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Novel insights linking ecological health to biogeochemical hotspots across the groundwater-surface water interface in mixed land use stream systems

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Increasing modifications in land use and water management have resulted in multiple stressors impacting freshwater ecosystems globally. Chemicals with the potential to impact aquatic habitats are still often evaluated individually for their adverse effects on ecosystem health. This may lead to critical underestimations of the combined impact caused by interactions occurring between stressors not typically evaluated together, e.g. xenobiotic groundwater pollutants and trace metals.

To address this issue, we identified sources and levels of chemical stressors along a 16-km groundwater-fed stream corridor (Grindsted, Denmark), representative for a mixed land use stream system. Potential pollution sources included two contaminated sites (factory, landfill), aquaculture, wastewater/industrial discharges, and diffuse sources from agriculture and urban areas. Ecological status was determined by monitoring meiobenthic and macrobenthic invertebrate communities.

The stream was substantially impaired by both geogenic and anthropogenic sources of metals throughout the investigated corridor, with concentrations close to or above threshold values for copper, nickel and zinc in the stream water, hyporheic zone and streambed sediment. The groundwater plume from the factory site caused elevated concentrations of chlorinated ethenes, benzene and pharmaceuticals in both the hyporheic zone and stream, persisting for several km downstream.

Impaired ecological conditions, represented by a lower abundance of meiobenthic individuals, were found in zones where the groundwater plume discharges to the stream. The effect was only pronounced in areas characterized by high xenobiotic organic concentrations and elevated dissolved iron and arsenic levels – linked to the dissolution of iron hydroxides caused by the degradation of xenobiotic compounds in the plume. The results thus provide ecological evidence for the interaction of organic and inorganic chemical stressors, which may provide a missing link enabling the reconnection of chemical and ecological findings. This study highlights the importance of stream-aquifer interfaces for ecosystem functioning in terms of biological habitat, and that multiple stressor systems need to be tackled from a holistic perspective.