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AN ANALYSIS OF FACTORS AFFECTING THE HIGH RADON CONCENTRATION IN DIFFERENT TYPES OF HOUSES

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ABSTRACT

This paper presents an analysis of indoor radon measurements carried out in municipality of Zubin Potok, northwestern part of Kosovo and Metohija. Annual measurements in two rooms of each house were performed by solid state nuclear track detectors commercially known as Gammadata. Average indoor radon concentration in different type of houses varied from 29-326 Bq/m^3. A different year of house's construction including various types of building materials were selected for survey. A detail analysis showed that the differences in radon concentration occur between various building materials used for construction, flooring level, type of room and behavior of inhabitants. It was found that building materials in some houses contribute additionally to indoor radon.

Keywords: Indoor radon concentration, house, building materials.

INTRODUCTION

Radon is unique gaseous product in uranium and thorium decay series. Two, the most prominent isotopes are radon (Rn-222) and thoron (Rn-220) which occurs in disintegration of series U-238 and Th-232, respectively. Their importance increases with their half-lives; 3.825 days for radon, and 55.6 seconds for thoron (UNSCEAR, 2006). The occurrence of Rn-222 in mineral grains is the result of direct emanations of radium Ra-226. The most significant sources of radon are granite, uranium ores, volcanic and phosphate rocks, gneisses, *etc*. Since soil originates by the decomposition of rocks, it could be a major source of radon in indoor air. Soil gas radon can enter buildings through cracks by pressure-driven mechanism. The relatively long half-life allows it enough time to transport and homogenous mixing in a room (UNSCEAR, 2006; Gulan, 2015; Vuckovic et al., 2016). Radon exhalation from the soil depends on several factors: concentrations of radium in soil, permeability and moisture of soil, state of vegetation cover, weather conditions. Meteorological conditions, lifestyle and occupant's habits could contribute more-less to the radon variations in indoor environments.

Average annual effective dose from different sources of radiation is presented in Fig. 1. Major contribution to public exposure relate to inhalation of radon and thoron (UNSCEAR, 2008). This is because people spend more time indoors in homes or workplaces (about 80%); that's the way to radon inhalation, and hence increasing the potential risk to lung cancer (UNSCEAR, 1993; ICRP, 1993; Darby et al., 2005; WHO, 2009). No level of radon is considered to be safe.

A number of European countries (United Kingdom, Sweden, Norway, Spain) established national guidelines for radon of 200 Bq/m^3 for both existing houses and new construction; other countries (Finland, Germany, Greece, Italy) determined 400 Bq/m^3 as upper limit for existing houses and 200 Bq/m^3 for new construction (CEC, 1990; Alghamdi & Aleissa, 2014).

Worldwide indoor radon concentrations vary widely from a few Bq/m^3 to more than $7 \cdot 10^4$ Bq/m^3 in high-background area (UNSCEAR, 2006). The higher indoor radon concentrations occur in the autumn or early winter and lower in the summer (Kurnaz et al., 2011; Alghamdi & Aleissa, 2014). Seasonal variation of radon indoors affects several parameters: the object, the source of radon, household habits, air ventilation and heating.

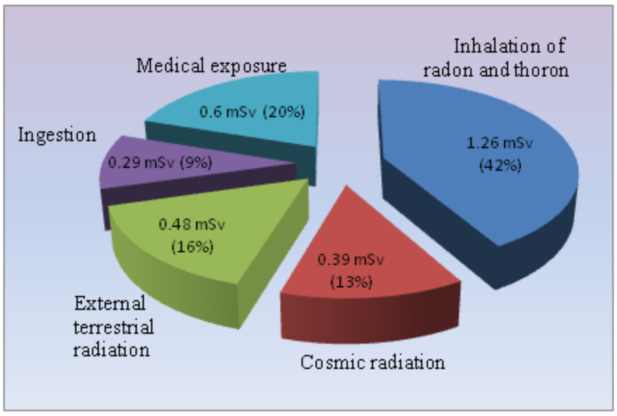

Figure 1. Average annual effective dose from different sources of radiation (UNSCEAR, 2008)

Active and passive methods (techniques) for radon monitoring have been developed. First method is used for short-term radon measurements and for preliminary inspection of sites. Second method which allows long time measurements (from 1 month to 1 year) is more suitable. Some recent large-scale surveys in Balkan region were performed with passive monitoring devices (Kavasi et al., 2007; Forkapic et al., 2007; Žunić et al., 2010; Milić et al., 2011; Stojanovska et al., 2012; Gulan et al., 2012; Gulan et al., 2013; Gulan, 2015; Vuckovic et al., 2016).

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The aim of this paper was to investigate possible differences and influence of building characteristics on indoor radon concentration based on specific analysis, as well to estimate impact of geology on high indoor radon.

EXPERIMENTAL

Materials and methods

Annual indoor radon measurements were conducted from April 2011-2012 in Zubin Potok municipality, northwest part of Kosovo and Metohija. In order to investigate the factors affecting the indoor radon, the preliminary survey was carried out in two rooms of five specific houses selected according to few criterion. This included the following items:

a) different types of house;

b) different year of house's construction;

c) different types of building materials used for house's construction;

d) different room's type;

e) measurement points at different floor of house.

