1999 International Ash Utilization Symposium, Center for Applied Energy Research, University of Kentucky, Paper #35.

http://www.flyash.info

Acid Mine Drainage Abatement Using Flue Gas Desulfurization Byproduct: Water Quality Aspects

Mikko Lamminen[1], Jim Wood[2], Harold W. Walker[1], Yu-Ping Chin[2],

[1]Department of Civil and Environmental Engineering and Geodetic Science, The Ohio State University, 470 Hitchcock Hall, Columbus, OH 43210; [2]Department of Geological Sciences, The Ohio State University, 275 Mendenhall Lab, Columbus, OH 43210

KEY WORDS: Acid Mine Drainage, Flue Gas Desulfurization, Reclamation

ABSTRACT

In this study, the potential of using flue gas desulfurization (FGD) byproduct to remediate environmental problems posed by acid mine drainage was investigated. The primary goals of this project were to utilize an FGD grout to (1) seal mine openings and decrease the flow of AMD leaving mine voids, and (2) to improve the water quality of AMD entering receiving waters. To investigate the potential for using FGD in this dual-purpose role, American Electric Power (AEP) in conjunction with Ohio State University injected and sealed the Roberts-Dawson mine site near Coshocton, Ohio with 23,000 cubic yards of FGD grout. Since grouting was completed, a decrease in flow from some mine openings has been observed. However, re- surfacing of AMD has occurred immediately downgradient of sealed mine openings. No increase in pH or decrease in metals has been observed which indicates the quality of AMD has not improved. FGD may be a viable option for reducing the flow and the net flux of acid at abandoned mine sites. However, remediation most likely requires effective coverage of mine surfaces, in addition to the sealing of mine openings, in order to prevent short-circuiting of AMD around intact seals.

INTRODUCTION

Acid Mine Drainage (AMD) is a serious water quality problem in states where coal mining is prevalent. AMD forms when oxygen in abandoned mine voids reacts with iron pyrite and water producing acid and sulfates. Streams receiving AMD have low pH values and high metal concentrations. The Ohio Environmental Protection Agency (OEPA) estimates that over 3000 miles of Ohio streams have degraded water quality as a result of AMD.

To mitigate the effects of AMD, a number of recent projects have examined the use of coal combustion byproducts (CCB) to seal abandoned mines and treat AMD [1, 2, 3]. Beneficial re-use of CCBs reduces the volume of material entering landfills and also conserves existing natural resources. Previous studies have demonstrated the effective re-use of CCBs in agricultural applications [4, 5, 6], for remediation of mine spoil [7, 8], and as a substitute for clay in low permeability liners [9, 10].

In this project, flue gas desulfurization (FGD) material was used in an attempt to reduce the amount of AMD leaving the Roberts-Dawson mine. The Roberts-Dawson mine is located on the border of Coshocton and Muskingham counties in southeastern Ohio. Between September 30, 1997 and January 17, 1998, over 23,000 yd^3 of FGD grout were injected into the mapped portion of the mine. The injection program utilized an FGD grout to seal the mine openings and coat the mine surfaces. The goal of the injection program was reduce AMD by creating a physical barrier to flow and by neutralizing acid in the mine voids. In addition, it was hypothesized that the impermeable seal would raise water levels in the mine, and thus reduce the oxidation of pyrite and the generation of new AMD.

In this paper, surface water quality at the Roberts-Dawson mine is summarized for a 2 ½ year period (9 months pre-grout and 1 year, 9 months post grout). In particular, data are presented regarding the quantity and quality of drainage leaving the main seeps at the mine site. These results elucidate some of the factors affecting the successful remediation of abandoned coal mine areas using FGD material.

WATER QUALITY MONITORING

Extensive surface and groundwater water quality monitoring was conducted at the Roberts-Dawson site, both before and after grouting operations. Important surface water sampling locations are shown in Figure 1. This paper will focus on the quantity and quality of AMD exiting the four main seeps (shown within the box in Figure 1). Groundwater sampling (sites not shown) was carried out upgradient of the mine, within the mine voids, as well as downgradient from the mine area. A complete list of the water quality parameters examined in this study is shown in Table 1.

