Reducing Nitrogen Removal Uncertainty for Operation of Mississippi River Sediment Diversions: Nitrate Reduction Rates In Turbulent Flow Conditions

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Between 1932 and 2016, Louisiana lost 4833 km² (1866 mi²) of coastal land.

Wetland loss rate: \( \sim 30 \text{ km}^2 \text{ yr}^{-1} \) (11.6 mi²)
Sea Level Rise + Subsidence

- Global sea level rise: 3.2 mm each year
- Relative sea level rise: 10 mm per year

Current rates of marsh accretion are not sufficient to maintain pace with relative sea level rise
Sediment Diversions

- Divert sediment from the Mississippi river to coastal wetlands
- Can build new land and aid existing wetlands
Concern: Nitrate Loading

- Will deliver significant amounts of nitrate, possibly degrading water quality in receiving basins
- 1.5 million metric tons
- $5 billion+ devoted to diversions
Fate of Nitrate?

A paucity of data on nitrate reduction rates near diversion outfall

- Where turbulent conditions and sediment suspension occurs

Objective:
Determine rates and spatial variability of nitrate reduction in turbulent surface water environments
Study Site: Wax Lake Delta

- A 12,000 acre growing delta on the coast of Louisiana
- Receives diverted sediment from the Atchafalaya river
- Sediment delivery to the delta is similar to sediment delivered by diversions

Adapted from NASA
Sampling Design

• Three sites in the mudflats of Wax Lake Delta

• Twelve intact cores collected at each site
  - Nine for evaluating nitrate reduction under turbulent conditions
  - Three for soil physiochemical analysis
Gust Erosion Microcosm System (GEMS)

- Mimics shear stress conditions on core surface sediment
- Manipulates shear stress by controlling spinning rate of erosional heads on the water column of sediment cores
Experimental Design

Three levels of shear stress:

- 0.45 Pa (High; proximal diversion flows)
- 0.2 Pa (Medium; distal diversion flows)
- 0 Pa (Zero)

- 10 cm water column of a 2 mg L\(^{-1}\) NO\(_3\)-N solution

- Solution circulated through cores for 24 hours; water samples collected every 2 hours
Experimental Design

Cores with 0 shear stress:

- Flooded with a 2 mg L⁻¹ NO₃⁻N solution
- Samples were collected over 24 hours to measure NO₃⁻ loss
# Results: Soil Characteristics

<table>
<thead>
<tr>
<th>Soil Parameter</th>
<th>Site 1</th>
<th>Site 2</th>
<th>Site 3</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture Content (%)</td>
<td>47.3 ± 4.71</td>
<td>57.2 ± 6.57</td>
<td>41.8 ± 3.28</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Bulk Density (g cm⁻³)</td>
<td>0.62 ± 0.14</td>
<td>0.45 ± 0.10</td>
<td>0.79 ± 0.11</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Total Carbon (g kg⁻¹)</td>
<td>10.1 ± 1.70</td>
<td>14.1 ± 3.93</td>
<td>8.17 ± 0.92</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Total Nitrogen (g kg⁻¹)</td>
<td>0.87 ± 0.10</td>
<td>1.30 ± 0.34</td>
<td>0.78 ± 0.06</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Total Phosphorus (g kg⁻¹)</td>
<td>566 ± 44.08</td>
<td>714 ± 174.23</td>
<td>543 ± 36.7</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Extractable NH₄⁺ (mg kg⁻¹)</td>
<td>7.33 ± 1.5</td>
<td>12.6 ± 3.11</td>
<td>6.52 ± 0.82</td>
<td>&gt;0.05</td>
</tr>
</tbody>
</table>
Results: Nitrate Reduction Under Turbulent Conditions

Nitrate reduction significantly increased with increasing shear stress/turbulence.
Nitrate reduction rates were:

• **10x** higher for medium (0.2 Pa) stress conditions
• **16x** higher for high (0.45 Pa) stress conditions

Significant increases in nitrate reduction can occur by turbulent conditions.

Nitrate reduction rates observed were among the highest ever recorded in coastal Louisiana.
Summary: Turbulent Conditions

Provide increased interaction between microbes in the sediment and nitrate in the water column

Aerobic (obligate aerobes)

Anaerobic (facultative aerobes)
Implications

• Sediment resuspension from diversions increases nitrate reduction rates

• Reduction rates are likely to increase closer to the diversion outfall

• N removal will be spatially variable and depends upon shear stress applied by diverted water

If studies in do not account for the sediment resuspension, calculated rates of nitrate reduction are likely to be underestimated.
Acknowledgements

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Thank You!