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Radon concentrations in soil of the city of Podgorica, Montenegro

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RESUMEN.

Se midieron las concentraciones de radón en suelo de la ciudad de Podgorica, capital de Montenegro, utilizando radiómetros pasivos. Los radiómetros se colocaron a una profundidad de 70-80 cm, en pozos perforados, y se expusieron detectores de nitrato de celulosa durante 14 días. La media aritmética de las concentraciones de radón en 17 sitios fue de 37 kBq/m^3, con una desviación estándar de 16 kBq/m^3. La distribución de frecuencias de los niveles de radón en el suelo fue casi simétrica. Esta investigación muestra que los niveles de radón en suelo sobre la falla geológica, en una situación asísmica, no son mayores que los niveles en otras áreas de la ciudad. Las concentraciones de radón en suelo en una zona de contacto entre el terreno plano y la zona montañosa no fueron en general mayores que en otros sitios de la ciudad.

PALABRAS CLAVE: Radón, suelo, detectores de trazas, falla geológica.

ABSTRACT

Radon concentrations in soil of the city of Podgorica, capital of Montenegro, were measured using passive radiometers. The radiometers were placed in the soil at a depth of 70-80 cm, in refilled holes, and cellulose nitrate detectors were exposed during 14 days. The arithmetic mean of the radon concentrations at 67 locations is found to be 37 kBq/m^3, with a standard deviation of 16 kBq/m^3. The frequency distribution of radon levels in soil is almost symmetrical. This investigation shows that the radon level in soil above the geological fault, in a non-seismic situation, is not higher than in soil of other city areas. The radon concentrations in soil at a contact zone between flat terrain and rocky hills are not found to be generally higher than elsewhere in the city area.

KEY WORDS: Radon, soil, track detectors, geological fault.

INTRODUCTION

The main source of indoor radon is usually the ground below a house. Diffusion is a general process of radon transportation through the ground (UNSCEAR, 1988). Due to the relatively short decay time of radon, the range of radon transport by this way is limited to a few meters. However, an upward gas flow through cracks and caverns in the ground, caused by difference in pressure, can give a range of radon transport up to several hundred meters (Fleisher and Mogro-Campero, 1981).

Podgorica is the capital of Montenegro. The elevated parts of terrain in the region of Podgorica and its surroundings consist of Upper Jurassic carbonate rocks, while the low parts are Quaternary sediments (conglomerates and gravels), 20 to 40 m in thickness. The soil is of a sandy clay type, up to 2 m thick. Numerous cracks and caverns are present in the Upper Jurassic limestones and dolomites. A uranium content of 1.2 μg/g was found in samples of these rocks (Boreli *et al.,* 1983), while the soil of this area has an uranium content of up to 5 μg/g (Pirc *et al.,* 1991).

It is assumed, by geological evidence, that two regional and many local geological faults, mutually interconnected, intersect the city area.

We have measured radon in soil of the Podgorica city area to find out:

- what are the radon levels in the soil,
- whether the geologic fault, in non-seismic conditions, influences the radon level in the soil above it,
- whether a contact zone between elevated and flat parts of terrain has an increased radon permeability.

METHOD OF MEASUREMENT

Radon concentration in soil is measured using the RRC "Kurchatov Institute" passive radiometer (Uvarov and Kulakov, 1995), specially designed to prevent thoron, dust and moisture penetration into the detector chamber.

The radiometer has an aluminum cylindrical chamber (inner diameter of 3.2 cm and volume of 17 cm^3) and a cover, with a plastic layer between them. There are twelve holes on the chamber wall for radon entrance, each one 6 mm in diameter, which are covered with a 35 μm thick polyethylene layer. The detector in a drum-type support is fixed to a central holder. The holder is lined with 13 μm thick aluminized mylar absorber, which decreases α-particle energy and protects the cellulose nitrate detector (CND) from spontaneous electrostatic charges. Radon penetrates into the radiometer through a polyethylene layer by diffusion. Decay products plate out on the inner surface of the radiometer. The CND used (Russian-made, K-8 type, thickness of 13 μm, density 1.49 ± 0.01 g/cm^3) enables only detection of α-particles emitted by radon products which are plated out on the Al-mylar. The radiometer is very convenient for measurement of radon activity in wet soil. Its sensitivity is 0.7 ± 0.2 (track/cm^2)/(kBq·h/m^3), when chemically etching CND for 100 minutes in 5 N NaOH solution at a temperature of 50 °C. The background of the CN detector is then 70 ± 20 track/cm^2. Detectors are read out with a spark counter. Error of radon measurement is about 30 %.