Passive method of radon measurements with solid state nuclear track detectors (SSNTD) was applied. The CR-39 detectors, known as Gammadata were deployed on shelves of furniture at height of 1.5 m above floor and at the distance of 20 cm from the walls of living rooms/kitchens and bedrooms.

After exposure, the detectors were collected, packed and transported for the shortest possible time to laboratory. They were subjected to standard protocols of etching and readout of alpha tracks in well-controlled calibration chambers for radon. Uncertainty of radon measurements was less than 16% (Gulan, 2015).

In the term of geomorphology, Ibar valley is dominated on the relief of investigated area; this was a result of exogenous influences: glacial erosion, fluvial erosion and denudation; orogenesis was created on the basis of the huge mass of limestone rocks. The alluvial surface around River Ibar was created due to the erosive expansion of soft phyllites. Extensions consist of Quaternary sediments with alluvial (river terraces) and dilluvial horizons in the sludge layer, the sand and gravel. Terraces consist of gravel, marl and limestone, and rather than serpentinite and crystalline schists, which also depends on the geological composition of the terrain (Strategija razvoja opštine Zubin Potok, 2013).

RESULTS AND DISCUSSION

A range of indoor radon concentration in different houses varied from 29-421 Bq/m^3. Some important notes were observed. An analysis for each investigated house follows.

The lowest, but the same value of radon concentration in both rooms was measured in a floor house built from bricks 30 years ago. The approximate uniformity in radon distribution exists in the different rooms on the same floor. If the walls, ceilings and floors are made of the same building materials on the same floor, possible differences in the concentration of radon between the two rooms on the same floor can appear due to habits of the household, heating and ventilation (Denman, 2007).

Two floor houses of different age were subjected to investigation; one built 3 years (new house) and other 30 years (old house) before measurements. Radon concentrations were higher at ground level of both, new and old houses (246 Bq/m^3 and 156 Bq/m^3), respectively. It was expected, since earlier studies about impact of floor level on radon concentration confirmed that radon concentrations in multi-story building were higher in basement, *i.e*. ground level (Chao et al., 1997; Kurnaz et al, 2011; Popovic & Todorovic, 2006). Surprisingly, relatively high radon concentrations of 192 Bq/m^3 and 86 Bq/m^3 were noted at floor rooms of new and old houses, respectively. On the one hand unexpected, the average radon concentration was higher in new house. A type of this house is large ground-living room with open stairways to first floor. One reason for difference in radon concentration is tightly closed PVC doors and windows in new house in comparison to wooden joinery in old house. Also, high radon concentration in these cases could be probably induced by exhalation from walls of mortar and lime. The old house had wallpapers. Some building materials have been recognized as possible sources of high radon concentration, like materials containing by-product gypsum. Nonetheless, high content of radionuclides in nearby soil could affect radon accumulation.

Radon concentrations were 73 Bq/m^3 in living room and 65 Bq/m^3 in bedroom of prefabricated ground-floor house built 10 years ago. This is very rarely type of house in Kosovo and Metohija, and because of that it was very interesting for survey. Construction is quite different from commonly built houses in this area, since it only has strong concrete slab, wooden floor and plasterboard walls filled with Styrofoam (polystyrene foam). It is notable that radon is almost equal in both rooms, although their purpose and distance from front door are different.

The highest radon was measured in ground-floor house built from local stone and mud approximately 70 years ago. This house is without slab and floor is decking. The relevant differences in radon occurred between rooms of the house; concentration was 231 Bq/m^3 in the kitchen and 421 Bq/m^3 in the bedroom. The first reason of such a large difference could be existence of radon source in certain parts of the house. Secondly, purpose of room (*i.e.* bedroom), as well as its higher distance from the front door could affect the difference in concentration of 190 Bq/m^3. Bedrooms are usually smaller than living rooms or kitchen, and more often closed, and consequently less ventilated (Alghamdi & Aleissa, 2014). Some studies found that building materials used for construction of houses represent a significant source of indoor radon (Righi & Bruzzi, 2006). Useful information about geological features near building was obtained from occupants; since Ibar River flows through Zubin Potok, there are mostly sandy soils. Some authors reported that a significant correlation has been found between indoor radon and geological characteristics of nearby soil (Sundal et al., 2004).

Seasonal variation in indoor radon concentration (such are various meteorological conditions, usage of ventilation systems, *etc.*) was avoided by annual measurements. Using the active method for radon measurements in certain sites can show accurate reason for obtained results. Further investigation will include more houses; a survey will be focused to determination of soil radioactivity near houses, with aim to get any correlation between indoor radon and radium in soil.

CONCLUSION

Indoor radon concentration in bedroom of old house exceeds level of 400 Bq/m^3, and also, 200 Bq/m^3 in other room. The main reasons of higher indoor radon accumulation in ground houses could be radionuclides in the nearby soil, building materials, poor ventilation and behavior of inhabitants.

Remark: One can conclude that the factors responsible for the degree of radon hazard in investigated houses could be assigned to one of groups:

- characteristics of underlying geology,
- type of building materials used for construction.

But, some abovementioned parameters by clubbing together could more-less contribute to higher radon levels, too.

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