Indoor radon concentrations above bauxite ground

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RESUMEN

El contenido de uranio en bauxita es en general varias veces mayor que su valor promedio en la corteza terrestre. Existen muchos depósitos de bauxita en la región de Niksich, Montenegro. Algunas viviendas se han construido sobre estos depósitos y hay casas cuyos cimientos están directamente en suelo de bauxita. Las medidas de radón en interiores en esta región se realizaron en ese tipo de viviendas, así como en casas sin bauxita. El radón se midió en el sótano usando detectores de nitrato de celulosa que se expusieron durante tres meses en el invierno. Los resultados muestran que el suelo de bauxita produce un alto nivel de radón en interiores. Sin embargo, todas las concentraciones se encontraron por debajo del nivel de tolerancia de 400 Bq/m^3 adoptado en Yugoslavia, excepto en dos casas construidas en suelo de bauxita donde las concentraciones alcanzaron 540 y 676 Bq/m^3.

PALABRAS CLAVE: Radón en interiores, detectores de trazas, suelo de bauxita.

ABSTRACT

Uranium content in bauxite is generally several times higher than its average occurrence in the Earth's crust. Bauxite deposits in Montenegro are widespread in the Niksich region. Some settlements are built above these deposits, and some detached family houses have basements directly in bauxite ground. Indoor radon measurements in this region were performed in such places, and in places where there is no presence of bauxite. Radon was measured on the ground floor, using cellulose nitrate detectors exposed 3 months during the winter season. The results show that bauxite ground produces a high indoor radon level. However, all measured concentrations are below the tolerance of 400 Bq/m^3 adopted in Yugoslavia, except in two houses built directly on bauxite ground, where indoor radon concentration reached 540 Bq/m^3 and 676 Bq/m^3.

KEY WORDS: Indoor radon, track detectors, bauxite ground.

INTRODUCTION

The main reason for the growing interest in radon concentrations in homes and workplaces is of health nature: about 50 % of effective equivalent dose that the human population receives from natural background sources comes from inhaled radon (^{222}Rn) and its short-lived decay products, now called radon progeny. Deposition and retention of inhaled radon progeny in the lungs bring about an α-exposure of bronchial epithelium with high biological effectiveness, generating an increased risk of lung cancer.

Radon in the air inside a building (indoor radon) comes mainly from the ground below and around the building, from building materials, and from other less important sources.

According to UNSCEAR (1988), the world-wide arithmetic mean value of annual radon concentration in the outdoor air (1 m above ground) is 5 Bq/m^3, while for the air in dwellings is 40 Bq/m^3. In European countries, the median values of indoor radon concentrations range from 9 Bq/m^3 (Poland) to 60 Bq/m^3 (Switzerland). Some results of indoor radon measurements are on the level of a few hundreds Bq/m^3, rarely of a few thousands Bq/m^3.

The International Commission on Radiological Protection (ICRP, 1994) recommends that the annual effective dose from radon in dwellings should not exceed 10 mSv, and that the choice of action level should be limited to a range of about 3 - 10 mSv. This range of the effective dose corresponds to radon concentrations of about 200 - 600 Bq/m^3 (calculated with an annual occupancy of 7000 hours and an equilibrium factor of 0.4). In Yugoslavia the adopted action levels are: for the dwellings already existing a radon concentration of 400 Bq/m^3 is allowed, and for future buildings 200 Bq/m^3.

OBJECTIVES AND METHOD OF MEASUREMENTS

The uranium content in bauxite is generally several times higher than its average content of 2.5 µg/g in the Earth crust (Kogan *et al.*, 1969). Red bauxite deposits, present in many parts of Montenegro, are especially widespread in the Niksich region. Some settlements are built there above bauxite deposits, and some detached family houses even have basements dug directly in bauxite ground. Uranium in bauxite from this region is found in concentrations from 4 µg/g to 14 µg/g (Vukotich, 1981).

With the goal to find out whether bauxite ground brings about an elevated indoor radon concentration in houses built on it, we have conducted radon measurements in the Niksich region not only in such places (settlements Zagrad and Brsno), but also in the town of Niksich and its suburb settlement Kochani, where there is no presence of bauxite deposits.

The geology of this region is very complex. In the town area, including the suburb settlement Kochani, the terrain is made of Quaternary sediments represented by gravel, sand and clay. These sediments are up to 50 m thick, and they cover Upper and Lower Jurassic carbonaceous rocks. Brown soil makes the surface part of this terrain. The area of the settlements Brsno and Zagrad, near the town of Niksich, is predominantly made of Upper Triassic dolomite and limestone. On these rocks, Jurassic red bauxite deposits are found, and are being exploited. Otherwise, a buavitza soil type is present on top of this terrain.

