THE ROLE OF GROUNDWATER AND RECIRCULATED SEAWATER IN THE TRANSPORT OF NUTRIENTS TO THE COASTAL WATER, A CASE STUDY FROM THE CARMEL COAST, ISRAEL

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Abstract

A study of nutrient concentrations in Dor Bay suggests that the groundwater discharging directly to the bay is a mixture of three components: (1) nitrate and silica-rich groundwater, (2) nitrate and silica-depleted recirculated seawater, (3) depleted saline water (salinity of 31), which is the result of mixing between recirculated seawater and denitrified fresh groundwater. Subterranean estuarine processes are reflected just in the slightly elevated concentrations of ammonium and possibly phosphate in the discharging water. This suggests that the nutrients are being mainly carried to the bay by the fresh groundwater, while the role of recirculated seawater in this conveyor is merely secondary.

Keywords: Coastal Processes, Estuaries, Hydrology, Eastern Mediterranean, Nutrients

Submarine Groundwater Discharge (SGD) is now widely accepted as a major factor affecting coastal water quality. More specifically, it was suggested by several authors [1,2] that the recirculation of seawater and the mixing with fresh groundwater in the aquifer (the 'subterranean estuary') is a dominant factor in the transport of some nutrients and other solutes to the sea. During 2006-8, we conducted a detailed study of the composition of groundwater discharging from the sea floor at Dor Bay (Carmel coast, northern Israel). As detailed below, our results suggest that while fresh groundwater is a major source of nutrients to the coastal water, recirculated seawater, even when mixed with fresh groundwater, carries a relatively small amount of nutrients to the sea. Two different geological units are discharging to Dor Bay, a Pleistocene calcareous sandstone (locally called 'Kurkar') and an overlying Holocene sand unit. The two are hydrologically separated by a confining clay unit. ^{222}Rn time series and seepage meter studies suggest that SGD at Dor is on the order of 10 cm/d, and that about half of it is recirculated seawater. Based on radon and salinity, it was established that fresh goundwater discharge was mainly from the underlying Kurkar unit, while seawater recirculation was restricted to the shallow sand. Nitrate concentrations were high in onshore groundwater and very low in the bay water (200-400 and <3 µM NO_3+ NO_2, respectively). The concentrations in water discharging from seepage meters deployed on the bay floor were at the mid range (2-130 µM NO_3+ NO_2). On a diagram of nitrate versus salinity, all discharging water plot in a narrow zone between two mixing lines that meet at the high-nutrient fresh water end. Silica concentrations also suggest mixing between nutrient-rich groundwater (100-400 µM) and nutrient-poor seawater. These results suggest that the groundwater discharging to Dor Bay is composed of three components: (1) nutrient-rich Kurkar groundwater, (2) nutrient-depleted recirculated seawater and (3) nutrient-depleted water with salinity of 31. Component (3) is probably the result of mixing between recirculated seawater and fresh groundwater that underwent denitrification. We identify the latter as sand groundwater, which likely resided for a relatively long time in the bay sediments. This implies that in Dor Bay, nitrates and silica are conveyed to the sea just by the fresh groundwater (which also suffered partial denitrification), and that seawater recirculation and its subterranean mixing with fresh water have no effect on nitrate and silica mobilization. Phosphate was very low both in the seawater and in the Kurkar groundwater, while relatively high in the sand groundwater (0.1-0.2 and up to >4 µM, respectively). Seepage meter water contained up to >1 µM of PO_4, probably due to a contribution from the sand groundwater or to the recirculation of seawater in the subterranean estuary. Similarly, ammonium was quite low both in bay water and in all onshore groundwater ($\leqslant$4 µM), while higher in saline groundwater and in water discharging from the bay floor (up to 20 µM), obviously due to seawater recirculation. However, it was still one order of magnitude lower than the nitrate concentrations in these water samples. To conclude, the main conveyor of nutrients (nitrate and silica) to Dor Bay is the fresh groundwater, while the effect of seawater recirculation in the subterranean estuary is restricted to a relatively small load of ammonium, may be also of phosphate, that is carried by the discharging water. Low nutrients in the recirculated seawater as compared with the fresh groundwater were also reported from other SGD sites (e.g. [3,4]). However, in other cases (e.g. northern Gulf of Mexico) recirculated seawater was characterized as nutrient-rich [5]. It is suggested that the difference between the SGD sites is in their nutrient source. While at Dor and similar sites, nutrients are mainly land-derived, thus bwing mainly transported by fresh groundwater, the nutrients at other sites are derived by remineralization of marine organic matter in the subterranean estuary [5], thus being enriched both in the fresh groundwater and in the recirculated seawater.

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