Water Management for Power Systems
RIC FWP

PIs: Eric Grol, McMahan Gray, Nicholas Siefert, Erik Shuster, Djuna Gulliver, Dustin McIntyre, Tim Skone

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HQ Project Manager: Sam Thomas
Technology Manager: Briggs White
Senior Fellow: David Miller

May 17, 2021
Program Goal

The Water Management for Power Systems FWP seeks to reduce water consumption at both new and existing fossil power plants, as well as to decrease the cost of treating power plant effluent streams by converting them into valuable resources.

Tasks:

- Task#2: Guiding R&D for Treatment of Fossil Power Plant Effluent Streams  
  Principal Investigator: Eric Grol
- Task#3: Selective Removal of Heavy Metals from Effluent Streams  
  Principal Investigator: McMahan Gray
- Task#4: Concentrating Wastewater Effluent Streams & Resource Recovery  
  Principal Investigator: Nicholas Siefert
- Task#5: Impact of Water Use of Power Systems  
  Principal Investigator: Erik Shuster
- Task#6: Biological Treatment of FGD Effluent Streams  
  Principal Investigator: Djuna Gulliver
- Task#7: Characterization of FGD Effluent Streams  
  Principal Investigator: Dustin McIntyre
- Task#8: Water Management for Fossil-Based Hydrogen Production  
  Principal Investigator: Timothy Skone
## EPA Limits on Effluent vs. FGD Compositions

### 2020 New Final Ruling

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Unit</th>
<th>Avg</th>
<th>Monthly Avg Lim</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic, total</td>
<td>(ug/L)</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>Mercury, total</td>
<td>(ng/L)</td>
<td>13</td>
<td>34</td>
</tr>
<tr>
<td>Selenium, total</td>
<td>(ug/L)</td>
<td>16</td>
<td>29</td>
</tr>
<tr>
<td>Nitrate/nitrite as N</td>
<td>(mg/L)</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

### EPA Data Collected during Initial Rule Making

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Unit</th>
<th>PP June 22 2010</th>
<th>MF July 12 2010</th>
<th>A Aug 2 2010</th>
<th>BC June 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic, total</td>
<td>(ug/L)</td>
<td>160</td>
<td>937</td>
<td>120</td>
<td>240</td>
</tr>
<tr>
<td>Mercury, total</td>
<td>(ng/L)</td>
<td>2,080,000</td>
<td>166,000</td>
<td>50,300</td>
<td>291,000</td>
</tr>
<tr>
<td>Selenium, total</td>
<td>(ug/L)</td>
<td>15,000</td>
<td>3,400</td>
<td>1,500</td>
<td>6,600</td>
</tr>
<tr>
<td>Nitrate/nitrite as N</td>
<td>(mg/L)</td>
<td>160</td>
<td>72</td>
<td>14</td>
<td>16</td>
</tr>
</tbody>
</table>

[Link to Aug 31, 2020 Ruling](#) Published Oct 13 2020 to Federal Register
# Table XIV-1—Long-Term Averages and Effluent Limitations and Pretreatment Standards for FGD Wastewater for Existing Sources (BAT/PSES)\(^a\)

<table>
<thead>
<tr>
<th>Subcategory</th>
<th>Pollutant</th>
<th>Long-Term average</th>
<th>Daily maximum limitation</th>
<th>Monthly average limitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirements for all plants not in the VIP or subcategories specified below (BAT &amp; PSES).</td>
<td>Arsenic (µg/L) ...............</td>
<td>4.98</td>
<td>18</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Mercury (ng/L) .............</td>
<td>13.48</td>
<td>103</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>Nitrate/nitrite as N (mg/L)</td>
<td>2.14</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Selenium (µg/L) ............</td>
<td>15.87</td>
<td>70</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>Arsenic (µg/L) ..................</td>
<td>^5.0</td>
<td>5</td>
<td>NA</td>
</tr>
<tr>
<td>Voluntary Incentives Program for FGD Wastewater (existing direct dischargers).</td>
<td>Mercury (ng/L) .............</td>
<td>5.44</td>
<td>23</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Nitrate/nitrite as N (mg/L)</td>
<td>0.89</td>
<td>2.0</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td>Selenium (µg/L) ............</td>
<td>7.35</td>
<td>10</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>Bromide (mg/L) .............</td>
<td>0.200</td>
<td>0.2</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>TDS (mg/L) ...................</td>
<td>86.06</td>
<td>306</td>
<td>149</td>
</tr>
<tr>
<td></td>
<td>Arsenic (µg/L) ...............</td>
<td>5.98</td>
<td>11</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Mercury (ng/L) ..............</td>
<td>159</td>
<td>788</td>
<td>356</td>
</tr>
</tbody>
</table>

\(^a\) BAT effluent limitations for EGUs that will permanently cease the combustion of coal by December 31, 2028, are based on the previously established BPT limitations on TSS and are not shown in this table. The BAT effluent limitations for TSS for these EGUs are: Daily maximum of 100 mg/L; and monthly average of 30 mg/L.

\(^b\) Long-term average is the arithmetic mean of the quantitation limitations because all observations were not detected.

\(^c\) Limitation is set equal to the quantitation limit for the data evaluated.

