CHARACTERIZATION AND RECOURCE RECOVERY POTENTIAL OF PRECIPITATES ASSOCIATED WITH ABANDONED COAL MINE DRAINAGE[1]

by

Candace L. Kairies[2], George R. Watzlaf, Robert S. Hedin and Rosemary C. Capo

Abstract. Sludge samples from untreated and passively treated mine drainage discharges were characterized using INAA, ICP-AES, XRD and SEM. Iron content ranges from 25 to 68 dry wt%, and goethite is the dominant mineral (40 - 90 dry wt%). The majority of particles have a spiky spherical morphology (0.5 - 2.0 μm diameter). Within several passive treatment systems, iron content remains relatively constant, and concentrations of Mn, Co, Ni, and Zn increase, while As concentration decrease.

Additional Key Words: passive treatment, goethite, iron oxides, mine drainage sludge.

Introduction

Abandoned coal mine drainage can contain acidity, sulfates and metals (e.g., iron, aluminum and manganese) that pollute thousands of miles of rivers and streams. An estimated 100,000 tons of iron per year in the United States alone is added to these waterways (Hedin 1998).

Depending on the chemistry of a discharge, various treatment methods have been developed to remediate mine drainage contaminated water. Passive treatment of net alkaline drainage typically consists of a series of ditches, ponds and aerobic wetlands that aerate and detain water allowing the iron to oxidize, precipitate and settle (Watzlaf et al. 2000). Hedin et al. (1994) estimated that these types of systems remove 10 to 20 $gd^{-1}m^{-2}$ of iron.

[1]Poster paper presented at the 2001 National Meeting of the American Society for Surface Mining and Reclamation, Albuquerque, New Mexico, June 3-7, 2001. Pub. by ASSMR, 3134 Montavesta Rd., Lexington, KY 40502.

[2]Candace L. Kairies, Ph.D. Candidate, Dept. of Geology and Planetary Science, University of Pittsburgh, 321 OEH, Pittsburgh, PA 15260. George R. Watzlaf, Environmental Engineer, National Energy Technology Laboratory, U. S. Department of Energy, Pittsburgh, PA 15236.
Robert S. Hedin, Hedin Environmental, 195 Castle Shannon Blvd., Pittsburgh, PA 15228.
Rosemary C. Capo, Associate Professor, Dept. of Geology and Planetary Science, University of Pittsburgh, 321 OEH, Pittsburgh, PA 15260.

Net acidic drainage must first be neutralized, which can be achieved through the use of an anoxic limestone drain (if the water is devoid of dissolved oxygen, aluminum and ferric iron), or a reducing and alkalinity-producing system (Watzlaf et al. 2000).

Over time, these systems accumulate iron-rich solids that reduce the effective volume of the ponds, wetlands or ditches. As a result, the detention time within the system decreases, lowering its ability to treat contaminated water. Most passive systems are constructed to hold 10 to 30 years of precipitates. Regardless, the pond sludge must eventually be cleaned out to maintain treatment effectiveness, resulting in removal and disposal costs. Most sludges are comprised of 25 to 68 dry wt% iron, and represent a potential economic resource.

Iron oxides are commonly used by industry as pigments, colorants, catalysts, and as additives to feeds and fertilizers. They are either mined from ore deposits, produced synthetically, or form as a by-product during steel making (Hedin 1996). Depending on the application, the iron content of the iron oxides can vary (26 – 95%). If the iron oxides are to be used as additives to cosmetics or food, limits on As (<3 ppm), Pb (<10 ppm) and Hg (<3 ppm) must be met (Code of Federal Regulations, 2000). The price of commercial iron oxide ranges from $0.11 to over $2.75 per Kg ($100 - $2500 per ton) (Hedin 1998). The iron oxide market in the United States is about 160,000,000 kg/yr (175,000 tons/yr), some of which is imported (Hedin 1996).

Proceedings America Society of Mining and Reclamation, 2001 pp 278-279
DOI: 10.21000/JASMR01010278

https://doi.org/10.21000/JASMR01010278

The objective of this study is to characterize precipitates associated with untreated and passively treated coal mine drainage in order to determine how they compare to iron oxides used in industry based on iron and trace metal content, particle size and morphology. If the iron oxides are of sufficient purity, they could be recovered and sold to offset treatment costs.

Methods

Over fifty sludges and associated water samples originating from three different coal seams were collected from passively treated and untreated discharges located in Pennsylvania and Maryland. Major and trace elements were determined using an inductively coupled argon plasma atomic emission spectrometer (ICP-AES) following acid digestion and by instrumental neutron activation analysis (INAA). Mineralogy and morphology were determined using a Phillips X'PERT diffractometer and a scanning electron microscope, respectively.

Results and Discussion

Table 1 summarizes the preliminary results of the elemental analysis of the precipitates. The majority of the particles are spherical and hedgehog-like, and range from 0.5 - 2.0 μm in diameter. In several passive treatment systems, the iron content in the sludge remains relatively constant as water flows through the system. Associated trace element concentrations of Mn, Co, Ni, and Zn appear to increase, and As decreases. Goethite, the dominant mineral phase in the samples, ranges from 40% to 98%, with the majority of precipitates containing >80%. Minor minerals (<2%) present in the sludge samples include gypsum, ferrihydrite, clays and manganese oxides, with some samples containing <5% quartz. In one passive system, crystallinity decreases from the beginning to the end of treatment.

Table 1. Summary of mine drainage sludge composition.

Element	Content (dry)
Fe	25 - 61 wt%
Mn	0.01 - 3.59 wt%
S, Al	<2 wt%
As	Up to 3000 ppm
Co	Up to 1060 ppm
Ni	Up to 700 ppm
Pb	13 - 41 ppm
Zn	Up to 760 ppm
Cd, Cu	<5 ppm

The Lowber site (net alkaline discharge, Irwin Syncline, southwestern PA) is currently undergoing a resource recovery effort under the direction of R. S. Hedin of Hedin Environmental, Pittsburgh, PA. Preliminary results of sludge characterization from this site suggest it may be suitable for use as a resource (highlights of the recovery effort will be presented).

Conclusions

Our initial findings indicate that some sludges are suitable for industrial and manufacturing uses. Certain precipitates contain anomalously high concentrations of trace elements, which may prevent use as an additive to cosmetics or food (e.g., As). These associations could be related to the depositional environment of the coal seam from which the discharge originates. Subsurface cation exchange and sorption processes can influence the trace elements that accumulate in the sludge. Sequential extraction procedures will be carried out to help determine trace element associations and to assess how tightly trace elements are bound to the iron hydroxide precipitates.

Literature Cited

Code of Federal Regulations Title 21: Food and Drugs, §73.2250. 2000 (revised).

Hedin, R. S. 1998. Potential recovery of iron oxides from coal mine drainage. In: 19th Annual West Virginia Surface Mine Drainage Task Force Symposium (Morgantown, WV, April 7-8).

Hedin, R. S. 1996. Recovery of iron oxides from polluted coal mine drainage. Technical proposal submitted with a patent application filed with the U. S. Patent and Trademark Office on April 15.

Hedin, R. S., R. W. Nairn and R. L. P. Kleinmann. 1994. Passive treatment of coal mine drainage. U.S. Bureau of Mines IC 9389, 32p.

Watzlaf, G. R., K. T. Schroeder and C. Kairies. 2000. Long-term performance of alkalinity-producing systems for the treatment of mine drainage. p. 262-274. In: Proceedings of the 19th National Meeting of the American Society for Surface Mining and Reclamation (Tampa, FL, June 11-15).

https://doi.org/10.21000/JASMR00010262