Produced Water Resources in the Illinois Basin as a Supplemental Source of Water for Coal-Based Power Plants

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Objective

- Evaluate feasibility of using non-traditional water sources for cooling and/or process water for coal-based power plants in Illinois Basin
  - CO₂ Enhanced Oil Recovery (EOR)
  - Coal-Bed Methane (CBM)
  - Active and abandoned coal mines

Participants

- NETL/DOE
- University of Illinois at Urbana-Champaign
- Illinois Department of Commerce and Economic Opportunity/Illinois Clean Coal Institute
- Midwest Geological Sequestration Consortium
- CBM and coal mine companies
Power and Thermoelectric Freshwater Demand

- 30% increase in power demand in U.S. and Illinois by 2030
- 55-160% increase in Illinois thermoelectric water consumption by 2030 (28-50% increase in U.S.)
- Significant increase in thermoelectric water consumption with CO₂ capture
- Additional water demand for biofuels and hydrogen industry

![Graph showing energy consumption trends from 1980 to 2030](image)

<table>
<thead>
<tr>
<th></th>
<th>U.S. (BGD)</th>
<th>Illinois (BGD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total withdrawal</td>
<td>346</td>
<td>14</td>
</tr>
<tr>
<td>Thermoelectric</td>
<td>135 (39%)</td>
<td>11.3 (82%)</td>
</tr>
<tr>
<td>Total consumption</td>
<td>100</td>
<td>1.2</td>
</tr>
<tr>
<td>Thermoelectric</td>
<td>3 (3%)</td>
<td>0.4 (33%)</td>
</tr>
</tbody>
</table>

Nontraditional Sources of Water for Power Plant Usage

❑ DOE/NETL previous and on-going supported studies
  ➢ West Virginia University
    • Techno-economic study on using coal-mine discharges for power plant cooling systems in the Pittsburgh Basin
    • Modeling of using mine water for thermoelectric power generation in the Pittsburgh Basin
  ➢ University of Pittsburgh - Carnegie Mellon University
    • Reuse of three types of impaired water for power plant cooling
  ➢ EPRI
    • Use of produced water from oil and gas fields to supplement freshwater use in SJPS in New Mexico
  ➢ Sandia National Lab
    • Use of saline water from CO₂ sequestration in deep saline aquifers, for power plant cooling
  ➢ Nalco Company
    • Utilization of advanced separation and chemical scale inhibitor technologies to use impaired water in re-circulating cooling systems
  ➢ Others
Scope of Work

Task 1. Water Characterization

Task 2. Water Treatment: Conventional and Innovative

Task 3. Techno-Economic Analysis and Optimization

Produced Water
CO2-EOR
CBM
Coal Mine

Coal-slurry water

IGCC Plant

Cooling water
Boiler water

PC Power Plant

FGD water
Cooling water
Boiler water
Task 1. Produced Water Characterization

1.1 Geographic Distribution

1.2 Water Quantity

1.3 Water Quality

- Identify locations and estimate quantity of produced water resources
- Collect available produced water quality data
- Characterize water samples from selected sources: TDS, TSS, pH, TPH, TOC, alkalinity, and different cations and anions
- Map produced water quantity and quality data
Produced Water from CO$_2$-EOR

- CO$_2$-EOR is one option that may provide economic incentives for CO$_2$ storage
- A portion of produced water will be re-injected and the rest should be properly managed
Oilfields of Illinois Basin

- More than 1000 oilfields
- ~14.1 Billion bbl (Bbbl) Original Oil in Place (OOIP)
- Only 20-40% of OOIP recovered by standard methods
- CO$_2$-EOR can recover up to 10% of OOIP (~1.4 billion bbl)
- Twenty largest oilfields selected (~8.2 Bbbl OOIP)
Current Produced Water Production from Oilfields in Illinois Basin

- Oil Production in Illinois Basin (2007)

- Estimated Produced Water from Oil Recovery in Illinois Basin

- ~1/3 of total oil production from EOR in Illinois
  - 138 million barrels water production
  - water-to-oil ratio of ~42 bbl water/bbl oil

