Effects of Irrigating With Treated Oil and Gas Product Water on Crop Biomass and Soil Permeability

Presented to:

Strategic Center for Natural Gas and Oil

US Dept. of Energy - NETL

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http://www.westernresearch.org/
Who is WRI?

- WRI is a research, technology development and contract services organization serving the energy and highway materials industries.

- WRI is a former U.S. DOE Energy Technology Laboratory specializing in oil shale and underground coal gasification.

- WRI has two major Federal contracts:
  - Cooperative Agreement with the U.S. DOE wherein we work jointly with industry to support the needs of the coal and power industries.
  - Contract with the FHWA to apply asphalt chemistry to specifications for better highway performance.
1924 Petroleum Experiment Station Established
   - To study characteristics of high-sulfur crude oil in Wyoming

1964 First Year of Asphalt Research
   - Research has continued under Strategic Highway Program & FHWA

1977 Laramie Energy Technology Center (LETC)
   - Lead for U.S. DOE oil shale & underground coal gasification programs

1983 Western Research Institute
   - LETC is de-Federalized. Cooperative Agreement with DOE established
Project Background
An estimated 25 trillion cubic feet of CBM is in the PRB of Wyoming and Montana alone. Equivalent to the gas reserves of the Gulf Coast.

51,000 wells are expected to be in service in the PRB area in the next 10 years.

Surface disturbance of approximately 212,000 acres (3% of project area).

An estimated 3.07 million acre ft of produced water generated over the next 10 years.

An estimated 4-8 trillion gallons of CBM produced water is expected to be generated over the potential 30-35 year play of the Powder River Basin CBM.
Economic Impact

- Federal Royalties - $1.7 billion
- State Royalties - $252 million
- Sales Tax - $124 million
- Severance to WY - $1.3 billion
- Ad Valorem (Counties) - $1.5 billion

FEIS, Jan. 2003
Produced Water Mgmt. Costs

- Surface Discharge - $818 million
- Infiltration - $505 million
- Containment - $593 million
- Land Application Disposal - $26 million
- Injection - $130 million
- Total Est. Cost for CBM Produced Water Management - $1.57 billion

FEIS, Jan. 2003
Implications to Development

LEGEND

Coal Zone SAR Values

- <5
- 5-10
- 10-15
- 15-20
- 20-25
- 25-30
- 30-35
- 35-40
- 44-45
- 45-50
- 50-55
- 55-60
- 60-65
- >65
Gas/Water Production in PRB

Data obtained from Wyoming Oil and Gas Conservation Commission website
Field and laboratory evaluations of land applications of CBM produced water (e.g., mineral amendments to soil and water)

CBM produced water treatment (e.g., barium)

Enhanced methane production

Remote sensing
Produced Water Management
Land Application of Produced Water

- Near Buffalo, WY
- Feasibility study using soil columns in the laboratory
- Pilot-scale field irrigation project employing soil and water amendments
Soil Core Study in the Laboratory

- Reconstructed soil cores from A horizon material
- Soil left untreated or amended with equivalent of 2.5 tons gypsum/acre
- CBM produced water percolated through cores for 75 hours
Soil Cores
EC & SAR

- Electrical Conductivity (EC)
- Sodium Adsorption Ratio (SAR):

\[ SAR = \frac{[Na]}{\sqrt{\frac{[Ca] + [Mg]}{2}}} \]
Figure 1. Concentration of ions is greatest immediately adjacent to the platelet and decreases with distance from the platelet.

From: Hanson et al. 1999
### Water Quality

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Creek</th>
<th>CBM</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAR mmol$^{1/2}$ L$^{-1/2}$</td>
<td>0.7</td>
<td>24</td>
</tr>
<tr>
<td>EC µS/cm</td>
<td>636</td>
<td>1,380</td>
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<tr>
<td>Alkalinity</td>
<td>207</td>
<td>802</td>
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<tr>
<td>TDS</td>
<td>470</td>
<td>910</td>
</tr>
<tr>
<td>HCO$_3$</td>
<td>237</td>
<td>853</td>
</tr>
<tr>
<td>CO$_3$</td>
<td>8</td>
<td>62</td>
</tr>
<tr>
<td>Cl</td>
<td>3</td>
<td>13</td>
</tr>
<tr>
<td>F</td>
<td>0.2</td>
<td>0.9</td>
</tr>
<tr>
<td>SO$_4$</td>
<td>137</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Ca</td>
<td>75</td>
<td>9</td>
</tr>
<tr>
<td>Fe</td>
<td>100</td>
<td>560</td>
</tr>
<tr>
<td>K</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Mg</td>
<td>30</td>
<td>4</td>
</tr>
<tr>
<td>Na</td>
<td>28</td>
<td>344</td>
</tr>
</tbody>
</table>
Figure 1. Assessing the effect of salinity and sodium adsorption ratio on infiltration rate.

