DAIRY MANURE TREATMENT & NUTRIENT RECOVERY

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OBJECTIVES

- Research and develop novel waste-to-resource technologies capable to convert organic wastes into value-added fuel and chemical products
- Fulfill commercialization and technology transfer of new waste-to-resource concepts
- Educate the next generation of engineers, scientists and policymakers on waste utilization design and practice

Anaerobic Digestion Research and Education Center (ADREC)
Manure Management Challenges & Opportunities
Recent Headlines

• Yakima, WA
  • 5 dairies
  • Lawsuit over groundwater contamination
  • Finding that manure is considered a solid waste when not beneficially

• Lake Erie
  • Blue-green algae blooms
    • Phosphorus is the trigger
    • Nitrogen impacts toxicity
  • City of Toledo water supply contaminated
Carbon Footprint of Milk

17.6 lb CO$_2$e/gal

51.5% at the farm
## Nutrient Value of Manure (per cow)

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Production (lb/cow/yr)</th>
<th>Potential Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen (N)</td>
<td>223-260</td>
<td>$174</td>
</tr>
<tr>
<td>Phosphorus (P$<em>{2}$O$</em>{5}$)</td>
<td>40-69</td>
<td>$32</td>
</tr>
<tr>
<td>Potassium (K$_{2}$O)</td>
<td>88-146</td>
<td>$88</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>$294</strong></td>
</tr>
</tbody>
</table>

Nutrient and Fertilizer Value of Dairy Manure

[https://www.uaex.edu/publications/PDF/FSA-4017.pdf](https://www.uaex.edu/publications/PDF/FSA-4017.pdf)
The U.S. Dairy Industry is at a Critical Juncture

Current State

- Increasing regulatory and societal pressure about manure management
- Litigation
- Surface and ground water issues related to nitrogen and phosphorus in the wrong places
- Erosion in consumer trust

Desired State

- Dairy farms help resolve societal issues related to water pollution and GHG emissions
- Producers realize economic benefits from voluntary actions
- Dairy industry improves social license to operate and increases consumer trust

Source: Innovation Center for U.S. Dairy & Newtrient, LLC
Nutrient Recovery

Dissolved Air Flotation

Thermal Conversion

Belt Press

Clarification
Nutrient Recovery System

Legend
- Manure
- Concentrate
- Filtrate
- Recycle ($Q_R$)
Significant Research & Development
Nutrient Recovery System

Coarse Solid – Liquid Separation

Liquid Manure

QR

Coarse Fiber
## Coarse Solid-Liquid Separation Approaches in the U.S. ($/cow)

<table>
<thead>
<tr>
<th>Technology</th>
<th>Performance</th>
<th>OPEX</th>
<th>CAPEX</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary &amp; Secondary Mechanical Screens</td>
<td>15 – 30%</td>
<td>15 – 25%</td>
<td>$5 – 6</td>
<td>$32 – 36</td>
</tr>
</tbody>
</table>

*Frear, C. 2013. Review of Nutrient Recovery Technologies*
Nutrient Recovery System

- Coarse Solid – Liquid Separation
- Fine Solid – Liquid Separation
- Coarse Fiber
- Fine Solids & Phosphorus
- Effluent Filtrate
  Tea Water

\( Q_R \)
Fine Solid-Liquid Separation

• Why
  • Phosphorus limited
  • Reduced truck traffic or cost
  • Field distance
  • Desire to irrigate
  • Nutrient market opportunity

• Solids use
  • Soil amendment & fertilizer
  • Compost
Fine Solid-Liquid Separation

• Phosphorus, organic nitrogen & colloidal solids are target
  • Phosphorus separation >70%
• Particle sizes less than 250 micron
  • As fine as 0.01 micron
• Technologies:
  • Sequential separators
  • Chemical additions
    • Belt filter presses
    • Dissolved air floatation
  • Clarifiers
  • Ultrafiltration
Membrane Separation Technologies

MF – micro
UF – ultra
NF – nano
RO – reverse osmosis

Membrane Technology Comparison

http://www.kochmembrane.com/Learning-Center/Technologies.aspx
Fine Solids Products
# Fine Solid-Liquid Separation Approaches in the U.S. ($/cow)

