

Groundwater vulnerability to changes in land use and society in India

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Abstract In many parts of India, the freshwater pollution crisis has become evident at different times in response to population growth, agricultural intensification, urbanization, industrialization and *ad hoc* management approaches. Average groundwater recharge from rainfall varies widely (<8–20%). Groundwater in many places is polluted by salinity, F (<1–46.0 mg L⁻¹), NO₃ (<20–1600 mg L⁻¹), and heavy metals Zn (3–41 µg L⁻¹), Cu (5–182 µg L⁻¹), Fe (279–1067 µg L⁻¹), Pb (31–622 µg L⁻¹), Ni (<1–105 µg L⁻¹), Cd (<1–202 µg L⁻¹). Slow infiltration of agricultural/urban surface runoff mixing with available pollutants in cross-sector wastes is responsible for groundwater pollution. Over-exploitation problems have induced the intermixing of highly polluted water with freshwater along specific flow-pathways and this has increased the lateral extension of the groundwater pollution problem. Groundwater vulnerability to pollution has been assessed using the integration of information on groundwater recharge, contamination characteristics, isotope fingerprinting, the Software PHREEQC for aqueous and mineral saturation index, and GIS. The freshwater crisis across India associated with groundwater pollution can be better managed by the strict enforcement of regulatory measures restricting unplanned water abstraction and waste disposal, guided by overarching ethical considerations.

Key words groundwater; recharge; pollution; exploitation; vulnerability; land-use; society; isotope; India