View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by Scientific Open-access Literature Archive and Repository

Site-specific radon regimes of a cave system (*)(**)

J. HAKL (1), I. HUNYADI (1), I. CSIGE (1), G. GÉCZY (2) and K. BOLNER-TAKÁCS (3)

(1) *Institute of Nuclear Research of the Hungarian Academy of Sciences H-4001 Debrecen POB 51, Hungary*
(2) *Eötvös Loránd University, Department of Physical Geography, Ludovika square 2 H-1083 Budapest, Hungary*
(3) *Ministry for Environment and Regional Policy, Authority for Natural Conservation Speleological Department - Költõ str. 21, H-1121 Budapest, Hungary*

(ricevuto il 9 Giugno 1998; approvato il 18 Dicembre 1998)

Summary. — The spatial and temporal variation of air-borne ^{222}Rn concentration was continuously measured during 1990-94 with monthly changed etched track detectors in the Pál-völgy and Mátyás-hegy caves, Budapest, Hungary in order to identify site-specific behaviour of radon variations. We found winter minimum and summer maximum levels at each measuring site. In the Pál-völgy cave these end values increased with the distance from the entrance. The maximum-to-minimum ratio, however, showed a broad peak between the entrance and deep cave region. This behaviour can be attributed to the seasonal and depth dependence pattern of the advective dilution effect caused by intrusion of outside radon free air. Far from the entrance radon concentration goes to a saturation value, which approaches the level found in a highly unventilated remote cavity of the cave. In the Mátyás-hegy cave the maximum-to-minimum ratios were small and nearly constant, indicating that the measuring sites belong to deeper parts of the system. The higher maximum values, on the other hand, are attributed to smaller passage sizes of this part. High similarity was found in the temporal variation of radon concentration in the neighbouring parts of the two caves, which reinforced the assumed but by man unpenetrable connection between them.

PACS 92.60.Sz – Air quality and air pollution.
PACS 29.40 – Radiation detectors.
PACS 01.30.Cc – Conference proceedings.

1. – Introduction

Limestone contains about 1.3–2.5 ppm uranium. ^{238}U is the parent element of a radioactive decay series and the noble gas, ^{222}Rn, as one member of this is continuously

(*) Paper presented at the "Fourth International Conference on Rare Gas Geochemistry", Rome, October 8-10, 1997.
(**) The authors of this paper have agreed to not receive the proofs for correction.

© Società Italiana di Fisica

produced in cave environment. The worldwide distribution of cave radon was found to be log-normal with geometric mean of 1130 Bqm^{-3} and geometric STD of 6.3. Due to the special karst morphology the caves are able to communicate with the atmosphere through the overburden under the influences of changing pressure or temperature. The most common and apparent phenomenon discovered in the majority of the investigated caves throughout the world was the seasonal change of radon activity concentration. For more detailes see Hakl *et al.* (1997) and its references.

A small but complex cave system was selected for the present study. The Pál-völgy and Mátyás-hegy hydrothermal caves are below the inhabited Rózsadomb area of Budapest, Hungary, a part of the Buda Mountains. The two nearby situated caves are accommodated in the Upper Eocene limestone and marl. They represent a labyrinth of intersecting passages of rather uniform character. The orientation of this declining rectilinear maze pattern closely coincides with the directions of the NE-SW and NW-SE tectonic lines. Bigger chambers and halls are found at the intersections. The passage arrangement follows the general south dip of the host Eocene limestone. The cave entrances open at 205 m above sea level and dip up to 220 m and down to 110–120 m above sea level. The recently explored lengths are 12.4 km and 5.0 km, whereas the horizontal extensions are $970 \times 400\ m^2$ and $290 \times 170\ m^2$ for the Pál-völgy and Mátyás-hegy caves, respectively. Both caves have very similar morphology. The two systems must have been one cave in the past, however there is no known present

