Effects of dissolved carbon dioxide, zinc, and manganese on the cadmium to phosphorus ratio in natural phytoplankton assemblages

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ABSTRACT: We report the results of a field study, in productive waters off California, of the factors that control the particulate cadmium (Cd) : phosphorus (P) composition of natural assemblages of marine phytoplankton, the dominant vector of both elements to the deep ocean. Controlled shipboard incubation experiments (~2-4 d) demonstrated that while manipulation of pCO_2 and dissolved zinc (Zn) and manganese (Mn) concentrations had little effect on the species composition or C: nitrogen (N) : P ratios of natural, diatom-dominated phytoplankton assemblages, their Cd : P ratio was negatively correlated to each of these variables. The particulate Cd: P ratios of phytoplankton were two to five times higher for cells grown at low pCO_2 than for cells acclimated to growth at pCO_2 at or above atmospheric equilibrium values. Addition of Zn to incubations at five- to 20-fold above background concentrations decreased Cd uptake and phytoplankton Cd: P ratios across pCO_2 and Mn treatments and suppressed short term Cd uptake rates by a factor of approximately two to four, compared to controls. A broad pattern of Mn suppression of Cd uptake was also evident in our incubations. We propose that natural variability in surface water pCO_2 and dissolved Zn and Mn, related to water mass history and biological drawdown, likely govern the degree of Cd uptake and, therefore, the evolution of the dissolved Cd : PO_4 ratio in recently upwelled, high-productivity surface waters.