Farm Based Anaerobic Digestion & Nutrient Recovery

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Concentrated CAFO Regions

Due to expense of transporting liquid manure, soils nearby to some CAFOs have become over-burdened with phosphorus, nitrogen, and/or salts (USDA APHIS, 2005). Some regions now report levels in excess of national and state standards for PM 2.5 air quality, surface P, and groundwater nitrate.
Meanwhile, worldwide consumption of inorganic nitrogen is increasing and nearing present production capacity, while fuel and fertilizer cost parallel each other in elevation. Meanwhile, studies report a future peak phosphorus below world demand.
Benefits of AD

Anaerobic digestion has been shown at the commercial-scale to lead to odor reduction, waste stabilization, pathogen reduction, and GHG emission reductions. Beyond these benefits, the AD process is also of interest to dairy operations because the methane (CH$_4$) rich biogas can be used to generate electricity and heat.
Economics of AD

AD of dairy manure is economically viable given certain scale and received electrical sale prices. The practice of co-digestion can have a large impact as shown by Frear et al. (2011) in a Lynden WA case-study, with revenues nearly QUADRUPLING as compared to manure-only baseline and substrates contributing, either directly or indirectly, 72.3% of all receipts.

~ 4 cows per KW or 110 ft$^3$ biogas/cow per day
Nutrients and AD

Anaerobic digestion does **NOT** reduce the mass of total N and P within the manure stream, it only in-part mineralizes organic N and P to inorganic forms, ammonia and phosphate, respectively. Fiber separation removes only a fraction of the nutrients, representing roughly 10-20% of N and 5-20% of P depending upon manure and screening.

**per cow per year basis**

<table>
<thead>
<tr>
<th></th>
<th>Influent</th>
<th>Effluent</th>
<th>Post-Fiber</th>
<th>Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tons Solid</td>
<td>3.3</td>
<td>1.9</td>
<td>1.3</td>
<td>-61%</td>
</tr>
<tr>
<td>Pounds N</td>
<td>336</td>
<td>336</td>
<td>276</td>
<td>-18%</td>
</tr>
<tr>
<td>% Ammonia</td>
<td>50</td>
<td>67</td>
<td>69</td>
<td>+38%</td>
</tr>
<tr>
<td>Pounds P</td>
<td>58</td>
<td>58</td>
<td>49</td>
<td>-16%</td>
</tr>
</tbody>
</table>

**Flow Diagram**

- Anaerobic Digester
- Fiber Separation
- Lagoon Storage
Incorporation of dedicated nutrient recovery systems within farms and AD systems is an important next step given the growing demand for fertilizer, its increasing price and future scarcity, and need for export of excess nutrients from CAFOs.
Impact and Importance

Large CAFOs (EPA definition) produce annually nearly 170 million dry tons of manure. Factoring in known concentrations of N and P within respective animal manures (ASAE, 2005) yields annual productions on large CAFOs of nearly 9.5 million tons N and 1.6 million tons P, representing 5.8 and 1.0% of the dry mass fractions, respectively. With mean annual US consumption of N and P inorganic fertilizers being roughly 12 and 2 million tons, respectively (US ERS, 2012) large CAFO manure streams then represent 79 and 84% of total demand.
Approach Choice

Phosphorus Removal
• Screens/Settling
• Decanting Centrifuge
• Polymer Flocculation
• Struvite Crystallization
• Biological

Nitrogen Removal
• Nitrification/De-nitrification
• Annamox
• Membranes
• Traditional Ammonia Stripping
WSU/DVO Approach

DVO (Chilton, WI) has licensed the technology and is presently commercially demonstrating at two sites in the US (Dairy—Lynden WA; Poultry—Fort Recovery OH)

Pros
- Ammonia Stripping with Settling
- N and P recovery combined
- No tower, no media blocked by solids
- No chemical input for pH

Cons
- Still need acid for ammonia product
- Ammonia product is solution
- P-solids difficult to naturally dewater
- Longer retention time, energy input
P-Solids Settling after Aeration

Area below black line is mass of small solids that still remain in solution after AD, fiber separation and 2 days settling (containing over 80% of the phosphorus in the AD effluent). Area below red line is mass of solids that remain in solution after aeration and three days settling. Area between is amount of solids and P that settle out thanks to aeration.
Ammonia Salt Product

After 18 hour micro-aeration at 140°F, the resulting stripped gases are sent to a two-stage acid contact tower for reaction to form ammonium salt solution. Several acids could be used for the process with pluses/minus for each as highlighted below:

<table>
<thead>
<tr>
<th>Product Information</th>
<th>Conc. (%)</th>
<th>Fertilizer</th>
<th>Density (g/mL)</th>
<th>$/MT solution (^a)</th>
<th>$ Sales/MT N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonium Sulfate (NH(_4))(_2)SO(_4); 132 MW</td>
<td>38</td>
<td>8:0:0:9(S)</td>
<td>1.22</td>
<td>$161</td>
<td>2,013</td>
</tr>
<tr>
<td>Ammonium Nitrate NH(_4)NO(_3); 80 MW</td>
<td>57</td>
<td>20:0:0</td>
<td>1.27</td>
<td>$283</td>
<td>1,415</td>
</tr>
</tbody>
</table>

\(^a\) Bulk retail price of solid product converted to solution value based on concentration of product

<table>
<thead>
<tr>
<th>Cost of Acid</th>
<th>$/MT acid</th>
<th>MT acid/MT N</th>
<th>$ Acid cost/MT N produced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulfuric Acid (93%) 98 MW</td>
<td>210</td>
<td>3.76</td>
<td>790</td>
</tr>
<tr>
<td>Nitric Acid (98%) 63 MW</td>
<td>350</td>
<td>2.30</td>
<td>805</td>
</tr>
</tbody>
</table>
Commercial Demonstration 1

Vander Haak Dairy in Lynden WA is home to the first commercial demonstration and application to a dairy AD practicing active co-digestion. Constructed late fall 2011, beta-testing and trouble-shooting through Spring 2012.

Target Reductions
- 70% Ammonia Removal
- 80% Phosphorus Removal
- 50% Total Nitrogen Removal

Ammonium Sulfate Product
- 450 gallon/day of 40% solution
- 8:0:0:9S fertilizer on dry values

Phosphorus Solids Product
- 2 tons/day wet product (70% moisture)
- 3:3:2:3Mg:4Ca:1Fe fertilizer (dry)
Wenning Poultry is home to the first commercial demonstration and application to poultry AD operation (1 million caged layer). Constructed Spring 2012, beta-testing and trouble-shooting through Fall 2012.

Figure 3: Left—CH$_4$ production as factor of TAN concentration and use of AD effluent as reclaim water (i.e. 20:20:60 refers to 20% seed, 20% AD effluent, 60% fresh water); Right—Schematic for W$_1$ dilution water
Demonstration Issues

- Optimizing correct aeration retention time, aeration rate, and temperature during continuous flow to remove high percentage of ammonia from manure at reduced energy and time.
- Control production of foam
- Suitable AD system heat recovery systems to supply adequate heat needs from engine waste heat
- Sequence of treatment steps for optimization of solids removal, ammonia production and product quality
- Operation of acid towers for consistent, high quality, high percentage ammonia salt product at neutral pH
- Cost effective solids harvest and dewatering
- Noise control
- Determination of preferred equipment (pumps, aerators, valves, blowers, etc.)
Contacts

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