

DEGREE

Ph.D.

TITLE

Metal retention by synthetic organo-mineral complexes

CONTACT INFO

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HYPOTHESIS

The fate of a trace metal in soils is governed by thermodynamic principles but metal (re)distribution depends ultimately on kinetic constraints.

SUMMARY

Did you know that soils act as a barrier or filter that can prevent contamination of surface and ground waters, as well as the transfer of trace metals to biota? And that these beneficial effects of soils are a result of the retention capacity of its solid constituents, namely, clays (layer silicates), iron and aluminium oxides, and organic matter? Although most studies have focused on understanding the interactions between metals and single soil constituents, soil solids are intermixed and form complex structures called organo-mineral complexes.

An organo-mineral complex is a synthetic assemblage of two or more different phases (e.g. iron oxides, organic matter, and silicate clays) that emulates a soil particle. When organo-mineral complexes, rather than individual phases, are used for metal retention studies, three different scenarios have been proposed. The first, known as the linear additive model, proposes that an organo-mineral association act as a noninteractive sorbent mixture, and thus the sorption capacity of an organo-mineral association is the simple sum of the sorption capacity of individual phases. Positive and negative deviations from the linear additive model have been observed and are referred to as supra-additive or antagonistic, respectively. Accordingly, the supra-additive model proposes that new high affinity metal complexation sites are created and that the overall retention of a specific metal might be underestimated, if the linear additive model is used to predict metal fixation in soils. In contrast, the antagonistic model proposes that the phases interfere between each other and that the overall retention of a specific metal might be overestimated, if the linear additive model is used to predict metal fixation in soils. Using ternary model associations for sorption of inorganic and organic contaminants, it has been shown that the amount and nature of the surface that remains available after an inter-association of single soil constituents is the critical parameter determining the sorptive behavior of the resultant complex and that it will ultimately determine the reactivity of the ternary complex towards solutes. As intimate associations among individual components might cause some modification of their sorptive properties, the interactions among soil solids should be taken into account in the development of deterministic, surface complexation models

if substantial deviations from reality want to be avoided. A better understanding of the contribution to trace metal binding by the sorptive surfaces present in soils is necessary to predict the fate of trace metals in natural soils.

I invite you to study these processes using both natural and synthetic phases representing the main solid constituents encountered in soils in a particle reproduced synthetically by coating a clay mineral with alumina and humic acids to better understand interactions with metals under controlled ionic strength, pH, and temperature conditions. A predetermined concentration of trace metals (let's say, Cd, Cr, Ni, and/or Cu) can be added to the organo-mineral complex, and the metals' partitioning and redistribution behavior can be followed over time. Metal solubility measurements and speciation can then be performed using a variety of techniques including ion selective electrodes, differential pulse anodic/cathodic stripping voltammetry (DPA/CSV), inductively coupled plasma optical emission spectroscopy (ICP-OES), and hydrogeochemical modeling. The concentration of dissolved organic carbon (DOC) released to the solution phase should also be monitored. The partitioning should also be determined using wet chemistry approaches. And here the most exciting part comes. You will learn transmission electron microscopy coupled with X-ray energy disperse spectroscopy (TEM-EDS) to unveil interactions between metals and soil solid phases at the nano scale level. You will accomplish these objectives through the application of basic soil chemical principles using the soil systems mentioned above. The knowledge you gain through your investigation will improve the general understanding of changes in the behavior of metals across soils of varied composition. Furthermore, the scientific community could benefit with better tools to develop more effective remediation techniques and establish safer metal loadings to soils.

QUALIFICATIONS

The applicants are expected to hold an Msc degree or equivalent in Chemistry, Environmental Chemistry or any related subject. The student should have a strong interest for and general expertise in chemistry, wet chemistry, and spectroscopic methods. Experience from previous research in the field is a merit. Knowledge of other analytical techniques is valuable. Excellent communication skills orally and writing are required, both in English and Spanish.

ACTIVITIES

- Literature review
- Development of the experimental approach
- Development of the experimental work
- Data analysis
- Writing
- Publishing
- Teaching

TIMING

Four years

PROJECT DELIVERABLES

- Thesis
- One paper in an index international journal
- One oral presentation in an international conference
- Four short communications for general public in nationwide newspapers