Leaching of Dry Flue Gas Desulfurization Materials from Different Flue Gas Sources in China

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Application of Dry Flue Gas Desulfurization (DFGD) Process in China

- Coal Combustion Electricity Generation
- Iron and Steel Sintering
- Circulating-Fluidizing-Bed (CFB) Boiler
- Others
Potential Applications of DFGD Materials in China

- Light-weight Concrete
- Highway Embankment
- Construction Fill
- Coal mine Reclamation
- Fertilizer
- Soil Amendments
- Others
Leaching under Pre-selected Scenarios

- Scenario One
  - Utilization as a fill material for mine reclamation at varying pH

- Scenario Two
  - Release of constituents to infiltration when using as a fill material or disposal in a monofill

- Scenario Three
  - Water flows around a DFGD material with a lower hydraulic conductivity comparing to its surroundings (e.g., sands or geotextile materials)
DFGD Materials

- Liaoyang, LYS1
  - Coal-fired power plant
- Meshane, MSS2
  - Iron and Steel sintering plant
- CFB+CFB-FGD, S3
  - Circulating fluidized-bed boiler with DFGD polishing unit
## DFGGD Materials

<table>
<thead>
<tr>
<th></th>
<th>Liaoyang (LY S1)</th>
<th>Meishane (MS S2)</th>
<th>CFB+CFB-FGD (S3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture content</td>
<td>%</td>
<td>1.27</td>
<td>3.54</td>
</tr>
<tr>
<td>Mercury Hg µg/kg</td>
<td>0.56</td>
<td>4.83</td>
<td>0.70</td>
</tr>
<tr>
<td>Phosphorus P mg/kg</td>
<td>284</td>
<td>29</td>
<td>323</td>
</tr>
<tr>
<td>Potassium K mg/g</td>
<td>1.85</td>
<td>1.90</td>
<td>5.46</td>
</tr>
<tr>
<td>Calcium Ca mg/g</td>
<td>331</td>
<td>313</td>
<td>108</td>
</tr>
<tr>
<td>Magnesium Mg mg/g</td>
<td>5.82</td>
<td>32.2</td>
<td>5.86</td>
</tr>
<tr>
<td>Sulfur S mg/g</td>
<td>103</td>
<td>110</td>
<td>22.9</td>
</tr>
<tr>
<td>Aluminum Al mg/g</td>
<td>6.42</td>
<td>1.63</td>
<td>83.3</td>
</tr>
<tr>
<td>Sodium Na mg/kg</td>
<td>662</td>
<td>797</td>
<td>831</td>
</tr>
<tr>
<td>Zinc Zn mg/kg</td>
<td>36.0</td>
<td>39.7</td>
<td>65.0</td>
</tr>
<tr>
<td>Arsenic As mg/kg</td>
<td>10.6</td>
<td>&lt;5</td>
<td>12.4</td>
</tr>
<tr>
<td>Barium Ba mg/kg</td>
<td>261</td>
<td>181</td>
<td>670</td>
</tr>
<tr>
<td>Beryllium Be mg/kg</td>
<td>0.85</td>
<td>0.25</td>
<td>4.27</td>
</tr>
<tr>
<td>Cadmium Cd mg/kg</td>
<td>0.28</td>
<td>4.44</td>
<td>0.95</td>
</tr>
<tr>
<td>Cobalt Co mg/kg</td>
<td>3.22</td>
<td>0.72</td>
<td>8.63</td>
</tr>
<tr>
<td>Chromium Cr mg/kg</td>
<td>11.8</td>
<td>3.4</td>
<td>28.9</td>
</tr>
<tr>
<td>Lithium Li mg/kg</td>
<td>86.1</td>
<td>21.3</td>
<td>548</td>
</tr>
<tr>
<td>Nickel Ni mg/kg</td>
<td>5.75</td>
<td>0.65</td>
<td>17.8</td>
</tr>
<tr>
<td>Lead Pb mg/kg</td>
<td>5.4</td>
<td>136</td>
<td>38.3</td>
</tr>
<tr>
<td>Antimony Sb mg/kg</td>
<td>13.0</td>
<td>9.4</td>
<td>15.4</td>
</tr>
<tr>
<td>Selenium Se mg/kg</td>
<td>&lt;6.0</td>
<td>14</td>
<td>11.8</td>
</tr>
<tr>
<td>Silicon Si mg/g</td>
<td>1.84</td>
<td>1.67</td>
<td>3.66</td>
</tr>
<tr>
<td>Strontium Sr mg/kg</td>
<td>298</td>
<td>195</td>
<td>413</td>
</tr>
<tr>
<td>Thallium Tl mg/kg</td>
<td>&lt;1.6</td>
<td>&lt;1.6</td>
<td>&lt;1.6</td>
</tr>
<tr>
<td>Vanadium V mg/kg</td>
<td>21.2</td>
<td>4.11</td>
<td>57.6</td>
</tr>
</tbody>
</table>
DFGD Materials

