CHAPTER 5

CONCLUSIONS AND SUGGESTIONS FOR FUTURE WORKS

This research was conducted to investigate physical, chemical properties and leaching characteristics of the arsenic-iron sludge as a by-product of the arsenic removal by coagulation/co-precipitation with ferric chloride as well as to examine utilization potential of the sludge. Moreover, all available results of this research were put together to develop a framework for evaluating economic and environmental feasibility of each management option. Although that this research consists of six sub-parts, the following conclusions could be drawn:

5.1 The Leaching Behavior and the Factors Controlling Leachability of the Raw Arsenic-Iron Hydroxide Sludge

When arsenic-iron hydroxide sludge was subjected to both TCLP and LP-NO.6, arsenic was supposed to be both mobilized and immobilized by desorption and resorption under the influence of pH and As-to-Fe ratios of the sludge. The pH controlled not only sorption efficiency but also dissolution and reformation of hydroxide surface while As-to-Fe ratios of the sludge indicated sorption capacity. Owing to the fact that, the leaching behavior of arsenic from the sludge was controlled by pH, the leachabilities by TCLP and LP-No.6 were insignificantly different. In addition to pH and As-to Fe ratios of the sludge, the other two factors played crucial roles on controlling arsenic leachability of the sludge are weathering resistibility and resorption potential of the sludge. The most stable sludge is the sludge that has both high weathering resistibility and resorption potential. However, such sludge seems unrealistic in this study owing to the fact that although the dewatered sludge has higher resorption potential, it has lower weathering resistibility due to having smaller particle sizes and higher surface areas while the opposition is true for the dried sludge.

5.2 Potential of Arsenic-Iron Hydroxide Sludge to be Hazardous Waste

The amount of arsenic in the sludge may vary widely, depending on an initial arsenic concentration and a finished water target. Therefore, the sludge has potential to be hazardous in some cases. This research was conducted to investigate potential of sludge to be hazardous waste as a function of initial arsenic concentrations and finished water targets. It was found that the sludge produced from the removal of initial arsenic concentrations from 140 to 12,790 μg/l to comply with the drinking water standards of 10 and 50 μg/l of arsenic was unlikely to be hazardous waste. In contrast, the sludge from pretreatment of Ion Exchange brine to some TBLLs can be classified as hazardous waste. This results in the conclusion that of the two factors, a finished water target seems to play the more crucial role in determining degree of hazard of the sludge.

5.3 Effect of Arsenic-Iron Hydroxide Sludge on the Compressive Strength of the Solidified/Stabilized Matrices

The addition of arsenic-iron hydroxide sludge could physically and chemically reduce the compressive strength of the mortar. Physically, replacing cement with the sludge means reducing amount of cement undergoing hydration. Moreover, the encapsulation of the sludge in the matrices means reducing bearing areas, which unsurprisingly leads to the reduction of the compressive strength of the matrices. Chemically, under a cementitious environment in the cement matrices, arsenic bonded to the sludge might be desorbed and react with calcium ions to form the calcium arsenic compounds. These compounds are supposed to inhibit hydration by calcium complexation, surface adsorption, and/or protective/coating/osmotic bursting. Addition of lime and waste-to-binder ratio in the matrices seems to be the important factors encouraging formation of calcium-arsenic compounds.

5.4 The Leachate Characteristics of the Solidified/Stabilized Arsenic-Iron Hydroxide Sludge

The formation of $CaHAsO_3$ in the extraction fluid is believed to immobilize arsenic leached from the arsenic-iron hydroxide sludge in the basic solution of which pH is around 12. The formation potential of $CaHAsO_3$ is determined by pH because pH controls arsenic speciation. Under the saturation of calcium ions of which pH is above 12, waste-to-binder might be the most important factor controlling leachability of arsenic-iron hydroxide. The other factors such as water-to-binder ratios and lime-to-binder ratios of the matrices are unlikely to play an important role in determining the leachability of arsenic-iron hydroxide because the saturation of calcium ions and the pH of 12 exist in the leachate of all S/S mixtures. In the same way, the leachate characteristics of the sludge subjected to the TCLP is insignificantly different from those subjected to LP-NO.6 due to the fact that both desorption of arsenic and formation of $CaHAsO_3$ are pH-controlled mechanisms.

5.5 Utilization Potential of the Solidified/Stabilized Matrices and Evaluation of the Three Management Options

Although the addition of the arsenic-iron hydroxide sludge physically and chemically reduces compressive strength of the mortar. The utilization of the solidified/stabilized sludge as an interlocking concrete paving block is also possible according to TIS 827-2531 (1988). The mix portion for this purpose is water-to-binder ratio of 0.4, waste-to-binder ratio of 0.15, and lime-to-binder ratio of 0. In contrast, according to ASTM C936 (ICPI), this solidified/stabilized product cannot meet the strength requirement to be utilized as an interlocking concrete paving block. Therefore, to utilize the solidified sludge as an interlocking concrete paving block according to ASTM C936, the solidification/stabilization of the sludge in form of concrete should be further investigated.

Among the three options, utilization of dried sludge is cost-effective when a large number of populations is affected by arsenic contamination because the capital cost for the utilization is very expensive. Unless there are many populations affected, dewatered sludge disposal may be the most cost-effective option.

5.6 Suggestions for Future Works

1. A long-term leaching test should be conducted on both the untreated sludge and the solidified/stabilized sludge to ensure safe disposal and utilization.

2. The solidification/stabilization of sludge in form of concrete should be further investigated for the utilization as interlocking concrete paving block according to ASTM C936.

3. The solidification/stabilization of arsenate-iron hydroxide sludge should be investigated to examine the influence of arsenic speciation on sludge stability and reaction with cement components.