RADON MONITORING IN DOMICA CAVE, SLOVAKIA – A PRELIMINARY RESULTS

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Abstract: Three stable monitoring stations equipped with an automatic measuring and registration instruments for continual microclimatic, hydrological and hydrochemical monitoring are installed in Domica Cave, southern Slovakia. In one of them (Virgin Corridor) the devices for continual monitoring of radon activity concentration in the cave atmosphere have been set up in June 2010. The external meteorological station situated nearby the cave includes sensors for measurements of air temperature, relative humidity, wind speed, wind direction, global radiation, rainfall amount and evaporation. From June to December the hourly radon activity concentration ranged 230 – 4,740 Bq/m^3. Periodic daily and non-periodic short term variations of ^{222}Rn activity concentration were registered. The research has been carried out with the regard to the possible health risk of people working in the cave, as well as the relationship between radon activity concentration changes and meteorological and cave microclimatic conditions have been investigated.

Keywords: radon, variations, cave, monitoring, meteorological conditions

INTRODUCTION

Radon (^{222}Rn), a product of ^{226}Ra decay in ^{238}U decay series, is a naturally occurring radioactive noble gas with half life of 3,82 days. Radon and its short-lived decay products are the most important contributors to the human exposure from natural sources (UNSCEAR 2000). Monitoring of ^{222}Rn activity concentration in the underground places such as mines (Veiga *et al.* 2004), tunnels (Lam, 1988), show caves (Thinova & Burian 2008) and underground monuments (Hafez & Hussein 2001) is performed mainly due to assess the radiological hazards to occupational workers. On the other hand, radon is used as a natural radioactive tracer of air movement in caves to enable better understanding of their microclimate (Fernandez-Cortes *et al.* 2009).

Radon activity concentration in underground environments is usually characterized by the large temporal variations (Eff-Darwich *et al.* 2002, Perrier *et al.* 2007, Barbosa *et al.* 2009, Perrier & Richon 2010).

After the decree by the Slovak government (345/2006) the action level for ^{222}Rn activity concentration in underground workplaces (tunnels, mines, caves) is 1,000 Bq/m^3 in average per one year. At sporadically used workplace this limit is related to an average radon activity concentration during the stay of working staff. In show caves the typical remedial action like forced ventilation cannot be used because it alters the internal microclimatic conditions which are important for the conservation of the cave decoration. The only way to reduce radon exposure to guides and other workers is to apply a radiation protection system based on restrictions in the amount of time spent in the cave.

In this paper the preliminary results of the continual ^{222}Rn activity concentration monitoring in the atmosphere of the show cave Domica are presented.

EXPERIMENTAL SITE

Domica Cave is situated on the south-western edge of the Silická Plateau in the Slovak Karst National Park (south-eastern Slovakia), close to the state border with Hungary. Cave is formed mainly in the Middle Triassic Wetterstein limestones of the Silica nappe by the corrosive and erosive activities of Styx River and Domica Brook and smaller underground tributaries draining waters mainly from the non-karst part of the basin. It is an upper part of the Domica-Baradla cave system with the total length of 25 km. Natural radioactivity of rocks (Triassic carbonates, sinters, fluvial sediments and cave soil) measured using gamma-ray spectrometry is relatively low (Štelcl *et al*. 2004).

METHODS

Three stable monitoring stations equipped with an automatic measuring and registration instruments for continual microclimatic, hydrological and hydrochemical monitoring are installed in this cave and operated by Microstep-MIS company (Gažík *et al*. 2009). In one of them (Virgin Corridor) continual monitoring of radon using an alpha detector Barasol have been set up in June 2010. The detector is placed 1,3 m above the cave floor and 1,5 m from the walls. Among others, the internal air temperature, CO_2 content and wind speed have been continually monitored there. The external meteorological station situated nearby the cave includes sensors for measurements of air temperature, relative humidity, wind speed, wind direction, global radiation, rainfall amount and evaporation. Data from all stations are recorded automatically every 10 minutes.

RESULTS AND DISCUSSION

Radon activity concentration in the atmosphere of Domica Cave exhibits daily and short-term variations. At this stage of the investigation the seasonal variation cannot be correctly evaluated. Hourly time series of ^{222}Rn activity concentration in the Domica Cave compared with hourly time series of

