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Evaluating the Vulnerability of Mountain Springs: A Case Study in Italy to Prioritize Conservation and Management Strategies

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This research introduces a methodology for evaluating the protection zone of vulnerable mountain springs using an hydrogeochemical approach. Mountain springs play a crucial role in maintaining the ecological balance and ensuring the well-being and resilience of communities residing in mountainous areas. These resources frequently serve as the primary freshwater supply in numerous mountainous regions, their impact extends beyond these areas by catering to diverse applications, including agriculture, farming, hydropower generation, artificial snowmaking, and industrial utilization.

Despite their importance, mountain springs are under increasing threat due to climate change and human activities and thus need to be preserved and managed to ensure a sustainable use and conservation. In this study, we assess the vulnerability of two mountain springs located in a karstic water system in the Northern Italy mountainous region. Particularly we analyze the hydrogeological and hydrogeochemical parameters of the two mountain springs, together with the oxygen and hydrogen isotopic composition ($\delta^{18}O$ and $\delta^{2}H$) and d-excess of both the springs and the rainwater of the area. The considered parameters were continuously measured from September 2018 to September 2021. The main goal is to assess the geochemical and hydrological processes that control the springs water quality and the isotopic composition of precipitation and use them for formulating effective springs protection measures. Our results show that the vulnerability of mountain springs is influenced by various factors that include the use of the resource, the meteorological conditions, and the hydrogeology of the area. We propose a method that integrates the Vulnerability Estimator for Spring Protection Areas index with the use of the water stable isotopes to identify springs' protection zones that takes in consideration the recharge area of the aquifers feeding the springs. Our study contributes to the development of a framework for assessing the vulnerability of mountain springs and highlights the importance of integrating the geochemical characteristics and the anthropic pressure in the conservation and management of these critical freshwater resources. This study is part of Next Innovation Ecosystem Program "Interconnected Northeast Innovation Ecosystem (iNEST)" supported by the European Union.