A three-step process of manganese acquisition and storage in the microalga *Chlorella sorokiniana*

Abstract

Metabolism of metals in microalgae and the adaptation to metal excess are of significant environmental importance. We report here a three-step mechanism that the green microalga *Chlorella sorokiniana* activates during the acquisition of and adaptation to manganese (Mn), which is both, an essential trace metal and a pollutant of waters. In the early stage, Mn^{2+} was mainly bound to membrane phospholipids and phosphates in released mucilage. The outer cell wall was reorganized, and lipids were accumulated with a relative increase in lipid saturation. Intracellular redox settings were rapidly altered in the presence of Mn excess, with increased production of reactive oxygen species that resulted in lipid peroxidation and a decrease in the level of thiols. In the later stage, Mn^{2+} was chelated by polyphosphates and accumulated in the cells. The structure of the inner cell wall was modified and the redox milieu established a new balance. Polyphosphates serve as a transient Mn^{2+} storage ligand, as proposed previously. At the final stage, Mn was stored in multi-valent Mn clusters that resemble the structure of tetramanganese-calcium core of the oxygen-evolving complex. The present findings elucidate bioinorganic chemistry and metabolism of Mn in microalgae, and may shed new light on water-splitting Mn clusters.