From: Hanson et al. 1999

Water Quality
Saturated Hydraulic Conductivity

Hydraulic Conductivity - K (cm/s)

Time (min)

Creek water

CBM water
Field Study
## Field Study

### Soil Amendments
- 0.5 tons sulfur/acre
- 1.5 tons gypsum/acre
- Combination
- None

### Water Amendments
- Sulfur burner
- Gypsum injection
- Combination
- 50:50 blend with Creek water
- None
Amendment Application Areas
Soil SAR

A Horizon

Creek Water

Soil Amendments

Creek: CBM Blend

Water Amendments

Water & Soil Amendments

Bt1 Horizon

Treatments

SAR (mmol\(^{1/2}\) L\(^{-1/2}\))

Creek Water

Soil Amendments

Creek: CBM Blend

Water Amendments

Water & Soil Amendments
Soil SAR

SAR (mmol/L\textsuperscript{1/2})

Treatments

Baseline, CBM, gypsum soil, CBM, gypsum inject water, sulfur water, CBM, gypsum inject water, sulfur water, gypsum soil, CBM creek blend 50:50, Creek
Conclusions

- CBM - Elevated sodium concentrations and SAR values in first two soil horizons
- Creek water or blend – No difference
- Combination of water and soil treatments most effective for reducing Na and SAR
Cooperative Agreement:
No. DE-NT0005681

- WRI submitted to NETL in June 2008

Regarding RFP DE-PS26-08NT00209-00: Environmental and Unconventional Oil – Technology Solutions for Oil and Gas Resource Development

Under CFDA No. 81.089 Fossil Energy Research and Development.

- Accepted August 2008
Funded in September 2008

~2-year project

Effects of Irrigating with Treated Oil and Gas Product Water on Crop Biomass and Soil Permeability
MWH Americas, Inc. – Fort Collins, CO

Poudre Valley Environmental Sciences, Inc. – Fort Collins, CO
1. Assess RO and EDR as viable treatment technologies for CBM and conventional oil and gas produced water.

2. Determine optimal blends of treated/untreated produced water for irrigation with regards to good crop quality/health and soil permeability.
Treat CBM and conventional oil/gas produced water using pretreatment (as necessary) and RO and EDR.

Use various blends of treated/raw water to irrigate crop species in 2 soils from production areas in Wyoming.

Use same blends to irrigate soil columns with 1, 2, and 3 year’s worth of water.
1. Project Management Plan (accepted)
   Technology Status Assessment (accepted)

2. Experimental & analysis plan development (in progress)

3. Conduct irrigation experiments

4. Data analysis and final report
Task 3

1. Lease greenhouse space at UW facility (completed).

2. Collection of soil, water, and plant seeds.
Pretreat with DAF and organo-clay filtration (organics)
Reverse Osmosis (inorganics)
**Task 3.3 (cont)**

Electrodialysis Reversal (inorganics)

\[
2e^- + 2 \text{H}_2\text{O} \rightarrow \text{H}_2 + 2 \text{OH}^- \\
\text{H}_2\text{O} \rightarrow 2 \text{H}^+ + \frac{1}{2} \text{O}_2 + 2e^- \\
\]

Cathode (-)

- 2e-
- 2H2
- 2OH-
- 2Na+
- SO4^{2-}

Anode (+)

- 2e-
- ½ O2
- 2H+
- 2Na+
- SO4^{2-}

E-stream

C-stream (Concentrate)

D-stream (Product)

E-stream

C-stream Feed

D-stream Feed

Courtesy EET Corporation

www.eetcorp.com
Irrigate crop species (i.e., alfalfa & western wheatgrass) planted in representative soils from production areas in Wyoming in greenhouse with blends of treated/untreated water.

Endpoints: Tissue chemistry & health/forage quality.
Irrigate soil cores with blends of treated/untreated water (1, 2, & 3 season’s worth of water).

Endpoints: Soil/leachate chemistry & soil hydraulic conductivity.
Task 3.3 (cont)

- Air inlet tube
- Water column (25”)
- Air bubbles
- Soil/water interface
- Soil column (12”)
- Decreasing water level
- Level of constant head pressure
- Leachate collection
Questions/Comments/Advice?