Relationship between carbon availability and biogenic manganese oxide formation

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Biological precipitation is the major pathway for $MnO_{2(s)}$ formation under most environmental conditions, and can occur in ecosystems ranging from fresh water to marine systems to soils and sediments. These minerals are highly reactive and are known to attenuate plumes of toxicant metals, contribute to carbon cycling, and serve as electron acceptors for respiration of manganese-, iron- and sulfate-reducing bacteria. The ability to oxidize $Mn(II)_{(aq)}$ enzymatically is widespread among the bacterial and fungal domains of life. However, the physiological reasons for Mn oxidation are entirely unclear.

Enzymatic oxidation of $Mn(II)_{(aq)}$ to Mn(III, IV) leads to the extracellular accumulation of $MnO_{2(s)}$ nanoparticles. In many bacterial species, $MnO_{2(s)}$ precipitation begins when bacterial cells experience carbon starvation and/or enter into stationary phase. This observation implies that $MnO_{2(s)}$ accumulation requires the absence of reducing carbon substrates, since the latter may readily to reduce any enzymatically oxidized Mn back to $Mn(II)_{(aq)}$. The hypothesis guiding this work is that the concentrations of nutrients and secondary metabolites in the extracellular medium control the accumulation of MnO2(s) in bacterial suspensions.

In this study we investigate the relationship between carbon source and biogenic $MnO_{2(s)}$ formation in *Pseudomonas putida* GB-1 cultures. Bacterial growth, medium composition (pH, O_2, carbon source, and secondary metabolites), Mn concentration and Mn oxidation state were measured in batch incubations over 120 hrs. Our data show that the onset and kinetics of Mn oxidation are especially sensitive to the concentration of glucose supplied in the growth medium, even under similar conditions of bacterial growth rate, amount of biomass and suspension pH. These data suggest that decreasing the glucose concentration decreases the concentrations of secondary metabolites that inhibit the formation of Mn oxides.