Using Stabilized Flue Gas Desulfurization Material to Reclaim Highwalls and Mitigate Acid Mine Drainage

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Stingy Run Fly Ash Impoundment
Highwalls and Pits Around Stingy Run Impoundment
Reclamation using Fixated FGD Material

- Utilizing large volume of fixated flue gas desulfurization materials
  - FGD by-product (calcium sulfite) stabilized with fly ash and lime

- Goals
  - Encapsulate acid mine drainage (AMD) producing materials
  - Neutralize AMD
  - Re-contour highwalls

- Approaches
  - Year I: field investigation; laboratory test; bench-scale study; numerical analysis of design approaches; background water monitoring
  - Year II and III: permitting, water quality monitoring, construction of the demonstration project
Mineral Composition of Gavin Stabilized FGD Material

- Hannebachite ($\text{CaSO}_3 \cdot 0.5\text{H}_2\text{O}$)
- Portlandite ($\text{Ca(OH)}_3$)
- Hematite ($\text{Fe}_2\text{O}_3$)
- Magnetite ($\text{Fe}_3\text{O}_4$)
- Quartz ($\text{SiO}_2$)
- Mullite ($3\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$)
- Maghemite ($\text{Fe}_2\text{O}_3$)
- Ettringite ($\text{Ca}_6\text{Al}_2(\text{SO}_4)_3(\text{OH})_12 \cdot 26\text{H}_2\text{O}$)
Chemical Reactions between AMD and Stabilized FGD Material

- Neutralization of AMD
  \[
  \text{Ca(OH)}_2 + 2H^+ \rightarrow \text{Ca}^{2+} + 2H_2O
  \]

- Portlandite
  \[
  C_6\text{Al}_2(\text{SO}_4)_3(\text{OH})_12 \cdot 26\text{H}_2\text{O} + 12H^+ \rightarrow
  2\text{Al}^{3+} + 6\text{Ca}^{2+} + 3\text{SO}_4^{2-} + 38\text{H}_2\text{O}
  \]

- Ettringite
  \[
  \text{Fe}_2\text{O}_3 + 6H^+ \rightarrow 2\text{Fe}^{3+} + 6H_2O
  \]
  \[
  \text{Fe}_3\text{O}_4 + 8H^+ \rightarrow 2\text{Fe}^{3+} + \text{Fe}^{2+} + 8H_2O
  \]

- Iron oxides

- Iron hydroxides, Chrysotile (Mg$_3$Si$_2$O$_5$), diaspor (AlHO$_2$), bixbyite (Mn$_2$O$_3$), barite (BaSO$_4$)

Formation of potential secondary minerals
Neutralization Capacity

![Graph showing neutralization capacity with various data points and lines indicating different lime concentrations and geochemical models.]
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Full-scale Demonstration

- Approximate Highwall Location
- Approximate Measurement of Distance

Start Point

1000 ft
2000 ft
3000 ft
4000 ft

Approximation Highwall Location

Drainage-way for AMD Discharge during Excavation

Proposed Road Entrance from Plant

Proposed Pomeroy Monitoring Well Sites

Proposed Deep Monitoring Well Site
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- Approaches
  - Laboratory test: batch and column leaching studies, development of geochemical kinetic model
  - Bench-scale study: effectiveness of different reclamation design, numerical analysis of design approaches.
  - Field: water monitoring and full-scale demonstration
Water Quality Monitoring
Groundwater Monitoring
Surface Water Monitoring
**Bench Scale Testing**

**Objective:** Calibrate geotechnical and geochemical models to be used for full-scale demonstration project design

- Assessment of AMD infiltration in absence and presence of coal drain
Bench Scale Testing

12'

4'

1

4'

~2.5 tons
### Bench Scale Model Configurations Tested

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Test 1</strong></td>
<td>FGD dumped Water, No Geotextile - Transducers at bottom</td>
</tr>
<tr>
<td></td>
<td>Calibrated model for effective permeability ratio (steady state modelling)</td>
</tr>
<tr>
<td><strong>Test 2</strong></td>
<td>FGD dumped Water, Geotextile (1ft long, 1ft height from bottom) - Transducers above and below geotextile</td>
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<tr>
<td></td>
<td>Flow rates increased significantly</td>
</tr>
<tr>
<td><strong>Test 3</strong></td>
<td>FGD lightly compacted AMD, No Geotextile - Transducers at bottom</td>
</tr>
<tr>
<td></td>
<td>Calibrated model for effective permeability (transient modelling) for lightly compacted FGD</td>
</tr>
<tr>
<td><strong>Test 4</strong></td>
<td>FGD lightly compacted AMD, Geotextile (1ft long, 0.5ft height from bottom) - Transducers at bottom</td>
</tr>
<tr>
<td></td>
<td>The presence of Geotextile does not decrease the flow rate</td>
</tr>
<tr>
<td><strong>Test 5</strong></td>
<td>FGD well compacted AMD, No Geotextile - Transducers at bottom</td>
</tr>
<tr>
<td></td>
<td>Short Term- Calibrated model for effective permeability (transient modelling) for well compacted FGD</td>
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<tr>
<td></td>
<td>Long Term (In progress)-Change of AMD property with longer contact time</td>
</tr>
</tbody>
</table>
Geotechnical Modeling

- Seep/w is used to predict flow of water through FGD with and without geotextile

- Steady-State Analysis
  - Calibrated model for effective permeability ratio using Steady-State Analysis (Test 1)
Geotechnical Modeling