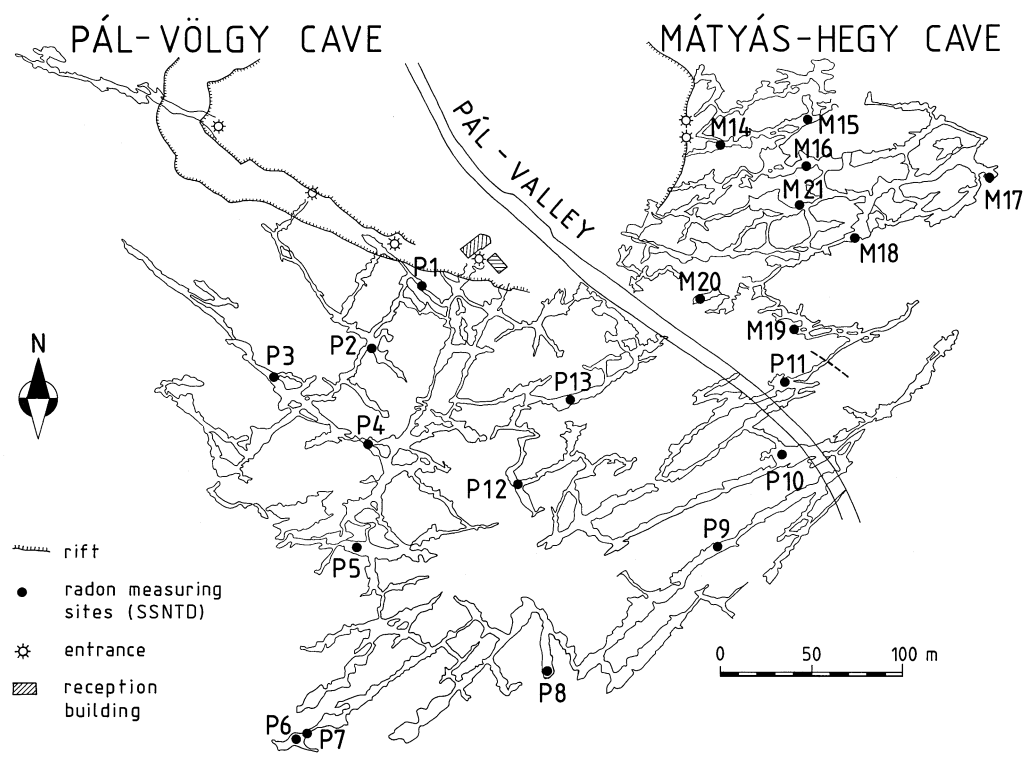

Fig. 1. – The horizontal map of the Pál-völgy and Mátyás-hegy caves, Budapest.

