Geochemical Journal, Vol. 46, pp. e17 to e19, 2012

EXPRESS LETTER

The 2010 Korean soil preservation act: Will stabilization techniques still be feasible?

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(*Received December 14, 2011; Accepted February 1, 2012; Online published February 27, 2012*)

Korean Ministry of Environment (MoE) has implicated regulations to determine if the levels of environmental contaminants exceed regulations levels. The Korean MoE adopted a partial extraction method which extracts the exchangeable fraction for heavy metals or metalloids because concern was targeted on the environmentally available fractions. However, in 2010, they have revised the test method to a total extraction using aqua regia which can extract the residual fraction as well as environmentally available phases. If one follows the new standard method, solidification/stabilization (S/S) could not meet the new criteria, since the total concentration of heavy metals and metalloids in soil would not be changed after S/S procedures as remediation technique.

Keywords: Korean MoE, solidification/stabilization (S/S), total extraction, aqua regia, residual phase

INTRODUCTION

Over the past decade, the Korean Ministry of Environment (MoE) has implemented various regulations to better preserve the environment and to ensure the quality of life for future generations. In 1996, the Korean MoE suggested that the Korean soil environment standard test (KST) be used to investigate the soil and determine if the levels of environmental contaminants exceed regulation levels in accordance with the Korean Soil Preservation Act. Korean soil contamination criteria include both warning and action levels (Korean MoE, 2002). In particular, the action level expresses a significant contamination status, calling for immediate control actions such as the suspension of land development with significant risks to human health and ecosystem. The warning levels are approximately 40% of the action levels and the objective is to proactively prevent more serious soil contamination than its current state (Lim *et al.*, 2009).

In 1996, Korean MoE adopted a partial extraction method for contaminants (0.1 N HCl for Cd, Cu, Pb, Cr^{6+} and 1 N HCl for As) because concern was targeted on the environmentally available fractions of contaminants and partial leaching was regarded as a method to extract the relatively weak combine fraction of the contaminants when compared with the sequential extraction analysis. In 2010, the Korean MoE has revised the test method to a total extraction using aqua regia (Korean MoE, 2009). Regulation levels have been also elevated to accommodate this revision of the extraction method (Table 1). This change in method implies that the target of contamination in soil for most heavy metals and As includes not only the environmentally available phase but also the residual phase.

Heavy metals as well as metalloids cannot be created or produced, nor can they be removed or decomposed. As there is no permanent removal method, one can use already known mechanisms such as precipitation, concentration, and adsorption to move them from one place to another more stable site (Hanh *et al.*, 2010). Among the remedial techniques, solidification and stabilization (S/S) has been considered as one of the most promising and effective treatments for heavy metals and metalloids in soil and tailings from mining areas (Choi *et al.*, 2009). In order to meet the new Korea soil standard criteria, one may have to remove all chemical species of heavy metals

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Table 1. Korean soil contamination criteria before/after revision

Metal (mg/kg)	Before revision (0.1 N/1 N HCl extraction)				After revision (aqua regia digestion)					
	Warning level		Action level		Warning level			Action level		
	A[a]	B[b]	A	B	1[c]	2[d]	3[e]	1	2	3
As	6	20	15	50	25	50	200	75	150	600
Cd	1.5	12	4	30	4	10	60	12	30	180
Cu	50	200	125	500	150	500	2,000	150	1,500	6,000
Pb	100	400	300	1,000	200	400	700	600	1,200	2,100
Cr^{6+}	4	12	10	30	5	15	40	15	45	120
Zn	—	—	—	—	300	600	2,000	900	1,800	5,000

[a]*Farmland, paddy field, orchard, ranch lot, school lot, park, temple lot et al.*
[b]*Factory lot, railway, highway, etc.*
[c]*Farmland, paddy field, orchard, ranch lot, school lot, park, temple lot et al.*
[d]*Forest land, salt farm, waterfield, etc.*
[e]*Factory lot, parking place, railway, highway, etc.*

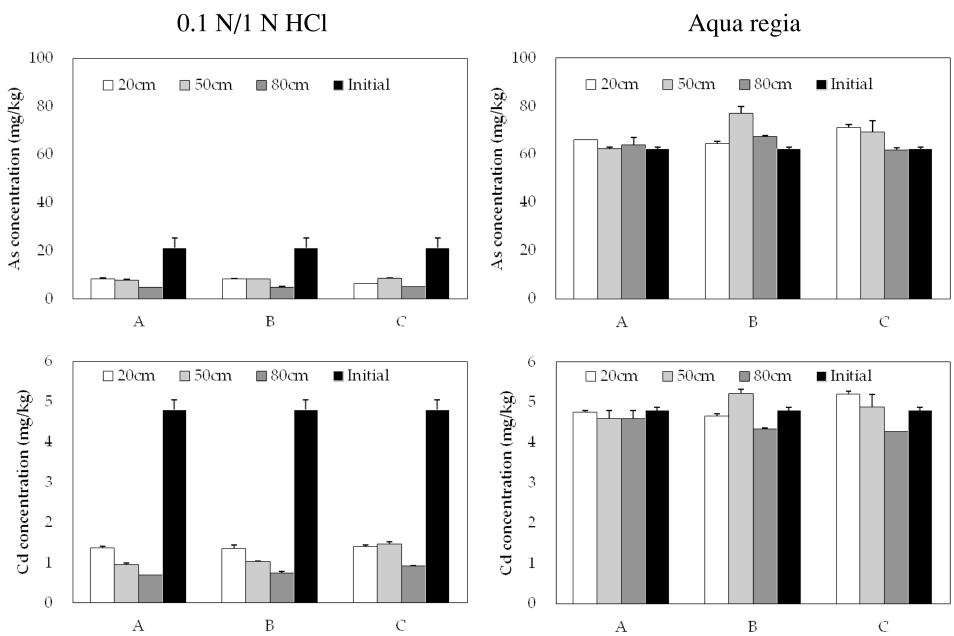

Fig. 1. Extraction of As and Cd by 0.1 N/1 N HCl and aqua regia with depth after biostabilization. (A) glucose 20 mM injection, (B) glucose 20 mM and phosphate 1000 mg/L injection, (C) 50% LB medium injection.

