Modelling seasonal variations of the oxic-redox boundary in coastal sediments of the Western Baltic Sea

M. Schlüter
E. Sauter
E. Suess

GEOMAR Research Centre, Wischhofstr. 1-3, 24148 Kiel, Germany

Seasonal variations of biogeochemical processes were investigated by in situ O_2-measurements, pore water, and sediment analysis at two sites in the western Baltic Sea. Over a period of ~1.5 years samples were collected every 3-4 weeks. The seasonal variations of the Chl.-a content and pore water concentrations of dissolved O_2, Mn, Fe, H_2S, SO_4 and CH_4 are reported. By numerical modelling we investigated the seasonal variation of bioturbation, bioirrigation, and of the oxic redox boundary.

Chl.-a profiles were used to model the depth of the mixed layer and intensity of bioturbation. Dissolved Cl concentrations were applied as a conservative tracer to model seasonal variations of bioirrigation. For both sites a very similar temporal pattern of bioturbation and irrigation was determined. In spring and fall the effect of bioirrigation for the pore water concentration is important at both sites and a five to seven fold enhancement of solute exchange, related to diffusional transport, was calculated. The temporal pattern of bioirrigation coincides with the Chl.-a (eq.) inventory of the surface sediments and with investigations of the settling of plankton blooms in this region. During summer, when low oxygen levels were observed in bottom waters irrigation rates are low. The relatively increasing importance of irrigation processes operating close to the sediment surface suggests an upward movement and migration of burrow-dwelling organisms, as a response to low O_2-concentrations. Considering bioirrigation by non-local transport, modelling of the annual distribution of Cl in the pore water leads to a close agreement with field observations.

Based on the results of the bioturbation and irrigation model and our O_2 in situ data we computed the oxic-redox boundary. The apparent oxygen utilisation by dissolved anorganic species was considered by the flux of reduced species into the oxic zone. The kinetics of oxygen consumption by organic carbon degradation was coupled to the influx and distribution of Chl.-a. in the sediment. This attempt was used, since Chl.-a. is a suitable proxy for the total influx of primary produced organic carbon in this organic–rich near shore environments. The fit of the model, considering biological transport processes, to the field data provides a suitable estimate about seasonal variations of degradation rates in the sediment and about the shift in the redox boundary due to the influx of primary produced organic matter (e.g. plankton blooms). By modelling degradation rates of e.g. 1.9×10^{-5}, 2.9×10^{-5}, 5.4×10^{-5}, and $8.4 \cdot 10^{-5}$ (s^{-1}) were calculated for spring, summer, fall and winter. The depth of oxic redox layer varied between 12 to 5 mm during the year. Since master parameters of the model are the influx of organic matter and the physicochemical state of the bottom water, we consider this attempt as a step toward a dynamic understanding of redox processes in coastal environments.