

Modelling reactive transport of Si and ²²²Rn to constrain tide-induced seawater infiltration rates at a meso-tidal beach

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ABSTRACT

The intertidal zone is known to be an important reactor facilitating a full set of biogeochemical reactions, especially where seawater enters the intertidal recirculation cell (often referred to as upper saline plume – USP). Here every tidal cycle delivers large amounts of reactive organic matter, oxygen and nutrients to benthic and subsurface microbial communities. Improved measurements techniques allow for detailed mapping of pore water concentrations, however quantification of the biogeochemical turnover rates based on these measurements critically depends on the knowledge of water residence times. As conservative tracer tests in the inter-tidal zone are extremely difficult to carry out, reactive tracers such as silica and radon may serve as a constraint for the calibration of flow and transport models to describe the pore water flow dynamics and residence times within the infiltration zone of the USP. In the present work we tested the suitability of using the reactive tracers dissolved silica (Si) and radon (²²²Rn) in a ‘dual-reactive-tracer’ modeling approach to quantify residence times in a meso-tidal (tidal range 2.7m) sandy beach on Spiekeroog Island, Germany. We set up a 2-dimensional vertical cross-sectional unconfined groundwater flow and reactive transport model for the northern beach of Spiekeroog Island, with a lateral fresh groundwater inflow into the beach system and a periodic diurnal tide boundary (3rd type boundary condition) in the intertidal zone. Modelling was carried out with the USGS groundwater flow software MODFLOW and the reactive transport modeling software PHT3D2.17. For the flow simulations, aquifer properties from laboratory investigations and a previously calibrated flow groundwater model (Beck et al, 2017) for this site were applied and slightly adjusted to match measured hydraulic heads. Further, kinetic silica dissolution was simulated by applying a rate constant derived from laboratory Si dissolution experiment by Ehlert et al., (2016) utilizing sediment samples from the investigated site. In our reactive transport simulations, the dissolution rate constant was also not subject to calibration. In addition, ²²²Rn production and decay were simulated. Thereby, ²²²Rn concentrations from deeper sampling points in low lying discharge zones were assumed to be in equilibrium with the surrounding sediment. Under consideration of radioactive decay from ²²²Rn to ²¹⁸Po, this allowed constraining the ²²²Rn production rate that result from the decay of sediment- and pore water- derived ²²⁶Ra. The simulation results were compared to (i) measured groundwater levels, (ii) observed Si concentrations that were measured via pore water sampling in different depth between 0 and 1m and approximately every 10m along a 100m profile from the tidal high water position to tidal low water position, and (iii) observed ²²²Rn concentrations measured in different depths between 0 and 2 m at the tidal high water position. The model could reasonably well replicate the measured groundwater levels, as well as observed Si and ²²²Rn concentrations. Given the fact that the reactive transport model was not subject to calibration, the overall approach, i.e., to estimate residence times in the infiltration zone of the USP from the comparison of two independent

reactive tracers in a reactive transport modeling framework appears promising. The model will further be used to quantify the biogeochemical turnover rates of oxygen and nitrate introduced into the beach sediments.

REFERENCES

Beck, M, Reckhardt, A., Amelsberg, J., Bartholomä, A., Brumsack, H.-J., Cypionka, H., Dittmar, T., Engelen, B., Greskowiak, J., Hillebrand, H., Holtappels, M., Neuholz, R., Köster, J., Kuypers, M.M., Massmann, G., Meier, D., Niggemann, J., Paffrath, R., Pahnke, K., Rovo, S., Striebel, M., Vandieken, V., Wehrmann, A., Zielinski, O. (2017), The drivers of biogeochemistry in beach ecosystems: A cross-shore transect from the dunes to the low water line, *Marine Chemistry*, 190, 35-50.

Ehlert, C., Reckhardt, A., Greskowiak, J., Liguori, B.T.P, Böning, P., Paffrath, R., Brumsack, H.-J., Pahnke, K. (2016), Transformation of silicon in a sandy beach ecosystem: Insights from stable silicon isotopes from fresh and saline groundwaters, *Chemical Geology*, 440, 207-218.

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