Geologic and hydrodynamic effects on shallow groundwater-surface water exchange and chemical fluxes to an estuary

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ABSTRACT

Fluxes of nutrients and other chemicals from aquifers to coastal waters can have adverse impacts on ecosystems. While solute concentrations may change along groundwater flowpaths toward the sea, they can also be modulated near the point of discharge in the shallow benthic zone below the sediment-water interface. This benthic reactivity depends on the supply of reactants from both groundwater and surface water and the duration of contact in the mixing zone. These factors are closely tied to physical processes: fluxes from above and below as well as mixing and residence time in the benthic zone. We characterized heterogeneity in benthic exchange and associated solutes in the Delaware Inland Bays (USA), which are impacted by severe eutrophication. The spatial and temporal variability in benthic fluxes resulting from surface water hydrodynamics and sediment heterogeneity was simulated by linking hydrodynamic circulation models with mathematical solutions for benthic exchange forced by current-bedform interactions, tides, and waves. Total fluxes driven by the three mechanisms were similar, but mechanisms were dominant at different locations and times. Storms were an important factor, increasing wave-driven exchange by orders of magnitude. The spatial distribution of permeability, including near-surface sediments and larger-scale geologic features, also strongly controlled submarine groundwater discharge and benthic exchange rates. High-resolution measurements from a hand resistivity probe, groundwater sampling, and measurements of biogeochemical parameters in transects across paleochannel features within the estuary were used to characterize stratigraphic effects on both the nature of the physical exchange processes and solute concentrations and fluxes. By modifying patterns of groundwater flow, discharge, and mixing between fresh groundwater and saline surface water, stratigraphic features influence the geochemistry in the subsurface and near the sediment-water interface, affecting rates and patterns of geochemical fluxes to coastal waters.

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