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IMMOBILIZATION OF TOXIC HEAVY METALS USING HYDROTALCITE MINERALS: POSSIBLE APPLICATIONS FOR DECONTAMINATION OF POLLUTED LAND AND WATER

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Abstract

Layered Double Hydroxides (LDHs), Hydrotalcite minerals, are applicable to immobilize anionic species of toxic heavy metals such as Cr, As, Se and Hg. In this paper a preliminary result of laboratory experiment with heavy metal contaminated water is reported.

Keywords: Layered double hydroxides (LDHs), Hydrotalcite, Heavy metals, Adsorption

Clay minerals, zeolites, and hydrotalcite - layered double hydroxides (LDHs) - are very promising substitutes for environmental protection and remediation of heavy metal contaminated sites, due to their ion-exchange, adsorption, high versatility, easily manipulated properties, and low costs.

Clay minerals such as smectite, halloysite, illite, and kaolinite, have a large area and net negative charge on the external surface of particles, which causes remarkable adsorption property with cationic species. Similarly zeolites, naturally occurring almino-silicates minerals, show cation-exchange property. For environmental protection, these two mineral groups, clays and zeolites, have been applied for immobilization of cationic species of toxic heavy metal pollutants, such as Cu, Pb, Zn, Cd, Hg, etc. In contrary, layered double hydroxides (LDHs), also called hydrotalcite, have positively charged brucite-type lattice structure with balancing anions such as Cl^-, CO_3^{2-}, SO_4^{2-} etc, which can be replaced by other anions resulting strong anion-exchange property. General chemical formula is expressed as follows: $M(II)_{1-x}M(III)_x(OH)_2[A^{n-}]_{x/n} \cdot yH_2O$, where M(II) is divalent metal cation such as Mg^{2+}, M(III) is trivalent metal cation such as Al^{3+}, and A is balancing anion. The LDHs are applicable to immobilize anionic species of toxic heavy metals, such as CrO_4^{2-}, $Cr_2O_7^{2-}$, $H_2AsO_3^-$, AsO_4^{3-}, SeO_3^{2-}, SeO_4^{2-}, $HgCl_4^{2-}$, etc.

Mixing treatment of these mineral materials is effective to treat complicated contamination by multiple heavy metals constituting cationic and anionic pollutants. In this paper the author introduces positive results of laboratory experiment for immobilizing toxic heavy metals in water.

1. Materials and Method

A initial water solution (multiple metal contamination material) was prepared for the concentration of 1.0 mg/L in each metal, Pb, Zn, Cu, Cr(VI), Cd, Hg, As, and Se, where three metals, Cr(VI), As, and Se, are anionic species. The water solution (pH7) was treated by mixing 5 wt% LDHs. We used following four different balancing-anion type LDHs for the experiment, individually:

i) Natural hydrotalcite $CO_3^{2-} >> SO_4^{2-}$

ii) Synthetic hydrotalcite - balancing anion CO_3^{2-} type (2 samples)

iii) Synthetic hydrotalcite – balancing anion SO_4^{2-} type (2 samples)

iv) Synthetic hydrotalcite – balancing anion Cl^- type.

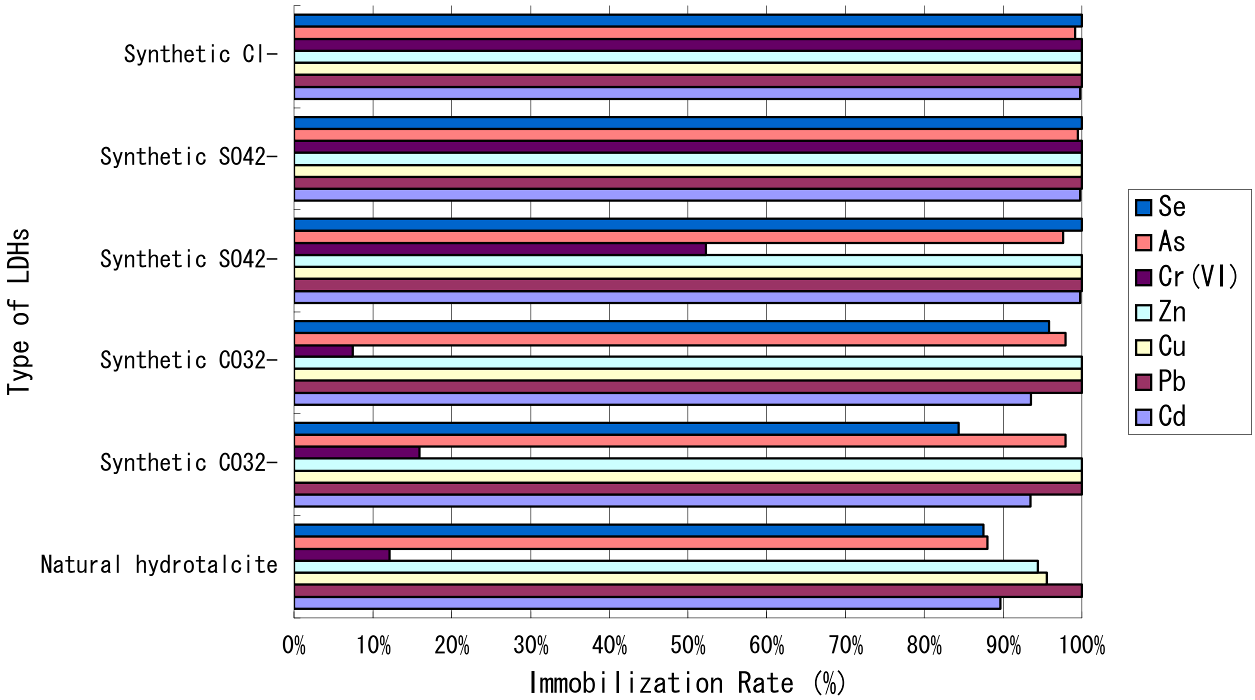

Figure 1: Immobilization rate of toxic metal ions in water solution by different types of LDHs. The concentration of metal ions in the water solution was measured using ICP.

2. Results and Interpretation

One day after the mixing treatment of each LDH, significant immobilization of toxic metal ions could be observed in the water solution. After the treatment pH shifted to alkaline side (pH 8-9). The results are summarized in Figure 1, where the immobilization rate is deduced from the following equation: Ratio (%) = 1 – (Concentration after the treatment) / (Concentration before the treatment). It means the immobilization is more intense when the rate increases. All types of LDH are effective for the immobilization, but natural hydrotalcite and CO_3^{2-} balancing type synthetic hydrotalcites are not very effective for the immobilization of Cr(VI). On the other hand, the Cl^- balancing type synthetic hydrotalcite is the most effective for all metals, which marks 99-100% of immobilization rate. The immobilization effect is observed with both anionic and cationic metals, which suggests that the effect is caused not only by the anionic adsorption and/or anionic exchange of LDHs but by a precipitation of insoluble metal hydroxides (M+OH) under alkaline conditions.

3. Conclusions

Present results of experiment demonstrated that the LDH minerals are quite effective for immobilizing toxic metals in contaminated water. In particular, Cl^- balancing synthetic hydrotalcite shows universal effect for various metals. The LDH minerals can immobilize toxic anions, which has been insufficient by previous mineral immobilization techniques using clay minerals and/or zeolites. The LDH mixing technique can be widely applied for the mitigation of soluble metal pollutants in wastewater, waste and contamination land. The technique was registered as the Japan Patent. No.2000-012012, 323832.