Before grouting, AMD exited the four main seeps into a small creek and then entered a collection pond. Generally, the small creek was unaffected by AMD upstream of the four main seeps. Seeps 2, 3, and 4 drain the mapped portion of the mine while seep 1 discharges water from an unmapped mine area. Discharge out of seep 2 was larger than for seeps 1, 3 and 4, and therefore, it is referred to as the “main seep”. Surface water in the beaver pond on the west side of the mine was also unaffected by AMD prior to grouting. After leaving the collection pond, AMD enters Wills Creek, a local reservoir.

RESULTS

Prior to grouting operations, background water quality of surface water and groundwater was collected at the Roberts-Dawson site for approximately 9 months (12/96 to 8/97). Water exiting the main seeps exhibited the characteristic signature of acid mine drainage with pH values around 3-4, sulfate concentrations generally greater than 100 mg/L, and iron levels around 25 mg/L. Groundwater monitoring wells within the mine voids showed similar ranges of pH, iron and sulfate prior to grouting. Upstream from the seeps, water quality reflects the local soil characteristics and hydrology with pH values of approximately 6.5 and low levels of sulfate, iron and other metals.

Table 1. Water quality parameters measured at the Roberts-Dawson Site

Parameters	pH, alkalinity, acidity, conductivity, sulfate, Al, As, B, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Ni, Pb, P, S, Si, Sr, Zn

The seeps from the Roberts-Dawson mine contribute a significant fraction of the total flow in the adjacent creek, and therefore, significantly influence the water quality of this small creek. Just downstream of the seeps, the pH of the creek drops down to less than 4 with high levels of iron and sulfate. AMD makes only a minor contribution to Wills Creek Reservoir, and therefore, no impacts related to AMD were detectable in the reservoir.

Grouting of mine voids and placement of FGD grout were carried out between September, 1997 and January 1998. As mentioned above, one objective of this project was to examine the influence of grouting on the discharge of AMD from seeps 1-4. In Figure 2, the flow of AMD out of the main seep (site 2) is shown as a function of sampling date, both before and after grouting operations. As can be seen, the flow varies from a low of approximately 7.6 cfs in December of 1997 to a high of 303 cfs in January 1999. High flow events were also observed in January of 1998 and April of 1999 and depended on seasonal conditions, with high flows occurring during times of intense rainfall or during snow melt. The grout seal remained intact during the course of sampling. However, re-routing of AMD occurred after January 1997, which resulted in AMD surfacing from the ground approximately 50 meters from the mine opening at site 2. As a result, the amount of discharge during low flow conditions was similar both before and after grouting.

In Figure 3, the flux of iron from the main seep (site 2) is shown as a function of sampling date, before and after grouting. The data demonstrate that the flux of iron is seasonal with the largest fluxes occurring during the storm events or snowmelts of January 98, January 99, and April 99. Similar trends for other typical AMD constituents such as protons and sulfate were also observed (data not shown). No samples were collected during major flow events prior to grouting. Therefore, it is difficult to compare what impact grouting may have had on the flux of these elements during storms. It should be noted, however, that the concentrations of most hazardous constituents (e.g., Cr and As) continue to be below drinking water standards.

During "low flow" conditions, the flux of iron appears to have increased over pre-grout levels. Between the pre-grout period of January 97 and August 97, the average flux of iron was 1.26 ± 1.0 g/min. After grouting, the average flux of iron increased to 18.8 ± 9.3 g/min between the period of April 98 to December 98. Based on the data in Figure 2, the flow from site 2 was fairly constant during these two low flow periods. For example, between January 97 and August 97 the average flow was 71.2 ± 18.1 cfs. After grouting, the average flow between April 98 and December 98 was 79.2 ± 26.7. This represents a 10% increase in flow over pre-grout conditions. The flux of iron, however, increased by more than 10-fold. Similar increases in protons and sulfates were also observed. Thus, grouting operations appear to have increased the flux of AMD constituents exiting the main seep at the Roberts-Dawson site.

