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Effect of ionic migration on nutrient transport in sediments

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Reactive transport models assume molecular diffusion and advection as the primary mass transport processes that regulate nutrient distribution in aquatic sediment. Although, in principle, ionic migration can contribute to the movement of charged species, its contribution is typically neglected in biogeochemical studies. This omission stems from the assumption that electric fields do not develop in benthic system to relevant extents. However, evidences from geophysics and the growing field of electromicrobiology indicate that electric fields may develop in sediments. Here we investigate the occurrence and regulation of electric fields in fresh and brackish water sediments, and experimentally validate their influence on the mass transport of sulfate in laboratory incubation. Our data show that electric fields of intensities spanning between 0.1 and 7 $V.m^{-1}$ develop in surface sediments due to diffusion potential or in association to the presence of filamentous (cable) bacteria able to conduct electric currents over centimeter distances. To highlight the net contribution of ionic migration to mass transport, we measured the vertical transport of sulfate into artificial sediment cores, immersed in freshwater, in the presence and absence of a vertical electric field of 3 $V.m^{-1}$. Experimental data align with modelling estimations based on the Nernst-Plank equation to show a deeper penetration of sulfate in the sediment in the presence of the electric field compared to controls, within 20 hours. In the presence of the electric field, ionic migration accounted on average for 50 % of the whole sulfate flux, indicating that ionic migration is a non-negligible mass transport process in sediments where electric fields are present. Nutrients that regulate microbial activity in organic rich sediment (e.g. NO_x^-, NH_4^+, Fe^{2+}, PO_4^{3-}) will also migrate within electric fields. The extent of such mass transport process in natural sediment is currently being investigated.