Remediation of As contamination in the mining area

- Lessons from the Korean experience

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Abstract

Several hundreds of abandoned metal mines in Korea are the major anthropogenic sources of As contamination to the nearby environment and similar issues have been raised in all around the world including Canada, China, Indonesia, Japan, Spain and the United Kingdom. The Chungyang area in Korea is adjacent to the abandoned Au-Ag mine, the Gubong mine, which was closed in the 1970s. Large amounts of mine wastes have been remained without proper restoration and transported into the vicinity area. This relocation of mine waste took place mainly during the summer season due to heavy rains and became the serious problem because of the sequential contamination of groundwater and crop plants.

Stabilization using proper additives is an effective soil remediation technique to reduce As mobility in soil. Numerous studies have reported that Fe-containing materials, which are amorphous Fe-oxides, goethite and hematite, were effective in As immobilization and acid mine drainage sludge (AMDS) may be potential material for As immobilization. The AMDS is the by-product from electrochemical treatment of acid mine drainage and mainly contains Fe-oxide. Batch experiments, continuous flow column experiments and field applications were carried out to assess As immobilization efficiency and feasibility. In addition, grown rice grain was analyzed by XANES to confirm the As immobilization from the determination of chemical speciation.

For the assessment of stabilization, we used to determine the As concentration in crop plants grown on the field site but it is not easily applicable because of time and cost. Therefore, we may need simple monitoring technique to measure the mobility or leachability which can be comparable with As concentration in crop plants. We selected several As extractability test using single extractions to predict the As mobility for the field soils. Amount of leached As concentration by single extraction was different among each extraction protocol with the characteristics of soil and extractant. Single extractions were statistically interpreted and these extractions leached by similar mechanism showed the high similarity by cluster analysis. As result, one representative single extraction can be suggested as the best monitoring tool for the investigation As leachability and mobility in the soil stabilization process.

Results and Discussion

The Chungyang area in Korea is located in the vicinity of the huge abandoned Au-Ag mine, the Gubong mine, which was closed in the 1970s (Kim *et al.*, 1998). Large amounts of mine wastes have been remained and the mobilization of mine waste can be manly occurred during the summer heavy rainfall season. Soil contamination from this mobilization may become an urgent issue because it can cause the contamination of groundwater and crop plants in sequence. From the previous study, the significant positive relationship was reported between As concentrations in soil and those in rice from the Chungyang area. This As contamination of rice may cause the human health problems and the remediation of contaminated soil is urgent agenda to prevent the influences on human health.

In situ treatment such as stabilization using proper additives is an effective soil remediation technique to reduce As mobility in soil. Numerous Fe-containing materials such as amorphous Fe-oxides, goethite and hematite, were known to be effective in As immobilization via sorption, binding, and precipitation (Zhang et al., 2004). Acid mine drainage sludge (AMDS) can be strong candidate material for As immobilization in field because AMDS mainly contains Fe-oxide.

The sequential extraction analysis for the remediated plots was performed. The As fraction in the AMDS- and limestone- amended plots showed an increase in the F3 fraction (Amorphous and poorly crystalline hydrous oxides of Fe & Al) but F4 (Crystalline Fe oxyhydroxide) and F5 (Residual) remained similar. These results indicate that the mobile fraction of As can be changed into immobile fraction by the remediation process (Fig. 1). The rice grain took up 0.72 mg kg^{-1} of As in the control plot in the year 2010. The plot containing AMDS showed the lower average of As concentration in the rice grain in suggesting that As immobilization occurred in the soil (Fig. 2). Arsenic speciations in the soil and rice grain are shown in Fig. 3 by XANES analyses. The results showed that As(V) was observed in the soil and rice grain in reflecting that the As in rice grain was transferred from the soil. This XANES spectrum was determined for the control plot rice grain of no remediation due to the low As concentration in rice grain. In conclusion, the AMDS may act as the effective additive for the enhancement of As immobilization in the soil.

