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A MODEL FOR PREDICTION OF RADON CONCENTRATION IN THE POSTOJNA CAVE

ASTA GREGORIČ, univ. dipl. ing. geol.
Study programme: **Ecotechnology**
Jožef Stefan International Postgraduate School
Supervisor: **Assoc. Prof. Dr. JANJA VAUPOTIČ**
Course Leader: **Assoc. Prof. Dr. ALEKSANDER ZIDANŠEK**
Jožef Stefan Institute, Jamova 39, 1000 Ljubljana

Introduction

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 (Vaupotič, 2008). 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. 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 (Hakl et al., 1997). In our study, we intend to predict radon concentration (C_{Rn}) in the cave air on the basis of this temperature difference.

Experimental

Measurements of C_{Rn} in the Postojna Cave were carried out continually (recorded once per hour) from July 2005 to October 2009 in the Great Mountain hall (with some interruptions because of failure of instrument. Outdoor temperature (T_{out}) has been recorded at the Postojna meteorological station and provided by the Environmental Agency of the Republic of Slovenia.

1. Seasonal pattern

Winter regime: $T_{out} < T_{cave}$

- Chimney effect: the warmer radon-rich cave air is released to the colder outdoor atmosphere, allowing the inflow of fresh air with low C_{Rn} (Fig. 3).
- $T_{out} \approx T_{cave}$: The air movement is very low → C_{Rn} reaches its maximum
- $T_{out} < -6$°C: ice and snow on the surface above the cave prevent the cave air from escaping the cave → C_{Rn} grows higher.

Summer regime: $T_{out} > T_{cave}$

- The vertical air movement stops or is minimal and the horizontal air movement has the main influence on C_{Rn} in the cave.

The effect of the difference between T_{out} and T_{cave} on C_{Rn} is delayed for 3 days, presumably because of the distance of the Great Mountain from the entrance (cca 2 km).

2. Building the model

- Dataset: July 2005 to October 2007
- The one dimensional transport equation provided by Nazaroff (1992) can be transformed to the following equation:

$$\frac{dC}{dt} \approx -\frac{k_i|\Delta T|C}{L} - \lambda C + \Phi$$

C ... radon concentration (Bq m^{-3})
t ... time (s)
ΔT ... the difference between T_{out} and T_{cave} (K)
L ... the distance from the entrance (m)
λ ... radon decay constant (s^{-1})
Φ ... radon source term (Bq m^{-3}s^{-1})

- C_{Rn} reached its maximum (2800 Bq m^{-3}) in summer when the air draught in the cave was minimal or zero → Φ was calculated: 5.9×10^{-3} Bq m^{-3} s^{-1}.
- The k values were calculated for the summer (k_1) and winter regime (k_2) separately (Table 1).

k_i	T_{out}	k (mm s^{-1}K^{-1})	C_{Rn} (Bq m^{-3})
k_1	T_{out} > 10°C	0.193 ± 1.072	
k_2	-6°C < T_{out} < 10°C	1.8 ± 31.137	
	T_{out} < -6°C		644 ± 235

Table 1: Constant k for summer and winter regime.

3. Testing the model

For testing the model the dataset from November 2007 to October 2009 was used. The correlation coefficient between measured and predicted C_{Rn} is **0.76**.

