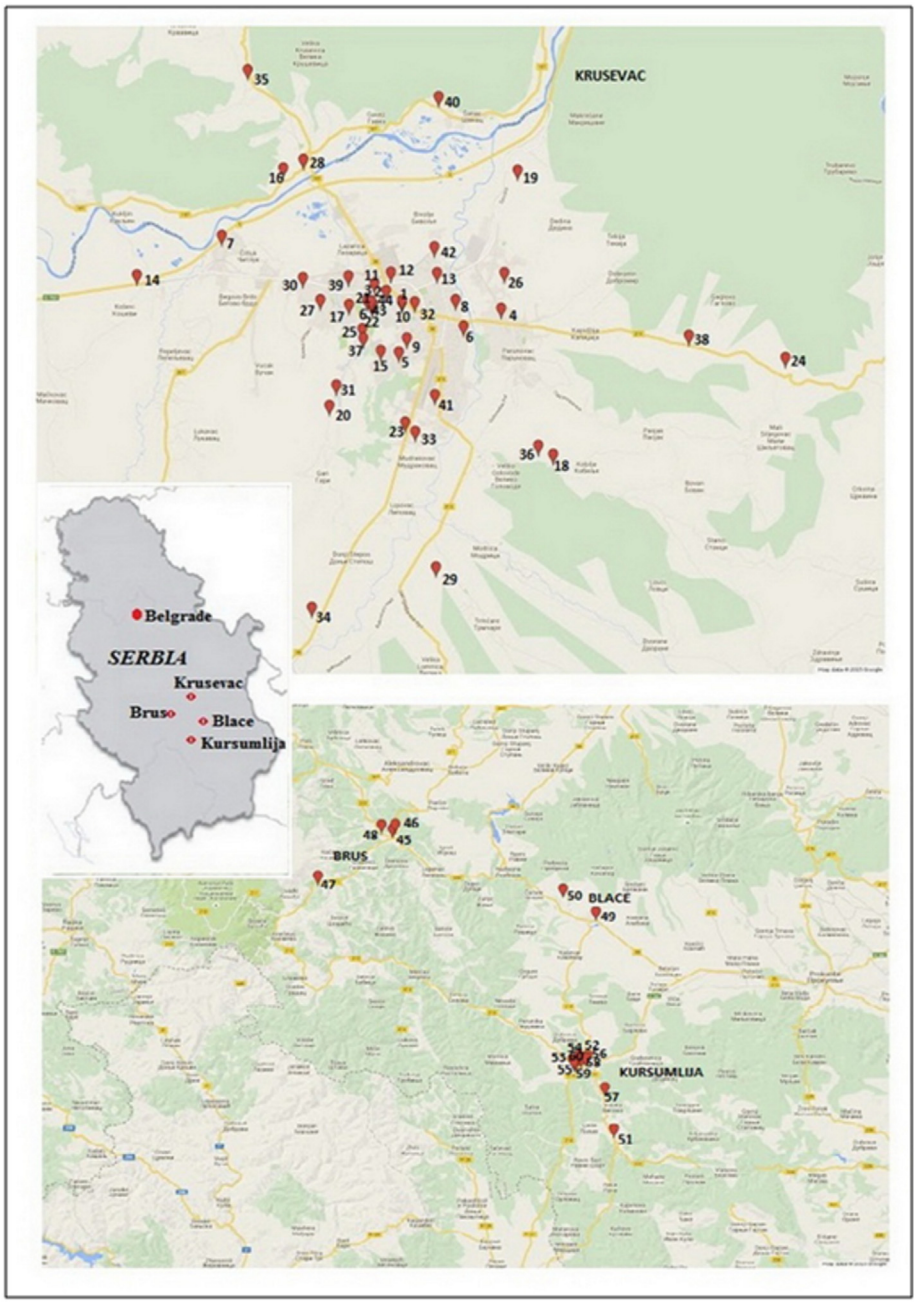

Fig. 1. Map of investigated places in central and southern part of Serbia.

64 500 inhabitants while 131 386 inhabitants live in the surrounding areas. Municipality of Brus (43°23′N, 21°02′E) stretches in the central and south-eastern part of Serbia. Around 5000 inhabitants live in this town. Blace (43°17′N, 21°17′E) is small municipality located on eastern slopes of mountain Kopaonik and south-western slopes of mountain Jastrebac. About 6000 inhabitants live in this town. Kursumlija (43°08′N, 21°16′E) is situated in the western part of southern Serbia with around 22 000 inhabitants.

This part of Serbia was affected by strong tectonic events in the geological past which reflected in the proliferation of igneous and metamorphic rocks. In geological terms this area is rich in granitoide, diabases of Cretaceous age, and also rich in schist (Lower Triassic) and carbonate rocks (Upper Triassic) (Sehic, 2007).

3. Materials and methods

Indoor radon and thoron measurements were carried out from November 2014 to February 2015. The time interval of exposure was 90 days. Detectors were placed in rooms where people spend most of the day (living room or kitchen). A great variability of thoron concentration with increasing the distance from wall caused a well-planned and defined placement of detectors (Mishra et al., 2014). Since the measurement of indoor radon and thoron concentration were performed simultaneously, detectors were placed at an optimal distance of 20 cm from walls. Indoor radon and thoron concentrations were measured using passive discriminative dosimeters developed at NIRS, Chiba, Japan (Doi et al., 1994; Zunic et al., 2010), Fig. 2.