Anaerobic Digestion of Dairy Manure: Implications for Nutrient Management Planning

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Brian Aldrich
Manure Management Program
Dept. of Biological & Environmental Engineering

Cornell University
Plug-flow Digester
Anaerobic digestion is not new. What is new is it’s application to animal waste management on a large scale.
“We are just at the beginning of the methanogenic era.”

Prof. William Jewell,
Dept. of Biological & Environmental Engineering
Cornell U. - Sept. ’04
Definition of Anaerobic Digestion

• Anaerobic digestion is a microbial oxidation process which occurs in the absence of oxygen, and converts organic carbon to methane and carbon dioxide (a mixture called “biogas”).
Benefits of Anaerobic Digestion

• Odor control
• Pathogen kill
• Weed seed kill
• Biogas → heat digester + other uses
• Improved consistency for liquid-solid separation
• Electricity production (optional)
Advantages of Treated Manure with Less Odor for CNMP Planning

• Can be spread in summer on hay with fewer complaints from neighbors.
• “Summer’ means drier soil, less runoff.
• Near immediate crop uptake.
• Summer application may mean access to steeper or wetter fields.
• May be able to spread on fields previously unavailable for spreading, due to proximity to neighbors.
Spring Application of Digested Manure on Corn Ground with Spray Gun
Summer Application of Manure to Hay with a Draghose
Composting of Separated Solids
Diesel Engine
Retrofitted to run on biogas
Generator

(Diesel “gen-set”)
Combined heat and power ("CHP") systems both:

1. Combust biogas to produce electricity
2. Capture heat from the engine block
Heat is captured from the engine block using a heat exchanger, and used to heat the manure in the digester.
Heat Exchanger

cold fluid in

warm fluid in

cooled fluid out

warmed fluid out

Precision Graphics
Definition of Volatile Solids

“Those solids in water or other liquids that are lost on ignition of the dry solids at 550° centigrade.”

In anaerobic digestion, “volatile solids” are the fraction of the manure solids that are easily converted into biogas. (The organic fraction.)
“Hydraulic Retention Time” (HRT) is the time it takes manure to pass through the digester.
Three Microbial Populations

1. Hydrolysis
   - Extracellular enzymatic breakdown of complex organic molecules (produces sugars, fatty acids, amino acids)

2. Acid fermentation
   - Intracellular conversion of above products into organic acids

3. Methane fermentation
   - Methanogens that are obligate anaerobes use organic acids to produce CH$_4$, CO$_2$, H$_2$S, NH$_4$
What’s in Biogas?

- ~ 40% carbon dioxide
- ~ 60% methane
- + trace elements, including hydrogen sulfide (highly caustic!)
Biogas Produced from One Cow per Day

- **Raw Manure**: 100 lbs.
- **87 lbs. Water**
- **13 lbs. Total Solids**
- **11 lbs. Volatile Solids (Available for biogas production)**
- **2 lbs. Ash**
- **4 lbs converted to biogas**
- **7 lbs. not converted to biogas**

Potential for producing biogas

Efficiency of most digesters for producing biogas
Take-Home Message #1:

• Anaerobic digestion alone does not result in a large decrease in mass!
  – Aside from the effluent, the only way for mass to leave the digester is in the form of biogas.
  – Typically ~ 5% reduction in mass left to return to cropland
Implication for CNMP Planners:

• Even with anaerobic digestion, you still have a lot of “stuff” (mass, nutrients) to find a home for!!

• The remaining solids are usually separated from the liquids post-digestion. Planners need to find out what is done with those solids:
  – Spread on cropland?
  – Composted and exported off the farm?
  – Recycled as bedding?
Take-Home Message #2:

• If a farm is considering a digester, it is extremely important that the appropriate phosphorus index be calculated for all fields on the farm.

• Whole-farm P balance

• Need to make sure that the farm has an adequate land base for spreading manure (or a plan to export nutrients if it does not).
What happens to N-P-K in the digester?

- Influent and effluent samples were taken from three digesters over a period of two years
- ~ monthly intervals
- Analyzed for Total N, Total P, Ammonia-N and Ortho-P
Sampling raw manure from transfer pit prior to digestion ("influent")
Sampling digested manure from the exit end of the digester ("effluent")
Take-Home Message #3:

- The total amounts of N and P remain about the same!
- But there is a shift from organic to inorganic forms (comparing digester influent to effluent)
  - 37% more N in the ammonia form
  - 26% more P in the Ortho-P form
Percent Increase in Ammonia and Ortho-P in Digested Dairy Manure
Can digester effluent nutrient values be applied directly to crop fertility recommendations?

The answer is no because …..
Take-Home Message #4: Manure goes from the digester to **storage**!
Things that can happen to digested manure in storage:

- Untreated manure may bypass the digester, going directly to the storage.
- Washwater may be pumped directly to the storage.
- Gaseous loss processes may continue ...
- Does treated manure activated with methanogens stimulate methane production in the storage? *(We don’t know.)*
Take-Home Message #5:

- To make crop fertilizer recommendations, manure samples are still needed from the storage and/or from the manure application equipment as close as possible to the time of spreading.
Implications of the Shift Towards Ammonia

- If manure tests from the storage or the manure application equipment bear out an increase in the ammonia fraction, then the need for rapid incorporation to minimize volatile losses of N will be even more significant.
- Presidedress Soil Nitrate Test
Nutrient management plans for farms with digesters that accept food waste need to include food waste P imports in the whole-farm P balance.
Cornell Manure Management Program

Brian Aldrich
David Belcher
Jean Bonhotal
Curt Gooch
Scott Inglis
Norman Scott

www.manuremanagement.cornell.edu

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