Coastal karst aquifers and submarine springs: a new scientific and technological challenge for Mediterranean groundwater resources

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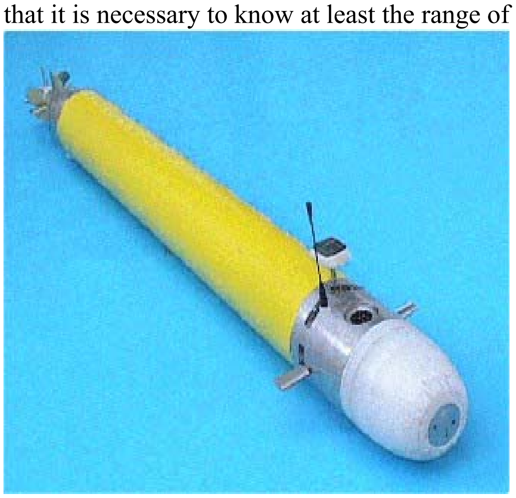
Karst submarine springs, KSMS, occur along all the world's calcareous coasts. They are particularly frequent in Mediterranean countries, as coastal brackish springs. Their origin is related to the Messinian salinity crisis. This crisis occurred in the Mediterranean basin around 5.5 Ma, and corresponds to major lowering of sea level at about -1500 m (Clauzon, 1982) caused by the closure of the Strait of Gibraltar. The lowering of sea level was responsible for major karst development at depth, driven by the entrenchment of main valleys into deep gorges, for example the so-called "Rhone canyon", which is now filled with impermeable Pliocene marine and continental sediments. These sediments filled in the karst aquifers, whose outlets are now overflow artesian springs. Conditions such as these may increase groundwater residence time to as much as several thousand years, whereas it is commonly less than a year in well developed karst aquifers. These conditions also favour the discharge of fresh water below sea level in the form of KSMS, at depths generally not exceeding -50 m, and also favour sea water intrusion into karst aquifers, resulting in brackish springs. The discharge of some KSMS, assessed either by analysis of remote sensing imagery or by direct observation of submarine freshwater flow, has been estimated to be up to several m^3/s

Data from Crete and from the South of France indicate that these flow rates might be greatly overestimated. The flow rate is related to velocity, but at the sea bottom the velocity is driven not by the fresh water discharge, but by the density difference between freshwater and sea water. An analysis of the situation showed that the flow rate can be estimated, or even measured, in only two ways: 1) an indirect way consisting of a comparison of the observed fresh water plume in sea water to the one modelled from physical data (depth, shape of the sea bottom and spring, water density), and 2) a direct approach, by tapping the KSMS and conducting the fresh water flow in a pipe with a flow meter. The first approach was tested on a KSMS near Montpellier, at -29 m bsl and 180 m from the shore. According to divers, its discharge was estimated at around 1 m^3/s, but the comparison of modelled and observed plumes were in a good agreement for a discharge of around 50 l/s. The second approach was used on a KSMS of south-eastern France at -35 m, at 800 m from the shore. The flow meter indicated a discharge of around 40 l/s instead of the several hundred l/s estimated by a hydrogeologist diving in the spring.

Knowledge of the discharge and salinity of KSMS and their time variations is important, in order to assess the amount of groundwater resource discharging into the sea, and to evaluate its possible use for water supply. However, because of their karstic origin, these springs present seasonal variations in both discharge and salinity, so that it is necessary to know at least the range of variations.



To that end, a project involving several teams is developing the needed technology in two ways. The first consists of the development of a small autonomous underwater vehicle, AUV, for exploring the plume and monitoring salinity, temperature, pressure, and flow velocity along programmed trajectories. The AUV prototype is 1.80 m long, 20 cm in diameter, and weighs 60 kg; it can navigate up to -150m bsl, following a programmed trajectory (see picture). The first tests show that the entire plume may be explored in 3 to 6 hours, instead of the 3 days required by boat, with a 25 to 50 cm sampling step, instead of 2 to 5 m. The representation of the plume is more detailed and precise than that obtained from a boat. Moreover, it can be easily repeated for different hydrological and climatic conditions. The second approach is the development of a capture system for monitoring a KSMS. Some tests are being carried in France and the first applications will be in operation in the coming months on KSMS in Lebanon and Syria.