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Nuclear analytical study of transport processes of cave-surface interrelations

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Abstract

Measurements of Rn activity concentration have been performed in about 150 sub-surface and near-to-surface monitoring stations in different Hungarian karstic areas. They have shown that radon dissolved in circulating subsurface fluids migrates along cavems and fractures, as far as the velocity of transporting medium slows it. This type of migration, and the underground air circulation, are controlled by environmental factors, such as temperature difference between cave and outside, which has daily and annual variations.

Résumé

Des mesures de la concentration en radon ont été effectuées dans environ 150 stations hongroises situées en milieu karstique, à peu de profondeur. Ces mesures ont montré que, dissout dans les fluides qui circulent près de la surface du sol, le radon migre dans les cavités et les fractures, jusqû'à des distances qui dépendent de la vitesse du fluide qui le transporte. Ce type de migration, tout comme la circulation souterraine de l'air, dépend de facteurs de l'environnement, et en particulier de la différence de température entre cavité et extérieur, qui présente une variation journalière et une variation annuelle.

I. INTRODUCTION AND METHODS

From 1978, the Institute of Nuclear Research of the Hungarian Academy of Sciences has been performing *in situ* environmental radon activity concentration measurements in different karstic areas of Hungary, in about 150 sub- and near-to-surface monitoring stations in different substances (cave air, soif, water).

In the beginning, the radon activity concentration was registered by monthly changed integrating nuclear Crack detectors using diffusion cup technique (SO MOGYI *et al.,* 1984). This type of detector gives an integrated ,court, which is proportional to the mean radon activity concentration for a given exposure Lime.

Since 1991 I P controlled automatic field radon monitors were also applied in a few cases. By this method the time resolution of measurements was significantly increased and was limited to only a few hours.

II. RADON TRANSPORT PHENOMENA

The underground radon transport is a complicated multidimensional two components (radon and carrier fluid) transport through heterogeneous media where diffusion and flow may equally be significant. A general quantitative description of the above mentioned process is hardly possible due to the "fractal" nature of border conditions, which would be necessary to know to solve the appropriate differential equations.

In spite of these uncertainties, some kind of global tendencies can be well recognized on radon records. The comparison of radon activity concentrations of karstic streams originating from different environments showed a great difference both in time and space.

Few surface streams showed apparent seasonal changes, which in turn may be related to the general seasonal change in cave air radon activity concentrations, which was the most apparent phenomenon found in almost all cases (CSIGE *et al.,* 1989; HAKL *et al.,* 1991; ATKINSON *et al.,* 1983; QUINN, 1988).

These seasonal changes can be explained by air circulation which emerges in a seasonally reversed direction through karstic strata. These underground winds, in a seasonally changing direction, wash out the air from the radon rich fracture systems of karstic terrains. If this air current is going in direction rock or soil surface -> fracture system -> galleries -> entrance, then an increased radon level can be measured inside the caves. In winter, when flow direction reverses, the fresh atmospheric air dilutes the radon concentration in the caves.

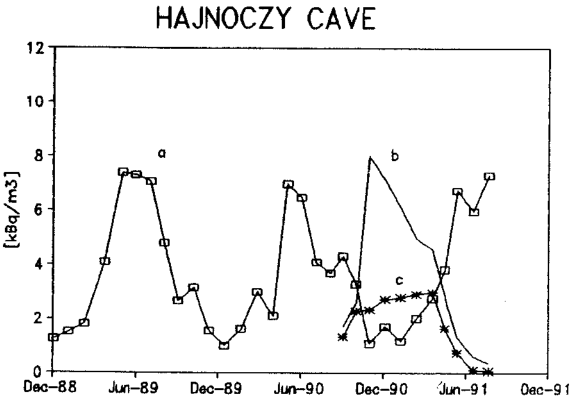

Figure 1 : Variation of the radon activity concentration (a) in the air of a Hajnóczy cave, (b) in the surface soil, (c) in the air of an open fracture on the upper side of the hill, where the cave is èmbedded.

In accordance with this model, an increased radon exhalation was also detected in winter at the top of the biggest Hungarian vertical karstic cave system, in a vertical, a few metres deep, fracture and in covering soil above the Hajnóczy cave and in some potholes. It is worth to mention that, due to gravitational reasons, in ail of these cases only winter minima could be expected.

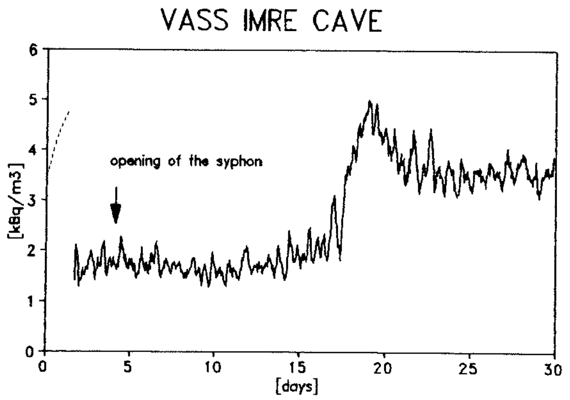

Figure 2 : Hourly radon activity concentrations in the Vass Imre cave. Daily changes and the effect of the opening of the syphon are well traceable on this record.

In Fig. 1, the most convincing experimental results are represented. The last three years section of the mean radon activity concentration observed in the air of the Hajnóczy cave (a) is shown together with the radon activity concentration measured simultaneously in the surface soil (b) and in the air of an open fracture (c) on the upper side of the hill, where the cave is embedded.

Further details of the above mentioned transport process can be found on the records of continuous automatic radon monitors. A daily change is also an apparent phenomenon but with smaller relative amplitudes as it can be seen on the summer data record from the Vass Imre cave on Fig. 2.

The impact of the opening of a syphon on radon concentration is also shown on the same Fig. 2. The most interesting features of this process are the few days long time scale changes and the overshot of the curve. Both of these phenomena are related to the appropriate differential equation (JANSSENS *et al.,* 1984), which is dependent on time. The calculated time constant is in good accordance with radon decay constant, so this response can be attributed to the overall shift of radon profiles in the cave walls itself, which the air movement induces (HAKL, 1992).

The figure clearly shows that opening of further free space significantly changed radon concentration, the change of which can be attributed to the increased air circulation. The other effect was found in winter: in this case, by opening of the syphon, radon activity concentrations decreased.

HI. CONCLUSIONS

Field measurements of radon showed that, in karstic regions, radon dissolved in circulating subsurface fluids migrates along caverns and fractures, as far as the velocity of transporting medium allows it. This type of migration, and die underground air circulation, are controlled by environmental factors, such as temperature difference between cave and outside, which has daily and annual variations. Other scale changes can be attributed to the karst structure itself, the more detailed study of which is in progress.

IV. ACKNOWLEDGEMENT

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