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## Hydrogeological and hydrochemical characterization to assess wells vulnerability in the scope of Water Safety Plans, a case study in Northern Italy.

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Groundwater is a key resource to fulfil human drinking needs worldwide. Therefore, guaranteeing a safe and constant supply of drinking water to the public has been an important focus at European level. Recently, the EU approach to drinking water monitoring radically changed, moving from the simple water quality monitoring, toward a more comprehensive risk assessment, involving the whole supply chain from collection to distribution. Particularly, EU Directives 2015/1787 and 2020/2184 endorsed the Water Safety Plan (WSP) system which requires a detailed assessment of every possible dangerous event.

Groundwater extraction constitutes the first step of the supply chain, and therefore the most vital. In this work, an approach to assess groundwater wells vulnerability in the scope of WSP is proposed, considering natural and anthropogenic hazards, through a hydrogeological, hydrochemical and hydrodynamical characterization. The study area is the Lake Iseo morainic amphitheatre (ca. 180 km<sup>2</sup>) in the Brescia province, Northern Italy. Particularly, 17 wells have been analyzed, serving 4 municipalities.

Two main dangerous events have been considered as possible hazard for the collected groundwater: a) anthropogenic impact from the surface, related to the land use, and b) natural contamination by reduced species consequent to the degradation of natural organic matter.

Groundwater extraction vulnerability to these two dangerous events has been assessed, considering several hydrogeological aspects: a) the kind of the exploited aquifer (shallow, confined, semiconfined), b) groundwater depth for the shallow aquifers, c) permeability of the vadose zone for the shallow aquifers and d) red-ox conditions of the collected groundwater.

To assess these parameters, lithostratigraphic, chemical and piezometric data were analyzed, reaching a deep understanding of the system by characterizing the different exploited groundwater bodies from a hydrogeological, hydrochemical and hydrodynamic point of view.

Hydrogeological sections were elaborated, covering the whole amphitheater, 7 in the N-S direction and 7 in the W-E direction. The interpretation of these sections allowed to identify the distribution

of the main aquifer bodies and the relationships between the various hydrogeological units. To evaluate the red-ox conditions and perform groundwater quality characterization, chemical data were analyzed, including major ions and red-ox sensitive species, through boxplot and statistical analysis. Furthermore, piezometric levels were analyzed to identify groundwater depth, flow directions and watersheds. Of the 17 wells, one resulted to be confined with reducing conditions. Among the remaining, 7 are semiconfined while 9 are shallow, with oxidizing conditions in both cases. Concerning groundwater depth, 13 present values above 40 m, 2 between 20 m and 40 m, and 1 below 20 m. As regards the vadose zone permeability, 9 present high permeability, 7 medium. Totally, in terms of vulnerability to anthropic impacts, one well has low vulnerability, 9 medium and 6 high, while in terms of vulnerability to natural contamination one well has high vulnerability and the remaining low.

This approach allowed a deep understanding of the system and constitutes a reproducible methodology to assess groundwater wells vulnerability to natural and anthropogenic contaminations.

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