Abstract

A multi-year cave monitoring was performed in Bunker Cave, located in the massive Devonian limestone of Iserlohn (Sauerland/NRW), in order to improve the understanding of the processes in the karst system. The results should lead to an enhanced interpretation of geochemical data of stalagmites as a continental palaeoclimate archive.

Bunker Cave was monitored with respect to its cave air measuring temperature, relative humidity, CO$_2$ partial pressure and $\delta^{13}$C. CO$_2$ partial pressure and $\delta^{13}$C were also measured in soil air. Furthermore drip and soil water were analyzed for their $\delta^{18}$O, $\delta^D$, $\delta^{13}$C$_{DIC}$, cation and anion composition, as well as rain water for the amount, $\delta^{18}$O and $\delta^D$. At several drip sites in the cave drip rates were measured both manually and automatically. Recent calcite precipitates were sampled on watch glasses and their $\delta^{18}$O- and $\delta^{13}$C-values determined. In addition, crystal morphology and growth rate were studied. For implementation two holocene/recent stalagmites were investigated for their macroscopic and microscopic crystal morphology, C/O-isotopic composition and Mg/Ca-ratio. They were dated using the Th/U-method.

Bunker Cave is a dynamically ventilated cave due to its two entrances with a constant temperature of 10.6°C representing the mean annual surface temperature of 10.5°C. The humidity is also constant at 93%. Evaporation can thus be excluded for this cave system. The CO$_2$-content of the cave atmosphere (600-900 ppmv) is coupled with the seasonal and temperature dependent cycle of the CO$_2$-content of the soil air (2000-5000 ppmv).

None of the drip sites shows a direct response to rainfall events, but drip rates increase several months after the main infiltration phase. Each drip site has its own specific model of discharge with a mixture of seepage and more or less fissure flow. The discharge is variable at the different drip sites ranging from 5.8 ml/min at drip site 1 to 0.001 ml/min at drip site 8.

Chemical water analyses show that both pH-value (7.60-8.04) and $\text{SI}_{\text{calcite}}$ (0.30-0.66) depend on the CO$_2$-content of the cave atmosphere. Higher amount of calcite precipitation was observed during winter when cave CO$_2$ (600 ppmv) is lower. Cation and anion analyses allow distinguishing between different parts of the cave, and SO$_4^{2-}$ and NO$_3^-$ were pointed out as proxies for the residence time. Low SO$_4^{2-}$ and high NO$_3^-$-values suggest a shorter residence time for drip sites 1 and 5.
(“Chamber 1”), higher $\text{SO}_4^{2-}$- and lower $\text{NO}_3^-$-values indicate longer residence time for drip sites 2, 3, 6, 7 and 8 (“Chamber 2” and “Photographer’s Chamber”).

The $\delta^{18}\text{O}$- and $\delta\text{D}$-signal of the drip water are constant over the monitoring period. This implies a major mixing reservoir in the soil and epikarst zone. Furthermore, $\delta^{18}\text{O}$ (-8.0‰) and $\delta\text{D}$ (-54.5‰) reflect the infiltration weighted mean of the precipitation with -8.1‰ for $\delta^{18}\text{O}$ and -55.1‰ for $\delta\text{D}$. The seasonal isotopic composition of precipitation is temperature dependent, which results in a long term temperature signal in the drip water. The $\delta^{13}\text{C}$-values of the drip water are influenced by kinetic effects due to fast degassing of $\text{CO}_2$ and are depend on the drip rate. Lower drip rates are coupled with high $\delta^{13}\text{C}$-values and vice versa.

These kinetic effects depend on the drip rate as documented by the C/O-isotopic analyses of the recent calcite precipitates. This results in an influence of both temperature and precipitation on the $\delta^{18}\text{O}$-values. The $\delta^{13}\text{C}$-values depend on drip rate and therefore, on precipitation. These findings demonstrate an important input for the interpretation of stalagmites.

The analysis of the macroscopic and microscopic studies as well as the results of the C/O-isotopic composition and the Mg/Ca-ratio of stalagmites BU 1 and BU 4 in combination with the findings of the monitoring allows a relatively reconstruction of precipitation in the Holocene. The stalagmites show a relative dry Atlanticum followed by a wetter Subboreal and a very humid Subatlanticum.

The results of the cave monitoring provide a relevant/essential background for the interpretation of speleothems. In general cave monitoring is important to understand the processes in the karst and for interpretation of speleothems in terms of palaeoclimate.