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Soil and building material as main sources of indoor radon in Băiţa-Ştei radon prone area (Romania)

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ABSTRACT

Radon contributes to over than 50% of the natural radiation dose received by people. In radon risk areas this contribution can be as high as 90–95%, leading to an exposure to natural radiation 5–10 times higher than normal. This work presents results from radon measurements (indoor, soil and exhalation from building materials) in Băiţa-Ştei, a former uranium exploitation area in NW Romania. In this region, indoor radon concentrations found were as high as 5000 Bq m^{-3} and soil radon levels ranged from 20 to 500 kBq m^{-3}. An important contribution from building materials to indoor radon was also observed. Our results indicate two independent sources of indoor radon in the surveyed houses of this region. One source is coming from the soil and regular building materials, and the second source being uranium waste and local radium reached material used in building construction. The soil as source of indoor radon shows high radon potential in 80% of the investigated area. Some local building materials reveal high radon exhalation rate (up to 80 mBq kg^{-1} h^{-1} from a sandy-gravel material, ten times higher than normal material). These measurements were used for the radon risk classification of this area by combining the radon potential of the soil with the additional component from building materials. Our results indicate that Băiţa-Ştei area can be categorized as a radon prone area.

1. Introduction

Radon (^{222}Rn) is present in both indoor and outdoor air because the parent radionuclide of it (^{226}Ra) in the ^{238}U decay series occurs in trace amounts throughout the Earth's crust. Once formed, ^{222}Rn, (with a half life of about 3.82 days), because it is chemically inert, can migrate through soil or foundation material, to reach the indoor atmosphere. Radon gas from soil, considered the most important source, enters house mainly through cracks in the building structure. Moreover, radon also enters from building material and from the water supply, and the concentration can reach high levels if air exchange is reduced (Cosma et al., 1996 a).

Radon contribute in average with about 50% at the natural exposure of people in the whole world and it is considered as responsible for between 3 and 14% of lung cancer death, being proved the second main cause for this illness after smoking (WHO, 2009). In radon risk areas (radon prone areas) this contribution can be much higher, growing the natural dose exposure of 5–10 times. Over time, epidemiological studies have demonstrated an evidence of correlation between radon exposure and lung cancer, even in case of low levels of radon in residential buildings. Unfortunately, the effort of the authorities to work towards in order to reduce the number of lung cancers related to radon exposures is still far from successful in some countries (WHO, 2009).

Radon concentration in indoor air has been measured in many countries worldwide in a large number of buildings mostly as a result of the application of radon policies and regulation requirements (WHO, 2009; UNSCEAR, 2006; ICRP 115, 2010). The approach of indoor radon studies in connection with radon gas from soil and building material are due to presence of such factors linked to the underlying geological formations and building structure, which could lead to increased levels of radon inside houses (Barros-Dios et al., 2007). Several studies have performed radiological measurements in areas with a former uranium mine and have revealed a significant association between the uranium content of soil and high indoor radon concentration (Singh et al., 2002; Somlai et al., 2006; Barros-Dios et al., 2007). Although, radon from soil and rocks and from the basement of the buildings represents the main radon sources. Another study in UK indicates that radon emanation from building materials have significant contribution to increased indoor radon concentrations in some houses (Denman et al., 2007).

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The present study represents a part of an extensive research on indoor radon exposure in the region of Transylvania-Romania. The most important high background radiation area in Transylvania was located in Băiţa-Ştei (Bihor County), where the highest indoor radon concentrations have been found (Cosma et al., 2009; Sainz et al., 2009; Truţă-Popa et al., 2010; Cucoş-Dinu et al., 2012). Another radon prone area was identified at Herculane Spa situated in a granitic zone (Cosma et al., 1996 a, Cosma et al., 1996 b).

The aim of this work is to highlight a connection between the high indoor radon levels and the underlying soil and building material identified both as the main radon sources for houses of Băiţa-Ştei radon-prone area.

2. Material and methods

The area of Băiţa-Ştei is located in the Bihor Mountains (NW part of Romania) in the neighborhood of "Avram Iancu" and "Băiţa" uranium mines. This includes the town Ştei and few villages (Băiţa-Plai, Băiţa-Sat, Nucet, Fânaţe, Cîmpani etc.), with a total of approximately 15.000 inhabitants (see Fig.1).

2.1. Indoor radon measurements

Integrated indoor radon measurements were performed in 335 dwellings of Băiţa-Ştei area between 2008 and 2010, in randomly selected houses. For indoor radon level measurements CR-39 track-etched detectors were used, according to the NRPB Measurements Protocol (Sainz et al., 2009; Miles and Howarth, 2000). Solid state track detector CR-39 is used widely in the field of health physics, such as for radon monitoring or neutron dosimetry. Alpha track detectors are not expensive, reliable and easy to use. Every CR-39 detector was placed under the cap of a cylindrical polypropylene container of 5.5 cm height and 3.5 cm diameter, with a small opening in its upper part which prevents radon decay products and also thoron (^{220}Rn) entering (RADOPOT). Only alpha particles from ^{222}Rn that diffuse into the container and from the two polonium isotopes (^{218}Po and ^{214}Po) produced inside, can hit the detector (Sainz et al., 2009).

