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Impact of heavy-metals on selenium bioreduction and speciation: biomineralization and bioremediation

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Selenium (Se) exists in different oxidation states in nature depending on the environmental redox conditions. Se-oxyanions i.e. selenate (SeVI) and selenite (SeIV) which are found in oxic environments, are stable and highly soluble in nature. Elemental selenium (Se0) and selenide (Se-II) are less soluble and mobile and found in anaerobic environment. While limited information is available on the microbial oxidation of Se(0), the bioreduction of Se(IV) and Se(VI) in to Se(0) and Se(-II) by Se-respiring microorganisms are ubiquitous in nature. But, in extremely reducing environment after binding with metals, Se is often detected in sediments and rocks as metal selenide minerals along with the natural sulfide minerals including pyrite and chalcopyrite. However, limited information is available on the impact of metals on Se-reducing microorganisms and Se-speciation in environmental conditions.

So, the effect of heavy metals on microbial reduction of Se(IV) and Se-speciation under anaerobic condition in the presence of granular sludge (mixed microbial communities) was investigated to understand the fate of bioreduced Se and heavy metals. While, Se(IV) bioreduction was inhibited in the presence of Cd(II) due to the metal toxicity, Pb(II) showed no toxic inhibition on Se-reducing microorganisms. Notably, the formation of Se(0) and Se(-II) varied greatly in the presence of heavy metal type and initial concentration. Interestingly, while Pb(II) was immobilized onto the granular sludge via PbSe, $PbCO_3$, PbO biomineralization, Cd(II) was biomineralized only as CdSe in the biomass which were confirmed by XPS and XRD analysis.

In case of Cd(II), formation and immobilization of a more complex CdSe/CdS core/shell biominerals was also observed due to the interaction between Cd(II) ions of the CdSe and the sulfhydryl (–SH) groups of the biomass. However, no such interaction and biomineralization for Pb(II) was observed in the biomass. Formation of Metal-Se(0) (e.g. Se(0)-Cd(II)) complex due to the adsorption of metals onto the Se(0) nanoparticles was also observed. The implication of this results will, thus, not only help to understand the metal-Se interaction in nature and its speciation, but can also help in developing a process for simultaneous removal of heavy metals and selenium as metal selenide biomineralization from wastewater.