Selenium uptake and volatilization by microalgae

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Biomethylation and subsequent volatilization of selenium (Se) provide a major natural source of atmospheric Se and thereby contribute to the global cycling of this essential trace element. Microorganisms such as microalgae may play an important role in the natural biomethylation and volatilization of Se but the underlying biochemical mechanisms that control the uptake and metabolism of Se as well as the volatilization of methylated Se compounds are still largely unknown.

Therefore, we investigated Se methylation as a function of Se uptake and intracellular Se concentrations in the model green microalgae *Chlamydomonas reinhardtii*. We simultaneously quantified aqueous- and intracellular Se compounds over time in microcosm exposure experiments and used biochemically-based mathematical models to gain insight in the uptake and methylation mechanisms.

C. reinhardtii internalized selenite a factor 10 more efficiently than selenate and different membrane-transporter systems were involved in the uptake of these Se species. Both exposure to selenite and selenate led to the synthesis of up to 4 mM intracellular organo-Se compounds. Exposure to selenite induced a much higher uptake of Se compared to exposure to selenate and led to the formation of intracellular zerovalent Se (up to 81% of intracellular Se). Furthermore, *C. reinhardtii* produced volatile methyl-selenides (dimethyl selenide and dimethyl diselenide) with rates of up to 160 amole $Se \cdot cell^{-1} \cdot h^{-1}$, indicating that up to 81% of the accumulated intracellular Se could be volatilized.

The kinetics of Se uptake, metabolism and methylation could be quantitatively described with biochemical models. The obtained model parameter values illustrate that intracellular selenate reduction may be the rate-limiting step for the production of methylated Se and that the methylation of Se as well as the formation of zerovalent Se become significant at intracellular Se concentrations exceeding 1 mM. Our results indicate that microalgae may internalize and methylate Se both rapidly and efficiently, which could have significant consequences for the environmental fate of Se and its global distribution at large.