The KARMA Project


Photo: Nico Goldscheider

Early Warning System for karst groundwater contamination

Key findings

KARMA test sites found comparable water quality issues dealing with turbidity and fecal contamination and applied fluorescence-based methodologies for quick water quality assessment.

Specific Early-Warning Systems were designed and implemented in Lez and Ubrique systems considering turbidity and complementary easy-to-measure parameters.

A complete EWS, including continuous record of rainfall and water parameters, data transmission and deployment of warning levels for the water managers was achieved at Ubrique test site.

Introduction

In the last decades, the availability of drinking water worldwide has been constrained due to quality issues. This situation is especially noticeable in the Mediterranean area, where karst aquifers have traditionally been exploited as a reliable source for drinking water supply and constitutes one of the most vulnerable regions to climate change (Hartmann et al., 2014). In some karst systems, the presence of a well-developed network of fractures and conduits provokes that contaminants and pathogenic microorganisms may be rapidly transferred from the surface to the groundwater capture points during recharge events. The hydroclimatic and geological features result in a high vulnerability to contamination of certain springs or boreholes intended for drinking purposes. Hence, an adequate management during such high-risk periods is essential to avoid public health issues. Nowadays, the implementation of monitoring networks for continuous recording of physical-chemical water parameters, as well as real-time data transmission, constitute strategic tools to forecast and rapidly detect contamination episodes.

EWS strategies

Within this context, the concept of Early Warning System (EWS) comprises a set of techniques designed to optimize groundwater catchment in terms of water quality (Grayman et al., 2001). In the frame of KARMA project, EWS strategies were tested at Lez (France) and Ubrique (Spain) karst systems, which are intended for drinking water supply. The karst area of Hochifen-Gottesacker (Austria) was included as a complementary test site focused on the development of EWS techniques. The EWS implementation procedure was realized according to three steps described by Marín et al., (2021) and mainly consisted in (1) continuous records of natural responses to generate a sufficiently large and representative database to perform (2) the statistical analysis for the identification of the optimal EWS parameters (those which allow a quickly, reliable and economical detection of the arrival of polluted groundwater at any supply point) and workflow development. The fi- The final step (3) entails the system launching with operational perspective.

The existence of previous investigations at these study areas exposed that the main water quality issues were related with high turbidity periods and associated fecal contamination after intense rain events that impede groundwater use for water supply population. Thus, in KARMA test sites, spring discharge as well as hydroclimatic and physical-chemical parameters of water (electrical conductivity, temperature and turbidity) were continuously monitored. Furthermore, fluorescence-based techniques and microbiological culture-based methods (i.e. *E. Coli*) were commonly used to detect organic and bacteriological contamination. According to the features of each system, specific techniques were applied at each test site to better identify groundwater origins and contaminant transport processes: Cl^- and Dissolved Oxygen (DO) in Lez system, Particle Size Distribution (PSD) and bacterial enzymatic activity (β-d-glucuronidase) in Hochifen-Gottesacker and PSD, trace elements and Rn^{222} in Ubrique test site.


Figure 1: Algarrobal spring at Ubrique test site during a contamination event with high turbidity.

KARMA - Karst Aquifer Resources availability and quality in the Mediterranean Area

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The KARMA project aims to achieve a better karst groundwater management across the scale of the Mediterranean area, single catchments and selected springs.

Water quality issues and Early-Warning parameters

During KARMA period, several flooding events with associated turbidity were registered at the three test sites. Maximum turbidity records varied between ≈15 NTU at Lez spring (France) and ≈340 NTU at Algarrobal spring (Ubrique test site, Spain, Fig. 1). The maximum activity of E. coli measured during KARMA period apparently showed proportional values with turbidity between test sites: ≈480 CFU/100mL at Lez spring and ≈2970 CFU/100mL at Algarrobal spring (Ubrique test site, Spain). The statistical analysis allowed to determine the main correlations between water parameters and fecal contamination indicators. In Lez and Ubrique systems, those resulted to be turbidity and protein-like fluorescence. In the Austrian test site, an apparently good correlation between particle size distribution and turbidity together with β-d-glucuronidase was found. Hence, a common stage was achieved at the three test sites: the identification of (1) potential hazardous substances for human health and (2) “Early Warning” parameters. More refined protocols were developed facing the implementation of individual EWS (France and Spain test sites) with the definition of the EWS workflow (Fig. 2) and specific thresholds that activate the warning alerts adapted to hydrogeological features, contamination type and operational characteristics of the drinking water distribution system.

