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FIRST RESULTS OF THE RADON CONCENTRATION MONITORING IN ABALIGET AND KISPAPLIKA CAVES

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Summary: Radon concentration has been investigated in Abaliget and Kispaplika caves, Mecsek Mountains, Hungary for 9 month. Track-etched detectors were used to measure the radon levels of cave air inside the passages. Our primary aim was to gain information about both the radon concentration levels and the convectional characteristics of these caves. Meteorological data provided by the Public Limited Company for Radioactive Waste Management was used to analyse the possible direction of airflow inside the caves. Both caves were characterized by higher summer and lower winter values and the changes of radon concentration were governed by the inside and outside temperature difference induced ventilation of the caves.

Key words: radon, track-etched detector, cave air circulation, Mecsek Mts.

1. INTRODUCTION

Radon (^{222}Rn) is usually present in the natural environment, since most natural materials contain uranium. Soils usually have 2-3 g t^{-1} of ^{238}U, therefore the radon level of pore-air varies from 7 to 220 kBq m^{-3} having a mean at 27 kBq m^{-3} (Hakl 1992). Due to the continuous mixing in the air column, the radon concentration of free air has a much lower range (0.001-0.1 kBq m^{-3}). In enclosed places radon can be significantly enriched due to the limited ventilation. The radon concentration of cave air ranges from 0.1 to 20 kBq m^{-3} around the world (Hakl et al. 1997). In Mecsek Mts. generally high radon values have been reported, exceeding the mean levels recorded in other Hungarian caves (Koltai et al. 2010).

As radon is an inert gas that has a 3.8-day half-life, it can easily diverge from its parent substance and therefore it can be used as an excellent tracer of underground airflow (Hakl 1997, Dezső and Molnár 2001). Since carbonate rocks are highly fractured radon transport measurements can be particularly useful in the microclimate studies of limestone caves (Hakl et al. 1997). The primary factors governing the migration of radon are temperature, humidity and rock porosity whereas air movements caused by temperature differences or rapid atmospheric pressure changes can have a secondary influence on it, as well (Papp et al. 2004).

The radon concentration of cave air was monitored in several small caves in Western Mecsek Mts. with the aim of studying the characteristics of cave air flow between 1992 and 2007 (Zalán 1998, Koltai et al. 2010, Koltai et al. 2012). Microclimate measurements in Abaliget Cave started in 1992 and were carried out for several years (Zalán 1995, Hakl et al.

1996, Várhegyi 1996). The temperature, relative humidity and radon concentration of cave air was continuously monitored at three different sites inside the cave. In Kispaplika Cave no radon measurement has been carried out before.

In the present paper we would like to summarize the preliminary results of the 9-month-long radon concentration monitoring done in Abaliget and Kispaplika caves.

2. MATERIALS AND METHODS

2.1. The study area

The geological structure of Western Mecsek is characterized by an anticlinal with an eastern-western line of strike. The rocks of the anticlinal are particularly stressed, fragmented and moved by faults (Barta and Tarnai 1999). In Western Mecsek karstic rocks geologically belong to one single block, however, on the surface they can be found in three different zones. The Abaliget and Kispaplika caves are located in the Abaliget-Mecsekrákos fracture and Misina in a 40 km^2 territory. The area is divided by the drainage basins of eight efflux caves. The catchment areas of Abaliget and Kispaplika caves are 15.25 km^2 and 0.85 km^2, respectively (Ország 2003). Both caves were formed in the Lapis Limestone Formation, a thin-bedded, well-karstifiable Anisian limestone (Ország 2003).

Abaliget Cave is the longest cave in Mecsek Mts. with its 1.7 km horizontal and 52 m vertical dimensions. The main passage is 450 m long and ends in a sump. A large room (Large Chamber), which has a 22x12x10 m extension, can be found approximately 20 m above the sump (Fig. 1). Kispaplika Cave is rather small: 52.6 m long and 26 m deep. Apart from the three shafts the passages are quite narrow (Fig. 2).

