Digestate - Maximizing its Value and Use

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On-Farm Anaerobic Digestion Research Project

Anna Crolla – Alfred College June 2015
Anna’s Project Objectives

- Monitor on-farm digesters and evaluate digestate quality and digester performance
- Evaluate whether current digester design standards (i.e. minimum retention time, temperature, and volatile solids reduction) are appropriate for ensuring sufficient anaerobic digestion
- Determine whether operational and output-based methods can be alternatives to the current 20-day HRT requirement
- Compare Ontario digester operation standards with other jurisdictions

On-Farm Anaerobic Digestion Research Project

Evaluating digestate quality to maximize energy production
Anna’s Preliminary Data Results

• FOS/TAC and acetic acid concentrations are good indicators of possible digester upset
• Reduction of solids ranges between 50 to 70% (wet basis) in digester system – which is typical for digester systems
• 1 to 2 log reduction in bacteria indicators (*E.coli* and *Salmonella*)
• *Salmonella* typically present in lower concentrations
• Digester monitoring is on-going at all digester systems in study
Project Outcomes
More Questions:

• Compare digestate quality to raw untreated manure

• Identify the most significant variables that influence anaerobic digester treatment performance

• Identify which parameters are most suitable indicators of minimum anaerobic digestion treatment (e.g. HRT, VS reduction, VFAs, etc.)

• Identify other parameters that may be suitable to measure anaerobic digestion treatment
Digestate use for Agriculture Land

- **Sources**
  - Farm - manure-based with additions
  - Municipal – food waste plus additions

- **Advantages of Agricultural Digestate Use:**
  - Composition will vary with inputs – nutrient testing is important
  - Good balance of available crop nutrients
  - Opportunity for liquid -solid separation (additional opportunities)
  - Lower odour and pathogens relative to manure
  - Ideal for spring/ in-crop application

Evaluating digestate quality to maximize crop production benefits/minimize environmental impact
Maximizing the Benefit of Digestate:

- Nutrient benefit
  - What to test for
- Soil Health benefits
- Environmental considerations
  - Runoff
  - Leaching
  - Preferential flow
  - Ammonia loss
    - Infield & Storage
  - Application timing

Anaerobic Digestion is promoted for reducing Greenhouse gas emissions

Good digestate management will further enhance the GHG mitigation benefits
What an Agricultural Analysis Looks like

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>ANALYSIS RESULT</th>
<th>POUNDS PER 1,000 GAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Matter</td>
<td>2.8 %</td>
<td></td>
</tr>
<tr>
<td>Nitrogen (Total)</td>
<td>0.442 %</td>
<td></td>
</tr>
<tr>
<td>NH4-N</td>
<td>3.095 ppm</td>
<td>30.9</td>
</tr>
<tr>
<td>Phosphorus (Total)</td>
<td>0.0683 %</td>
<td></td>
</tr>
<tr>
<td>Phosphate (P as P2O5) **</td>
<td>0.1525 %</td>
<td>15.2</td>
</tr>
<tr>
<td>Potassium (Total)</td>
<td>0.0684 %</td>
<td></td>
</tr>
<tr>
<td>Potash (K as K2O) **</td>
<td>0.0797 %</td>
<td>8.0</td>
</tr>
<tr>
<td>Organic Matter *</td>
<td>1.9 %</td>
<td></td>
</tr>
<tr>
<td>Carbon:Nitrogen Ratio (C:N)</td>
<td>2 : 1</td>
<td></td>
</tr>
<tr>
<td>Sulfur</td>
<td>3.345 ppm</td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>8.00 ---</td>
<td></td>
</tr>
<tr>
<td>Conductivity (@ 25 deg C)</td>
<td>17.72 ms/om</td>
<td></td>
</tr>
<tr>
<td>Sodium</td>
<td>0.07 %</td>
<td>7.3</td>
</tr>
<tr>
<td>Aluminum</td>
<td>145.4 ppm</td>
<td></td>
</tr>
<tr>
<td>Boron</td>
<td>1.0 ppm</td>
<td></td>
</tr>
<tr>
<td>Calcium</td>
<td>0.1249 %</td>
<td>12.5</td>
</tr>
<tr>
<td>Copper</td>
<td>3.3 ppm</td>
<td></td>
</tr>
<tr>
<td>Iron</td>
<td>654.4 ppm</td>
<td></td>
</tr>
<tr>
<td>Magnesium</td>
<td>0.0105 %</td>
<td>1.1</td>
</tr>
<tr>
<td>Manganese</td>
<td>4.4 ppm</td>
<td></td>
</tr>
<tr>
<td>Zinc</td>
<td>9.8 ppm</td>
<td></td>
</tr>
</tbody>
</table>

Helps determine macro and micro nutrient content - reduce commercial fertilizer needs - and helps determine best management.
Maximizing the Benefit of Digestate - Nutrients

