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High spatial variability of nitrate in the hard rock aquifer of an irrigated catchment: Implications for water resource assessment and vulnerability

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Irrigated agriculture has large impacts on groundwater resources, both in terms of quantity and quality. Among agricultural-borne non-point source pollutants, nitrogen has been the focus of many studies due to its ubiquitous impact on ecosystems. Mapping the spatial heterogeneity of groundwater quality is not only essential for estimating the level of groundwater contamination but also to assess the impacts of different types of agricultural systems. However, low density of long term monitoring wells limits adequate description of highly heterogeneous aquifers. This issue has been addressed either by developing geo-statistical methods or by neglecting groundwater lateral transport.

In peninsular India the development of minor irrigation led to high density of borewells which constitute an ideal situation for studying the heterogeneity of groundwater quality. The annual groundwater abstraction reaches 400km3, which leads to depletion of the resource and degradation of water quality. Nitrate (NO_3) contamination in groundwater has been rising for the last decades due to overuse of fertilizers combined with the intensive borewell irrigation. In the Berambadi catchment (84 km2, Southern India), which is part of ORE BVET/ Kabini CZO, we studied the relative influences of land use, agricultural practices and soil/aquifer properties on NO_3 concentration in groundwater based on the monitoring of >200 borewells (monthly water table level and seasonal chemistry).

Nitrate concentration in Berambadi span over two orders of magnitude with hotspots up to 400ppm. Three contrasted situations were identified according to groundwater level and gradient: i) Hot spots of NO_3 were associated to deep groundwater levels (30 to 60 m) and low groundwater gradient, suggesting that in the absence of lateral flow and with small groundwater reserve, local agricultural practices severely affected groundwater quality due to recycling through pumping and return flow; ii) On the contrary, when groundwater gradient was high, NO_3 concentrations were low to moderate, suggesting that significant lateral flow prevented NO_3 enrichment; iii) Finally, low NO_3 concentrations were also found in situations where gradient was small but groundwater was shallow and hence reserve was large: these zones are potentially vulnerable to intensification of pumping and fertilizer application. Subsequent decline in groundwater level would then lead to rapid degradation of groundwater quality.

We propose that the groundwater level and gradient mapping could be used in hard rock aquifers to delineate zones affected or vulnerable to intensification of irrigated agriculture. Wells located in low gradient zones are suitable for assessing the impacts of local agricultural systems. To the contrary, wells located in zones with high gradient (well mixed) are more representative of the average groundwater quality of the catchment, and hence should be used in priority for regional mapping of groundwater quality.