

Use of natural tracers in the study and characterization of flow in karst systems

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Karst systems are highly heterogeneous, and respond rapidly to rainfall events. To understand flow behaviour as a function of the surface hydrology in these systems, the use of geological, hydrodynamic and hydrochemical tools is required. Parameters such as conductivity, temperature, and pH, and inorganic natural tracers and environmental isotopes are often used in order to define groundwater flow conditions (Leaney and Herczeg, 1995; Martin and Dean, 1999, Ladouche *et al.*, 2000). Combining this approach with a hydrodynamic one highlights the hydrogeological behaviour of the aquifer being investigated (Katz *et al.*, 1998; Nativ *et al.*, 1999; Burk *et al.*, 2004). The geochemical characteristics of karst groundwater are highly variable in time and space. Because some tracers may originate either at the surface or inside the aquifer, or may be changed by human activity, other natural tracers should be looked for. Recent research on the experimental karst system of Vaucluse (southeastern France) highlighted that total organic carbon (TOC) was a sensitive tracer of rapid infiltration in karst systems (Emblanch *et al.*, 1998; Batiot *et al.*, 2001a, 2003). In conjunction, the nature of TOC in soil waters (input signal) and spring waters (output signal) was studied by spectrofluorometry (Batiot *et al.*, 2001b). This approach may give new information about karst functioning and its self-purification capacity. The characterization of the different water types that are involved in karstic flow (fast infiltration, unsaturated zone, and saturated zone) is made possible by combining this approach with the study of other natural tracers,

These new tools require some refinement, and we will therefore apply them to a typical Mediterranean hydrosystem composed of a karst aquifer and an intermittent stream, which acts as a contaminant source to groundwater. This work, whose goal is to understand the interactions between the two parts of the hydrosystem, is just beginning. The "Causse d'Aumelas" karst aquifer is located 20 km west of Montpellier. The aquifer catchment area is about 200 km², and the aquifer is composed of about a 2000 m thickness of Jurassic carbonate deposits. During low flow, a 9-km stretch of the Coulazou, a 29-km long river, becomes a sink when it crosses the karst terrane of the Causse. About fifty karst features, which can function alternatively as sink holes or springs, have been located in the Aumelas-Coulazou hydrosystem. In order to understand the interactions between surface water and groundwater, hydrodynamic and hydrochemical monitoring has been carried out on springs, boreholes, swallow holes, and the Coulazou surface waters, with the first monitoring station located upstream of the karst terrane, and the other downstream. Discharge rates at the springs and at the Coulazou monitoring stations are measured. Electrical conductivity, temperature, and pH also are measured at each point and the water is sampled twice a month to study hydrochemical tracers (major and trace elements, TOC, ¹³C).

This "multiparameter" approach underlines the behaviour of the hydrosystem and the phenomena of flow inversions. The understanding of these specific links between surface and subterranean waters is fundamental to characterize the vulnerability of the aquifer and to protect water resources.

References

- Batiot C., Emblanch C., Blavoux B. (2001a). Caractérisation du fonctionnement des systèmes karstiques par la variabilité des teneurs en COT à leur exutoire. Expérimentation sur différents aquifères du Sud-Est de la France. 7^{ème} colloque d'Hydrologie en pays calcaire et milieu fissuré, Besançon, 27-30.
- Batiot C., Emblanch C., Blavoux B., Fabiano A. S., Pucci B. (2001b). Intérêt de l'utilisation du COT (Carbone Organique Total) dans l'étude du transit de l'eau au sein des aquifères karstiques. 4th IHSS-France, November 2001.
- Batiot C., Liñan C., Andreo B., Emblanch C., Carrasco F., Blavoux B. (2003). Use of TOC as tracer of diffuse infiltration in a dolomitic karstic system : the Nerja Cave (Andalusia, Southern Spain). *Geophysical Research Letters*, 30, N°22, 2179-2183.
- Burk S., Liedl R., Sauter M. (2004). Identification of localised recharge and conduit flow by combined analysis of hydraulic and physico-chemical springs responses (Urenbrunnen, SW Germany). *Journal of Hydrology*, 286, 179-193.
- Emblanch C., Blavoux B., Puig J.M., Mudry J., (1998). Dissolved organic carbon of infiltration within the autogenic karst hydrosystem. *Geophysical Research Letters*, 25, (9), 1459-1462.
- Katz B.G., Catches J.S., Bullen T.D., Michel R.L. (1998). Changes in the isotopic and chemical composition of groundwater resulting from a recharge pulse from a sinking stream. *Journal of Hydrology*, 211, 178-207.
- Ladouche B., Probst A., Viville D., Idir S., Baqué D., Loubet M., Probst J.L., Bariac T. (2000). Hydrograph separation using isotopic, chemical and hydrogeological approaches (Strenbach catchment, France). *Journal of Hydrology*, 242, 255-274.
- Leaney F.W. and Herczeg A.L. (1995). Regional recharge to a karst aquifer estimated from chemical and isotopic composition of diffuse and localised recharge (South Australia). *Journal of Hydrology*, 164, 363-387.
- Martin J.B. and Dean R.W. (1999). Temperature as a natural tracer of short residence times for groundwater in karst aquifers. In: karst modeling. Proceedings of the Symposium held February 24 through 27 1999, Charlottesville, Virginia, *Karst Waters Institute Special Publications*, 5, 236-242.
- Nativ R., Günay G., Hötzl H., Reichert B., Solomon D.K., Tezcan L. (1999). Separation of groundwater-flow components in a karstified aquifer using environmental tracers. *Applied Geochemistry*, 14, 1001-1014.