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Nitrogen behavior in a tropical subterranean estuary and a groundwater seepage zone

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Submarine groundwater discharge (SGD) can transport large amounts of nutrients into the coastal ocean. During transport from land into the ocean, nutrients are often modified in the subterranean estuary (STE). In some cases, denitrification can remove nitrogen, while in some STEs mineralization can produce nitrate. As a consequence, nutrient concentrations of discharging groundwater are often different than terrestrial groundwater, making it difficult to estimate nutrient concentrations of SGD. We investigated nutrient concentrations in a STE and in a groundwater seepage face at Varkala Beach in southwestern India, in order to clarify the groundwater nitrogen transformations along the land-ocean continuum. The coastal area is densely populated with an intensive agricultural land use. Therefore groundwater flowing into the sea may have high nutrient concentrations, typical for a coast in India. During post monsoon period of 2018, groundwater samples were obtained from the STE across the beach on a meter scale, and from the seepage face on a centimeter-decimeter scale. Groundwater nitrogen concentrations varied across the salinity gradient in the STE, indicating non-conservative removal of nitrogen. The seepage face had fresh groundwater (salinity < 1 PSU) at 10 centimeters sediment depth. In these samples, nitrogen concentrations followed a conservative mixing between fresh groundwater and seawater with high nitrogen concentrations of 400 μmol/L in fresh groundwater. Sediment core incubations also resulted in high nitrogen fluxes from the groundwater seepage zone, when compared to sediment cores sampled outside of the seepage zone. STE samples over the meter scale suggest non-conservative removal of nitrogen, probably due to long residence times of groundwater or mixtures of different types of groundwater. However, nitrogen concentrations in the groundwater seepage face are high and similar to groundwater nitrogen concentrations in the hinterland, probably promoted by rapid groundwater flow from the hinterland in permeable sediments. SGD studies may use terrestrial nutrient endmembers in groundwater to calculate a nutrient flux from a water flux in such settings.