MEAN RESIDENCE TIME OF DRIP WATER IN POSTOJNA CAVE, SLOVENIA

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Abstract. Postojna Cave (Slovenia) is one of the most famous karst caves in South Eastern Europe. Drip water is one of the factors that determines cave interior. During 2010 and 2011 monitoring of drip water in Postojna Cave was performed at 9 locations within the Cave. Drip rate was measured and the isotopic composition ($\delta^{18}O$) of drip water was determined. Rain water was collected at Zalog pri Postojni and its $\delta^{18}O$ composition determined. Variations in $\delta^{18}O$ of drip water range from -8 to -10 ‰. The mean residence time was estimated based on the assumption of complete mixing, and for different drip sites it varies between 7 months and several years.

Key words: Postojna Cave, isotopic composition, drip water, MRT

INTRODUCTION

Postojna Cave (Slovenia) is famous karst cave in South Eastern Europe. Comprehensive investigation of percolation water drip rate and its chemical composition has been undertaken with the aim to monitor recent geochemical and stable isotope characteristics (Mandić, 2013). The interest in measurement of drip rates is to improve our knowledge of seepage dynamics in karst terrains (Genty and Deflandre, 1998). The rate at which water infiltrates into the cave is related to effective rainfall (water excess), the caprock lithology, structural and tectonic settings, and storage in the epikarst (Sondag et al., 2003). Also, drips sites within the same cave may be highly variable, even if the drip sites are close to each other (Beddows et al., 2006). In this paper mean residance time of drip water from different locations in Postojna cave is determined, based on stable isotope $\delta^{18}O$ composition of precipitation and drip water.

SITE DESCRIPTION

The Postojna Karst is situated on NW part of the Dinaric Karst (Figure 1), on the border of the sub-Mediterranean climate of the North Adriatic Sea and the continental climate of central Slovenia (Gospodarič and Habič, 1976). It is composed of mostly Cretaceous carbonate rocks while Triassic and Jurassic dolomites appear on the northern and north-eastern side and Eocen flysch on the western and south-western part (Šebela, 1998).

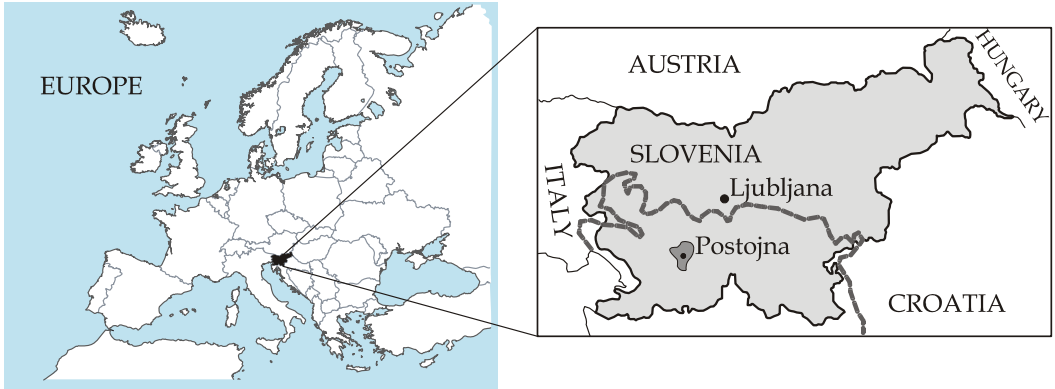


***Figure 1**. Map of Europe with position of Slovenia (left); (right) map of Slovenia with Postojna Karst area (darker shadowed area). The boundary of the Dinaric karst (- - -) is shown (Gams, 1974).*

In the last period of six years (2006 – 2011) average air temperature is 9.9 ± 0.4 ºC and average precipitation amount is 119 mm. Data for amount of precipitation and temperature (Figure 2) are provided by National Meteorological Service of Slovenia (meteo.si).

