Effects of progressive oxygen depletion on sediment diagenesis and fluxes: A model for the lower St. Lawrence River Estuary

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ABSTRACT: We applied a diagenetic model to examine the effects of a decadal-timescale progressive decrease in bottomwater oxygen concentration on sediment geochemistry and fluxes across the sediment-water interface. The model was calibrated using geochemical data acquired over the last 30 yr in the lower St. Lawrence River Estuary (Canada), where the bottom-water oxygen concentration has been decreasing at an average rate of 1 μmol L^{-1} yr^{-1} over the past 70 yr. Benthic fluxes calculated from the model are comparable to fluxes derived from shipboard sediment incubations. By propagating the model forward in time and allowing the oxygen concentration to decrease further at 1 μmol L^{-1} yr^{-1}, we predict changes in the distributions and fluxes of iron, manganese, phosphorus, nitrogen, and sulfur. As the oxygen concentration decreases, the concentrations and distributions of reactive phases in the sediment change at an accelerating pace. Fluxes of reduced substances out of the sediment increase, reactive iron and manganese oxide phases become depleted, and the sediment becomes progressively enriched in iron sulfides. A notable exception is the efflux of phosphate, which remains invariant. At the study site, these changes are likely to become measurable within the next 20 yr. Model results are sensitive to the effects of decreasing oxygen concentrations on the benthos, the response of which we represent by two different approximations of the bioturbation and bioirrigation formulations: a gradual decrease and a thresholdtype decrease. The principal obstacle to reliable predictions of how sediments will respond is the lack of knowledge about the response of bioturbation and bioirrigation to decreasing oxygen in bottom waters.