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PAPER

A multi-method approach for groundwater resource assessment in coastal carbonate (karst) aquifers: the case study of Sierra Almijara (southern Spain)

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Abstract Understanding the transference of water resources within hydrogeological systems, particularly in coastal aquifers, in which groundwater discharge may occur through multiple pathways (through springs, into rivers and streams, towards the sea, etc.), is crucial for sustainable groundwater use. This research aims to demonstrate the usefulness of the application of conventional recharge assessment methods coupled to isotopic techniques for accurately quantifying the hydrogeological balance and submarine groundwater discharge (SGD) from coastal carbonate aquifers. Sierra Almijara (Southern Spain), a carbonate aquifer formed of Triassic marbles, is considered as representative of Mediterranean coastal karst formations. The use of a multi-method approach has permitted the computation of a wide range of groundwater infiltration rates (17–60%) by means of direct application of hydrometeorological methods (Thornthwaite and Kessler) and spatially distributed information (modified APLIS method). A spatially weighted recharge rate of 42% results from the most coherent information on physiographic and hydrogeological characteristics of the studied system. Natural aquifer discharge and groundwater abstraction have been volumetrically quantified, based on flow and water-level data, while the relevance of SGD was estimated from the spatial analysis of salinity, ^{222}Rn and the short-lived radium isotope ^{224}Ra in coastal seawater. The total mean aquifer discharge (44.9–45.9 hm^3 year^{-1}) is in agreement with the average recharged groundwater (44.7 hm^3 year^{-1}), given that the system is volumetrically equilibrated during the study period. Besides the groundwater resources assessment, the methodological aspects of this research may be interesting for groundwater management and protection strategies in coastal areas, particularly karst environments.

Keywords Carbonate rocks · Coastal aquifers · Groundwater resources · Water budget · Spain

Introduction

The hydrogeological balance of aquifer systems is a key issue for groundwater managers, planners and users; however, the evaluation of groundwater resources is not always easy. In fact, historical disagreements on water budget calculations among hydrogeologists are commonly documented in local/regional studies, which evidence the disparity in the used criteria. In many cases, all components of the water budget equation are accurately quantified, while in some others, individual water volumes are difficult to assess due to the system complexity and unknown components—e.g. groundwater transference between aquifer sectors, submarine groundwater discharge (SGD), etc.

Aquifer recharge has been traditionally estimated from the spatial analysis of available meteorological data. Unlike predominantly flat regions where precipitation patterns vary gradually, rainfall patterns in mountainous areas are often strongly conditioned by altitudinal gradients, resulting in

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