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Impacts of land-use and soil properties on groundwater quality in the hard rock aquifer of an irrigated catchment: the Berambadi (Southern India)

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Irrigated agriculture has large impacts on groundwater resources, both in terms of quantity and quality: when combined with intensive chemical fertilizer application, it can lead to progressive groundwater salinization. Mapping the spatial heterogeneity of groundwater quality is not only essential for assessing the impacts of different types of agricultural systems but also for identifying hotspots of water quality degradation that are posing a risk to human and ecosystem health.

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 400 km3, which leads to depletion of the resource and degradation of water quality. In the agricultural Berambadi catchment (84km2, Southern India, part of the environmental observatory BVET/ Kabini CZO) the groundwater table level and chemistry are monitored in ∼200 tube wells. We recently demonstrated that in this watershed, irrigation history and groundwater depletion can lead to hot spots of NO_3 concentration in groundwater, up to 360 ppm (Buvaneshwari et al., 2017). Here we focus on the respective roles of evapotranspiration, groundwater recycling and chemical fertilizer application on chlorine concentration [Cl] in groundwater.

Groundwater [Cl] in Berambadi spans over two orders of magnitude with hotspots up to 380 ppm. Increase in groundwater [Cl] results from evapotranspiration and recycling, that concentrates the rain Cl inputs ("Natural [Cl]") and/or from KCl fertilization ("Anthropogenic [Cl]"). To quantify the origin of Cl in each tube well, we used a novel method based on (1) a reference element, sodium, originating only from atmosphere and Na-plagioclase weathering and (2) data from a nearby pristine site, the Mule Hole forested watershed (Riotte et al., 2014). In the forested watershed, the ranges of Cl concentration and Na/Cl molar ratio are 9-23 ppm and 2.5-6, respectively, while in Berambadi Na/Cl drops down to 0.3 due to the addition of KCl-chlorine.

Natural [Cl] estimated in Berambadi groundwater was on average 44 ppm (from 8 to 170 ppm). This means that on average, evapotranspiration and recycling in Berambadi groundwater was 2 to 4 times greater than evapotranspiration in the nearby forest. Hot spots (8 to 20 times forest ET) were all located along the stream, associated with Vertisols and long irrigation history. Anthropogenic [Cl] ranged from 0 to 270 ppm, accounting for up to 90% of the total Cl in some wells. Hotspots were also associated with long irrigation history, however extreme values were found in the severely depleted groundwater area, associated with the nitrate hotspot.

Our approach allowed to quantify the respective contributions of groundwater recycling and chemical fertilizer inputs to the progressive salinization of groundwater. Using the AICHA model coupling the crop model STICS and a groundwater model under different climate scenarios, we show that the development of contamination hot spots can be mitigated by adequate management options.

Keywords: Groundwater quality; salinization; agriculture; hot spots