THE ROLE OF CLAY MINERALS, HYDROXIDES, AND TIMING OF DISSOLVED ORGANIC MATTER ADDITION IN THE COMPETITIVE SORPTION OF HEAVY METALS: A SOIL COLUMN APPROACH

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Introduction

In developing countries, waste water is often used for the irrigation of non-contaminated arable land. Since this wastewater contains a considerable amount of toxic heavy metals (HMs), this can negatively affect soil and groundwater quality (Wuana and Okieimen, 2011). The properties and amounts of soil constituents, such as clay minerals and oxides, determine the potential toxicity and mobility of HMs in the soil environment where these constituents often act as a filter for the contaminated water. The presence of dissolved organic matter (DOM) either in wastewater (concurrent with toxic HMs) or in the soil itself from manure can also significantly influence the mobility of HMs. Furthermore, the timing when HMs and DOM react with each other and the soil influences the mobility of HMs (Refaey et al., 2014).

Methods

To clarify such interactions, in the present study continuous flow column experiments were conducted using well characterized soil samples from Limburg, The Netherlands. The samples were amended with three different minerals: goethite, birnessite and smectite, and subjected to three different HM solution (Cu, Zn and Ni) flow scenarios: A) containing no DOM; B) sequential addition of first DOM and then HMs; C) concurrent addition of HMs and DOM. The modified dose-response model was used to fit the resulting breakthrough curves.

Results

In the absence of DOM (scenario A), Cu had a higher retention for soil-birnessite followed by soil-goethite. In contrast, Zn and Ni exhibited higher retention for soil-goethite followed by soil-birnessite. Prior addition of DOM (scenario B), resulted in a moderate enhancement in adsorption capacity (q_0) of Cu (8-25%), except for soil-goethite which exhibited a 10% reduction compared to the control (soil without mineral amendment) due to the blocking of binding sites. Meanwhile, both Zn and Ni exhibited a large reduction in their q_0 for all tested soils (1-36%) compared to the control experiment, confirming the preferential binding of Zn and Ni by the mineral phases. Concurrent addition of DOM and HMs in soil columns (scenario C) on the other hand gave rise to a large enhancement in q_0 for all tested metals compared to the control experiment, varying in the range of 141-299% for Cu, 29-102% for Zn and 32-144% for Ni. The Cu q_0 was approximately 1.5, 2 and 3 times greater than that of Zn and Ni in scenarios A, B and C respectively.

Conclusion

The current study indicates that not only the presence of DOM, but also the timing of its addition (sequentially or concurrently with HMs) plays a crucial role in determining HM adsorption on clay minerals. Such kinetic effects until now have been hardly taken into account, but are of great significance; for instance in agricultural soils such as in Egypt that may be exposed to HM polluted irrigation water as well as DOM-rich manure.

References

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