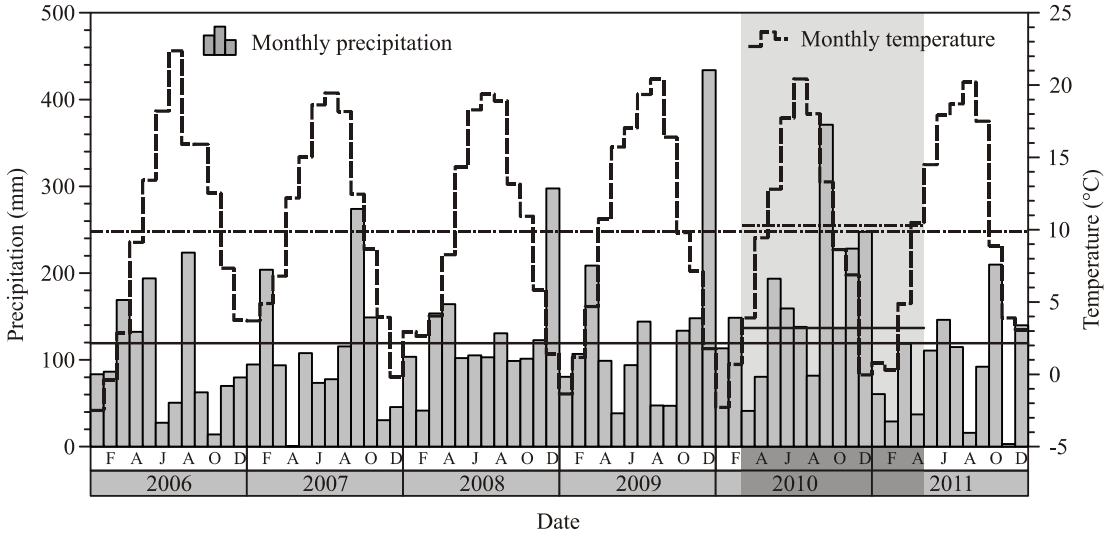
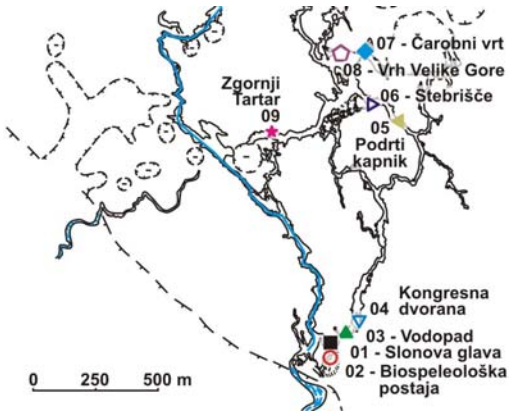


Figure 2. *Precipitation amount and monthly temperature in Postojna for period 2006 – 2011. Sampling period from March 2010 to April 2011 is shown by shadowed area. For both periods, mean precipitation amounts are marked by full lines and monthly temperature averages by dashed lines.*

SAMPLING AND MEASUREMENT

Monitoring in Postojna Cave was performed in the period from March 2010 to April 2011. Sampling of drip water was done at 9 locations within the cave (Figure 3). On the field air and drip water temperature were measured. Stable isotope composition of water ($\delta^{18}O$) were determined in Laboratory Centre for Isotope Hydrology and Environmental Analytics, Joanneum Research Institute (Graz) by dual inlet attached to a Thermo Fisher Scientific DELTA^{plus}XL isotope ratio mass spectrometer, with water equilibration unit as periphery. $\delta^{18}O$ values are reported relative to the VSMOW scale. Calibration of the mass spectrometer was accomplished using in-house water reference materials whose stable isotopic composition had previously been calibrated (Spötl, 2005). Precipitation has been sampled as integrated monthly sample of the rain water at Zalog pri Postojni. The rain was collected in a high-density polyethylene plastic (HDPE) canister (cca. 5 liter capacity), through a plastic funnel (IAEA, 1997). At the end of the month canister was replaced with the clean and empty one. Stable isotope composition ($\delta^{18}O$) of precipitation has been measured at the Jožef Stefan Institute in Ljubljana with IsoPrime mass spectrometer attached to MultiFlow Bio. Equilibration of sample with CO_2 was done prior to sample measurement.



Location number and name	Symbol
01 - Slonova glava	■
02 - Biospeleološka postaja	○
03 - Vodopad	▲
04 - Kongresna dvorana	▽
05 - Podrti kapnik	◀
06 - Stebrišče	▷
07 - Čarobni vrt	◆
08 - Vrh Velike gore	⬠
09 - Zgornji Tartar	★

Figure 3. *Sampling locations in the Postojna Cave (left). List of names of the sampling locations and their numbers, and the symbol applied in this paper (right)*

RESULTS AND DISCUSSION

Mean air temperature of the Postojna Cave measured on nine locations (01 – 09) from March 2010 to April 2011 is 10.6 ± 0.7 °C, and outside air temperature in the same period is 10.3 ± 7.1°C (Figure 2). Accordingly, it can be concluded that the mean temperature within the cave reflects average yearly temperature of outside air. The mean water temperature at locations close to the exit (01 – 04) is 9.7 ± 0.5 °C and for inner location (05 – 09) it is 10.4 ± 0.8 °C. Water temperature reflects mean air temperature at all sampling locations. All drip waters from sampling locations, according to their chemical composition, show similar properties because of the same geologic origin. They belong to the Ca-HCO_3 type of waters.
The $\delta^{18}O$ values of drip water vary between -10 and -8 ‰ with practically now seasonal variations (Figure 4), while variations in $\delta^{18}O$ of precipitation are higher, -11 to -5.6 ‰, with obvious seasonal behavior.