In addition to examining the flux of AMD constituents, analyses were carried out to investigate elements typical found in FGD, such as calcium. In Figure 4, the flux of calcium is shown as a function of sampling date at the main seep of the Roberts-Dawson mine. As was observed for

AMD constituents, the flux of these elements was very seasonal with the greatest fluxes occurring during storm events. During low flow conditions after grouting (April 98 to December 98), the flux of calcium was significantly higher as compared to months prior to grouting with similar flow rates (January 97 to August 97). It should be noted, however, that calcium is also naturally present. Therefore, it is difficult to separate the relative contributions of calcium from the grout and natural calcium sources.

CONCLUSIONS

The flux of AMD and grout constituents at the Roberts-Dawson mine is seasonally dependent with the largest fluxes occurring during storm events and snowmelt. The grouting operations have not reduced the amount or improved the quality of AMD entering local receiving waters at the Roberts-Dawson site. The concentrations of all hazardous constituents, however, are currently below drinking water standards. This project demonstrates that mine openings may be sealed using FGD grout. However, complete coverage of mine surfaces is likely required in order to prevent short-circuiting of drainage under or around mine seals and improve water quality.

REFERENCES

1 Gray, D. D., Head, W. J., Siriwardane, H. J., Sack, W. A., Burnett, M. Ziemkiewicz, P. F., Black, D. C, “Disposal of fluidized-bed combustion ash in an underground mine to control acid mine drainage”, *Proc. International Ash Symposium*, Lexington Kentucky, 1995.

2 Lyons, C., Petzrich, P., “The Maryland Haulback Project-the use of coal combustion by-products to abate acid mine drainage in a Maryland underground mine: a demonstration project”, *Proc. International Ash Symposium*, Lexington Kentucky, 1995.

3 Meiers, R. J, Golden, D., Gray, R., Yu, W.-C., “Fluid placement of fixated scrubber sludge to reduce surface subsidence and to abate acid mine drainage in abandoned underground coal mines”, *Proc. International Ash Symposium*, Lexington Kentucky, 1995.

4 Behel, D., “Utilization of coal combustion by-products in agriculture and land reclamation in the Tennessee Valley”, *Proc. International Ash Symposium*, Lexington Kentucky, 1995.

5 Stout, W. L., Daily, M. R., Nickeson, T. L., Svendsen, R. L., Thompson, G. P., “Agricultural uses of alkaline fluidized bed combustion ash: case studies”, *Proc. International Ash Symposium*, Lexington Kentucky, 1995.

6 Norton, L. D., “Utilization of desulfurization by-products as electrolyte sources to reduce soil surface sealing”, *Proc. International Ash Symposium*, Lexington Kentucky, 1995.

7 Stehouwer, R. C., Sutton, P., Fowler, R. K., and Dick, W. A., “Minespoil amendment with dry flue gas desulfurization by-products: Element solubility and mobility”, *J. Env. Quality*, 24, 165-174, 1995.

8 Stehouwer, R. C., Sutton, P., and Dick, W. A., “Minespoil amendment with dry flue gas desulfurization by-products: Plant growth”, *J. Env. Quality*, 24, 861-869, 1995.

9 Butalia, T. S., and Wolfe, W. E., “Re-use of clean coal technology by-products in the construction of impervious liners”, *Proc. International Ash Symposium*, Lexington, Kentucky, 1997.

10 Butalia, T.S., and Wolfe, W. E., “Evaluation of permeability characteristics of FGD materials”, *Fuel*, 78, 149-152, 1999.

