

Beyond first order kinetics for the degradation of organic matter

S. T. Lennartz¹, T. Dittmar¹

¹Institute for Chemistry and Biology of the Marine Environment, University of Oldenburg, Oldenburg, Germany

The enormous diversity of molecular compounds and microbial metabolisms makes it difficult to constrain how much of the organic carbon fixed by autotrophic organisms is respired back to CO₂ at a global scale. It is this balance that determines how much carbon reaches the ocean floor, is retained in the sediments or remains as recalcitrant dissolved organic carbon (DOC) in the water column. The lack of a quantitative understanding makes it difficult to dynamically include the fate of carbon inventories, such as DOC, into our future climate scenarios. Current ocean models implement organic carbon as a set of discrete reactivity pools, each decaying with first-order kinetics. However, this hypothesis of a first-order kinetic has never been empirically validated. Here, we propose a paradigm shift by describing organic carbon decay as a second-order process, governed by encounter rates between DOC molecules and heterotrophic bacteria. We use the 700 petagram inventory of DOC as an example. This mechanism implies that degradation is limited not by molecular lability alone, but by the probability of molecular encounters of their consumers in the dilute environment of the deep ocean. We support this concept through several lines of evidence, including statistical model fits, theoretical estimates and a global 3D numerical simulation. These results argue for a reconceptualisation of (D)OC dynamics, with implications for predicting (D)OC variability and future oceanic carbon storage.