Biophysicochemical process coupling controls nitrogen use by benthic biofilms

Arnon, Shai, Kimberly A. Gray, Aaron I. Packman

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ABSTRACT: A combination of macroscale and microscale observations was used to show that the interplay between hydrodynamic transport, local chemical conditions, and microbial metabolism controls nitrate use by benthic microbial communities. While it is usually assumed that interfacial transport and nutrient removal both increase monotonically with the velocity of the overlying flow, in laboratory flume experiments we observed substantially greater bulk nitrate removal under slower velocities (0.05 and 0.5 cm s^{-1}) than under a faster velocity (5 cm ss^{-1}), with the greatest rate of nitrate removal occurring under the intermediate flow condition. These results demonstrate that hydrodynamic control of solute transport, specifically here the flux of oxygen and nitrate from the water column to the benthic microbial community, causes facultative bacteria to shift between anaerobic and aerobic metabolism under different flow conditions. Aerobic metabolism is promoted by more rapid hydrodynamic transport conditions, while anaerobic metabolism is favored under low-transport conditions. This type of coupling is expected to regulate microbial activity in all surficial sedimentary environments and must be parameterized in order to forecast long-term average biochemical transformation rates in rivers and other dynamic aquatic systems.

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