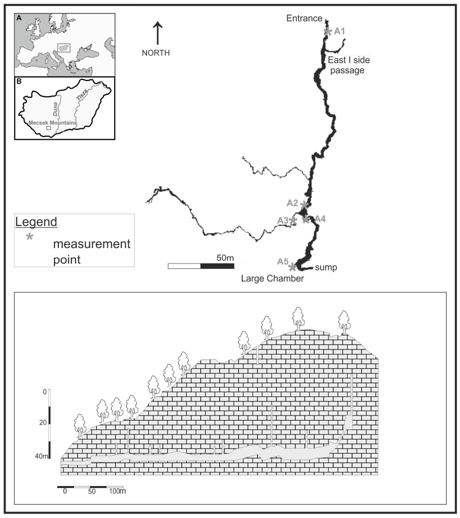

Fig. 1 The map and the longitudinal profile of Abaliget Cave

2.2. Methods

Radosys RSFV track-etch detectors were used for measuring radon concentration for a 9-month-long period in 2012-2013. In both caves, instruments were deployed at three different locations (Figs. 1, 2) and were changed within 1-3 month intervals. The underground data were comprehensively analysed in relation to mean ambient air temperature and atmospheric pressure. Meteorological data was collected at the closest weather station, located approximately 5 km from the research area. Both parameters were recorded at 10 minutes frequency. The weather station is run by Public Limited Company for Radioactive Waste Management.

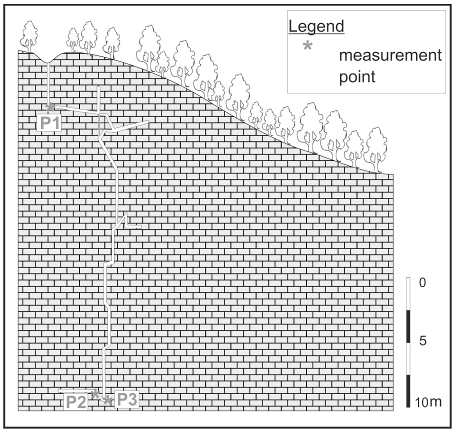

Fig. 2 The longitudinal profile of Kispaplika Cave with the measurement sites

3. RESULTS AND DISCUSSION

3.1. Radon concentration in the caves

The radon concentration of cave air shows a clear seasonal pattern. During the warm summer period the cave was characterized by radon levels varying between 6 and 16 kBq m^{-3}, while in winter much lower values (0.1-1.3 kBq m^{-3}) were recorded. Similar seasonal changes were reported during the previous monitoring (Zalán 1995, Hakl et al. 1996, Várhegyi, 1996). Furthermore, as Table 1 shows radon concentration significantly increased with the distance from the cave entrance except for elevated radon level periods when the detectors placed at A1 recorded higher values than the ones at A2. This might be the consequence of a radon-rich air contribution coming from the East I side passage.

Table 1 Mean radon levels (Bq m^{-3}) measured in Abaliget and Kispaplika caves, Mecsek Mts., Hungary

Place	Measurement period					
Abaliget Cave						
	26.08.12 - 30.09.12	30.09.12 - 29.10.12	29.10.12 - 02.01.13	02.01.13 - 17.02.13	17.02.13 - 24.03.13	24.03.13 - 03.06.13
A1	7.2**	3.6*	0.2*	0.1*	0.3*	2.8**
A2	5.1**	3.4*	0.4*	0.2*	0.6*	2.4**
A3	5.8**	4*	0.4*	0.2*	0.7*	4.9**
A4	7.9**	5**	0.5*	0.2*	1.0*	4.3**
A5	10.3**	16.7**	0.7*	0.6*	1.3*	6.3**
Kispaplika Cave						
	01.09.12 - 30.09.12	30.09.12 - 28.10.12	28.10.12 - 04.01.13	04.01.13 - 15.02.13	15.02.13 - 24.03.13	24.03.13 - 03.06.13
K1	4.2*	2.7*	0.1*	0.1*	4.3*	2.4**
K2	19.3**	17.2**	5.3**	0.3*	8*	5.1**
K3	21.0**	16.7**	5.1**	0.3*	8.2*	4.6**

* 1 sigma uncertainty is 15%, **1 sigma uncertainty is 40%

In horizontal caves with one entrance, like Abaliget Cave, there is usually a continuous inward airflow in winter and an outward one in summer. The direction of airflow is governed by the temperature difference inside and outside the cave. The direction of airflow turns when the surface temperature exceeds or falls below the cave air temperature. Consequently, high summer concentrations are driven by the outward cave airflow that brings the radon accumulated in the fractures of the rock matrix. On the contrary, in winter radon-poor air enters the cave from the surface while diluting the radon concentration of the passages. During transitional periods, when the surface and the cave air temperature are nearly identical, winter and summer flow regimes are following each other and therefore radon concentration fluctuates between two stable levels. Hakl et al. (1996) found the width of this transition phase to be 10°C, owing to the existence of a well-developed vertical fracture system in Abaliget Cave.

