Effects of Changing Redox Conditions

on the Bioavailability of Heavy Metals in Paddy Soils

Urbanization and industrialization in China and other countries caused tens of millions hectares of land to be polluted with heavy metals. This leads to unacceptable human health risks in many areas, because of consumption of crops, especially rice with high heavy metal levels. Rice is the most important staple crop for China and many other parts of Asia. This emphasizes the need for a thorough understanding of the processes determining the heavy metal uptake by rice plants. In general, plant uptake is determined by the speciation (i.e., chemical forms) of heavy metals in soil and plant-specific factors. The speciation of heavy metals depend on (competitive) interactions between heavy metals and other cations and sorbing soil constituents like organic matter, clay, and (hydr)oxides. Although redox conditions (i.e., the presence or absence of oxygen) are known to have a large influence on these interactions, only very little is known about the effects of (changing) redox conditions on the speciation of heavy metals. For rice, this is particularly important, because rice is mostly grown in paddy fields where alternating flooding and draining of the fields lead to continuously fluctuating redox conditions. The scientific challenge for predicting the effects of redox processes on the speciation and uptake of heavy metals is that many of the redox processes are relatively slow, leading to non-equilibium conditions in soil. The main goal of the proposed PhD research, therefore, is to determine how redox conditions and changes in these conditions affect the speciation of heavy metals and how this, in turn, affects the heavy metal uptake by rice plants. To meet this objective, a combination of laboratory, pot, and field experiments and soil chemistry modeling is proposed. In the laboratory, batch experiments will be performed in which redox conditions will be manipulated to determine their effects on heavy metal speciation under controlled conditions. Crucial in this PhD research is the measurement and prediction of heavy metal speciation and the (competitive) effect with other cations. For measuring the speciation of heavy metals, a field application of the Donnan Membrane Technique (DMT) will be used in-situ. For predicting the heavy metal speciation, advanced mechanistic speciation and sorption models will be used, which will be combined with kinetics of redox dependent chemical reactions. The in-situ use of DMT and the combination of advanced speciation modeling with redox kinetics have not been applied before, and are, therefore, considered scientifically very innovative.

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