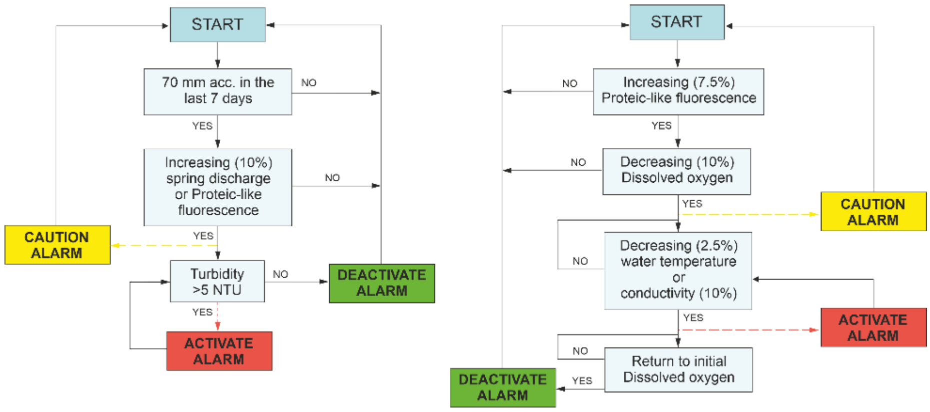
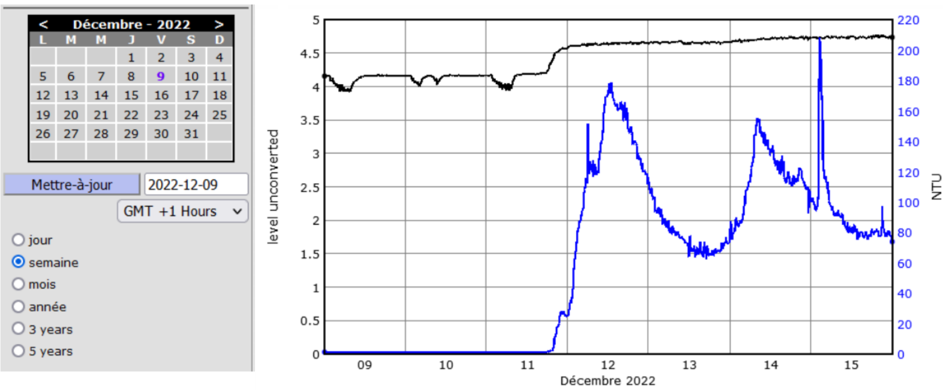


Figure 2: Architecture of Early-Warning workflows developed for Ubrique and Lez karst systems.



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○ jour
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○ 5 years

Figure 3: Online visualization of real time data during a flooding event in Algarrobal spring in December 2022.

Implementation and validation

The remote data gathering via telemetry systems and its integration with smart algorithms for deployment of warning messages is currently being developed and tested only in Ubrique test site (Spain). The launch of an online platform allowed to visualize in near (15 min) real time the measured values of rainfall, spring discharge, temperature, electrical conductivity, turbidity, protein-like fluorescence and battery load of the installed devices. As an example, Figure 3 shows the time series of rainfall in the recharge area and turbidity at Algarrobal spring in the online platform during the first test at the end of 2022. The ongoing step of the implementation consists on the validation phase, which is continously updated with newly acquired data and consist on the evaluation of system efficiency by analyzing key performance indicators (KPI) such as the rate of false warnings (positive or negative). The full implementation of the EWS in Ubrique test site can help decision makers to take the appropriate actions through the telemetry system and warnings sent by SMS to the municipal water company managers.

References and further Reading

- Grayman, W.M.; Deininger, R.A.; & Males, R.M., 2001. Design of Early Warning and Predictive Source-water Monitoring Systems. AWWA Res. Fdn, Denver.
- Hartmann, A., Goldscheider, N., Wagener, T., Lange, J., Weiler, M., 2014. Karst water resources in a changing world: Review of hydrological modeling approaches. Rev. Geophys. 52 (3), 218–242.
- Marín, A.I., Martín Rodríguez, J.F., Barberá, J.A., Fernández-Ortega, J., Mudarra, M., Sánchez, D., Andreo, B. 2021. Groundwater vulnerability to pollution in karst aquifers, considering key challenges and considerations: application to the Ubrique springs in southern Spain, Hydrogeol J, p. 29.

KARMA policy briefs present relevant scientific results of projects concerning a better karst groundwater management across the scale of the Mediterranean area, single catchments and selected springs.

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