Trace Element Sampling and Partitioning Modeling to Estimate Wastewater Composition and Treatment Performance at Coal Generators

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Regulatory Drivers and Alignment to Fossil Energy Objectives

Regulatory Drivers- Effluent Limitation Guidelines (2020)
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DOE FE Objective 1.1 – Develop cost-effective, environmentally responsible transformational technologies that will underpin coal-based facilities of the future
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DOE Water Security Grand Challenges - Reduce water impacts in the power sector

Regulatory Drivers- Effluent Limitation Guidelines (2020)
Statement of purpose

- Trace elements have variable concentration in coal, and behave predictably in air pollution control devices (APCD)
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- Trace elements have variable concentration in coal, and behave predictably in air pollution control devices (APCD).

- This model improves on existing predictions for trace element partitioning at coal-fired power plants (CFPPs) by (1) accounting for plant-level variability and (2) providing validation.
Project objectives

1. Develop a generalizable, open-source COntaminant behavior in Air, Liquid, and Solids (COALS) Controls Model to describe the quantity and partitioning behavior of trace elements B, As, Se, Pb, Hg, Cl and Br at US CFPPs.
2. Characterize removal performance for trace elements of concern within the best available technologies (BATs) under the Effluent Limitation Guidelines (ELGs) for Flue Gas Desulfurization (FGD) wastewater treatment.
Enable solid, liquid, and gas discharge management by modeling trace element behavior
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Develop typical FGD wastewater compositions for treatment technology development

Benefits for discharge management at CFPP

- Enable solid, liquid, and gas discharge management by modeling trace element behavior
- Develop typical FGD wastewater compositions for treatment technology development
- Identify cost-effective FGD wastewater treatment technology options

Industry collaboration

- The project uses data collected at LGE-KU partner facilities and includes non-steady state plant operation
- Partner facilities include Trimble County, Ghent, and Mill Creek Generating Stations

Trimble County Generating Station

Sample collection at Ghent generating station
Clean air act regulatory requirements have influenced the fate of trace elements at coal-fired power plants.

Percent change in the mass of Selenium entering U.S. CFPPs between 1993 and 2017.

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Attributional analysis of changes in the phase of trace elements exiting U.S. CFPPs

Simulated flue gas desulfurization wastewater composition shows different trends by air pollution control and coal rank.

**Graph:**
- Y-axis: Selenium
- X-axis: Concentration [mg/L]
- Legend:
  - Blue: csESP, wetFGD
  - Red: csESP, wetFGD, ACI
  - Green: FF, wetFGD
  - Purple: wetFGD, ACI

**Legend:**
- csESP = cold side electrostatic precipitator; ACI = Activated Carbon Injection; FGD = Flue Gas Desulfurization

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Competing ions can impact the performance of chemical precipitation and biological treatment, but the size and direction of the effect on removal efficiency are not known.

<table>
<thead>
<tr>
<th>Median Concentration (mg/L)</th>
<th>Chemical Precipitation Influent</th>
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<tbody>
<tr>
<td>Se</td>
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<tr>
<td>186</td>
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Competing ions can impact the performance of chemical precipitation and biological treatment, but the size and direction of the effect on removal efficiency are not known.

Significant impact on treatment efficacy could influence facility compliance with effluent limitations.
Regression analysis is used to project trace element removal performance using wastewater composition

\[ R = \frac{e^{\beta_0 + \beta_1 x + \beta_2 S + \beta_3 N + \beta_4 C}}{1 + e^{\beta_0 + \beta_1 x + \beta_2 S + \beta_3 N + \beta_4 C}} \]

**Modeled results for selenium**

<table>
<thead>
<tr>
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<th>CP (β)</th>
<th>BT (β)</th>
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<tbody>
<tr>
<td>Intercept</td>
<td>0.74 (0.38)</td>
<td>5.9*** (0.86)</td>
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<tr>
<td>Se</td>
<td>1.4e-4*** (3.0e-5)</td>
<td>2.6e-3*** (2.2e-4)</td>
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<tr>
<td>S</td>
<td>-1.1e-5 (1.7e-5)</td>
<td>2.5e-4 (2.6e-4)</td>
</tr>
<tr>
<td>N</td>
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<td>-4.2e-2*** (6.7e-3)</td>
</tr>
<tr>
<td>Cl</td>
<td>1.1e-4** (4.1e-5)</td>
<td>-5.0e-4*** (8.9e-5)</td>
</tr>
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<td>Adjusted R²</td>
<td>0.37</td>
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* Significant at the 0.05 level  
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### Impact of doubling the median concentration on removal efficiency

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<tr>
<td>Se</td>
<td>0.45%</td>
<td>1.11%</td>
</tr>
<tr>
<td>S</td>
<td>-0.27%</td>
<td>2.06%</td>
</tr>
<tr>
<td>N</td>
<td>-7.48%</td>
<td>-5.96%</td>
</tr>
<tr>
<td>Cl</td>
<td>11.7%</td>
<td>-62.0%</td>
</tr>
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Treatment costs at the baseline 550 MW NETL coal fired powerplant vary by expected chlorine load

Treatment costs for the fleet are poorly described by the median values for the fleet.

Partitioning fractions for fly ash change during powerplant ramping conditions for chlorine, arsenic, bromine and mercury

\[
\frac{FA_r}{FA_{ss}} = \text{Fold increase in partitioning to flyash under ramping conditions}
\]

\[
\frac{FA_r}{FA_{ss}} = 1
\]

No change in partitioning behavior under ramping conditions
Next steps for model development

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<tr>
<th>Task 5.0 - Ramping</th>
<th>Task 5.0 - GUI/Model Release</th>
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**Task 5** – Complete modeling of the relationship between ramping and APCD/WPCD performance using the data that has been collected at Partner Facilities and updates to graphical user interface.
Dissemination of results to industry

• 3 manuscripts published in Energy Policy and Environmental Science & Technology
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- Public GitHub project and Open Science Foundation project were created for the COALS Controls Graphical User Interface
Concluding remarks

• This project has successfully met objectives to predict trace element partitioning at CFPPs and identify FGD wastewater treatment costs
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• The objectives address water impacts in the power sector highlighted in DOE Water Security Grand Challenges
Acknowledgement and Disclaimer

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