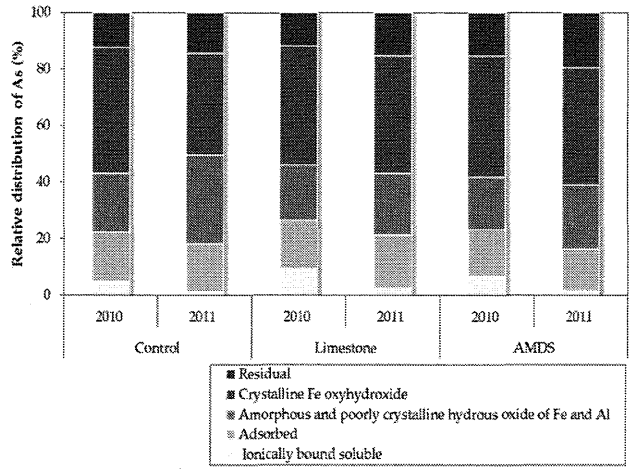

Fig. 1 Arsenic fractions in the remediated field soil plots using sequential extraction analysis (Ko *et al.*, 2015)

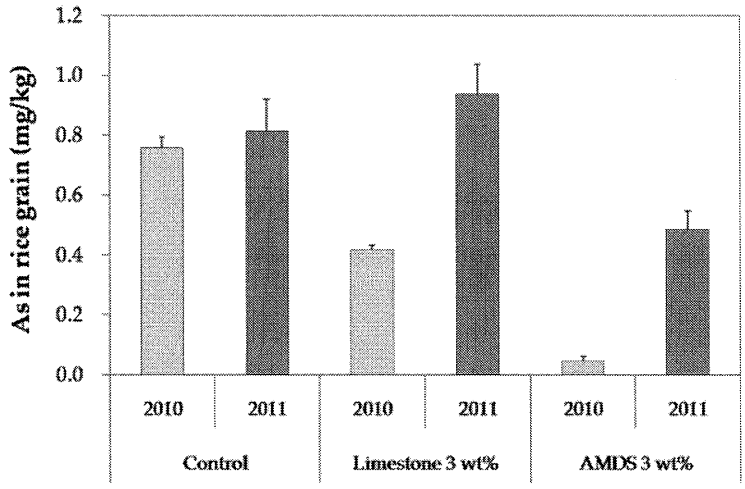

Fig. 2 Arsenic concentrations in rice grain (Ko *et al.*, 2015)

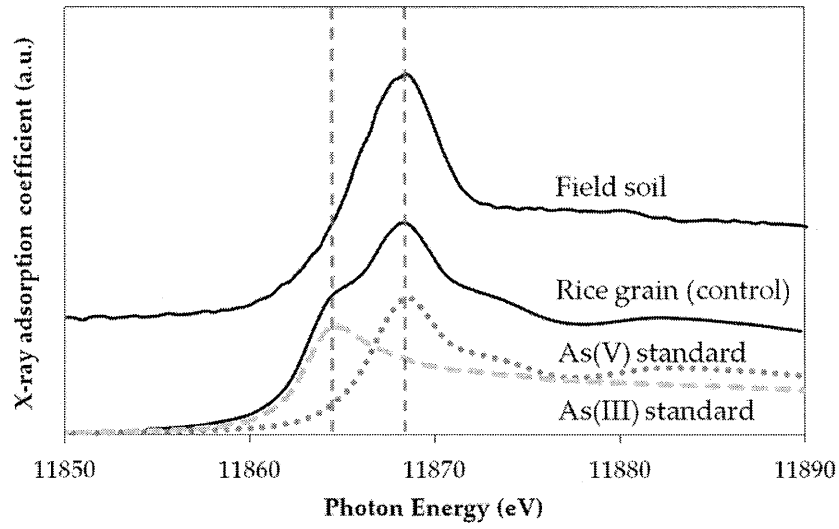

Fig. 3 As K-edge XANES spectra of As(III) standard, As(V) standard, field soil and rice grain. As(III) and As(V) peak values were 11864 eV and 11686 eV, respectively. (Ko *et al.*, 2015)

We compared several extraction methods to suggest the representative single extraction method for the monitoring of soil stabilization efficiency. The selected extraction methods using Mehlich 3, EDTA and DTPA were statistically compared using score and Mehlich 3 extraction methods using the mixture of NH_4F, EDTA, NH_4NO_3, CH_3COOH and HNO_3 was selected as the best predictor of the leachability or mobility of As in the soil remediation process.

References

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