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Combining groundwater vulnerability and hydrogeomechanics mapping in hydromineral systems (Caldas da Cavaca, Central Portugal)

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Hard-rock watersheds commonly exhibit complex geological bedrock and morphological features. Hydromineral resources have relevant economic value for the water thermal industry. The present work aims to achieve and further develop a hydrogeomechanical and a groundwater vulnerability approach in Caldas da Cavaca hydromineral system (Aguiar da Beira, Central Portugal). Caldas da Cavaca has a thermal tradition that dates back to the late 19th Century (e.g., Acciaiuoli 1952/1953 [1]; Teixeira et al. [2]).

A collection of several data, namely geology, hydrogeology, rock and soil geotechnics, borehole hydraulics, hydrogeomechanics, hydrogeomorphology and hydrogeophysical was retrieved from several key-sectors in Caldas da Cavaca site. Geographical Information Systems (GIS) technology was on the basis to organise and integrate the geodatabases and to produce all the thematic maps. To accomplish a comprehensive analysis and rock engineering conceptualisation of the site, a multi-technical approach were used, such as, field and laboratory techniques, hydrogeotechnical mapping and hydrogeomechanical scheme classifications and indexes evaluation. For the hydrogeomechanical analysis, the Hydro-Potential (HP)-Value, J_w Joint Water Reduction Index, Hydraulic Classification (HC) System were applied on selected rock slopes (Lagoa, Amores and Cancela). Hydrogeomechanical zoning (HGMZ) assessment was defined in the rock slopes. Also, a groundwater vulnerability to contamination assessment, based on GOD-S, DRASTIC-Fm, SINTACS, SI and DISCO indexes, was delineated.

The hydrogeomechanical zone HGMZ₁ of Lagoa slope achieved higher hydraulic conductivities (10^{-3} to 2 m/day) with poorer rock mass quality results (Rock Mass Rating, RMR=25), followed by the hydrogeomechanical zone HGMZ₂ of Lagoa slope, with poor to fair rock mass quality (RMR=40) and lower hydraulic parameters (ca. 10^{-2} m/day). In addition, Amores slope had a fair rock mass quality (RMR=45) and the lowest hydraulic conductivity (10^{-4} to 10^{-3} m/day). The hydrogeomechanical zones HGMZ₃ of Lagoa slope and HGMZ1 of Amores and Cancela slopes had a fair to poor rock mass quality (RMR=36-45) but were completely dry. GOD-S, DRASTIC-Fm, SINTACS and SI indexes indicated that most of the Caldas da Cavaca area fits in a moderate to high vulnerability categories. DISCO method indicated that the zones surrounding the hydromineral wells fit in a high vulnerability class, while the rest of the area fits in a low vulnerability category.

This multi-technical approach permitted to improve the hydrogeological conceptual model of Caldas da Cavaca hydromineral system area, which will be very useful to delineate wellhead protection areas, as well as to achieve a sustainable management of groundwater resources in the region.

References:

- [1] Acciaiuoli L (1952/53) Le Portugal hydromineral. 2 volumes, Direcção Geral dos Serviços Geológicos, Lisbonne.
- [2] Teixeira J, Chaminé HI, Espinha Marques J, Carvalho JM, Pereira AJ, Carvalho MR, Fonseca PE, Pérez-Alberti A and Rocha F (2015) A comprehensive analysis of groundwater resources using GIS and multicriteria tools (Caldas da Cavaca, Central Portugal): environmental issues. *Environ Earth Sci* 73(6):2699–2715.

