INDOOR RADON MONITORING AS A USEFUL PREDICTOR OF EARTHQUAKE OCCURRENCES IN THE BALKAN REGION

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Abstract

This study deals with continuous radon monitoring conducted to estimate the relationship between indoor radon measurements and potential occurrences of earthquake in the Balkan region. Radon monitoring was performed with the detector Airthings Corentium Home placed in the basement office of faculty building in Kosovska Mitrovica (N 42.897°, E 20.867°) in winter period of the 2020/21 (four months in continuity). According to the European Seismic Hazard Map this region is classified as moderate hazard area. Radon daily variations were noted and analyzed with the earthquakes of magnitude M>2.0 which occurred in forthcoming days in the Balkan region. Anomalous emanation of geo-gases are connected with the ground shaking, and spike-like peaks in radon concentrations could be caused by seismic events in the wider area. In monitoring site it was reflected like a gradual increase in radon concentrations, then a sharp drop (e.g. from 865 Bq/m^3 to 73 Bq/m^3 within 48 hours). About seven days later an earthquake of magnitude M=2.2 occurred at the distance of 10 km from measuring site, and has been followed with a series of earthquakes in the region. The results seem to indicate that radon is a good indicator of crustal activity and seismic movements.

Keywords: radon, monitoring, earthquake

INTRODUCTION

Radon (^{222}Rn) is a natural radioactive gas with half-life of 3.824 days, produced in soil and rocks by the decay of the radium (^{226}Ra) in the series of uranium (^{238}U). Since radon is a gas, it leaves the rocks and soils more easily and has much greater mobility than uranium and radium. Radon travels (by diffusion or convection) a great distance before it decays escaping into fractures in rocks and into the pore spaces between grains of soil. Its mobility is related to the permeability of the soil and to the degree of rock fracture. Radon moves more rapidly through permeable soils (coarse sand and gravel) than through impermeable soils (clays). It is moderately soluble in water. The behavior and distribution of radon in atmosphere is mainly governed by meteorological processes.

Radon is easily detectable and the most preferred as earthquake precursor in measurements of anomalous emanations of geo-gases (helium, hydrogen, carbon dioxide) in earthquake-prone regions. Abruptly emission the high concentrations of radon gas (along with releases of different gases: CO_2, CH_4, H_2S, SO_2, and H_2 suitable for radon transport to the earth's surface) through cracks could be attributed to strained rocks before the sudden slip. Spike-like peaks in the concentration of radon gas before a major earthquake appear due to pre-seismic stress or fracturing of the rock. Also, the short-term conspicuous changes of radon concentrations could be signed to a forthcoming earthquake. Radon measurements in soil and in groundwater have shown that spatial and temporal variations can provide information about geodynamical events usually performed at an active fault zone. The radon concentration in a spring increased constantly before an earthquake (M=5.2) on April 15, 1966 in Tashkent. This was the first evidence of radon in groundwater as precursor of earthquakes (Ulomov et al., 1967).

Anomalous radon concentrations were reported before the strong earthquakes. The strange behavior before an anomaly was reported like: a gradual increase in radon counts three months before the quake, then a remarkable increase two weeks and a sudden decrease one week before the shock, and after earthquake the radon levels returned to the pre-seismic events (Hatuda, 1953). There are also some of radon manifestations observed in studies: concentrations fluctuate around the mean value, showing some variations with peak values, about two or three times the mean value, preceding some seismic events; the anomalies are related to changes in crustal strain and indicated a probable relation with the local seismicity (Al-Hilal et al., 1998). On the other side, some authors reported quite significant radon anomaly, in particular over the fault line (Inceoz et al., 2006). Fifteen years continuous monitoring of geophysical events on Mt. Etna, which is characterized by tectonic and volcanic phenomena and by numerous earthquakes, showed that as well as the radon raises, the earthquake daily rate and strain release raise, correspondingly to the eruption beginning (Immè et al., 2005; Giammanco et al., 2009). Many studies were conducted to mark radon as a precursor of an earthquake and to prove the relationship of radon behavior and earthquake occurrence (Planinić et al., 2004; Ghosh et al., 2009; Kuo et al., 2010; Sac et al, 2011; Gregorič et al., 2012; Hwa Oh and Kim, 2015; Kim et al., 2018).

This study deals with continuous radon monitoring conducted with aim to link indoor radon measurements and potential occurrences of earthquake in Balkan region.

MATERIAL AND METHODS

Geology of study area

The Balkan region has a diverse geological structure and diverse relief. There are rocks of Paleozoic age (shale and serpentine), limestone, sandstone and volcanic rocks (andensite, dacite, gabbro). The geology which includes measurement site is as follows. The mountains around the Kosovo and Metohija valleys are built of rocks of different ages and origins. Kopaonik has a diverse geological structure, which affects the appearance of various ores and minerals. There are also volcanic rocks east of the Kosovo valley. At the bottom of the Kosovo and Metohija valleys are lake deposits (sands and clays). The fluvial and alluvial plains are covered with river sediments from Quaternary. An intensive magmatic and tectonic activity in the past caused different vertical movements and forming a network of seismogenic faults. A deep fault stretches in NW-SE direction following the river valley; it is the one of the strike direction of young (neotectonic) faults (Dimitrijević, 1997). This region is classified from moderate hazard to high hazard area according to the European Seismic Hazard Map which displays the ground shaking (in terms of the unit gravitational acceleration, g) (Giardini et al., 2013).

In the Balkan region anomalies appear at distances sometime much greater than typical source dimensions. The earthquakes occur in the field of strain higher than 10^{-9}, some of them being in the field of strain higher than 10^{-8}, while slip rate of active faults is 0.1-0.5 mm/y (Giardini et al., 2013).