Indoor radon concentrations are measured by an integral method, with the etched track detectors. Passive radiometers of the Research Center of Spacecraft Radiation Safety, Moscow, Russia, are used.

The diffusion chamber is a plastic cylinder (11.5 cm length and 3.5 cm diameter) with a cover. Radon penetrates into the chamber along the carving connection between the chamber and its cover. Two cellulose nitrate detectors (CND) of α-particles are placed on a special support and fixed with a holder in the central part of the diffusion chamber. We used the Russian-made CND (Pereslavl-Zalesskiy, K-8 type). It is a strippable detector, 13 μm in thickness and 1.49 ± 0.01 g/cm^3 density of cellulose nitrate.

After the exposure the detectors are chemically etched in 5 N NaOH solution at T=50°C, without stirring. The etching time of 90 min was chosen because of a good standard deviation of counter readings (below 20%) and a quite reasonable background of 30 ± 15 track/cm^2 (Uvarov and Kulakov, 1995). The CNDs were calibrated using Pu-239 and Ra-226 α-sources. Detectors are read out with a spark counter.

The radiometer was calibrated beforehand in a 0.5 m^3 radon box for different exposure times. Uranium ore was used as a radon source, with an average radon activity of about 5 kBq/m^3, measured with a ZnS scintillation detector. Sensitivity of the radiometer is: 2.8 ± 0.8 (track/cm^2)/(kBq·h/m^3) for the lower detector, and 3.4 ± 0.8 (track/cm^2)/(kBq·h/m^3) for the upper detector (Uvarov *et al.*, 1997).

Detector exposure time depends on the radon concentration level. Measurement lasting 100 days is recommended for the radiometer used if the radon concentration is about 2 - 1000 Bq/m^3, measurement time of 10 days if the concentration is 6 - 20 kBq/m^3, and only 3 days if the radon concentration is 20 - 70 kBq/m^3. The mean error of the radon measurement with the radiometer and method described above is about 50 % for radon concentrations in 2 - 20 Bq/m^3 range, and about 25 % for radon levels of 20 - 20000 Bq/m^3.

In houses of the Niksich region detectors were exposed 95 days, in the winter season, from the end November to the end of February. Radon was measured in dwellings on the ground floor, and radiometers were located in living rooms, 1.5 - 2 m above the floor.

RESULTS AND DISCUSSION

Though a relatively small number of radon measurements was performed, results presented in Table 1 clearly testify that radon concentrations in houses built on bauxite ground (settlements Brsno and Zagrad) are significantly higher than in houses above bauxite-free ground (settlement Kochani and town of Niksich). In the Zagrad settlement, three houses of those where radon was measured are built directly on bauxite ground (in the immediate vicinity of the bauxite outcrop), and two houses are built up the hill, somewhat farther from the outcrop. Indoor radon concentrations in the first three houses are 264 - 540 Bq/m^3, and in the second two 175 and 196 Bq/m^3. This is one more confirmation that the ground below a building is of prime importance for indoor radon concentration.

Beside this, one can see from Table 1 that indoor radon concentrations measured in the houses of the town area and Kochani are below the action level adopted in Yugoslavia. The same is valid even for the other houses, except in two cases where indoor radon concentrations are higher than 400 Bq/m^3.

When considering the results given in Table 1 one would have in mind that they represent, in fact, the highest indoor radon concentrations all the year round. This is because the measurements are performed during the winter season, when doors and windows are usually all tightly closed and dwellings are seldom and poorly ventilated. An indirect confirmation of the validity of this remark we can find in the radon data from the Brsno settlement. Indoor radon concentration of 676 Bq/m^3 (the maximum value found in the Niksich region) is measured here in a detached family house with the basement dug directly in bauxite ground. In its immediate vicinity there is a schoolhouse with broken entrance door and windows, built on the very same type of ground, where an indoor radon concentration

Table 1

Indoor radon concentrations in the Niksich region, measured in the winter season

Location	Number of measurements	Radon concentrations (Bq/m^3)	Arithmetic mean (Bq/m^3)
Town of Niksich	3	60, 78, 156	98
Kochani	5	96, 104, 104, 144, 152	120
Zagrad	5	175, 196, 264, 325, 540	300
Brsno	2	128, 676	402
Total	15	min=60 max=676	230

five times lower was measured. The high natural ventilation rate is evidently the cause of such a difference in indoor radon levels.

CONCLUSIONS

1. Red bauxite ground below house brings about a significantly elevated indoor radon concentration.

2. Indoor radon concentrations in the Niksich region are generally on the level of average concentrations measured in the countries of middle geographic latitudes.

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