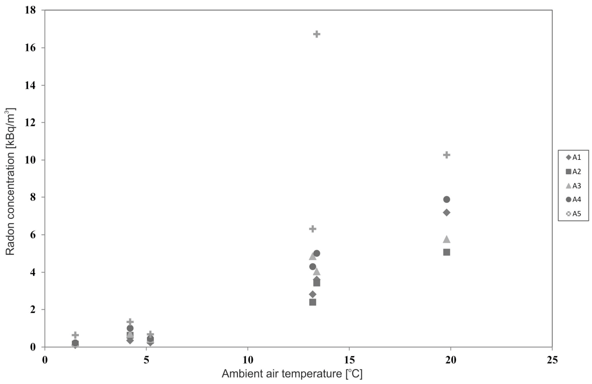

Fig. 3 Mean radon concentration as a function of mean surface air temperature

Table 2 Characteristic radon concentration of cave air in Mecsek Mts, during summer and winter periods (Koltai et al. 2010)

Name of the cave	Place of the detector	Period	Mean ^{222}Rn concentration [kBq m^{-3}]	
			Summer	Winter
Aktív	entrance zone	2000 – 2001	26.5	4.05
Sózó	entrance zone	1999 – 2002	19-20	1-2
Szuadó	entrance zone	2007 – 2008	-	25.35
Trió	end zones	2006 – 2007	7.6	10.5
Upper Szajha	entrance zone	2003 – 2004	1.1	0.4
Vadetetős	entrance zone	2003 – 2004	3.6	15
		2007 – 2008	2.71	2
	end zone	2007 – 2008	11.8	17.4
Pietró	entrance zone	1995 – 2005	2.5-3	7-8
Tüskés	entrance zone	2002 – 2005	2	6-7
Abaliget	entrance zone	2012 – 2013	7	0.1-0.2
	end zone		10	0.6
Kispaplika	entrance zone	2012 – 2013	4.2	0.1
	end zone		21	0.2

Similarly to Abaliget Cave, Kispaplika Cave was also characterized by higher summer and lower winter values. High and low radon concentration periods are mainly driven by air circulation changes inside the cave, induced by the temperature difference of the air inside and outside the cave. In winter the cold surface air sinks into the cave, it warms up inside and rises and comes out, creating an auto-circulation inside the cave. Even though in the case of narrow entrance vertical caves radon concentration changes are mainly controlled by atmospheric pressure (Géczy et al. 1988), these signals, if present, are masked by temperature induced changes of cave airflow owing to the used method.

On account of the preliminary results of the 9-month monitoring, both Abaliget and Kispaplika caves are characterized by similar values to the other caves monitored previously in the area. Winter values are slightly lower than in the other caves. The radon concentration of the caves located in Mecsek Mts. is particularly high, the source of which is still unrevealed. Several factors, for instance the poor ventilation of small and narrow passages or sediments acting as high radon sources can significantly contribute to the high radon concentrations measured over the years. In a previous study of a narrow entrance vertical cave (Vadetetős Cave), both rock and clayey sediment samples were collected in order to mark off the possible sources of radon. The analysed samples showed usual levels of ^{226}Ra and ^{232}Th (Koltai et al. 2012). Further investigation is needed as to locate the exact sources of elevated radon levels measured in some these caves.

3.2. Correlation coefficient among the variables

In both caves large correlation coefficients were found between outside air temperature and radon concentrations at the different measurement points (Table 2). The relationship is less strong in the case of Kispaplika Cave. In the first cave correlation coefficients become slightly higher with increasing distance from the entrance. In both caves the last measurement points at the end zones are characterized by the weakest relationships.

Table 3 Correlation coefficients between the radon concentration of cave air and the meteorological parameters at the different measurement points.

Measurement point	Correlation coefficient with mean ambient temperature	Correlation coefficient with mean ambient pressure
Abaliget Cave		
A1	0.92	0.43
A2	0.95	0.42
A3	0.95	0.25
A4	0.97	0.37
A5	0.60	0.29
Kispaplika Cave		
K1	0.97	0.31
K2	0.77	0.62
K3	0.77	0.61

4. CONCLUSIONS

During the 9-month monitoring both Abaliget and Kispaplika showed elevated summer and low winter radon levels. On the basis of statistical analyses the changes of cave air radon concentration are primarily governed by temperature difference induced cave air circulation. Although in Kispaplika cave air pressure changes might contribute to significant short term increases, the used method was not suitable to study the influence of atmospheric pressure variations. Moreover, with one exception (A1) radon concentration gradually rose with increasing distance from the entrance. During the elevated period, the detector at A1 measurement point recorded higher values than at A2 which might be a consequence of radon rich air coming from East I side passage.

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