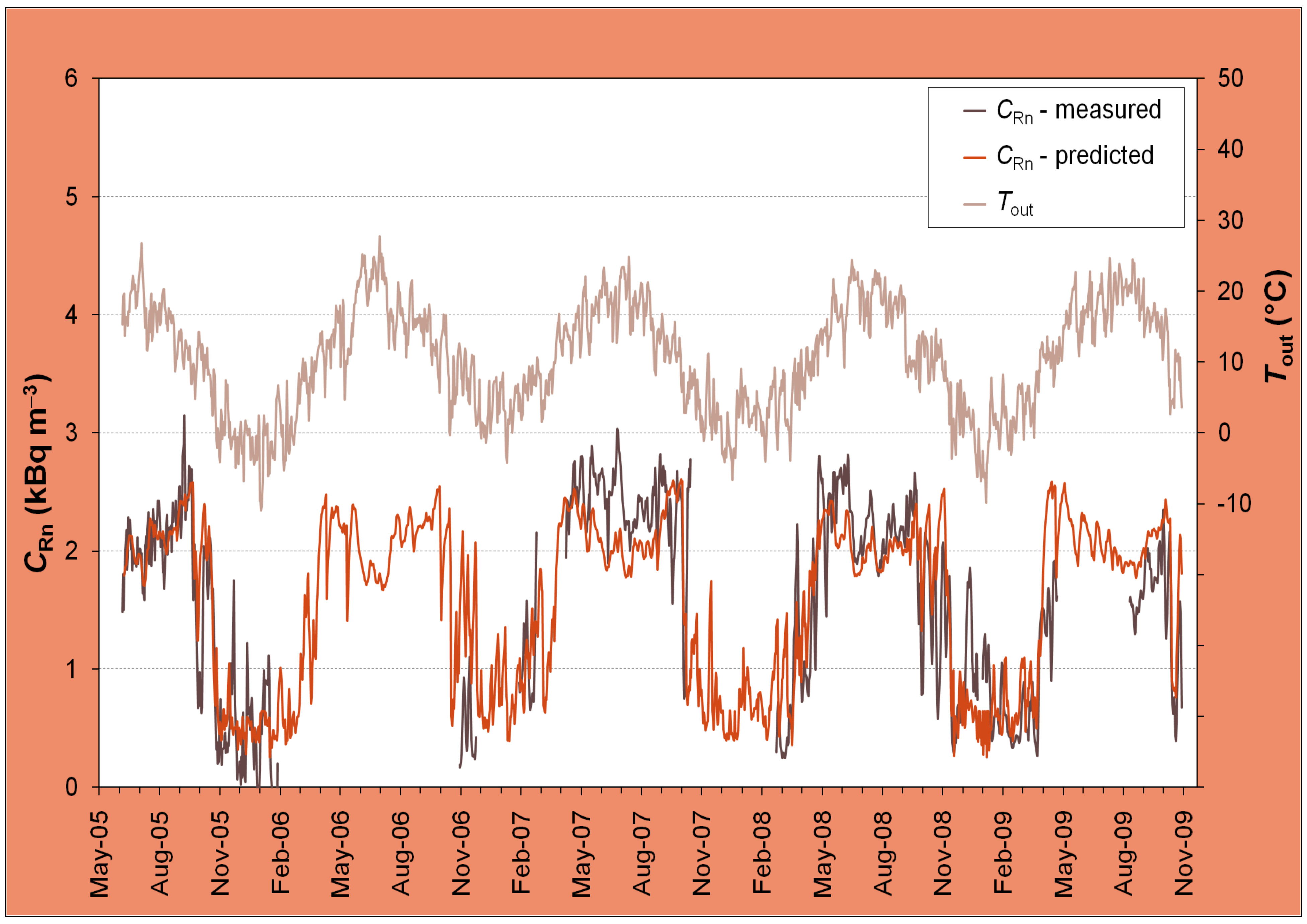

Figure 1: Comparison of predicted and measured C_{Rn} from July 2005 to October 2009.

Results

Our results have shown a good agreement between the measured and predicted radon concentration (Fig. 1). However this agreement is better in summer and winter months, whereas in the transitional period (from March to April and from October to November) the error of prediction is higher.

Conclusion

The model, developed on the results of our previous long-term radon monitoring in the Postojna Cave, provides a relatively good prediction of radon concentration in the cave air, simply on the basis of the difference in air temperature in the cave and outdoors. Although successful, the model may certainly not replace the measurements but could reduce markedly their number, without diminishing the level of reliability of data needed for dose estimates for the personnel working in the cave.

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, 675-684, 1997.

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

Vaupotič, J.: Nanosize radon short-lived decay products in the air of the Postojna Cave, Sci. Total Environ., 393, 27-38, 2008.