Beyond the Monod equation:

Developing a New Theory of Geomicrobial Kinetics

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This objective of this project is to develop a new rate law for the kinetics of microbial metabolisms in geological environments. The new rate law advances the study of geomicrobial and biogeochemical kinetics by accounting for both the thermodynamic control and microbial diversity in geological environments.

We will develop the new rate law based on: (1) a theoretical model for the thermodynamic control on microbial metabolisms; (2) the collision theory and requirement of microbial growth that delineate the maximum and minimum values of microbial kinetic parameters; and (3) an inverse theory that accounts for microbial diversity in the environment. The three theoretical bases of the new rate law prompt the three research tasks: (1) analyzing lake sediment samples to quantify the thermodynamic control in geological environments; (2) validating the theoretical estimation of the maximum and minimum values of the kinetic parameters; and (3) developing a new rate law that accounts for microbial diversity and thermodynamic control in geological environments.

We will develop the new rate law and apply to predicting the rates of methanogenesis in the sediments of the Howard Bay of Upper Klamath Lake in southcentral Oregon of USA. As shown by our preliminary study, sediment mixing at this site is insignificant and significant methanogenesis occurs in the sediments. Significantly, seasonal variations in the organic matter loading lead to a full range from small to large in the concentrations of electron donors, offering a natural experiment for developing the new theory of geomicrobial kinetics.

The new rate law developed in this proposal accounts for two critical, yet largely neglected, controlling factors in the environment, i.e., the availability of chemical energy and diversity of microorganisms. The new rate law therefore bridges the gap between empirical rate laws (e.g., the Monod equation) applicable for pure-culture under energy-rich conditions and the kinetics of diverse microorganisms in geological environments. The new theory integrates geochemistry and microbial diversity into geomicrobial kinetics and, therefore, advances the ongoing research efforts seeking to understand geological environments as habitats for diverse microorganisms. The new theory can be applied to the prediction of microbial activities in both natural environments and polluted areas, or in remote sites where direct sampling is not feasible or even where evidence of life is lacking.