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The kinetics of denitrification in permeable sediments

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Permeable sediments comprise the majority of shelf sediments, yet the rates of denitrification remain highly uncertain in these environments. Computational models are increasingly being used to understand the dynamics of denitrification in permeable sediments, which are complex environments to study experimentally. The realistic implementation of such models requires reliable experimentally derived data on the kinetics of denitrification. Here we undertook measurements of denitrification kinetics as a function of nitrate concentration and in the presence and absence of oxygen, in carefully controlled flow through reactor experiments on sediments taken from six shallow coastal sites in Port Phillip Bay, Victoria, Australia. The results showed that denitrification commenced rapidly (within 30 min) after the onset of anoxia and the kinetics could be well described by Michaelis–Menten kinetics with half saturation constants (apparent K_m) ranging between 1.5 and 19.8 μM, and maximum denitrification rate (V_{max}) were in the range of 0.9–7.5 nmol mL^{-1} h^{-1}. The production of N_2 through anaerobic ammonium oxidation (anammox) was generally found to be less than 10% that of denitrification. V_{max} were in the same range as previously reported in cohesive sediments despite organic carbon contents one order of magnitude lower for the sediments studied here. The ratio of sediment O_2 consumption to V_{max} was in the range of 0.02–0.09, and was on average much lower than the theoretical ratio of 0.8. The most likely explanation for this is that the microbial community is not able to instantaneously shift or optimally use a particular electron acceptor in the highly dynamic redox environment experienced in permeable sediments. Consistent with this explanation, subsequent longer-term experiments over 5 days showed that denitrification rates increased by a factor of 10 within 3 days of the permanent onset of anoxia. In contrast to previous studies, we did not observe any significant rates of oxic denitrification.