Radon concentration in soil gas strongly depends on the depth in soil, increasing with depth (Jonsson, 1995). Therefore, for the sake of interpreting results of our measurements correctly, we placed radiometers on each site at a depth of 70 - 80 cm in the ground and refilled the holes. Detectors are exposed for two weeks in the winter season.

RESULTS AND DISCUSSION

To examine whether the regional geological faults in the city area, in a non-seismic situation, have an evident impact on radon levels in the surface soil layer above them, in the direction of normal strike of one of the faults which passes through the Toloshi valley, 31 radon detectors were placed at the equidistance of 50 m, at a depth of (70 – 80) cm in the soil. As a reference area, nearby but out of the faults, the Beri valley was chosen, with similar soil characteristics, and 16 detectors were placed there in a straight line across the valley at the equidistance of 100 m.

At both locations detectors are exposed for two weeks during the month of December, and the soil was wet because of the rainy weather.

The arithmetic mean of radon concentrations in the soil of the Toloshi valley is found to be 39 kBq/m^3, with standard deviation of 14 kBq/m^3. Figure 1. shows the spatial distribution of radon concentrations (one detector is not found at the site), and Figure 2. the frequency distribution of radon levels, with median value $\mu_{1/2} = 37.2$ kBq/m^3.

The mean radon concentration in the soil of the Beri valley is 34 kBq/m^3, with a standard deviation of 12 kBq/m^3. Figure 3. represents the spatial distribution of radon concentrations there (two detectors were missing), and Figure 4. their frequency distribution ($\mu_{1/2}$= 32.0 kBq/m^3).

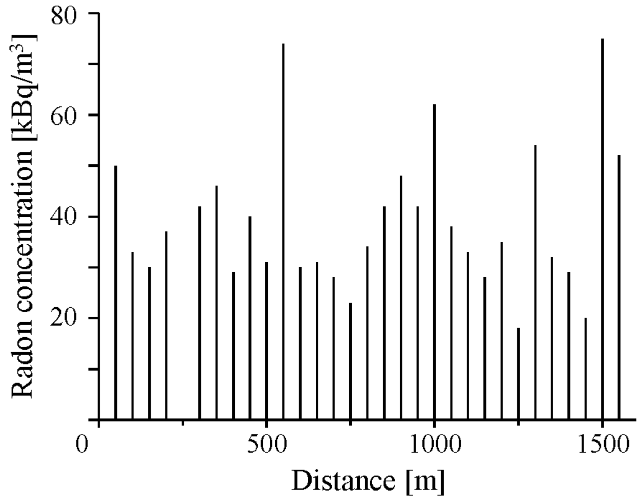

Fig. 1. Spatial distribution of radon concentrations in soil of Toloshi valley.

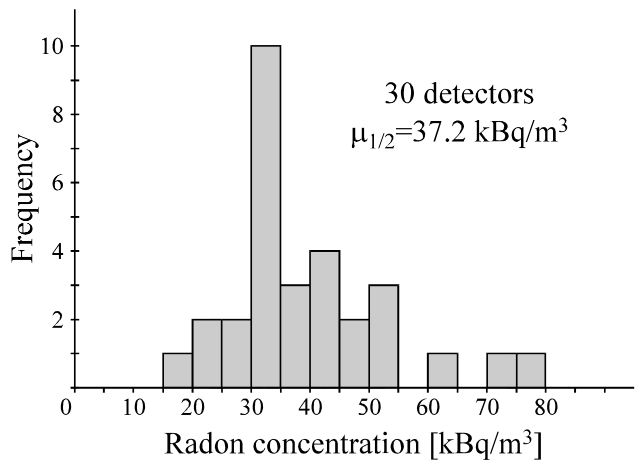

Fig. 2. Frequency distribution of radon concentrations in the soil of Toloshi.