\(^d\) Monthly average limitation is not established when the daily maximum limitation is based on the quantitation limit.
Overview of RIC’s Experimental Efforts

- **Cation Heavy Metal Removal:** $\text{Hg}^{+2}$, $\text{Pb}^{+2}$, $\text{Cd}^{+2}$, $\text{Co}^{+2}$
  - Task 3

- **Anion Redox Removal:** $\text{Se}^{IV/VI}$ to $\text{Se}$, $\text{As}^{III/V}$ to $\text{As}$, $\text{N}^{III/V}$ to $\text{N}_2$
  - Tasks 6

- **Brine Concentration:**
  - Existing MVR
  - **10-lb brine / Road Salt**

- **Fresh Water Make-up**

- **New UF/NF/RO Treatment Skid**
  - Task 4

- **LIBS Sensor**
  - Task 7 (Ending)

- **To meet existing regulations**

- **To recover resources and to achieve ZLD**

- **Fresh Water Make-up**
  - (Boron removal)

- **Limestone Make-up**

- **Barite**
  - (Drilling Additive)
Task 3: Selective Removal of Heavy Metals for Effluent Streams
Task 3: Selective Removal of Heavy Metals for Effluent Streams

Objective

- Design and test low-cost sorbents selectively remove heavy metal and other regulated species from FGD effluent

Results

- Three NETL sorbents selectively reduced Se concentrations below the EPA discharge limit from Somerset FGD water.
- Two NETL sorbents selectively reduced Hg concentrations below the EPA discharge limit (<5.1 ppt) from Longview FGD water, while simultaneously removing 99% of Mn, 99% of Al, 95% of Co, 99% of Ni, and 60-93% of Cd.

Tech Transfer

1 Journal article, 2 presentations, 3 patent applications

1. M. L. Gray, B. W. Kail, W. C. Wilfong, Q. Wang, Stable immobilized amine sorbents for REE and heavy metal recovery from liquid sources. Published April 2018, WO2018071730A1 (Licensed to PQ Corp.)


McMahan Gray, Function Materials Group
Task 6: Biological treatment of FGD effluent streams
Microbial Selenium Treatment of FGD Effluent
Enrichments of Anaerobic Selenium Oxyanion Reducers

Preom Sarkar ORISE

IC analysis shows evidence of up to 99.9% removal of selenate by microbes.

Literature review completed: White paper summarizing current state of knowledge on biological FGD effluent treatment with implications and path forward. “Biological Treatment of Flue Gas Desulfurization Wastewater”
SEM Imaging of Microbial Processes
Applied to Microbial Selenium Treatment of FGD Effluent

Meghan Brandi (LRST)

Scanning Electron Microscope
• Provides useful high-resolution visual element to research
• Biological samples require additional preparation

Nanospheres observed both attached to and within microbes:

Energy Dispersive Spectroscopy (EDS)
• Qualitative, semi-quantitative elemental analysis
• Capable of producing colorized phase maps, and much more

Image analysis for particle size distribution

Image analysis for particle size distribution

Nanosphere Size Distribution
SEM/EDS shows that Se, Au, Zn, and Pd are all found in the nanoparticles (Si from background)
Task 4: Concentrating Wastewater Effluent Streams & Resource Recovery
Overview of RIC’s Experimental Efforts

- **FGD Effluent**
  - Cation Heavy Metal Removal: $\text{Hg}^{2+}$, $\text{Pb}^{2+}$, $\text{Cd}^{2+}$, $\text{Co}^{2+}$
  - Task 3
  - LIBS Sensor (Task 7) Ending

- **Brine Concentration**
  - Existing MVR
  - 10-lb brine / Road Salt
  - Fresh Water Make-up

- **Anion Redox Removal**
  - SeIV/VI to Se, AsIII/V to As, NIII/V to $\text{N}_2$
  - Tasks 6
  - LIBS Sensor (Task 7) Ending

- **Brine Concentration**
  - Existing MVR
  - Fresh Water Make-up
  - Limestone Make-up
  - Barite (Drilling Additive)

- **New UF/NF/RO Treatment Skid**
  - Task 4
  - To recover resources and to achieve ZLD

- **To meet existing regulations**
Pilot Skid Designed to Operate on FGD Effluent

Objective: To achieve ZLD, to reduce freshwater consumption, and to recover resources.
Concentrating Wastewater Effluent Streams

Comparison between Minimum Theoretical Work and Actual Electrical Work Required

<table>
<thead>
<tr>
<th>Test</th>
<th>Inlet (g/L)</th>
<th>Recovery (%)</th>
<th>Theoretical Work</th>
<th>Actual Work</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1&amp;2</td>
<td>22</td>
<td>35</td>
<td>0.6</td>
<td>1.8</td>
</tr>
<tr>
<td>#3</td>
<td>50</td>
<td>40</td>
<td>1.8</td>
<td>2.5</td>
</tr>
<tr>
<td>#4</td>
<td>73</td>
<td>42</td>
<td>2.5</td>
<td>3.3</td>
</tr>
<tr>
<td>#5</td>
<td>106</td>
<td>38</td>
<td>3.3</td>
<td>5.7</td>
</tr>
<tr>
<td>#6</td>
<td>168</td>
<td>35</td>
<td>5.7</td>
<td>117</td>
</tr>
</tbody>
</table>

Potential for additional MVR baseline testing in Summer 2021 at UND EERC BEST
Program Goal

The Water Management for Power Systems FWP seeks to reduce water consumption at both new and existing fossil power plants, as well as to decrease the cost of treating power plant effluent streams by converting them into valuable resources.

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- **Task#8**: Water Management for Fossil-Based Hydrogen Production
  - **Principal Investigator**: Timothy Skone
• Tasks 2, 5, 8 covered in May 10th presentations

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Task 7: LIBS calibration and measurement of FGD water elements
Task 2: Guiding R&D for Treatment of Fossil Power Plant Effluent Streams
Task 5: Impact of Water Use of Power Systems
Task 8: Water Management for Fossil-based H$_2$ Production

December 4, 2020