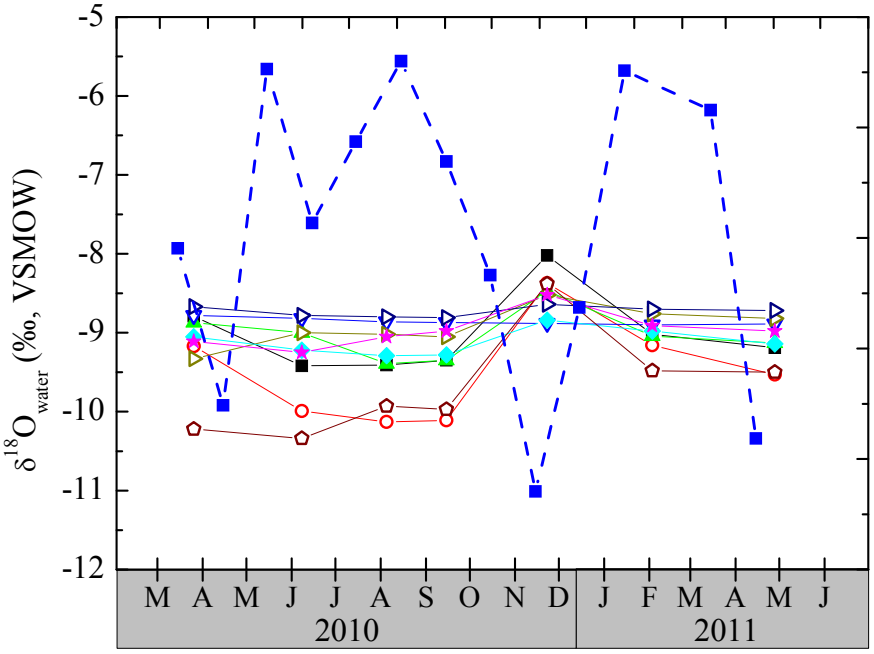


Figure 4: *$\delta^{18}O$ in drip water from nine sampling locations in Postojna Cave and precipitation (■) from Zalog pri Postojni. Symbols for drip sites 01 – 09 are defined in Figure 3.*

Mean residence time (MRT) can be estimated by applying exponential mixing model of water of various ages in epikarst (Maloszewski et al., 1983). The model compares yearly variations in $\delta^{18}O$ values in drip water and in precipitation, equation 1, under assumption of the complete mixing of water in epikarst.

$$MRT = \omega^{-1} \cdot \left(\frac{A_{prec}^2}{A_{dw}^2} - 1\right)^{\frac{1}{2}}, \qquad 1$$

where A_{prec} and A_{dw} are the amplitudes of $\delta^{18}O$ in precipitation and in drip water, respectively. Amplitudes are calculated as a difference of minimum and maximum values of $\delta^{18}O$ of precipitation and drip water, respectively. The ω equals 2π/T where T represents period of seasonal variations of $\delta^{18}O$ that equals 1 year. The obtained MRT's are presented in Table 1. For different locations calculated MRT is different, which can be due to differences in the overburden. Locations having short MRT (several months) are locations 01, 02 and 08. Location 08 shows the shortest MRT of 7 months. Locations 03, 05, 07 and 09 have MRT between 1 and 3 years, while locations 04 and 06 have the longest MRT of 10 and 7.5 years, respectively.

Table 1. Mean residence time (MRT) for monitored locations

Location	A_{prec} (‰)	A_{dw} (‰)	MRT (yr)
01	5.71	1.40	0.84
02	5.71	1.76	0.66
03	5.71	0.90	1.32
04	5.71	0.12	10.00
05	5.71	0.80	1.49
06	5.71	0.16	7.50
07	5.71	0.44	2.72
08	5.71	2.00	0.58
09	5.71	0.72	1.66

CONCLUSION

Monitoring of hydrochemical and stable isotope characteristics of drip water at 9 locations in the Postojna Cave environment was performed from March 2010 to April 2011. According to their chemical composition, drip waters from all studied sampling locations belong to the Ca-HCO_3 type of waters. $\delta^{18}O$ values of drip water do not show seasonal variations and the fluctuations are smaller than those of $\delta^{18}O$ in precipitation.

Exponential mixing model of drip waters was presumed and mean residence time calculated. The MRT varies for different sampling sites from 7 months to 10 years. Investigation should be continued by sampling of precipitation and drip water in order to evaluate oxygen and hydrogen ($\delta^{18}O$ and $\delta^{2}H$) isotope composition, to combine them with broader, regional scale precipitation data (Vreča et al., 2006). The data would enable further hydrogeological investigations important for Postojna Cave.

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