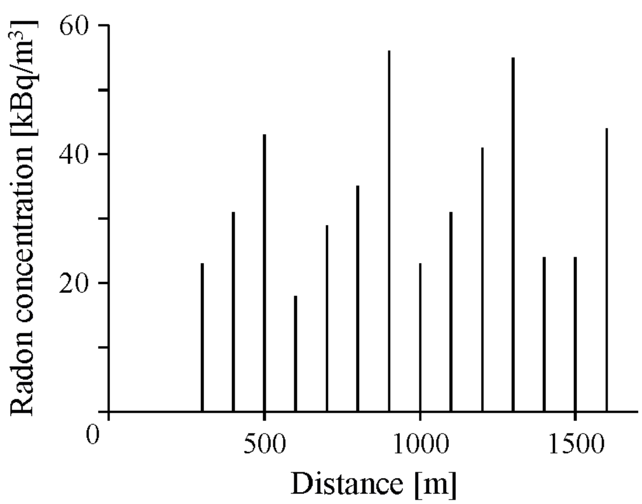

Fig. 3. Spatial distribution of radon concentations in soil of Beri valley.

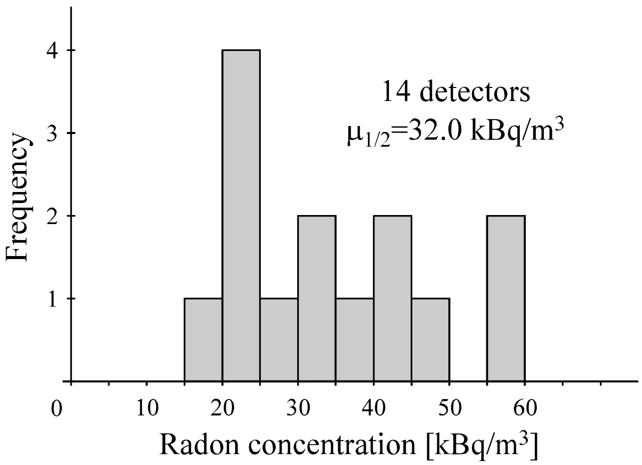

Fig. 4. Frequency distribution of radon concentrations in the soil of Beri.

These results do not reveal a significantly higher radon level in the soil of Toloshi than in the soil of Beri, nor a grouping of elevated radon concentrations in certain parts of the analyzed transect in the valley Toloshi. Therefore, in a non-seismic situation, the impact of the regional geological fault on the radon level in the soil above it is not evident. This could be explained in two ways: (i) the fault is too deep and radon can not reach from it to the surface of the ground by convection process, or (ii) the regional and local faults are interconnected in the city region so that they provide an almost uniform radon level in the soil of this area.

An earlier survey of indoor radon in Podgorica (Vukotich *et al.,* 1997) has revealed elevated radon concentrations (up to 1000 Bq/m^3) in some dwellings in the city quarter Momisichi, where the detached houses are built near the hill. Then we concluded that this is mainly due to a relatively high radon flow from the ground into these houses, because they usually have in the basement concrete slabs of low quality so that cracks in them are common.

This time we wanted to check whether a contact zone between rocks and sediments, as near hills, has an increased soil gas permeability. Therefore, we measured radon in soil at 10 locations in Momisichi, and at 13 locations in another one, about 3 km distant from it, the city quarter called Zabjelo, where the detached houses are also located around a hill. These measurements are performed also in the winter season and under similar weather conditions. The arithmetic mean of the radon concentrations in soil of Momisichi is found to be 49 kBq/m^3, with standard deviation of 25 kBq/m^3, and the corresponding values for Zabjelo are 29 kBq/m^3 and 17 kBq/m^3, respectively. These results mean that a contact zone between rocks and sediments does not provide, as a rule, an elevated radon level in soil. Furthermore, it can be seen from them that the radon concentrations in soil of Momisichi are the highest among all the measured in Podgorica, what proves once more our earlier conclusion with respect to the origin of the elevated indoor radon levels in this part of city.

The total number of our radon measurements in soil of the city of Podgorica is 67 (Figure 5.). The mean radon concentration obtained from all measurements is 37 kBq/m^3, and its standard deviation 16 kBq/m^3. The graph of cumulative proportion for distribution of the results is given at Figure 6. Its shape also shows that the frequency distribution of radon concentrations in soil of Podgorica is almost symmetric.

