

otherwise be harmful to the environment. Our investigation is mainly focused on clay mineralogy of the salt marsh sediment, metal associations in the environment of the modern (centennial) salt marsh sediment and possible relation between these metal associations and clay minerals involved. The studied salt marsh is located in the Skalingen Peninsula, West Denmark. About 85 percent of the deposited materials, including the heavy metals, was imported from the North Sea while only a small quantity of the materials was transported through the Varde River whose mouth is located about 10 km from the salt marsh, at the opposite side of the lagoon. A 25 cm high monolithic profile of the salt marsh sediment was collected and was cut into 1-cm slices. The rate of sediment accumulation, detailed grain size distribution, clay mineralogy, dating of the profile ( $^{210}\text{Pb}$  and  $^{137}\text{Cs}$ ), content of organic matter as well as 17 metals: K, Ca, Ti, Mn, Fe, V, Cr, Co, Ni, Cu, Zn, Br, Rb, Sr, Y, Zr, Nb were investigated. Principal components and factor analyses demonstrated strong positive loadings for most of the studied metals, fine grain fractions as well as organic matter, indicating a close relation among these components. Mn, Fe, Ni, Cu, Zn, Rb were found best correlated to the clay fraction (<2 microns), which comprises primarily illite, kaolinite, minor chlorite and lesser smectite/illite mixed layer. The concentration of smectite/illite mixed layer in the samples, after normalized to the grain size distribution, shows a strong correlation with the distribution of these metals, whereas the dominant components of illite and kaolinite in this grain size fraction do not show such relation notably.

**Key words** salt marsh; heavy metal; clay; sediment; environment

## Stable isotopes (S, Cl) and hydrochemical variations in a karstic ground water system, Guiyang, SW China

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A groundwater system in a karstic terrain is easily subject to pollution and its remediation is difficult once contaminated by human activities. The groundwater samples collected in both winter and summer seasons at Guiyang, SW China, show a wide range of variations in chemical composition and dominance of  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{SO}_4^{2-}$ , and  $\text{HCO}_3^-$  ions. The anthropogenic inputs include  $\text{Cl}^-$ ,  $\text{NO}_3^-$ ,  $\text{SO}_4^{2-}$ ,  $\text{Na}^+$ , and  $\text{K}^+$ , as judged from the relationships between different elemental ratios and sewage samples.  $\text{Cl}^-$  concentrations of all water samples in the study area vary from 0 to 3.9 mmol/L in winter and are higher than in summer. In most of the samples,  $\text{SO}_4^{2-}$  concentrations are high, ranging from 0.1 to 11 mmol/L. The studies show that the cycling of sulfur plays an important role in controlling water chemistry and fate of contaminants in groundwater. In order to understand the source of  $\text{SO}_4^{2-}$  and the geochemical cycling of some elements in the karstic groundwater environment, we have carried out a study on the variations of S and Cl isotope compositions, in addition to other isotopic tracers such as  $^{87}\text{Sr}/^{86}\text{Sr}$  and  $\delta^{13}\text{C}$  studied previously. The  $\delta^{37}\text{Cl}$  values of the groundwater samples present a seasonal variation, ranging from 0.00‰ to +2.03‰ in winter and from -1.46‰ to +0.29‰ in summer. The surface water samples show a similar range of variations as observed for groundwater. Two rainwater samples collected at Guiyang have a distinct isotopic signature (mean value is ~-3‰) compared to the  $\delta^{37}\text{Cl}$  values reported in literature. These results indicate that ground water is mainly derived from precipitation and suggest a fast recharge of the karst system by surface water. The  $\delta^{34}\text{S}$  values of  $\text{SO}_4^{2-}$  in the groundwater range from -20‰ to +22‰, with most of the values between -15‰ and +10‰ and no seasonality is observed for the  $\delta^{34}\text{S}$  values. Correlations between  $\delta^{34}\text{S}$  and  $\text{Cl}/\text{HCO}_3^-$ ,  $\text{Ca}/\text{SO}_4$ ,  $\delta^{13}\text{C}$  and  $^{87}\text{Sr}/^{86}\text{Sr}$  are in favor of mixing between at least 3 sulfur sources into the karst system: dissolution of sulfate evaporites, oxydation of sulfide minerals present in coal-containing strata and anthropogenic inputs including atmospheric inputs and domestic discharge. The covariations between  $\delta^{34}\text{S}$ ,  $\delta^{13}\text{C}$ , and  $^{87}\text{Sr}/^{86}\text{Sr}$  indicate that sulfuric acid produced via oxidation of sulfide minerals and organic sulfur probably takes a significant part in the dissolution of carbonate rocks in this karstic region.

**Key words** karst; groundwater; hydrochemistry; chlorine isotope; sulfur isotope

## Using the dual isotopes approach to identify the nitrate sources of karst groundwater, Guiyang, Southwest China.

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