Methods

Radon monitoring was performed with the detector Airthings Corentium Home which was placed in basement office of faculty building in Kosovska Mitrovica (N 42.897°, E 20.867°) in winter period of the 2020/21 (four months in continuity). Radon detector Corentium Home measures in range from 0-9999 Bq/m^3. Detection method is alpha spectrometry. The accuracy of device at typical concentration of 200 Bq/m^3 is 5-10% for measurement period from 7 days to two months, and uncertainty for one month measurement is less than 10%. Radon daily variations were noted and analyzed with any earthquake of magnitude M >2.5 which occurred in forthcoming days in the Balkan region. Besides meteorological parameters that influence radon fluctuations, these could also be connected with the ground shaking, since an active fault exists in this area.

The dilatancy model explained connection between the radon anomalies of chemical and physical parameters and seismic events (Scholz et al., 1973). Before an earthquake the cracks open, the diffusion of pore fluid increases, modified strength and pore pressure, and causes variations in the physical and chemical characteristics of the rocks. When the cracks start to form in the rocks the radon concentration increases. After that, the radon emission can be stable or decrease before the earthquake. The width of the zone involved by the stress loading is proportional to the magnitude and to the depth of the impending earthquakes. The pressure variations change the rocks characteristics creating the "precursor phenomena". According to an empirical relationship between earthquakes and indoor radon measurements proposed by Hauksson and Goddard (1981), the minimum magnitude M (the Richter scale) required for a radon anomaly at distance D (km) from the epicenter of an earthquake and the site of observed radon anomaly is:

$$M = 2.4\, log_{10} D - 0.43 \qquad (1)$$

RESULTS AND DISCUSSION

The results of indoor radon monitoring are presented in Fig.1. The mean radon concentration within the four months was 210 Bq/m^3, while daily radon variations ranged from 58-865 Bq/m^3. The measurements were analyzed and related with any earthquake of magnitude M>2.0 which occurred in forthcoming days in the Balkan region. Anomalous emanation of geo-gases are connected with the ground shaking, and spike-like peaks in radon concentrations could be caused by seismic events in the wider area. In monitoring site it was reflected like a gradual increase in radon concentrations, then a sharp drop (e.g. from 865 Bq/m^3 to 73 Bq/m^3 within 48 hours). About seven days later an earthquake of magnitude M=2.2 occurred at the distance of 10 km from measuring site, and has been followed with a series of smaller earthquakes in the region. The results seem to indicate that radon is a good indicator of crustal activity and seismic movements.

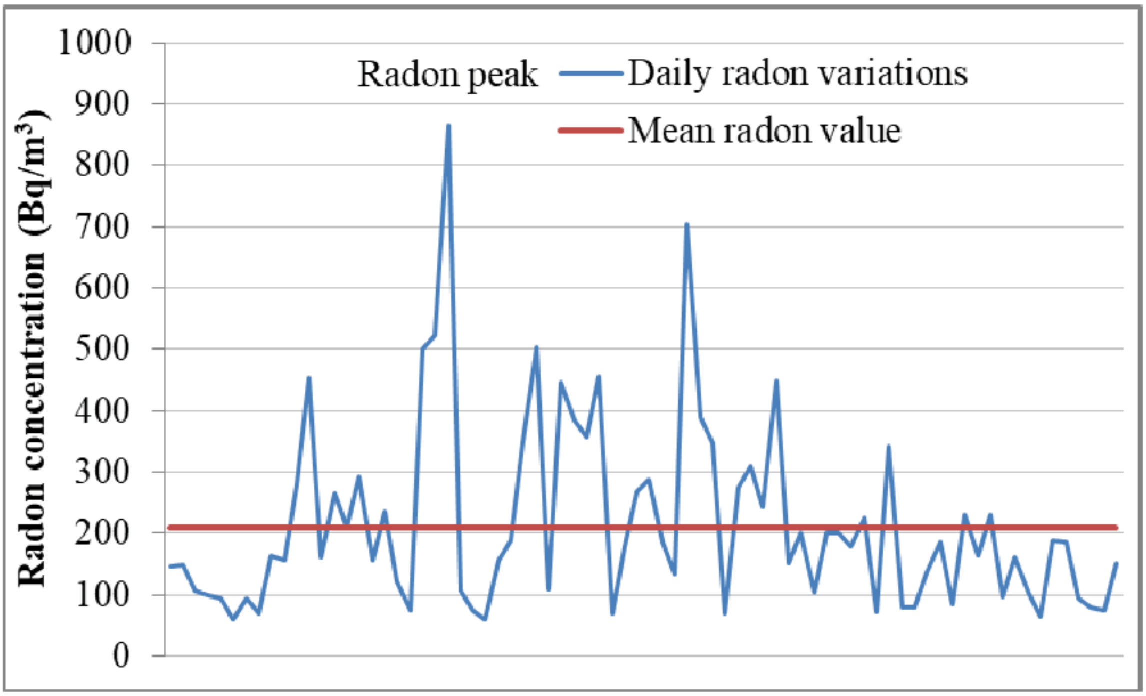

Figure1. Variation of indoor radon concentration

Anomalies which appear much faster are characterized as a short peak (duration: hours to days) in the radon concentration. These peaks can be either positive or negative and are often followed by an earthquake within about ten days. Any radon variation that can be considered "significant anomaly" must differ from the mean for ±2 standard deviations (Igarashi and Wakita, 1990).

CONCLUSION

Finally it could be concluded that continuous indoor radon measurements are a useful tool in investigations of geodynamical events connected with the ground shaking in the wider area. The results seem to indicate the radon as a good indicator of crustal activity such as earthquakes. However, more extended continuous data should be recorded, in particular near active faults, to find clear, causal relationship between radon and earthquake activity.

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