Tufa barriers and laminated carbonate incrustations in Krka National Park, Croatia, as modern climate indicators

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Recent carbonate precipitates (tufa and laminated incrustations) formed in the Krka National Park (Central Dalmatia, Croatia) were investigated. Stable isotope composition of carbonate precipitates ($\delta^{13}C$, $\delta^{18}O$), as well as river water chemical and isotopic composition (Ca^{2+}, Mg^{2+}, pH, total alkalinity, $\delta^{18}O$, δD, $\delta^{13}C$ of dissolved inorganic carbon) were analysed. Saturation indices for carbonate minerals (calcite, aragonite, dolomite) revealed that supersaturation (SI<0.3) was not necessarily sufficient for chemical precipitation of calcite. However, precipitation can take place in turbulent water at cascades, waterfalls, and mechanical burdens or in microenvironments created by plants. Laminated precipitate was formed form the spray on the ceiling of a concrete tunnel diverting the water masses to the Jaruga power plant.

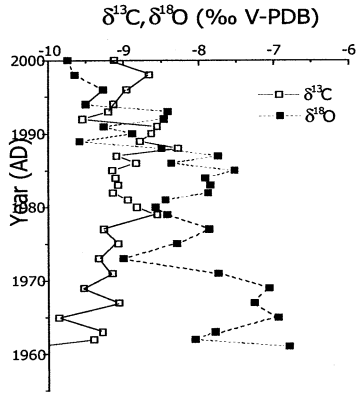

Figure 1: Carbon and oxygen isotopic composition of laminated carbonate over last 40 years

Three subsequently warmer periods (1960-1970, 1970-1990 and from 1990 on) can be identified from the $\delta^{18}O$ record, while the interpretation of carbon isotope signal is more debatable; higher $\delta^{13}C$ values can be attributed to increased biological productivity or to a change in input of soil-derived CO_2.

How can SUSTAINABILITY in groundwater use be determined?

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Problem

Sustainable use of groundwater resources has quantitative and qualitative requirements. Withdrawal has to be compensated by recharge and steady-state concentrations of contaminants should stay below official limits.

Approach

To define the actual quality condition of the aquifer and to observe its temporal evolution relevant parameters and contaminants have to be measured.

To predict the future evolution under a changing environment more sophisticated data (isotopes) and methods (numerical flow models) are necessary.

Questions

Foresighted groundwater management requires answers to the following questions: How can changes of mixing ratios and residence times be detected. How can changes of flow paths and of recharge conditions be recognized? How can trends be distinguished from natural variations?

Parameters and tools

Answers can be obtained with adequate tools and monitoring strategies which may be adjusted to the geochemical environment and the timescale of a groundwater system. In general physical (pressure heads, temperature, flow rate), chemical, biological and isotopical parameters have to be combined.

Integration

The interpretation and synthesis of the data includes the registration in a database, the descriptions of time series and spatial distributions of the measurements. In ideal cases and as the best available decision-making tool, a flow- and chemical transport model can be calibrated.

Examples

These topics are illustrated by selected field studies.