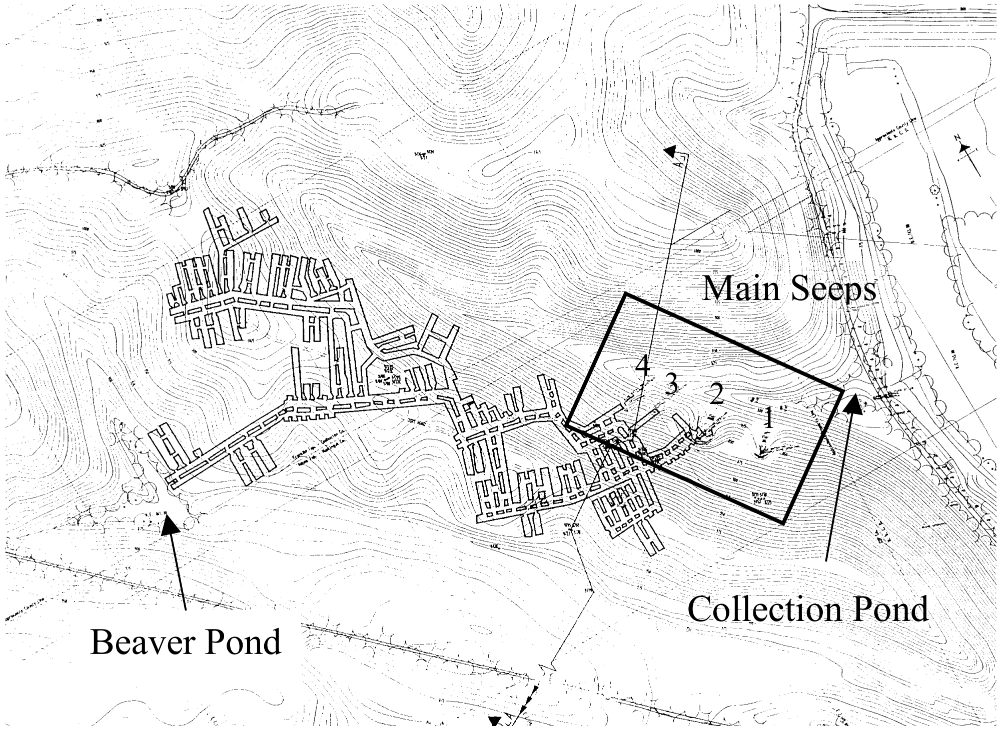

Figure 1. The Roberts-Dawson mine reclamation site. The boxed area contains the main seeps (numbered 1-4) and represents an area of concentrated surface water sampling.

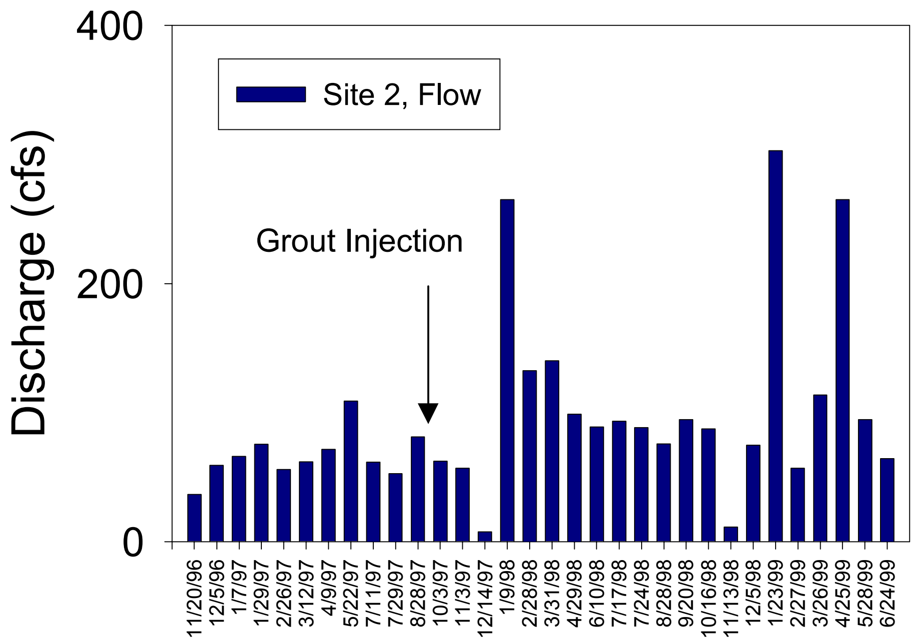

Figure 2. Flow rates from the main seep (Site 2) at the Roberts-Dawson mine before and after grouting. The arrow indicates the approximate date in which grouting of FGD began.