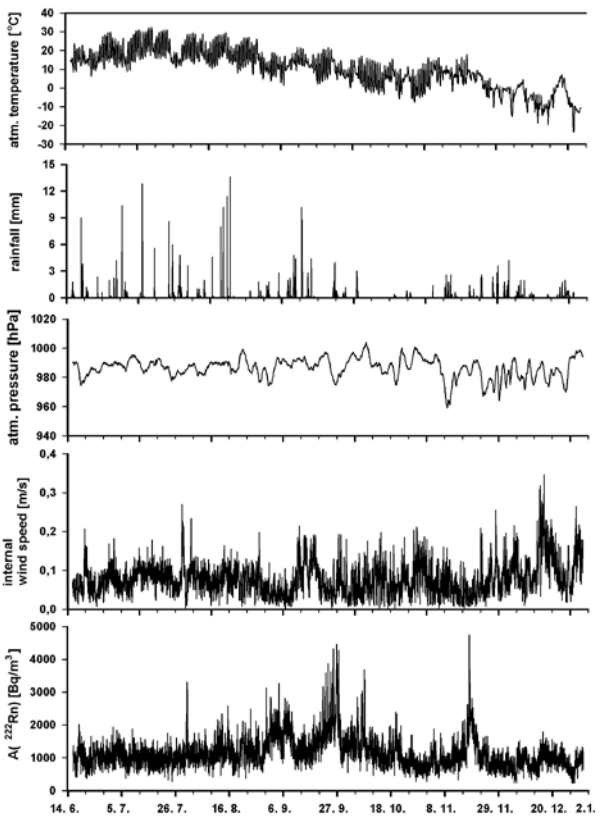

Fig. 1. Hourly time series of ^{222}Rn activity concentration and internal wind speed in the atmosphere of Domica Cave, atmospheric pressure, rainfall and atmospheric temperature.

Table 1. Monthly average and median values of ^{222}Rn activity concentration measured in the atmosphere of Virgin Corridor in Domica Cave.

A(^{222}Rn)[Bq/m^3]	July	August	September	October	November	December
average	1027,06	1180,88	1674,86	1146,40	1075,98	875,00
median	1008,17	1190,25	1644,50	1141,38	954,98	893,17

internal wind speed, atmospheric temperature, atmospheric pressure and rainfall are depicted in Fig. 1. The hourly averages of radon activity concentration ranged from 230 to 4,740 Bq/m^3, with median value 1,058 Bq/m^3. However, the values from 500 to 2,000 Bq/m^3 prevailed in the data set (Fig. 2). Daily averages of ^{222}Rn activity concentration lie in interval 480 – 2,700 Bq/m^3. Monthly averages and median values of ^{222}Rn activity concentration are displayed in Tab. 1. With exception of December, the action level for radon in underground workplaces was slightly exceeded.

Radon values measured in summer months as well as in the beginning of winter varied about 1,000 Bq/m^3. Short-term variations of ^{222}Rn activity concentration were registered mainly in autumn months. Their duration was from 4 to 10 days. The amplitudes of radon short-term variations ranged approximately from 600 to 2,000 Bq/m^3. No influence of atmospheric pressure, temperature and temperature gradient on short-term changes of radon activity concentration was observed. Short-term variations were also not associated with rainfall events.

From August to October the daily variations of ^{222}Rn activity concentration were observed. The internal wind speed measured in the Virgin corridor exhibits distinct daily variations that documented the changes of air flow in the cave during the day. Wind speed was small, typically less than 0,2 m/s, but occasionally reached up to 0,4 m/s. Radon daily variations were usually anticorrelated with the daily change of the internal wind speed (Fig. 3). The largest amplitudes of radon daily variations up to 2,300 Bq/m^3 were reg-

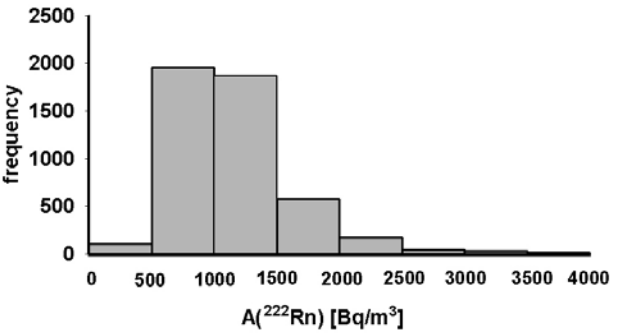

Fig. 2. Frequency distribution of ^{222}Rn activity concentration in the atmosphere of Domica Cave from June to December 2010.

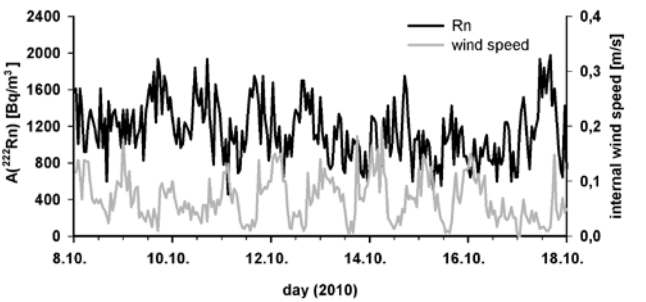

Fig. 3. Daily variations of ^{222}Rn activity concentration and internal wind speed.