- Transient Analysis
  - Effective horizontal permeability ($8 \times 10^{-3}$ cm/sec) with lightly compacted FGD (Test 3)
  - Effective horizontal permeability ($8 \times 10^{-4}$ cm/sec) with well compacted FGD (Test 5 short term)
    - Significantly increased the time taken for AMD to reach steady-state
Change of AMD Hydrochemical Property

- Bench Scale-Tests 4 and 5

- Using AMD collected from the site
- 24” head at the inlet
- Samples are collected from LL1, LL2, LL3, and/or outlet
Change of AMD Hydrochemical Property

![Graph showing pH vs. L/S Ratio for different locations such as Bench 4 LL1, Bench 4 LL2, Bench 4 LL3, Bench 4 Outlet, Bench 5 LL1, Bench 5 LL3, Bench 5 Outlet, and AMD Feed. The graph indicates changes in pH across different L/S Ratio values.]
Laboratory Column Testing

- Simulate AMD neutralization process under similar percolation condition as reclamation

- Two columns with different L/S flow rates
  - Column I: ~1.0 L/S per day
  - Column II: ~2.0 L/S per day

- Monitoring change of AMD water quality with extended L/S ratio

- Temporal trend can be described by coupling solute transport and geochemical models.
Change of AMD pH after Contacting Fixated FGD Material in Flow Through Column Test as a Function of L/S Ratio

![Graph showing the change of AMD pH as a function of L/S Ratio. The graph includes data for Column I and Column II, with separate lines for the pH at the inlet of each column. The x-axis represents the L/S Ratio, and the y-axis represents the pH and pH at the inlet. The graph shows a decrease in pH with increasing L/S Ratio, with Column I having a lower pH than Column II and both having a lower pH than the inlet.]
Constituents with Elevated Levels

The graph shows the normalized concentration (C_i/C_AMD) for various constituents across different columns and outlets. The x-axis represents the constituent type (K, B, Mo, Sr, Sulfate, Ca, Ba, V, pH), while the y-axis represents the normalized concentration on a logarithmic scale.

- **Column I** is indicated by red bars.
- **Column II** is indicated by grey bars.
- **Bench Scale Outlet** is indicated by white bars.

The box plots illustrate the distribution of concentrations for each constituent, with the box showing the interquartile range and the whiskers indicating the range excluding outliers.

- **K** and **B** show significant elevations, especially in Column I.
- **Mo** and **Sr** demonstrate moderate increases.
- **Sulfate**, **Ca**, and **Ba** show relatively stable concentrations.
- **V** and **pH** exhibit minimal variability.

This chart helps to identify constituents with elevated levels, aiding in the understanding of water quality and potential sources of contamination.
Elements with Decreased Concentration
Elements Showing First Flush Phenomenon

![Graph showing normalized concentration of various constituents (Na, Cl, Hg, Sb, Tl, Se, As, Cu, Be, Pb) across different columns (Column I, Column II, Bench Scale Outlet). The graph illustrates the first flush phenomenon for these elements, with normalized concentrations ranging from 0.01 to 1000.](image-url)
Summary

- Stabilized FGD material can be effective in neutralizing AMD
  - One pound of Gavin fixated FGD material is able to neutralize approximately 20 gallons of AMD (~160 L/S)

- Geotechnical Modeling
  - V/H permeability ratio
  - Effective horizontal permeability \((8 \times 10^{-4} \text{ cm/sec})\) with well compacted FGD

- Concentrations of COI
  - As, B, Pb, Hg, Mo, Se, and Tl exceeded MCL/DWEL during the early stage
  - Sb was constantly higher than MCL
  - All of the concentrations of COIs are lower than either Ohio Maximum Acceptable Leaching Concentration and/or EPA’s Toxicity level
Future Work

- Laboratory column test
  - Examine the environmental response beyond the neutralization capacity of the fixated FGD material
  - Coupling solute transport and geochemical kinetic models
    - Using data from column tests
    - Verified with bench-scale testing
    - Used to estimate the concentrations of COI for full-scale demonstration

- Bench-scale reclamation module
  - Model site specific demo project cross sections

- Full-scale demonstration
  - Permit application
  - Reclamation
  - Water quality monitoring/data analysis
Coal Combustion Products Program

Ohio State’s Coal Combustion Products Program focuses on sustainable, high-volume beneficial uses of coal combustion products (CCPs), primarily from sulfur dioxide scrubbing processes, in construction, reclamation, infrastructure rehabilitation, manufacturing and agricultural applications. This program advances the beneficial uses of CCPs from sulfur dioxide scrubbing processes as well as more traditional byproducts, including fly ash, bottom ash, boiler slag and fluidized-bed combustor ash. Re-use of CCPs provides a low-cost raw construction material; extends the life of landfills, and lessens the need for new ones; and helps keep energy production costs in check.
Funded by the Ohio Coal Development Office, Ohio State University, Ohio coal-fired utilities, ash marketers, private businesses and trade and farming organizations, the Coal Combustion Products Program improves and discovers technically sound, environmentally friendly and commercially competitive uses of CCPs in many interdisciplinary sustainable applications.

The program aids the CCP Industry through research, education, technology transfer and outreach in its efforts to:

- expand uses in proven areas, such as highway and agricultural applications;
- remove or reduce regulatory and perceptual barriers to use;
- develop new or under-used large-volume market applications, such as mine land reclamation; and
- place greater emphasis on sulfate and sulfite flue gas desulfurization byproducts utilization.

More than 500 animal feeding pads in more than 12 Ohio counties are made from coal combustion products, including feeding pads at The Wilds in Muskingum County.

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Deposit of iron oxide
Possible white barite deposit
Possible deposit of black bixbyite (MnO2)
Deposit of iron oxide
Comparison of Column and Bench Scale