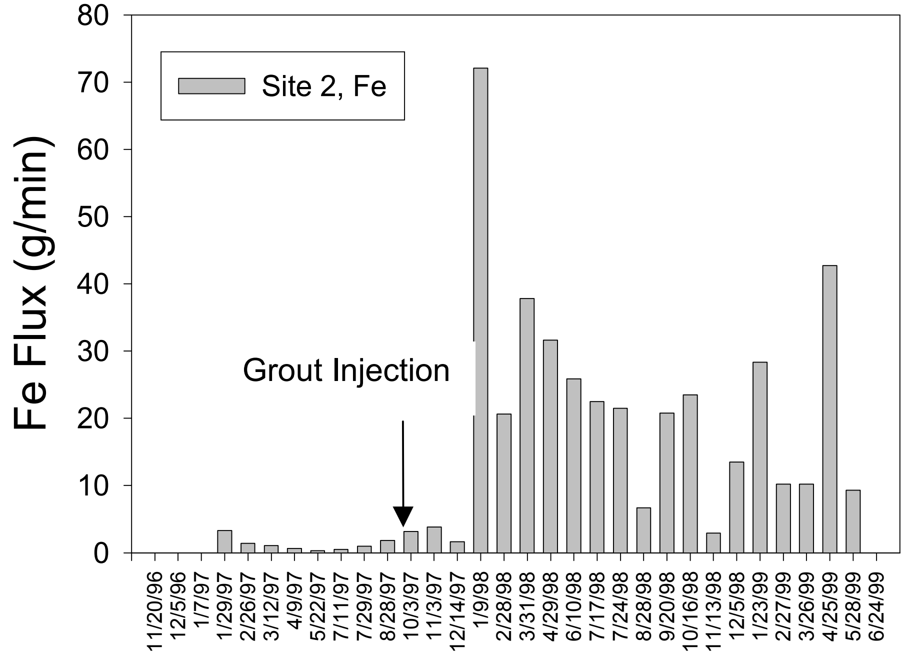

Figure 3. Flux of iron from the main seep (site 2) at the Roberts-Dawson Mine before and after grouting. The arrow indicates the approximate date in which grouting of FGD began.

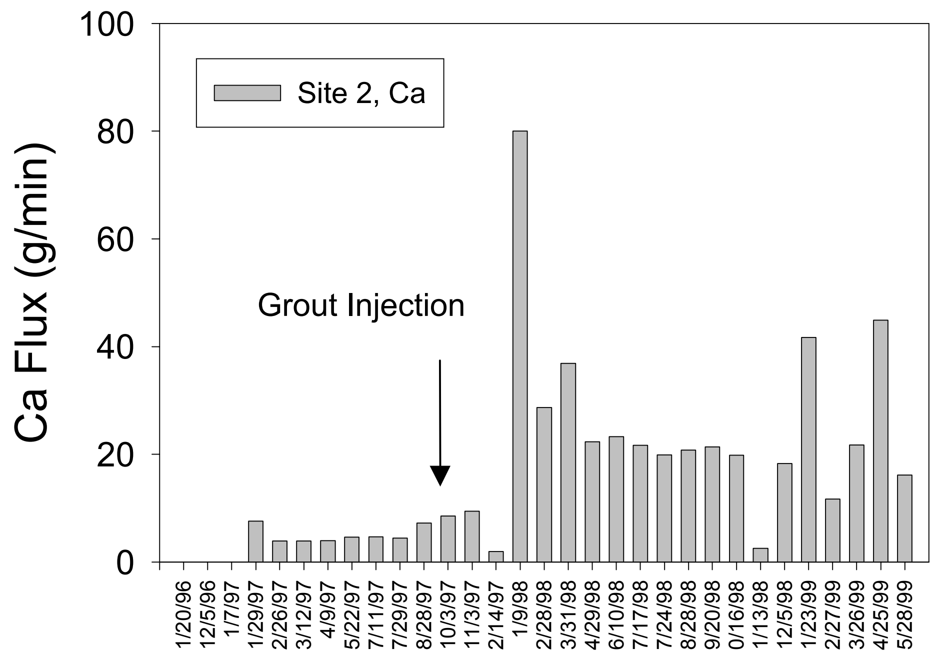

Figure 4. Flux of calcium from the main seep (site 2) at the Roberts-Dawson mine before and after grouting. The arrow indicates the approximate date in which grouting of FGD began.