Selenium in US Coals

- Selenium is found in coals in trace concentrations.
- USGS has reported concentrations in coal as high as 150 μg/g, but 0.5 to 5 μg/g is a more typical range for US coals.
- Selenium is often found in coal either associated with metal sulfide minerals, predominantly pyrite, or as an organically associated element.
- Selenium has also been observed to be associated with silicates in some coals.
- In low-rank coals, selenium is mostly organically bound, but in bituminous coals the element is split between organic and mineral association.
Selenium in US Coals: Example

- Data from Illinois State Geological Service (ISGS) for selected coals

![Graph showing the relationship between Se ppmw AR and Sulfur wt% AR for IL No.6, KY No.9, and KY No.11.](source: ISGS C499)
Behavior of Se in Coal-Fired Boilers

- Selenium mostly vaporized in the combustion zone
- Gas-phase SeO₂ reacts with surface of ash particles as flue gas cools
  - Se reacts with iron and calcium
  - Sulfur interferes with the reactions
- Implications for emissions and control
  - Efficient capture of Se by fly ash in boilers firing subbituminous and lignites
  - Poor capture of Se by fly ash in boilers firing high-sulfur bituminous
Fate of Selenium in APCDs

Selenium in Flue Gas

Particulate Collector

SO$_2$ Scrubber

Fly Ash

Solid & Liquid Discharge

Stack

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Selenium Mass Balance

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Selenium Mass Balance

Bituminous boilers: 25-80% Se in fly ash
50-95% removal of remaining Se in FGD

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Subbituminous boilers: 50-100% Se in fly ash 60-80% removal of remaining Se in FGD
Se Removal and Distribution in FGD

Removal of Se across scrubber much lower than removal of \( \text{SO}_2 \) in most cases

<table>
<thead>
<tr>
<th>Boiler</th>
<th>( \text{SO}_2 ) Removal</th>
<th>Se Removal</th>
<th>Gypsum Se</th>
<th>Blowdown Liquid Se</th>
<th>Blowdown Solids Se</th>
<th>Limestone Se</th>
<th>Make-up Water Se</th>
<th>WESP Effluent Se</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-1</td>
<td>97.8%</td>
<td>86.4%</td>
<td>10.1</td>
<td>2059</td>
<td>45.4</td>
<td>&lt;0.57</td>
<td>0.448</td>
<td>--</td>
</tr>
<tr>
<td>B-2</td>
<td>95.4%</td>
<td>75.3%</td>
<td>11.4</td>
<td>1690</td>
<td>23.9</td>
<td>&lt;0.57</td>
<td>0.448</td>
<td>--</td>
</tr>
<tr>
<td>C</td>
<td>95%&lt;sup&gt;1&lt;/sup&gt;</td>
<td>95.6%</td>
<td>1.3</td>
<td>96.5</td>
<td>8.64</td>
<td>&lt;0.62</td>
<td>2.22</td>
<td>36.5</td>
</tr>
<tr>
<td>D</td>
<td>92%&lt;sup&gt;1&lt;/sup&gt;</td>
<td>53.1%</td>
<td>3.5</td>
<td>1210</td>
<td>294</td>
<td>&lt;0.62</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>F</td>
<td>92.6%</td>
<td>57.1%</td>
<td>&lt;0.60</td>
<td>7.81</td>
<td>4.79</td>
<td>&lt;0.57</td>
<td>0.396</td>
<td>--</td>
</tr>
<tr>
<td>G-1</td>
<td>92%&lt;sup&gt;1&lt;/sup&gt;</td>
<td>82.6%</td>
<td>2.01</td>
<td>942</td>
<td>65.5</td>
<td>1.22</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>G-2</td>
<td>92%&lt;sup&gt;1&lt;/sup&gt;</td>
<td>78.7%</td>
<td>1.9</td>
<td>861</td>
<td>59.5</td>
<td>1.23</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

<sup>1</sup>Estimated

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**Input, Output, Removal of Se**

*Se inputs & stack emission in lb/TBtu*

<table>
<thead>
<tr>
<th>Plant</th>
<th>Se input (fuel)</th>
<th>Se input (FGD)*</th>
<th>Se stack emission</th>
<th>Se removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-1&amp;2</td>
<td>378.9</td>
<td>--</td>
<td>72.8</td>
<td>81%</td>
</tr>
<tr>
<td>B-1</td>
<td>368.5</td>
<td>2.4</td>
<td>12.6</td>
<td>97%</td>
</tr>
<tr>
<td>B-2</td>
<td>339.3</td>
<td>1.7</td>
<td>21.7</td>
<td>94%</td>
</tr>
<tr>
<td>C</td>
<td>168.5</td>
<td>6.8</td>
<td>1.2</td>
<td>99%</td>
</tr>
<tr>
<td>D-1</td>
<td>305.0</td>
<td>7.1</td>
<td></td>
<td>76%</td>
</tr>
<tr>
<td>D-2</td>
<td>344.2</td>
<td>7.1</td>
<td>74.6</td>
<td>79%</td>
</tr>
<tr>
<td>E</td>
<td>45.7</td>
<td>--</td>
<td>12.7</td>
<td>72%</td>
</tr>
<tr>
<td>F</td>
<td>115.7</td>
<td>0.6</td>
<td>0.8</td>
<td>99%</td>
</tr>
<tr>
<td>G-1</td>
<td>59.2</td>
<td>2.1</td>
<td>1.5</td>
<td>98%</td>
</tr>
<tr>
<td>G-2</td>
<td>46.7</td>
<td>1.5</td>
<td>1.3</td>
<td>97%</td>
</tr>
</tbody>
</table>

*Limestone and make-up water*

- Most Se came from coal - higher input on bituminous units
- Units without scrubbers (A and E): 81% and 72% Se removal
- Scrubbed units: 76% to 99% Se removal
Implications for Emissions and Control

- Unlike most HAP metals, Se can be gaseous (SeO₂) at temperatures in APCDs
- Se can be captured by fly ash, but not always removed with high efficiency by PCDs
  - Low-rank ash more effective at capturing Se than bituminous ash =>
  - FFs more effective than ESPs
Implications for Emissions and Control

- Significant portion of Se can enter FGD in gas-phase
  - Combination of PCD+scrubber removes >85% Se

- Removal of SeO₂ across FGDs less than removal of SO₂ (60%-90%)

- Selenium removed across FGDs could become an issue in wastewater discharge
  - More data needed on distribution within scrubber