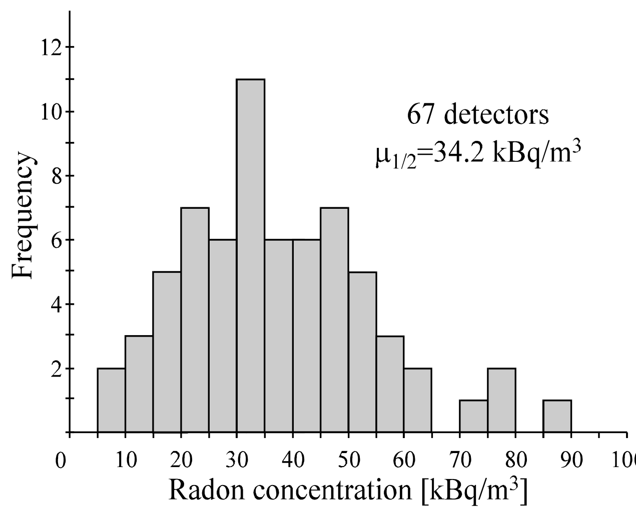

Fig. 5. Radon concentrations in soil of the city of Podgorica.

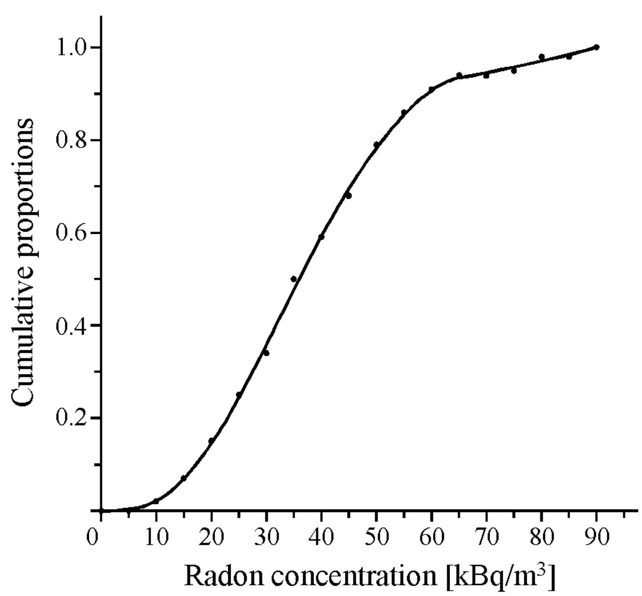

Fig. 6. Cumulative frequency of radon concentrations in the soil of Podgorica.

CONCLUSIONS

Our research has shown that the radon level in the superficial layer of soil above the geological fault, under non-seismic conditions, is not higher than in the soil of the other parts of the city area. In general, it is not found that the radon concentration in the soil at a contact zone between flat terrain and rocky hills are elevated. Radon concentrations in the soil of the city of Podgorica are moderate - they span a range (10 - 90) kBq/m^3, with a median value of 34 kBq/m^3.

BIBLIOGRAPHY

BORELI, F., D. DRAGOVICH, P. VUKOTICH, L. VUKCHEVICH and A. MARDJOKICH, 1983. Investigation of radioactive and rare elements in ores and rocks of Montenegro. Final report (in Serbian). Ministry of education and science of Montenegro.

FLEISHER, R. L. and A. MOGRO-CAMPERO, 1981. Radon transport in the earth: a tool for uranium exploration and earthquake prediction. Proceedings of the 11th Inter. Conf. on SSNTD, Bristol, p. 501.

JONSSON, G., 1995. Radon gas - where from and what to do? Radiat. Meas., 25, 537.

PIRC, S., R. SVRKOTA and M. PAJOVICH, 1991. Regional geochemical investigation on carbonate rocks in Yugoslavia. Annual report (in Serbian). Institute of Geology of Montenegro.

UNSCEAR, 1988. Sources, effects and risks of ionizing radiation. United Nations Scientific Committee on the Effects of Atomic Radiation, New York.

UVAROV, V. V. and V. M. KULAKOV, 1995. Use of radiometer with cellulose nitrate detector (CND) in indoor radon measurements in Omsk, 1993. *Radiat. Meas., 25,* 587.

VUKOTICH, P., S. DAPCHEVICH, N. SAVELJICH, V. V. UVAROV and V. M. KULAKOV, 1997. Indoor radon concentrations in the town of Podgorica - Montenegro. *Radiat. Meas., 28,* 755.

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