Remediation of arsenic contaminated soil with high gradient magnetic separation

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Abstract

Arsenic (As) is highly toxic and carcinogenic to humans. It is a frequently found contaminant in contaminated sites due to its many industrial applications such as tanning, wood preservation, pesticide and herbicide. We developed a combined process of dispersion and magnetic separation for the remediation of As contaminated soil. We collected the As contaminated silt loam soil from a smelting site. We tested the soil dispersion rate at various pH and concentrations of Na-orthophosphate, Na-pyrophosphate and Na-hexametaphosphate and determined an optimum dispersion condition. We also tested the change in As concentration of the soil after and before passing its suspension through a magnetic field. The dispersion rate increased with increasing phosphate concentration and showed the following order at the same concentration: hexametaphosphate > pyrophosphate > orthophosphate. The dispersion rate also sharply increased at the solution pH 11. We concluded that the optimum dispersion condition was pH 11 10mM Na-hexametaphosphate. The soil dispersed at the optimum conditions was separated into magnetic and nonmagnetic particles with a high gradient magnetic separator (HGMS) at 12,000 gauss. The bulk soil with 37.7 mg kg⁻¹ of As was separated into 20% of magnetic fraction and 80% of nonmagnetic fraction. The magnetic fraction had a higher As concentration, 48.0 mg kg⁻¹ but the nonmagnetic fraction had a lower As concentration, 20.0 mg kg⁻¹, comparing with the bulk soil. The result indicated that the high gradient magnetic separation combined with dispersion can be practiced for the remediation of As contaminated soil.

Keywords: arsenic, remediation, dispersion, HGMS.

1 Introduction

A high concentration of arsenic (As) of soil and water has been an environmental concern due to its toxicity and carcinogenicity. Elevated levels of As in the

environment occurs due to numerous anthropogenic processes such as agriculture, mining and mineral processing operations. The toxicity and mobility of As is dependent on the parent mineral form, oxidation state and mobilization mechanisms. The most prevalent As species in surface environments are arsenate [As(V)] and arsenite [As(III)]. Arsenic can adsorb on the surface of Fe oxides, Al oxides and Mn oxides [1]. Arsenic adsorption on the edges of clay minerals and on the surface of calcite has also been observed. It also coprecipitates with Fe oxides and Fe sulfides.

Remediation of As contaminated soils has been practiced with physical, chemical and biological methods such as solidification/stabilization, vitrification, soil washing, electrokinetics, soil flushing, pyrometallurgical recovery, biological treatment and phytoremediation [2]. We tested the efficiency of magnetic separation on the reduction of As concentration of contaminated soil.

2 Material and method

An As contaminated soil sample was collected near the smelting site. The sample was air-dried and the < 2 mm fraction was collected for further analysis and experiment. The pH and electrical conductivity (EC) of the soil were determined after the reaction of 1soil and 10water. The mineralogy of the soil was determined with an X-ray diffractometer. The ignition loss of the soil was determined by heating at 550°C and the cation exchange capacity (CEC) was determined with Ca-Mg method [3]. The dispersion rate of the soil was tested at various pH and concentrations of phosphates and sodium dodecyl sulfate (SDS) and the optimum dispersion condition was determined. The dispersed soil suspension at the optimum dispersion condition was separated into the magnetic particles and the nonmagnetic particles with a high gradient magnetic separator at 12,000 gauss. The As concentrations of the bulk soil, the magnetic soil particles and the nonmagnetic particles were determined the aqua regia extraction method [4]. The As concentrations of the dispersing solutions and the extracting solutions were determined with an ICP-OES.

Figure 1: Schematic presentation of high gradient magnetic separator.

3 Results and discussion

The chemical and mineralogical characteristics of the soil are shown in Table 1. The dispersion rate of the soil was increased with increasing the pH and the concentrations of phosphates and SDS of dispersing solutions (Fig. 1). For phosphate solutions, the combination of pH 11 and 10mM was the optimum condition for each phosphate. Hexametaphosphate was the most effective dispersing agent among phosphates at the same pH and the concentration. For SDS, the combination of pH 11 and 50 mM was the optimum dispersing solution. The As concentration of the dispersing solutions increased with increasing the pH and the concentrations of phosphates of the solutions. However, the concentration of SDS did not affect the As concentration of the dispersing solutions.

Table 1: The chemical and mineralogical properties of the soil.

pH	Electrical conductivity (S/cm)	Cation exchange capacity (cmol _c /kg)	Ignition loss (%)	Mineralogy
5.5	10.4	7.6	5.1	quartz, kaolinite, hematite

Figure 2: Dispersion rate at the various pH and concentration of phosphate and surfactant of the dispersing solutions.

The As concentration of the soil sample before dispersion and magnetic separation was 37.7 mg kg⁻¹. About 80% of soil particles were separated as magnetic fraction and 20% were separated as nonmagnetic fraction with the high gradient magnetic separator at 12,000 gauss. The As concentration of the magnetic fraction was 48.0 mg kg⁻¹ and but that of the nonmagnetic fraction was 20.0 mg kg⁻¹.

4 Conclusion

The results of this study indicate that the combined process of dispersion and magnetic separation can be practiced as a remedial process of As contaminated soils. The optimum dispersion condition was pH 11 10 mM Na-hexametaphosphate. The high gradient magnetic separation at 12,000 gauss can separate the soil particles into the magnetic fraction with higher As concentration and the nonmagnetic fraction with lower As concentration. The magnetic separation can concentrate As into a small volume.

References

- [1] Mandal, B.K. & Suzuki, K.T., Arsenic round the world: a review. *Talanta*, 58, pp. 201–235, 2002.
- [2] US EPA. Arsenic treatment technologies for soil, waste, and water. EPA-542-R-02-004, 2002.
- [3] Jackson, M.L. Soil chemical analysis-advanced course. Published by author, University of Wisconsin, Madison, WI, USA, 1956.
- [4] Relic, D., Dordevic, D., Sakan, S., Andelkovic, I., Miletic, S. & Duricic, J., Aqua regia extracted metals in sediments from the industrial area and surroundings of Pancevo, Serbia. *J. of Hazardous Materials*, 186, pp. 1893–1901, 2011.