In order to evaluate average indoor radon concentrations, the detectors were exposed in the inhabited areas of dwellings, such as bedrooms and living-rooms, at a height of 1.0–1.5 m from the floor, and for a time of 2 or 3 months. After the exposure, the etching process and the automatic reading of all detectors have been made in the Laboratory of Environmental Radioactivity of Babeş-Bolyai University, using RadoSys-2000 equipment (Elektronika, Budapest, Hungary).

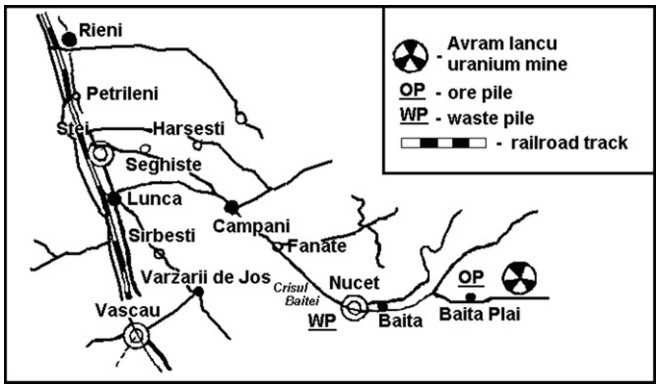

Fig. 1. The zone of Băiţa-Ştei radon-prone area (in Bihor County).

Radon concentration can be determined by counting the tracks in a given area. The individual error of radon measurements was estimated at less than 10%. The accuracy of the detection system has been periodically checked by the successful participation in national and international radon intercomparison exercises with National Institute of Physics and Nuclear Engineering (IFIN) of Bucharest, Radon Laboratory of Cantabria University, Spain and National Institute of Radiological Sciences of Chiba, Japan, during the period 2007–2011 (Cosma et al., 2009; Janik et al., 2009).

2.2. Radon in soil measurements

The preliminary radon in soil measurements in the area of Băiţa-Ştei were performed in 2010 autumn, when relatively dry conditions prevailed in the area. The aim of the measurements was the determination of the radon potential of soil, in order to classify this area from the point of view of radon risk. For this, 30 measurements of radon concentration in soil and of the soil permeability were performed, at 10 places in the whole area.

2.2.1. Method for measuring radon activity concentration in soil

The experimental method of the radon concentration measurements was based on the sampling of the soil gas and measuring the activity concentration of ^{222}Rn gas, using the LUK3C radon detector and accessories. The measurement principle of the LUK3C device lays on a scintillation detection technique with Lucas cells, by determining the activity directly from the alpha decay of ^{222}Rn and progeny. The efficiency of this technique is (2.2 counts sec^{-1}) to 1 Bq of radon activity deposited into the Lucas cell, when ^{222}Rn is in equilibrium with its progeny (Plch, 1997).

For the extraction of soil gas, a steel sampling probe was used. The probe was inserted into the soil to a minimum depth of 50 cm, and was retracted some cm back, in order to create a small cavity in soil for gas extraction. For soil gas sampling was used a Janet syringe with the volume of 150 ml (same volume as that of the Lucas cell). The syringe was connected to the upper end of the sampling probe. Before the measurement of the activity of the radon gas, the flux of radon gas from soil must forced by three consecutively extractions to avoid contaminating with atmospheric air. Only the third extraction of the soil gas (with volume of the syringe equal of Lucas cell) was introduced into the detector cell with the help of a preliminary vacuum technique. Before inserting the soil gas sample into the Lucas cell a delay time of about 3–4 min was used, for the decaying of ^{220}Rn (thoron) gas below to 10% of its initial content. Because the half-life of ^{220}Rn (55.6 s) is much shorter than the half-life of ^{222}Rn (3.82 days), thoron effectively decays in short time (5 min). After the insertion of the soil gas sample into the Lucas cell, the detector starts several countings (from 1 to 10) of the alpha decays from ^{222}Rn, and it stops when statistic errors become lower than 5%. Finally, the detector gives an average radon concentration, which was corrected by the background of the measurement process (Cosma et al., 2010). In this way, the total time of a single measurement is no more than 10 min. The scheme for the soil gas sampling and its insertion into the detector is shown in Fig. 2.

2.2.2. Method of measuring permeability of soil

Permeability measurements were performed by a method based on the measuring the empty time (i.e. flow rate) of a water column from a bottle, that was connected directly to the same probe inserted in soil, described in the method for measuring radon concentration in soil (see Fig. 2). For this, the two extremities of the bottle were equipped with two valves and the top part of the bottle (through the tap) was connected directly to the soil probe (see Fig. 3).