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Enhanced Removal of Arsenic and Antimony in the Mining Site by Calcined γ-Fe2O$_3$/Layered Double Hydroxide Nanocomposite

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Arsenic (As) and Antimony (Sb) have been recognized as harmful contaminants in aquatic environment due to its high toxicity and carcinogenicity. Especially, the contamination of arsenic in the mining areas is considered as a serious emerging environmental issue in Korea. Due to the hazardous effect of arsenic, the United States Environmental Protection Agency (US EPA) regulated maximum contamination level of arsenic to 10 μg/L in drinking water. The harmful effect on human health by excessive intake of antimony was also reported by previous studies, and severe contamination level (100 – 7,000 μg/L) of antimony reported in surface and groundwater of abandoned mining area in China and Slovakia. Therefore, US EPA regulated maximum contaminants level of antimony in drinking water to 6 μg/L.

In order to remove anionic contaminants in drinking water, various type of nanomaterials have been developed. Layered double hydroxide (LDH) is the artificial anionic clay that is based on the layered structure of positively charged brucite-like layers with interlayers of anions. The LDH is one of the promising nanomaterials for the removal of anionic contaminants because it has high selectivity for arsenic, phosphate, chromium and antimony. However, the biggest problem of LDH for wastewater treatment is that the particles cannot be easily separated after the removal of contaminants. In this study, magnetic nanoparticles (γ-Fe2O$_3$) supported LDH nanocomposite (γ-Fe2O$_3$/LDH) was investigated to enhance magnetic particle recovery and removal efficiency for arsenic and antimony.

The calcined γ-Fe2O$_3$/LDH nanocomposites synthesized by co-precipitation method, and the crystallographic properties of maghemite (γ-Fe2O$_3$) and layered structure of LDH were confirmed by X-ray diffraction. The nano-sized γ-Fe2O$_3$ (30 to 50 nm) was stably attached on the surface of LDH (100 to 150 nm) and O1s spectrum by X-ray photoelectron spectroscopy (XPS) explained that there are both physical and chemical complexation between γ-Fe2O$_3$ and LDH in the nanocomposite. The saturation magnetization of raw γ-Fe2O$_3$ and calcined γ-Fe2O$_3$/LDH nanocomposite were 63.2 and 14.3 emu/g, respectively. Although there was distinct decrease of saturation magnetization of calcined γ-Fe2O$_3$/LDH nanocomposite, the particles were rapidly separated by external magnetic field. The kinetic study revealed that the removal of arsenic and antimony reached equilibrium quickly at about 120 min for initial concentration of 50 mg/L. The regeneration rate of arsenic may retain 70% for five regeneration cycles by 0.5M NaOH with 5M NaCl solution, whereas antimony showed lower regenerability than arsenic due to the higher irreversible fraction in calcined γ-Fe2O$_3$/LDH nanocomposite. Consequently, the effective removal efficiency for arsenic and antimony with its easy magnetic separation makes γ-Fe2O$_3$/LDH nanocomposite be a potential for the field application in the contaminated sites including several mining sites in Korea.