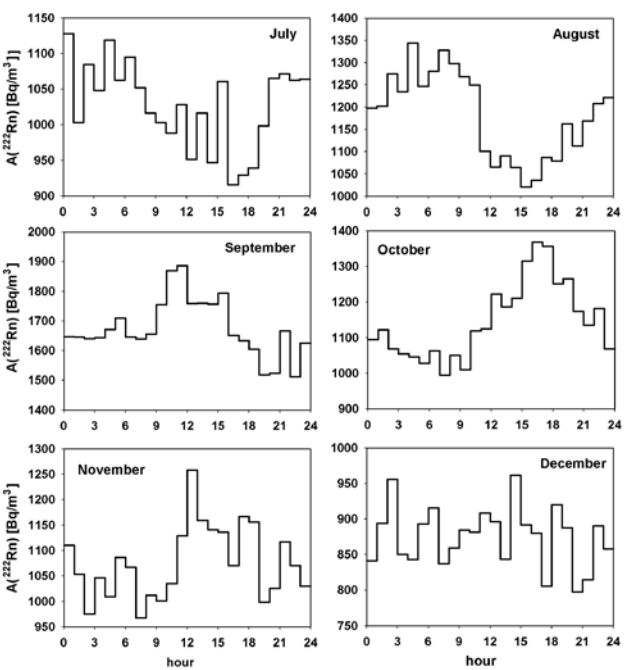

Fig 4. Daily waves of ^{222}Rn activity concentration in the atmosphere of Domica Cave.

istered in autumn months, from September to October; they were superimposed on radon short-term variations. Daily average wave of radon activity concentration clearly exhibits the shape and the amplitude of daily variation for a single month (Fig. 4). The position of radon maximum and minimum during the day was different for each month. In August the maximum was reached in the morning (7 – 9 a.m.), minimum at the afternoon (3 – 5 p.m.). In September, maximal values were measured at 10 – 12 a.m., minimum at 8 – 10 p.m. In October the reverse situation as in September was observed. The amplitudes

10 °C. After rainfall in summer months, as in this case, a sharp increase of water temperature in Styx River, as well as increase of air temperature in Virgin Corridor was observed, lasting approximately 2 days (Fig. 5). The change of internal air temperature can cause the change of air flow. However, not every significant increase of internal wind speed was accompanied by the rainfall event.

The second peak of ^{222}Rn activity concentration was recorded in the middle of November with duration of approximately 10 hours. Peak was superimposed on the radon short-term variation. At that time radon

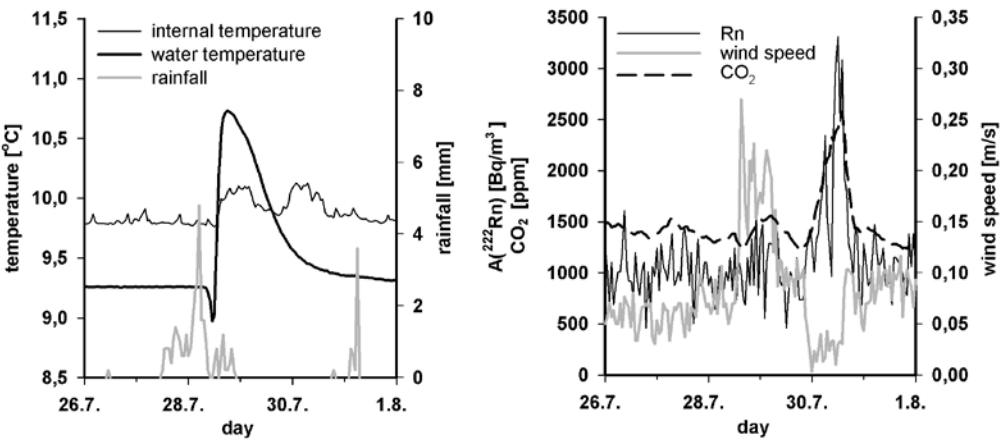

Fig. 5. Increase of internal temperature measured in the Virgin Corridor after the rainfall event (left). At the same time short-term increase of internal wind speed was measured. The decrease of internal wind speed was accompanied by the presence of ^{222}Rn activity concentration and CO_2 content peaks (right).

of the average daily waves were at the level up to 25 % of ^{222}Rn activity concentration mean values.

Moreover, two distinct peaks were distinguished in radon time series. First one occurred at the end of July, lasting for one day with maximum of 3,310 Bq/m^3. At the same time also peak in CO_2 content of the cave atmosphere was registered. The presence of both peaks was accompanied with the decrease of the internal wind speed, while a significant increase of wind speed was measured approximately 36 hours before both peaks appeared. Internal temperature measured in Virgin Corridor over a period of our investigation was relatively stable, about

concentration reached its maximum level 4,738 Bq/m^3 for the period of the monitoring. Contrary to the previous event in summer, no significant change of CO_2 content was registered. A weak decrease of internal wind speed was measured, too. However, in the following days a similar decrease of internal wind speed was not resulted in any radon peaks. No rainfall or internal temperature changes preceded this radon peak.

CONCLUSIONS

The preliminary results of ^{222}Rn activity concentration monitoring in the atmosphere

of Domica show cave exhibit moderately high radon levels from 230 to 4,740 Bq/m^3, with median value 1,058 Bq/m^3. Daily and short-term variations of radon activity concentration were observed, as well as two radon peaks. The highest radon levels were registered in autumn months.

To explain the ^{222}Rn activity concentration behavior in cave in detail, a further monitoring is needed.

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