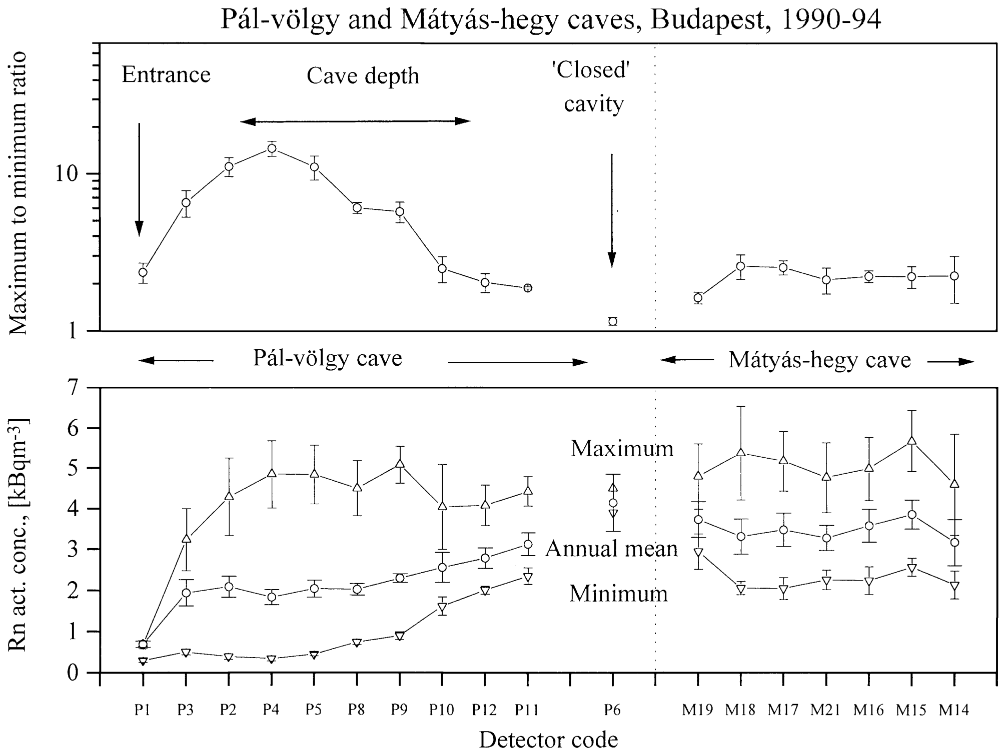

Fig. 2. – The spatial trend in the average summer maxima, annual means, winter minima and max/min ratios calculated for the 4-year-long observation period. The sequence of data points represents the main pathway of air circulation. For the plot the most characteristic points were chosen.

connection between them. Earlier published radon measurements by grab sampling were performed in the touristic part of the Pál-völgy cave (Szerbin, 1996).

2. – Materials and methods

For the purpose of air-borne radon concentration measurements we used opened diffusion cups (diameter: 5.5 cm, height: 12 cm) equipped with LR-115 type-II track detectors. The sensitivity of the radon monitor was 2.3 alpha-tracks $\cdot$ cm^{-2}/kBq $\cdot$ m^{-3} $\cdot$ h at standard etching conditions. The inverted cups were placed along the main passages more or less equidistantly. The 14 regular measuring sites in the Pál-völgy cave and 9 measuring sites in the Mátyás-hegy cave are shown on the horizontal map of the system in fig. 1. With monthly changed detectors 971 radon data were obtained in the two caves during the years 1990-1994.

3. – Results and conclusions

In the Pál-völgy cave we have observed regular seasonal variation at all but one measuring place. The average annual radon activity concentration is low, 0.7 $kBqm^{-3}$, at the entrance, but after 50 m it slowly increases with the distance to 3.1 $kBqm^{-3}$ (see fig. 2). While the maximum (summer) values, going soon to saturation, are scattered around 4.8 $kBqm^{-3}$ the annual mean and minimum (winter) values slowly increase in the same manner. The max/min ratio showed a broad peak between the entrance and deep cave region. This peak is characteristic for an intermediate zone (P2-P5) starting at 100 m from the cave entrance. Here the summer values are high and the winter values are similar to the entrance ones. This sequence of radon data can be interpreted by a ventilation pattern, which is characteristic for the vertical convective transport through relatively large openings. The direction of inside-outside temperature gradients results in stagnation of cave air in summer, while in winter the cold outside air sinks into the cave. Along P8-P11 the annual average radon data increase as a consequence of the slowing-down of the winter airflow. This sequence can be interpreted by the depth dependence of ventilation. As the cave is covered by highly impermeable marl, ventilation is restricted into the passages. In deeper parts of the cave, due to thermal equilibration, convective air exchange weakens, resulting in lower dilution by outside air. The reduced air flow results in higher average air-borne radon concentration. At one, highly isolated point (P6) we found the lowest seasonal effect in the radon record.

The radon regime of the Mátyás-hegy cave showed low winter and high summer values. The annual average was in the range 3.3–3.8 $kBqm^{-3}$, the max/min ratio was in the range 1.4–2.1, showing the closing effect of the overlying marl and the lack of large openings. There was a high similarity between the radon regimes in the neighbour parts of the Mátyás-hegy cave and the Pál-völgy cave. This result reinforces the already assumed interconnection of the two cave systems.

* * *

This work was supported in part by the Hungarian National Scientific Research Fund contract Nos. T 016558 and T 017560.

REFERENCES

HAKL J., HUNYADI I., CSIGE I., GÉCZY G., LÉNÁRT L. and VÁRHEGYI A., *Radon transport phenomena studied in karst caves, international experiences on radon levels and exposures*, *Radiat. Meas.*, **28** (1997) 675-684.

SZERBIN P., *Radon and exposure levels in Hungarian caves, Health Phys.*, **71** (1996) 362-369.