Phosphorus regeneration after death: Lysis and the microbial loop

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The availability of phosphate plays a critical role in limiting primary production in large regions of the oceans, including major ocean gyres. To meet their metabolic needs, microbes use a variety of strategies to overcome orthophosphate limitation. Up-regulation of enzymes such as alkaline phosphatase (APase) allows hydrolysis of ambient dissolved organic phosphorus (DOP) compounds extracellularly or in the periplasmic space enabling transport of orthophosphate into the cell. Cell lysis releases cell components, including enzymes, into the environment. Enzymatic activity following lysis is an important, unquantified mechanism in nutrient regneration and the microbial loop. Constraining and quantifying the flux of inorganic nutrients produced by lysed cells is essential to our understanding of the microbial loop and controls on ocean biogeochemistry. Using pure cultures of *E.coli* MG1655, *Synechococcus* WH7803, and *Prochlorococcus* MED4, we quantify patterns of nutrient release following cell lysis in relation to continued enzymatic activity. In addition, lysis experiments were carried out with surface ocean microbial communities in the North Atlantic to monitor nutrient release and regneration for a period of days following lysis. Our experiments show that APase activity is sustained for many days after lysis. We observed a significant intial release of orthophosphate that accompanies lysis. This is followed by increasing phosphate concnentrations in lysis solutions over a period of days. Our observations suggest this is due to a combination of direct hydrolysis of DOP released during lysis, solubilization and hydrolysis of particulate organic phosphorus, and possibly polyphosphate decomposition. Incubations with a range of individual DOP compounds spiked into the lysate show rapid release of orthophosphate from phosphomonoesters and pyrophosphate, modest release rates from phosphonates, and slow release from phosphodiesters. This work highlights the importance of extracellular nutrient regeneration pathways involving cellular debris for biogeochemical dynamics in marine ecosystems and ultimately the amount of carbon exported to the deep ocean.