and metalloids including not only the exchangeable fractions but also the more stable residual forms from soil. If one encapsulates or immobilizes metals and/or metalloids in the soil sample into residual forms (though there is no possibility of further movement into ecosystem from this remediation), it may still be regarded as a contamination because it remains within the soil as a residual phase that could be released through an aqua regia extraction. The result would be no change of total concentrations in the soil after application of S/S as a remediation technique.

Discussion

A pilot-scaled field study was conducted with stabilization by indigenous bacteria to As and Cd contaminated soils at a metal mine area in Korea (Fig. 1). Soil samples were collected at depths of 20, 50, and 80 cm and extracted by 0.1 N and 1 N HCl (for Cd and As, respectively) and aqua regia (Kim *et al.*, 2003) before and after the stabilization process. The stabilization of As and Cd in the soil was evaluated by both former and

Table 2. Comparison of extraction methods for soil analysis between in Korea and other countries

	Korea (mg/kg)		USA (mg/kg)	Germany (mg/kg)	Japan (mg/kg)
	Warning*	Acting*			
As	25	75	80	40	15
Cd	4	12		2	1
Cu	150	150		50	
Pb	200	600		300	
Cr^{6+}	5	15	400		
Zn	300	900		300	
Extraction methods	Acid digestion				Partial extraction
	HNO_3, HCl		HNO_3, HCl, H_2O_2	HNO_3, HCl	HCl

**Farmland, paddy field, orchard, ranch lot, school lot, park, temple lot, etc.*

present warning levels of Korean soil criteria. In the comparison of total As and Cd concentrations by aqua regia in accordance with the new Korean Soil Standard, there were no significant differences in concentrations between before (71 mg kg^{-1} for As and 4.8 mg kg^{-1} for Cd) and after the stabilization process (68 mg kg^{-1} for As and 5.3 mg kg^{-1} for Cd). The partial extraction, however, resulted in the significant reduction of As and Cd concentrations in soils after the stabilization process. The As concentration extracted by 1 N HCl was decreased by 61.4%, 60.5%, and 75.2% at depth of 20 cm, 50 cm, and 80 cm, respectively, after stabilization. Moreover, Cd concentration, which extracted by 0.1 N HCl after stabilization, was decreased by 33.3%, 42.9%, and 61.9%, respectively.

Concluding Remark

From these results one can conclude that soil remediation techniques, such as stabilization (which is regarded as the feasible technique for highly As contaminated soils) can be useful (or useless) depending on the revision of the Soil Preservation Act in Korea. Using the new standard method, stabilization techniques for heavy metals and/or metalloids will not meet the new criteria, if the revised soil policy in Korea does not consider the geochemical characteristics of contaminants in the soil. Moreover, compared with criteria suggested by other countries such as Japan, USA and Germany, the revised criteria of Korea is significantly strict (Oh *et al*., 2001). Even though the equivalent acid digestion method is used in Germany, however, the only As standard of Germany is higher than its warning level in Korea (Table 2). Arsenic standard for residential area in Japan was 15 mg kg^{-1} from using partial extraction method. Further discussion and supplementations should be followed with particular reference to the soils contaminated with high concentrations of heavy metals and metalloids and provided to the policy makers.

Acknowledgments—This work was supported by the "Innovative Technology of Ecological Restoration" project from Gwangju Institute of Science and Technology (GIST).

References

Choi, W. H., Lee, S. R. and Park, J. Y. (2009) Cement based solidification/stabilization of arsenic-contaminated mine tailings. *Waste Manage*. **29**, 1766–1771.

Hanh, H. T., Kim, J. Y., Bang, S. and Kim, K. W. (2010) Sources and fate of As in the environment. *Geosyst. Eng*. **13**, 35–42.

Kim, J. Y., Davis, A. P. and Kim, K. W. (2003) Stabilization of available arsenic in highly contaminated mine tailings using iron. *Environ. Sci. Technol*. **37**, 189–195.

Korean Ministry of Environment (2002) *Soil Environment Standard Test, Soil Environment Preservation Act*, 221 pp.

Korean Ministry of Environment (2009) *Soil Environment Standard Test, Soil Environment Preservation Act*, 291 pp.

Lim, M. H., Han, G. C., Ahn, J. W., You, K. S. and Kim, H. S. (2009) Leachability of arsenic and heavy metals from mine tailings of abandoned metal mines. *Environ. Res. Public Health* **6**, 2865–2879.

Oh, C. W., Yu, Y. H., Lee, P. G., Park, S. W. and Lee, Y. Y. (2001) The controversial points and a remedy on evaluation of heavy metal contamination in standard method for examination of soil in Korea. *J. KoSSGE* **6**, 68–83 (in Korean with English abstract).