Contaminants of emerging concern in Groundwater of Large Semi-Arid Irrigated Plains: Berrechid and coastal Chaouia Aquifers, Morocco

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ABSTRACT

Contaminants of emerging concern (CECs), including pharmaceuticals and personal care products (PPCPs), pesticides, and industrial chemicals, are increasingly detected in groundwater systems worldwide, particularly in semi-arid Mediterranean regions facing rapid urbanization, agricultural intensification, and evolving consumption patterns. Their occurrence and mobility are governed by complex interactions between anthropogenic pressures, aquifer vulnerability, and the physicochemical properties of the compounds.

This study investigates the diversity, spatial distribution, sources, and transfer mechanisms of CECs in the Berrechid–Chaouia coastal aquifers (Morocco), a strategic groundwater resource under strong urban, industrial, and agricultural influence. Groundwater samples were collected from 65 sites and analyzed for 79 target CECs using (SPE–UPLC–MS/MS). The contaminant dataset was interpreted alongside hydrochemical indicators to identify dominant transport processes.

Results reveal widespread contamination dominated by PPCPs and industrial compounds, primarily from untreated or insufficiently treated urban and industrial effluents. These CECs persist several kilometers downstream from discharge areas, reflecting the high vulnerability of the aquifer to surface inputs. Two main transfer regimes were identified. Persistent and mobile CECs show rapid and diffuse transport and are associated with weakly evaporated groundwater characterized by low total organic carbon and near-neutral pH. In contrast, less persistent CECs exhibit slower and more localized transfer, accumulating in groundwater affected by higher evaporation, elevated organic matter content, and more alkaline pH

These findings improve understanding of CEC behavior in semi-arid aquifers and underscore the importance of controlling urban and industrial discharges and promoting sustainable wastewater reuse to preserve groundwater quality in vulnerable regions.

Keywords: Contaminants of emerging concern; Groundwater; Berrechid aquifer; Semi-arid; PPCPs.