Physico-Chemical Treatments for Flue-Gas Derived Water from Oxy-Fuel Power-production with CO$_2$ Capture

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What is Integrated Pollutant Removal?

Energy recovery from CO$_2$ compression (energy integration). Cooling pre-compression-stage removes soluble impurities (mass-transfer integration).
Review of the IPR process
(installed at Jupiter Oxygen Burner Testing Facility, Hammond, IN)
Scale of Flow

- 350 MWe, ~ 400,000 lb/hr water as combustion product.
- Partial cooling-water offset
- Boiler feedwater-makeup offset
Materials Screened
(using ASTM standard method D 2035 for coagulation-flocculation jar test)

Materials Used as Coagulation Agents
- Alum \((\text{Al}_2\text{(SO}_4\text{)}_3\cdot18\text{H}_2\text{O})\)
- **Ferric Chloride** \((\text{FeCl}_3\cdot6\text{H}_2\text{O})\)
- Ferric Sulphate
- Xanthanate (Monomer-Organic Material)

Materials Used as Coagulation Aids
- **Poly acrylamide**
- Poly(diallyldimethylammonium chloride) - DADMAC
Cation Concentrations Across IPR
(Analyzed by Inductive Coupled Plasma (ICP))

- Concentrations less than 1.0 E-04: Be, Cd, Ce, Li, P, Pb, Sb, Se, Sn, Tl, V, Sr,
Anion Concentrations Across IPR
(Analyzed by Inductive Coupled Plasma (ICP))

- Concentrations less than 1.0 E-04: F, NO2, Br, PO4
### Treatment Targets

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Target Concentration (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe</td>
<td>0.3</td>
</tr>
<tr>
<td>Mo</td>
<td>0.1</td>
</tr>
<tr>
<td>Hg</td>
<td>0.002</td>
</tr>
<tr>
<td>Ni</td>
<td>0.1</td>
</tr>
<tr>
<td>Cu</td>
<td>1.3</td>
</tr>
<tr>
<td>Cr</td>
<td>0.1</td>
</tr>
<tr>
<td>Co</td>
<td>0.1</td>
</tr>
<tr>
<td>Ba</td>
<td>2</td>
</tr>
<tr>
<td>As</td>
<td>0.05</td>
</tr>
<tr>
<td>All other cations</td>
<td>0.1</td>
</tr>
<tr>
<td>All anions</td>
<td>0.1</td>
</tr>
</tbody>
</table>
Flocculation Experiments

- Analyze sample by ICP-MS/AAS
  - Blank
  - 1 mg/L
  - 2.5 mg/L
  - 5 mg/L
  - FeCl₃ + NaOH

- pH adjustment

- Rapid mix for 1 min (at different pHs) then flocculate for 20 min

- Settle for 1 hr

- Preserve with HNO₃ for total contaminant analysis
  - Immediate Analysis

- Filter supernatant (0.2 µm filter)

Metals:
- Blank
- 5 mg/L
- 2.5 mg/L
- 1 mg/L
- 0.5 mg/L

Contaminant:
- FeCl₃ + NaOH
Screening - - - Alum vs FeCl3

![Graph showing Turbidity Removal vs Dosage Concentration (mg/L) for Alum and FeCl3. The graph indicates a comparison of the effectiveness of Alum and FeCl3 in removing turbidity at different concentration levels.](image)

Test with FeCl3

Dosage Concentration (mg/L)

Turbidity Removal

- Alum
- FeCl3
Screening: Settling time using FeCl3
(with and without polyacrylamide)
Treatment with FeCl3
Pre- and Post-treatment:
Cations from water from spray-tower at system inlet
Cation removal from several water samples

- A Tower HX 12/1/09: 16.33
- B Tower HX 12/3/09: 14.13
- C Post Buffer Inject 12/1/09: 14.46
- D Post Buffer Inject 12/3/09: 13.41
- E Tower HX 12/3/09: 13.31
- F Tower HX 12/3/09: 14.45
Anions – a second step
(Follow Flocculation with R.O.)
Conclusions

• Of the materials tested, ferric chloride, supplemented with polyacrylamide was the most effective clarifying agent.

• Most of the cations removed, except mono- and di-valent ions.

• Anions remain at relatively high concentrations

• Recommending reverse osmosis for removal of remaining ions.
Future Work

- Reverse osmosis testing
- Models of IPR
  - Test Scale
  - Full Scale
- In-line clarification for recirculating spray tower
Thank you

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Aspen Modeling of Water Treatment systems

Predict the behavior of a process using basic engineering relationships such as mass and energy balances

Phase and chemical equilibrium

Reaction kinetics

With reliable thermodynamic data, realistic operating conditions and rigorous aspen plus equipment models, actual plant behavior can be simulated.
Design of Wastewater Treatment

Equalization Tank → Coagulation/Flocculation Unit → Mixing Tank → Filtration Unit → pH Correction Tank → Treated Water

- Lime
- Acid/Alkali
- Sludge
- Gypsum
Cooling with material absorption is repeated at each pressure step.