<table>
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<tr>
<th>Technology</th>
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<th>OPEX</th>
<th>CAPEX</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequential Screening + Advance Non-Chemical</td>
<td>24 – 30%</td>
<td>50-65%</td>
<td>$25 – 50</td>
<td>$57 – 136</td>
</tr>
<tr>
<td>Sequential Screening + Advance Chemical</td>
<td>45 – 55%</td>
<td>75 – 90%</td>
<td>$25 – 75</td>
<td>$130 – 150</td>
</tr>
<tr>
<td>Struvite Crystallization</td>
<td>30%</td>
<td>75%</td>
<td>$90 – 110</td>
<td>$100 – 150</td>
</tr>
</tbody>
</table>

Frear, C. 2013. Review of Nutrient Recovery Technologies
Nitrogen Recovery

• Why
  • Application restrictions
  • Desire to irrigate
  • Nutrient market opportunity

• Technology
  • Air stripping
    • Temp, pH & ammonia concentration sensitive
  • Biological conversion

• Product use
  • Nitrogen gas or fertilizer
  • Low nutrient water

http://nsspo.com/p1/Nitrification.htm
### Nitrogen Recovery Approach in the U.S. ($/cow)

**Frear, C. 2013. Review of Nutrient Recovery Technologies**

<table>
<thead>
<tr>
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<th>Performance</th>
<th>OPEX</th>
<th>CAPEX</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia Stripping</td>
<td>65 – 85%</td>
<td>85 – 90%</td>
<td>$100 – 190</td>
<td>$450 – 650</td>
</tr>
</tbody>
</table>
Nutrient Recovery System

Legend
- Manure
- Concentrate
- Filtrate
- Recycle ($Q_R$)
Salt (Water) Recovery Technology

MF – micro
UF – ultra
NF – nano
RO – reverse osmosis

http://www.kochmembrane.com/Learning-Center/Technologies.aspx
## Clean Water Approach in the U.S. ($/cow)

<table>
<thead>
<tr>
<th>Technology</th>
<th>Performance</th>
<th>OPEX</th>
<th>CAPEX</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salt Recovery</td>
<td>85 – 95%</td>
<td>$500–1,000</td>
<td>$1,500–1,800</td>
<td>Commercial</td>
</tr>
</tbody>
</table>

Frear, C. 2013. Review of Nutrient Recovery Technologies
Products & Markets

- Manure Solids Bedding
- Compost
- Manure Composite Boards
Products & Markets
Products & Markets

Nutrient Recovery System

Anaerobic Digestion

Coarse Solid – Liquid Separation

Fine Solid – Liquid Separation

Nitrogen Recovery

Salt Recovery

Water

Legend

- Manure
- Concentrate
- Filtrate
- Recycle (QR)
Raw vs. Digested Dairy Manure
Nutrient Recovery Advancing Quickly
Where do we stand today

- Manure application costs inexpensive
- Social pressure extremely high
- Manure handling & storage practices consistent
- Nutrient recovery technologies
  - Commercially viable technologies available
  - Capital and operational costs are high
  - Nutrients do not go away, still require management
  - Systems can be developed to address site specific needs
- Markets for products not yet developed
“Newtrient is excited to be a driver of positive change in the emerging industry of dairy manure use and management. By serving as a catalyst advancing new technologies, practices, products and markets, we help generate profits for farmers, while at the same time preserving and enhancing the environment.”

http://www.newtrient.com/#/Home/
Technology Advancement Process Steps

1. Catalog
   Catalog of existing technologies

2. Business information request
   Tech Providers share information and insights with Newtrient regarding their company and technologies

3. Technology information request
   Phone interviews to gain deeper insights into specific technologies

4. On-site visits
   TAT member(s) visits “showcase” installation(s) to conduct due diligence (e.g., Throughput, mass balance, economics)

5. Compile & assess and synthesize
   Information will be compiled, assessed and synthesized into catalogs

6. Informed decisions
   A 9-Point Criteria helps Newtrient make informed decisions
Questions?

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