# Methodological approach for investigation in Karst Hydrogeology

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## KEYNOTE LECTURE

It is established that karst aquifers constitutes around 12% of Earth surface and their resources are used for water supply 20-25% of world population, which justifies the global relevance of this type of aquifers. They are abundant in Mediterranean countries where their groundwater has been used along the history by all cultures and civilizations.

In spite of the importance and the long history of use by the humanity, the major advances on Karst Hydrogeology occurred after middle 20$^{th}$ century, on the basis of the predominantly geomorphological knowledge acquired in the previous century. The main reason for that was probably the complexity of karst system, its heterogeneity in the distribution of hydraulic properties (porosity and hydraulic conductivity), the different modalities of recharge (autogenic or allogenic; concentrated and diffuse) and the diversity of flow conditions from diffuse flow to conduit flow behavior. This diversity of conditions implies that methodologies of classical hydrogeology can be not directly applied to karst aquifers, and consequently techniques have been adapted or specially developed to investigate karst systems, starting from the always fundamental geological, geomorphological and hydrogeological background.

Hydrodynamic analysis (mainly spring hydrograph) inform about the changes in volume of water recharging and discharging the systems and how rapid these occur, but not about the transit or residence times and processes occurring. These aspects can be inferred from the hydrochemistry, considered as hydrodynamic interpretation of chemical composition of groundwater. Besides, natural hydrochemical tracers as total organic carbon and natural fluorescence of groundwater inform about the role of the epikarst-unsaturated-saturated zones in the functioning of the system. Isotopic data permit to contrast the chemical interpretations, both in terms of residence time (radioactive isotopes) or another concerns of the aquifer behavior (stable isotopes): mixing of waters, altitude of recharge, evaporation, etc.). Hydrothermal response is another useful complementary tool. However, the most effective methodology is dye tracers, which permit to probe the hydraulic connection between surface and groundwater, and to calculate flow velocity.

Each technique contributes to the knowledge of the karst aquifers but the most interesting approach is the integration of data from these different sources, avoiding the uncertainty of using only one. Thus, hydrogeological interpretation became more robust, which constitutes the basis of modeling, both conceptual and particularly mathematical procedures. There is an increasing number of numerical models (distributed, lumped and hybrid) in Karst Hydrogeology with diverse objectives from the integrated analysis of hydrogeological responses to the prediction and management of water resources under the impact of the global climate change. However, in many karst aquifers, the most interesting model is the conceptual one, which is basic for everything.