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Dependence of radon levels in the Postojna Cave on outdoor air temperature

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Postojna Cave is the biggest of 12 show caves in Slovenia. Because of elevated radon concentrations it has been under permanent radon survey since 1995. The influence of meteorological conditions on the radon levels and their temporal variations depends mostly on the shape of the cave, and the number and directions of cracks, corridors and fissures connecting the cave rooms with the outdoor atmosphere. It is a horizontal cave with a stable yearly temperature around 10 ˚C. The driving force for air movement in the cave, and thus the inflow of fresh air and release of the cave air to the atmosphere, is the temperature difference between the cave air and outdoors. In our study, we intend to predict radon concentration in the cave air on the basis of this temperature difference.

Measurements of radon concentration in the Postojna Cave were carried out continually (recorded ones an hour) from July 2005 to October 2009 in the Great Mountain hall (with some interruptions because of failure of instrument). The data from July 2005 to October 2007 were included in the analyses while the other part of the dataset was used for testing the model, which predicts radon concentration. Outdoor temperature has been recorded at the Postojna meteorological station and provided by the Environmental Agency of the Republic of Slovenia.

The cave behaves as a large chimney and in the cold period the warmer radon-rich cave air is released to the colder outdoor atmosphere, allowing the inflow of fresh air with low radon levels. The radon levels in the cave are the highest when the outdoor temperature is similar or lower as the cave temperature (10 ˚C) and, hence, the air movement is very low. Our calculations have shown that the effect of the difference between outdoor and cave temperature on radon concentration was delayed for three days, presumably because of the distance of the Great Mountain from the entrance (cca 2 km). When daily outdoor temperature drops below –6 ˚C, radon concentration no longer follows linear relationship with outdoor temperature and the concentration grows higher resulting in an average value of 644 $\pm$ 235 Bq m^{-3}. It is assumed that ice and snow on the surface above the cave prevent the cave air from escaping the cave. In summer, the vertical air movement stops or is minimal and the horizontal air movement has the main influence on radon concentration in the cave.

For data analysis, the one dimensional transport equation based on radon production, decay, molecular diffusion and air flow in a cylindrical void embedded in a rock matrix provided by Nazaroff (1992) has been used: $\frac{dC}{dt} \approx -\frac{k_{\text{i}|\Delta T|C}}{L} - \lambda C + \Phi$ (1). Here, C is the radon concentration [Bq m^{-3}], $t$is time [s], ΔT is the difference between outdoor temperature and cave temperature [K], L is the distance from the entrance to the Great Mountain [m], λ is radon decay constant (2.1$\times$10^{-6} s^{-1}) and Φ is radon source term [Bq m^{-3}s^{-1}]. Based on the temperature difference, this equation predicts radon concentration. In the analysis of the dataset from July 2005 to October 2007, the concentration reached its maximum (2,800 Bq m^{-3}) in summer when the air draught in the cave was minimal or zero. Under these conditions the radon source term of 5.9$\times$10^{-3} Bq m^{-3}s^{-1} was obtained. The k values were calculated for the summer (k_1) and winter regime (k_2) separately, and the averages of 0.19 $\pm$ 1.07 mm s^{-1}K^{-1} and 0.93 $\pm$ 31.13 mm s^{-1}K^{-1}, respectively, were obtained. The results have shown a good correlation between the measured and predicted radon concentration.

Nazaroff, W. W.: Radon transport from soil to air, Reviews of Geophysics, 30, 137–160, 1992.