Need to know the nutrient composition of the material using lab analysis

Pre AD = liquid dairy → Post AD = liquid hog

<table>
<thead>
<tr>
<th>Nutrients</th>
<th>Liquid1</th>
<th>Available kgs/m³</th>
<th>Liquid2</th>
<th>Available kgs/m³</th>
<th>Solid</th>
<th>~Available kgs/tonne</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Matter (%)</td>
<td>2.8</td>
<td></td>
<td>4.0</td>
<td></td>
<td>26.3</td>
<td>263</td>
</tr>
<tr>
<td>Total Nitrogen (%)</td>
<td>0.44</td>
<td>2.2</td>
<td>0.36</td>
<td>1.8</td>
<td>0.75</td>
<td>2.6</td>
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<tr>
<td>Ammonium-N (%)</td>
<td>3085</td>
<td></td>
<td>2062</td>
<td></td>
<td>2435</td>
<td></td>
</tr>
<tr>
<td>Total Phosphorus (%)</td>
<td>0.07</td>
<td>1.2</td>
<td>0.04</td>
<td>0.74</td>
<td>0.36</td>
<td>6.6</td>
</tr>
<tr>
<td>Total Potassium (%)</td>
<td>0.07</td>
<td>0.72</td>
<td>0.27</td>
<td>2.9</td>
<td>0.45</td>
<td>4.9</td>
</tr>
<tr>
<td>Magnesium (ppm)</td>
<td>100</td>
<td>0.1</td>
<td>500</td>
<td>0.5</td>
<td>2700</td>
<td>2.7</td>
</tr>
<tr>
<td>Sulphur (ppm)</td>
<td>335</td>
<td>0.34</td>
<td>284</td>
<td>0.3</td>
<td>1185</td>
<td>1.2</td>
</tr>
<tr>
<td>Calcium (ppm)</td>
<td>1250</td>
<td>1.25</td>
<td>1,400</td>
<td>1.4</td>
<td>8100</td>
<td>8.1</td>
</tr>
<tr>
<td>Zinc (ppm)</td>
<td>10</td>
<td>0.01</td>
<td>15</td>
<td>0.02</td>
<td>51.3</td>
<td>0.05</td>
</tr>
<tr>
<td>pH</td>
<td>8.0</td>
<td>7.8</td>
<td>8.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C:N ratio</td>
<td>2:1</td>
<td>4:1</td>
<td></td>
<td></td>
<td>15:1</td>
<td></td>
</tr>
<tr>
<td>Organic matter (%)</td>
<td>2</td>
<td>20</td>
<td>2.7</td>
<td>27</td>
<td>20.8</td>
<td>208</td>
</tr>
<tr>
<td>Conductivity (EC) ms/cm</td>
<td>17.7</td>
<td></td>
<td>16.4</td>
<td></td>
<td>4.72</td>
<td></td>
</tr>
<tr>
<td>Sodium (ppm)</td>
<td>700</td>
<td>0.7</td>
<td>900</td>
<td>0.9</td>
<td>1400</td>
<td>1.4</td>
</tr>
</tbody>
</table>
Maximizing the Benefits of Digestate – Soil Health

• Nutrients provide food for soil micro-organisms
• Microbial populations aid nutrient cycling
• Small source of carbon even after AD process
• Synergistic effect with cover crops for improving soil quality
Different Amendments provide Different Benefits to Soil

Organic amendments provide a variety of food for a diverse soil microbial population.
Diversity benefits the soil

- Sugars
- Cellulose
- Proteins
- Hemicellulose
- Polyphenols
- Lignin
- Humus

Bacteria

Actinomycetes

Cover crops
Digestate
Manure
Compost
When inputs or losses are changed, SOM quantity changes to a different level and a new steady state condition is reached.
Impact of Rain on Poor Structured Soils
Impact of Rain on Poor Structured Soils
Corn-Soybean Rotation
Conventional Tillage

Aggregate Stability in soil: The glue that holds the soil together

Long term sod
no tillage
Environmental considerations

- Runoff
- Leaching
- Preferential flow
- Ammonia loss – storage & in-field
- Timing of application
Digestate Application Management

Uniform application with narrow spacing application or shallow injection
- Increases infiltration into soil - reduces movement below root zone

Lower organic matter = ↓ viscosity & ↑ moisture content
- Increases risk of runoff / preferential flow to tile

Depending on AD feedstocks used, digestate often has a high pH with high ammonium-N (NH$_4^-$N) content
- Requires injection / incorporation / in-crop application to reduce NH$_4^-$N loss (volatilization)

Any late-summer / fall application should include cover crops to enhance nutrient uptake/ reduce leaching risk.
- Ammonium-N converts to nitrate-N which moves with water = below root zone during non growing season (leaching)
Phosphorus Losses from Application

- Ammonia volatilization & soil N > crop needs can contribute to ↑ N₂O emissions
- Late summer applied digestate: soil microorganisms convert NH₄-N to NO₃-N
- NO₃-N (nitrate) moves with water
- Light soils = ↑ leaching risk and heavy soils = ↑ denitrification risk
- Fall/winter season = in high risk of NO₃-N movement below the root zone

Spring injected Liquid Digestate = 23 lbs/1000 gal available N (2.3 kg/m³)
Late Summer injected Liquid Digestate = 10 lbs/1000 gal available N (1.0 kg/m³)

Difference = N lost below root zone or denitrified in saturated soils
Using NMAN3
Phosphorus (P) in the Winter Landscape

Zone of soil-water interaction (1-5 cm)

Infiltration / percolation?

