Hydrochemical evolution and hydrological zoning characteristics of a shallow groundwater system in Baiyangdian Wetland, North China Plain

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Abstract

A comprehensive understanding of the hydrochemical evolution and spatial patterns of shallow groundwater systems is essential for water resource management and wetland ecological restoration. The Baiyangdian Wetland is one of the most concerning areas because of the development of the Xiong'an New Area. The spatial characteristics of groundwater hydrochemistry and potential controlling factors associated with hydrochemical evolution remain unclear. In this study, hydrogeochemistry together with the hierarchical cluster analysis were used to elucidate the hydrochemical processes and hydrological zoning patterns of shallow groundwater systems in the Baiyangdian Wetland, North China Plain. The results showed that hydrochemical compositions of shallow groundwater had considerable spatial variations, which was closely related to the inflow rivers hydrochemistry and the dynamics of groundwater–surface water interactions. A significant increase in SO_4^{2-} concentration occurring at the cone of the depression was related to extensive pumping caused by anthropogenic activities. Anthropogenic activities were also a major factor controlling the spatial distribution patterns of shallow groundwater hydrochemistry. Ca^{2+}, Mg^{2+}, and SO_4^{2-} in the wetland and shallow groundwater were primarily derived from carbonate and gypsum dissolution, while Na^{+} and Cl^{-} originated from halite and silicate dissolution. Rock weathering predominated the geochemical evolution of shallow groundwater in conjunction with carbonate precipitation and cation exchange. The hydrochemistry of the shallow groundwater system presented distinct spatial zonation patterns that were classified into four clusters corresponding to seven subzones. In Zones I–IV, water-rock interaction was the dominant factor controlling shallow groundwater chemistry, which was driven by the positive groundwater–surface water exchange. The coupled effects of anthropogenic activities and river infiltration and mixing caused the high levels of dissolved components in Zones V–VII. This study provides deeper insight into the water cycle and hydraulic connections among different bodies, and will benefit the rational evaluation of hydrochemical evolution and wetland ecological restoration in the Baiyangdian Wetland.

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