



## **The potential of Mg-Fe layered double hydroxides and mixed oxides as perspective stabilizing amendments in soils with elevated As(V), Pb(II) and Zn(II) contents**

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The main aim of the study is to evaluate the potential of Mg-Fe layered double hydroxides (LDH) and mixed oxides (thermally treated LDHs; CLDHs) as perspective amendments for As(V), Pb(II) and Zn(II) stabilization in soils. Both LDHs and CLDHs have shown to be efficient (ad)sorbents of metals and metalloids in aqueous solutions; however, their stability and stabilizing efficiency in soils have not been intensively studied yet. To evaluate basic (ad)sorption characteristics of studied materials, (ad)sorption experiments (kinetics and isotherms) were coupled with solid-state analyses (XRD, SEM/EDX and XPS). The (ad)sorption mechanisms in the aqueous solution consisted of different processes including adsorption/interlayered incorporation (As), adsorption/surface-induced precipitation (Pb) and adsorption/surface-induced precipitation/isomorphic substitution (Zn). The stability tests of LDHs and CLDHs in deionized water and extracted soil solutions showed a slightly lower Mg(II) release from the CLDHs structure compared to the structure of LDHs. Contrarily, pH-static leaching experiments and incubation experiments showed LDHs as more stable and effective materials. Therefore, we concluded that the soil incubation significantly improved the stability of LDHs compared to CLDHs. The stability of materials in soils were also influenced by the formation of new phases corresponding to Mg-carbonates/silicates on the LDH/CLDH surface that was proved by the solid-state analyses (XRD and SEM/EDX) coupled with geochemical modeling (PHREEQC-3 hydrogeochemical code). Moreover, both LDHs and CLDHs significantly increased the pH value influencing thus the sorption/desorption mechanisms of metals and metalloids in the amended soils. The results of simple and sequential extractions showed that both LDHs and CLDHs significantly decreased the most labile fraction of As(V) and Zn(II) in the amended soils. A similar stabilization efficiency of Zn(II) was observed in soils amended by both materials; however, LDHs were significantly more effective in the stabilization of As(V). Contrarily, Pb(II) concentration remained the same since Pb(II) was predominantly bound to soil organic matter. The stabilization of As(V) was more likely influenced by adsorption on LDHs and CLDHs as no precipitation occurred at given conditions. Contrarily, the stabilization of Zn(II) was influenced by adsorption and precipitation of carbonates as well. This novel and comprehensive study using LDHs and CLDHs in real soils showed that these materials represent promising stabilization amendments in soils contaminated with metals and metalloids. In general, we recommend using pristine LDHs in soil remediation technologies rather than CLDHs due to their higher stability and stabilization efficiency. Although the synthesis of LDHs is relatively simple and economical, alternative synthesis methods of LDHs using low-cost reactants (e.g., waste materials) or modification with low-cost sorbents will be needed considering real applications.