Rain/Snow Melt

Particulate P from eroded soil particles

Dissolved P from soil solution

Surface Runoff

Tile Flow
Fall Applied Liquid & Solid Digestate with Cover Crop

Ammonium-N Loss from Liquid and Solid Digestate After Aug 19 application with Oat Cover Crop

Higher rates = takes longer for infiltration to occur
Losses are highest when digestate is “pooled” on soil surface

- Check – no application
- High rate liquid
- medium liquid
- low liquid
- High rate Solid
- low Solid

Days after application
Dosimeter Reading ppm/hr
Ammonia Loss – Average of Surface Application and Injected Digestate
August 19 – Sept 8, 2015

- Difference in N loss between injected and surface applied
  - N loss for surface applied >80%
  - N loss for injected ~20%
Comparing Ammonia Loss Trends – Injected and Surface Applied Manure to Digestate

- **R² = 0.8138**
- **R² = 0.8001**
- **R² = 0.8277**
- **R² = 0.8265**

**Dosimeter Readings (ppm/hr)** vs. **Hours After Application**

- **Check**
- **Injected digestate**
- **Surface digestate**
- **Surface manure**
- **Injected manure**
N Losses from Application

- Ammonia volatilization & soil N > crop needs can contribute to ↑ N₂O emissions
- Late summer applied digestate: soil microorganisms convert NH₄-N to NO₃-N
- NO₃-N (nitrate) moves with water
- Light soils = ↑ leaching risk and heavy soils = ↑ denitrification risk
- Fall/winter season = in high risk of NO₃-N movement below the root zone

Spring injected Liquid Digestate = 25 lbs/1000 gal available N (2.5 kg/m³)
Late Summer injected Liquid Digestate = 11 lbs/1000 gal available N (1.0 kg/m³)
(no cover crop)

Difference = N lost below root zone or denitrified in saturated soils
Using NMAN3
Method of Application – Deep or Shallow Injection

Goal: Rapid infiltration of digestate into soil and uniform distribution through the soil profile

Spring Soil Inorganic Nitrogen Content
Spring (May 24th – June 28th)

- Summer Application
- Fall Application
- Spring Application

Soil Inorganic Nitrogen (kg ha\(^{-1}\))

- Check
- Deep injection
- Shallow injection

N lost below root zone?

Deep Injection concentrates digestate in a narrow band ~ 15-20 cm below soil surface

Research from Dr. J Lauzon, U of Guelph

Manure Application Method
Minimizing the Ammonia Loss from Storages

- Digestate - often high pH; high ammonia/ammonium
- Low solids content – no crusting
- Varying temperatures in storage
- Above 20°C air temp increases risk of ammonia loss
Minimizing the Ammonia loss from Storages

Potential solutions: **Reducing Ammonia loss**

- Cover storage to capture methane/ammonia
- Simulate “crust” (i.e. chopped straw, floating balls, etc.)
- Backfill around storage
- Shading

<table>
<thead>
<tr>
<th>Cover</th>
<th>Ammonia loss reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straw</td>
<td>25 – 85 %</td>
</tr>
<tr>
<td>Geotextile</td>
<td>0 – 45 %</td>
</tr>
<tr>
<td>Oil</td>
<td>85 %</td>
</tr>
<tr>
<td>Natural crust</td>
<td>10 – 90 %</td>
</tr>
<tr>
<td>Floating Plastic</td>
<td>95 %</td>
</tr>
</tbody>
</table>

*English and Fleming, 2006*
Opportunities - Combining Digestate with Composting

Challenge:
- Liquid Digestate application is limited to growing season
- Late fall/winter/early spring production requires a lot of storage
- Digestate is relatively low in soil organic matter (SOM)
- To maintain current SOM levels (~2.5%) it would require about 25,000 gallons/ac (250 m³/ha) every year (= nutrient overloading)

Opportunity?
- Separate the digestate solids
- Mix in carbon source to meet ideal C:N and moisture levels
- Compost for:
  - wider application window
  - lower storage costs
- ~15 ton/ac (17 T/ha) /year to maintain SOM
Summary: BMPs for Digestate Management

To maximize nutrient and organic matter value of Digestate:

**Right rate**
- Frequent analysis for nutrient content (including pH)
- Calibrate equipment to apply the rate that meets crop needs
- Uniform application

**Right field**
- Select crop that needs the nutrients
- Ensure soil conditions maximize infiltration / minimize runoff

**Right application timing**
- Apply in spring or into growing crops
- Don’t apply in fall without a cover crop

**Right placement**
- Rapid incorporation/injection to minimize ammonium-N volatilization
- Avoid concentrated deep placement to minimize leaching /movement to tile

**Right storage management**
- Promote crusting during warm season
- Permanent cover helps eliminate storage losses
Application in 20 cm spacings with Dribble bar