- Liaoyang, LYS1
  - hannebachite, portlandite, quartz, calcite

- Meshane, MSS2
  - hannebachite, calcite

- CFB+CFB-FGD, S3
  - hannebachite, portlandite, quartz, hematite, calcite, anhydrite
Methods

- **USEPA Method 1313**
  - Intrinsic release of trace elements under pHs ranging from extremely acidic (~pH 3) to very strong alkaline (~pH 10) conditions
  - L/S ratio of 10mL extract/g-DFGD material
  - Equilibrium concentration as the worst case scenario

- **USEPA Method 1314**
  - Effect of liquid-to-solid ratio as infiltration percolating through a monolayer of DFGD material
  - Column study under equilibrium condition

- **USEPA Method 1315**
  - Release of trace elements under diffusion-controlled condition
Release of Constituents of Concern under Various pHs
Effect of pH

Samples
- Liaoyang pH 10.0
- Liaoyang pH 3.7
- Liaoyang pH 4.5
- Liaoyang pH 5.2
- Liaoyang pH 6.0
- Liaoyang pH 6.3
- Liaoyang pH 6.6

Component 1 (83 %)
Component 2 (14.8 %)
Component 2 (10.1 %)
Distribution of Constituents under Various pHs

\[ f_{i, \text{leachate}} = \frac{M_{i, \text{leachate}}}{M_{i, \text{leachate}} + M_{i, \text{leached solid}}} \]
Management Scenario:
Use as fill for mine land reclamation

- 25-meter deep DFGD material fill
- Groundwater with various pHs flowing through the DFGD fill at a flow rate of 0.01 m/day
Management Scenario:

- Release of constituents when using as a fill material or disposal in a monofill

DFGD Fill

\( \text{i} = 200 \text{ cm/year} \)

25 m
Release of Constituents of Concern over Time

- 25-meter fill under 200cm/year of precipitation
Management Scenario:

Water flows around a DFGD material with a lower hydraulic conductivity comparing to its surroundings (e.g., sands or geotextile materials)
Release of Constituents under Diffusion Control Condition

\[ M_t = \left[ 2 \rho C_0 \left( \frac{D_{obs}}{\pi} \right)^{\frac{1}{2}} \right] \times t^{\frac{1}{2}} \]

<table>
<thead>
<tr>
<th>Mean Interval, day</th>
<th>Ca, mg/L</th>
<th>Flux</th>
<th>Concentration</th>
<th>Accumulative Mass Release of Ca, mg</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.01</td>
<td>1</td>
<td>0.01</td>
<td>Liaoyang</td>
<td>1000</td>
</tr>
<tr>
<td>0.1</td>
<td>10</td>
<td>0.1</td>
<td>Liaoyang</td>
<td>2000</td>
</tr>
<tr>
<td>1</td>
<td>100</td>
<td>1</td>
<td>Liaoyang</td>
<td>3000</td>
</tr>
<tr>
<td>10</td>
<td>1000</td>
<td>10</td>
<td>Liaoyang</td>
<td>4000</td>
</tr>
</tbody>
</table>

Where:
- \( M_t \) is the accumulative mass release of calcium
- \( \rho \) is the density
- \( C_0 \) is the initial concentration
- \( D_{obs} \) is the observed diffusion coefficient
- \( \pi \) is the mathematical constant
- \( t \) is the time

Graphs showing the relationship between mean interval and calcium concentration, and the accumulative mass release of calcium for Liaoyang and Meishane.
Release of Constituents of Concern under Diffusion Control Condition

![Graph showing the release of constituents of concern under diffusion control condition. The graph plots various elements against $R^2$ values, with data points for Liaoyang S1 and Meshane S2. The graph indicates diffusion control conditions.](image-url)
Depth of Depletion after 100 Years under Diffusion Controlled Conditions

![Graph showing depth of depletion for various elements after 100 years under diffusion controlled conditions.]

- LY S1
- MS S2
Conclusions

- Except for Se, none of the constituents of concern in any of the leachates exceeded the toxicity characteristic limits. Se leaching could be affected by testing method.

- The release of constituents, in general, was more vigorous under acidic leaching conditions, except for Mo, Hg, P, Al, Cd, Cr, and As.
  - Mo was higher in the alkaline leachates
  - Hg, P, Al, Cd, Cr, and As were higher under both acidic and alkaline conditions

- B and Se were the most mobile constituents of concern
Conclusions

- The release of a number of trace constituents, i.e., As, Ba, Cr, Se, and Zn, was more significant during the early stage of the leaching process (L/S<2).

- Ca, sulfate, Al from MSS2, Si, Na from MSS2, Ba from MSS2, Sr from MSS2, As from MSS2, B from MSS2, Cr, and Tl are the constituents whose releases were controlled by diffusion processes.
Future Work

- Identify the speciation of Se and Hg in different DFGD materials using X-ray adsorption spectroscopy (XAS)
  - Se in S3 is more mobile than MSS2
  - Speciation might have play an important role
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.