Modeling Land Application of Food-Processing Wastewater in the Central Valley, CA

G. Miller¹, Y. Rubin¹, P. Benito¹, J. McLaughlin¹, Z. Hou², S. Hermanowicz¹, K.U. Mayer³

¹Civil and Environmental Engineering, University of California-Berkeley
²Geology, State University of New York-Buffalo
³Earth and Ocean Sciences, University of British Columbia

http://hilmarsep.com
Food Processing Wastewater in the Central Valley

- Over 600 facilities
- >$62 billion in revenue
- Water use: 80 million m³ yr⁻¹
- High in salinity (FDS), organic carbon, and nitrogen
- Typical disposal method: land application for irrigation
- Discharged to alluvial fan and floodplain deposits
## An Environmental Threat?

<table>
<thead>
<tr>
<th>Metric</th>
<th>Municipal Waste</th>
<th>Tomato Canner</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD (mg-O₂ L⁻¹)</td>
<td>450</td>
<td>820</td>
</tr>
<tr>
<td>FDS (mg L⁻¹)</td>
<td>720</td>
<td>1680</td>
</tr>
<tr>
<td>pH</td>
<td>6.7</td>
<td>5.4</td>
</tr>
<tr>
<td>Nitrogen (mg-N L⁻¹)</td>
<td>25</td>
<td>51</td>
</tr>
<tr>
<td>Flow Rate (gal d⁻¹)</td>
<td>2.6 x 10⁷</td>
<td>1.5 x 10⁶</td>
</tr>
<tr>
<td>Pathogens present?</td>
<td>Virtually certain</td>
<td>Very unlikely</td>
</tr>
</tbody>
</table>

Sources: food, disinfectants, processing chemicals
Groundwater Degradation?

Winery Example
1300 acres

Fixed Dissolved Solids (mg/L)

Nitrate (mg/L)
Regulating Food Processing Waste

- Study itself product of legal settlement
- Protect California’s environment, economy, or both?
  - Regulators vs. industry?
  - Water resources vs. economy? (Porter-Cologne Act)
- All agree on need for regulations based on science
  - What is the natural attenuation capacity of the soil?
  - Is there a safe agronomic rate for salinity application?
  - What discharge management processes are effective?
  - How do the economic costs of land application compare to those of the alternatives?
Modeling Challenges

• Very Large Scale
  – 600+ producers with a diversity of wastewater characteristics and application site hydrogeology

• Attenuation Processes
  – Condition specific rates, strong potential for interaction

• Data Deficiency
  – Few measurements in vadose zone, none long-term

• Disparate systems
  – Required complexity different for vadose and saturated zones
Modeling Strategy

Address diversity of sites and waste streams

Develop and implement model of waste attenuation

Run groundwater model to determine extent of degradation

Use “transfer functions” to describe UZ/SZ connection

Address diversity of sites and waste streams

Develop and implement model of waste attenuation

Run groundwater model to determine extent of degradation

Use “transfer functions” to describe UZ/SZ connection
### Land Application Conceptual Model

<table>
<thead>
<tr>
<th>Root zone</th>
<th>Root water uptake</th>
<th>Plant nutrient uptake</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Land application + precipitation + irrigation</td>
<td>Nitrogen, organic carbon, and salts from waste water</td>
</tr>
<tr>
<td>Unsaturated Zone</td>
<td>Root water uptake</td>
<td>Plant nutrient uptake</td>
</tr>
<tr>
<td>(MIN3P)</td>
<td></td>
<td>Ion exchange</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mineral dissolution/precipitation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Degradation of organic matter</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nitrification/denitrification</td>
</tr>
<tr>
<td>Saturated Zone</td>
<td>Groundwater flow</td>
<td>Mass loading to water table</td>
</tr>
<tr>
<td>(GMS)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Soil gas exchange with atmosphere**: $O_2$, $CO_2$, $N_2$
## Vadose Zone Model Scenarios

- 12 scenarios – 4 industries, 3 cases
- Best/worst case for nitrogen, saturation dependent
- Simulations implemented in MIN3P numerical code

<table>
<thead>
<tr>
<th>Case</th>
<th>Soil Saturation</th>
<th>Waste water composition</th>
<th>Best/worst?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>High for anaerobic (0.9 – 0.99)</td>
<td>High: NH$_4^+$, CH$_2$O, FDS Low: NO$_3$</td>
<td>Worst for NH$_4^+$</td>
</tr>
<tr>
<td>2</td>
<td>Low for aerobic (0.4 – 0.5)</td>
<td>High: NO$_3$+NH$_4^+$, FDS Low: CH$_2$O</td>
<td>Worst for NO$_3^-$</td>
</tr>
<tr>
<td>3</td>
<td>Moderate for mixed (0.8 – 0.9)</td>
<td>Low: CH$_2$O, FDS, NH$_4^+$, and NO$_3$ low relative to CH$_2$O</td>
<td>Best for both</td>
</tr>
</tbody>
</table>
Applied Waste Concentrations

Winery Waste Water Footprint

Waste Components
- Calcium (Ca\(^{2+}\))
- Magnesium (Mg\(^{2+}\))
- Potassium (K\(^{+}\))
- Sodium (Na\(^{+}\))
- Ammonium (NH\(_4\)\(^{+}\))
- Manganese (Mn\(^{2+}\))
- Zinc (Zn\(^{2+}\))
- Copper (Cu\(^{2+}\))
- Iron (Fe\(^{2+}\))
- Carbonate (CO\(_3\)\(^{2-}\))
- Phosphate (PO\(_4\)\(^{3-}\))
- Sulfate (SO\(_4\)\(^{2-}\))
- Chloride (Cl\(^{-}\))
- Nitrate (NO\(_3\)\(^{-}\))
- pH
- Labile organic carbon (CH\(_2\)O)
Example Transfer Functions

[Graphs showing changes in NO₃, NH₃, FDS, and CH₂O over time for Case 1, Case 2, and Case 3.]
Comparison to Groundwater Data

Case 1: 2400 mg L$^{-1}$

Case 2: 1400 mg L$^{-1}$

Case 3: 1300 mg L$^{-1}$

Case 1 & Case 3: Non-detect

Case 2: 18 mg-N L$^{-1}$
Degradation of Groundwater

- Layer 2

Layer 3
Conclusions

• Attenuation condition dependent, not necessarily sustainable
• Attenuation processes contributing most were dependant on the contaminant
• “Safe agronomic rate” questionable for FDS
• Lateral migration in groundwater limited
• Need for increased vadose zone monitoring and characterization
• Modeling can provide tool for policy makers, but does not offer definitive solution