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

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http://www.flyash.info/
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 Fixated FGD Material

- Hannebachite (CaSO₃ 0.5 H₂O)
- Portlandite (Ca(OH)₃)
- Hematite (Fe₂O₃)
- Magnetite (Fe₃O₄)
- Quartz (SiO₂)
- Mullite (3Al₂O₃ 2SiO₂)
- Maghemite (Fe₂O₃)
- Ettringite (Ca₆Al₂(SO₄)₃(OH)₁₂·26H₂O)
Chemical Reactions between AMD and Fixated FGD Material

- **Neutralization of AMD**

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

- **Ettringite**

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

- **Iron oxides**

  \[ \begin{align*} 
  \text{Fe}_2\text{O}_3 + 6H^+ & \rightarrow 2\text{Fe}^{3+} + 6H_2\text{O} \\
  \text{Fe}_3\text{O}_4 + 8H^+ & \rightarrow 2\text{Fe}^{3+} + \text{Fe}^{2+} + 8H_2\text{O} 
  \end{align*} \]

- **Carbonates**

- **Formation of potential secondary minerals**

  - Iron hydroxides, chrysotile (Mg₃Si₂O₅), diaspore (Al₃O₂), bixbyite (Mn₂O₃), barite (BaSO₄)
Neutralization Capacity

The graph illustrates the pH changes in Gallon AMD/Pound Fixated FGD for different treatments:

- **3.7% Lime** represented by red triangles.
- **4.7% Lime** represented by gray circles.
- **geochemical model** represented by blue squares.

The graph shows the neutralization capacity, with the x-axis indicating Gallon AMD/Pound Fixated FGD and the y-axis representing pH. The AMD 3.18 level is marked on both axes, indicating the pH level at which AMD 3.18 is reached.
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Full-scale Demonstration

Approximate Highwall Location
Start Point
1000 ft
Approximate Measurement of Distance
Drainage-way for AMD Discharge during Excavation
Proposed Road Entrance from Plant
Proposed Pomeroy Monitoring Well Sites
Proposed Deep Monitoring Well Site

Scale:

1000 ft

Approximate Measurement of Distance
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- Approaches
  - Field: Background water monitoring, permit application
  - 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.
Background Water Quality Monitoring
Establishing

Background Groundwater Quality
Establishing Background Surface Water Quality
Background Water Quality

Component 2 (21 %)
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

1
4
~2.5 tons
4'
12'
4'
## Bench Scale Model Configurations Tested

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

- Seep/w was 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 with lightly compacted FGD (Test 3)
  - Effective horizontal permeability with well compacted FGD (Test 5 short term)
    - Significantly increased the time taken for AMD to reach steady-state
Change of AMD Chemical Property

Bench Scale-Test 5 Long Term

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

![Graph showing changes in pH and L/S ratio for different locations: 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 illustrates the pH values at different L/S ratios.]
Laboratory Column Testing

- Simulating AMD neutralization process under similar percolation process 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
Comparison of Column and Bench Scale

L/S Ratio

Ca, mg/L

Lab Column I
Lab Column II
Bench 5 LL1
Bench 5 LL3
Bench 5 Outlet
Constituents with Elevated Levels

[Graph showing normalized concentration (C/C_AMD) for various constituents like K, B, Mo, Sr, Sulfate, Ca, Ba, V, and pH across different columns and outlets.]
Elements with Decreased Concentration

Normalized Concentration ($C_i/C_{AMD}$)

Constituent: Cr, Cd, Si, Co, Zn, Ni, Al, Mn, Fe

Column II

Bench Scale Outlet

Constituent
Elements Showing First Flush Phenomenon
Summary

- Fixated 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 with lightly and well compacted FGD

- Concentrations of COIs
  - 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
  - Geochemical kinetic model
    - Established using data from batch and column tests
    - Verified with bench-scale testing
    - Used to estimate the concentrations of COI for full-scale

- **Bench-scale reclamation module**
  - Model site specific demo project X-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.