- No data for IN and KY
Produced Water Potential from Future CO$_2$-EOR in Illinois Basin

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 largest oilfields in IL Basin</td>
<td>million</td>
</tr>
<tr>
<td>Estimated OOIP</td>
<td>8,200</td>
</tr>
<tr>
<td>CO$_2$-EOR potential</td>
<td>820</td>
</tr>
<tr>
<td>Assumed water-to-oil ratio</td>
<td>42</td>
</tr>
<tr>
<td>CO$_2$-EOR produced water potential</td>
<td>34,440</td>
</tr>
</tbody>
</table>
Produced Water Quality of Twenty Largest Oilfields in Illinois Basin

- Statistics from combined 279 and 29 data points from USGS and 1995 ISGS, respectively
- less than ~ 5% of samples have TDS below 30,000 ppm
- Na+ and Cl- are the dominant ions

<table>
<thead>
<tr>
<th></th>
<th>pH</th>
<th>TDS (mg/l)</th>
<th>Na (mg/l)</th>
<th>Ca (mg/l)</th>
<th>Cl (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>6.6</td>
<td>110,000</td>
<td>37,000</td>
<td>4,300</td>
<td>68,000</td>
</tr>
<tr>
<td>Std dev</td>
<td>0.6</td>
<td>34,000</td>
<td>11,000</td>
<td>2,600</td>
<td>21,000</td>
</tr>
</tbody>
</table>
- Total estimated Original Gas in Place (OGIP) ~ 22.1 trillion scf
- Recoverable OGIP (conventional and enhanced) ~ 16.4 tscf
- Produced water potential ~ 16.4 billion barrels (assuming 1 bbl water/1000scf gas)
Produced Water from Coal Mines in Illinois Basin

- Active underground mines
  - Illinois = 14
  - Indiana = 7
  - Kentucky = 10

- Most coal mines are relatively dry

- Significant water production
  - Only 3 mines, each up to 0.5 million gal/day

- Void volume of abandoned mines
  - ~ 5.3 billion cubic yards

Data sources: State Geological Surveys of Illinois, Indiana, and Kentucky, current as of August, 2009 (IL), December, 2008 (IN), and February, 2009 (KY).
Water Quality of Coal Mines in Illinois Basin

- Limited data available – no data available for organics
- Water quality varies in a wide range from freshwater to high salinity water -- Na\(^+\) and Cl\(^-\) dominant ions
- Overall water quality much better than oilfield produced water

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Min</th>
<th>Max</th>
<th>St. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.8</td>
<td>7.0</td>
<td>8.6</td>
<td>0.4</td>
</tr>
<tr>
<td>TDS (mg/l)</td>
<td>18,313.0</td>
<td>994.0</td>
<td>48,306.0</td>
<td>16,970.8</td>
</tr>
<tr>
<td>Na and K (mg/l)</td>
<td>6,592.2</td>
<td>406.0</td>
<td>17,059.0</td>
<td>6,023.8</td>
</tr>
<tr>
<td>Cl (mg/l)</td>
<td>10,443.1</td>
<td>150.0</td>
<td>29,250.0</td>
<td>10,662.0</td>
</tr>
<tr>
<td>Alkalinity (mg/l)</td>
<td>456.4</td>
<td>160.0</td>
<td>1,004.0</td>
<td>254.3</td>
</tr>
</tbody>
</table>

Water quality statistics of 21 ground water samples associated with Herrin Coal in Illinois. Source of original data: Gluskoter (1965)
Work in Progress

- **Water characterization**
  - Produced water sampling and analysis

- **Produced water treatment**
  - Conventional (de-oiling, filtration, coagulation, adsorption, membrane)
  - Innovative (advanced membrane systems and advanced materials)

- **Techno-economic analysis**
  - Assessment of current and future power plant water demand in IL Basin
  - Water treatment and transportation cost estimation
  - Overall optimization
Acknowledgements

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