Bunker Silage Storage
Leachate and Runoff
Management

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Feed Storage Leachate Studies

UW Biological Systems Engineering (Dr. Rebecca Larson and Michael Holly)
• 3 locations: Arlington Agricultural Research Station, Dairy Forage Research Center and private dairy bunker
• Total combined runoff monitored
• Monitored October 2011 to October 2012 (no wintertime monitoring)
• Discrete sample protocol to characterize individual storms

UW Discovery Farms
• 3 locations: 3 private dairy bunkers
• Both leachate collection system and overflow to VTA monitored separately
• Monitored October 2012 to December 2014 (with wintertime monitoring)
• Discrete and composite sample protocol to focus on annual loading trends
Leachate

(Silage) leachate – liquid produced in feed storage systems from compaction and ensilage of harvested crops.
Leachate Production Based on Dry Matter Content


**Recommended harvest moisture**
- 65 - 70% Corn Silage
- 60 - 65% Hay Silage

(Haigh, 1999)
Timing of Leachate Production

Patterns of effluent production. Silage DM content (g kg\(^{-1}\)): ——— 158; —— 182; ———— 219

Mc Donald 1981, Referencing Bastiman 1976
Runoff

(Feed storage) runoff – precipitation induced flow from feed storage systems as a result of rain/snowmelt contacting stored feed, litter, and spoilage piles; essentially “diluted leachate”.
### What is in leachate and runoff?

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Liquid Dairy Manure&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Leachate&lt;sup&gt;2&lt;/sup&gt;</th>
<th>Feed Storage Runoff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Matter</td>
<td>5%</td>
<td>5% (2-10%)</td>
<td>0 - 5%</td>
</tr>
<tr>
<td>Total N (mg/L)</td>
<td>2,600</td>
<td>1,500-4,400</td>
<td>20 – 1,400</td>
</tr>
<tr>
<td>P (mg/L)</td>
<td>1,100</td>
<td>300-600</td>
<td>8 - 660</td>
</tr>
<tr>
<td>K (mg/L)</td>
<td>2,500</td>
<td>3,400-5,200</td>
<td>n/a</td>
</tr>
<tr>
<td>pH</td>
<td>7.4</td>
<td>3.6-5.5</td>
<td>4 - 7</td>
</tr>
<tr>
<td>BOD (mg/L)</td>
<td>5,000-10,000</td>
<td>12,000-90,000</td>
<td>500 - 61,000</td>
</tr>
</tbody>
</table>

<sup>1</sup>Clarke and Stone 1995  
<sup>2</sup>Cornell 1994
Edge of Field vs Feed Storage Water Comparison

Average Rainfall Becoming Runoff

- Edge of Field
- Feed Storage

- 0%
- 20%
- 40%
- 60%
- 80%
- 100%
Edge of Field vs Feed Storage
Phosphorus Comparison

Average Annual Phosphorus Yield

Edge of Field (lbs/acre)  Feed Storage (lbs/acre)

Edge of Field

Feed Storage

0 2 4 6 8 10

0 200 400 600 800 1,000
Edge of Field vs Feed Storage Nitrogen Comparison

Average Annual Nitrogen Yield

- Edge of Field
- Feed Storage

Edge of Field (lbs/acre):
- 0
- 5
- 10
- 15
- 20
- 25
- 30

Feed Storage (lbs/acre):
- 0
- 500
- 1,000
- 1,500
- 2,000
- 2,500
- 3,000
Collection System Design

Current System Design (NRCS Code 629)

- Capture all leachate
- Capture 1st flush runoff
  - Engineered based on urban runoff system design
  - Percent collected based on feed storage area and VTA sizing
- 25-year/24-hour storm diversion

Future system design

- EPA has expressed concerns to DNR about current operation/design of VTAs meeting WPDES “no discharge” requirements
- More efficient alternative systems?
Collection System Design

Objectives

• Comply with “no discharge” requirement while minimizing storage and handling costs

- Total containment up to a 25-year, 24-hour storm event

  vs.

- Collect high concentration liquid
- Modify VTA design/operation of VTA, if possible
Collection Designs are Numerous
Does a First-Flush Exist?

(Taebi & Droste, 2004)
Normalized Phosphorus Data

Farm A Normalized Events - TP

Event Load

Event Volume

0% 20% 40% 60% 80% 100%

0% 100%
Normalized Phosphorus Data

Farm B Normalized Events - TP

Event Load

Event Volume

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Normalized Phosphorus Data

Farm C Normalized Events - TP

Event Load

0% 20% 40% 60% 80% 100%

Event Volume

0% 20% 40% 60% 80% 100%
First flush prevalence compared to urban definitions (all farm data combined):

<table>
<thead>
<tr>
<th></th>
<th>Strict (80/30)$^a$</th>
<th>Moderate (40/20)$^b$</th>
</tr>
</thead>
<tbody>
<tr>
<td>TP</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>TKN</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>0%</td>
<td>0%</td>
<td>3%</td>
</tr>
</tbody>
</table>

$^b$ Deletic (1998)

TPn = 116, TKNn = 118
Why doesn’t first flush exist?

Runoff concentrations are highly dependent on flow

Influenced by contact and residence time with stored feed, feed litter, and spoilage piles
Concentration-flow Relationship

Concentration-flow Relationship

Concentration-flow Relationship

Concentration-flow Relationship

All constituents reacted similarly

Constituent Correlations

- All constituents (TP, TDP, TKN, Conductivity, COD, TS) were statistically correlated EXCEPT pH which was least correlated and inversely proportional

- This would allow for real-time monitoring of a constituent to determine collection or no collection
## Nutrient Speciation

<table>
<thead>
<tr>
<th></th>
<th>TP (lbs)</th>
<th>TDP</th>
<th>TKN (lbs)</th>
<th>Ammonia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L1</td>
<td>1,204</td>
<td>93%</td>
<td>4,412</td>
<td>37%</td>
</tr>
<tr>
<td>L2</td>
<td>1,106</td>
<td>89%</td>
<td>4,550</td>
<td>24%</td>
</tr>
<tr>
<td>Farm B</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L3</td>
<td>283</td>
<td>91%</td>
<td>1,029</td>
<td>32%</td>
</tr>
<tr>
<td>L4</td>
<td>1,480</td>
<td>85%</td>
<td>5,893</td>
<td>23%</td>
</tr>
<tr>
<td>Farm C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L5</td>
<td>13</td>
<td>88%</td>
<td>78</td>
<td>28%</td>
</tr>
<tr>
<td>L6</td>
<td>71</td>
<td>87%</td>
<td>374</td>
<td>23%</td>
</tr>
</tbody>
</table>
Annual Loading

Investigated

- Timing of loading
- Load collected vs. load to VTA
- Volume collected vs. load collected

Seasonality and a few events

- Snowmelt
- Big rains
- Filling
Total P Loading

2013 Cumulative Total Phosphorus Loading: Farm B

- Collected
- To VTA

Snowmelt


Load (lbs)

601 lbs
56 lbs
Total P Loading

2014 Cumulative Total Phosphorus Loading: Farm B

Load (lbs)

- Collected
- To VTA

Hay & Corn Silage

879 lbs

227 lbs
Design Concepts

Alternative designs
- Low Flow only
- Continuous

Current design

Time

Flow
Collection Design Comparisons

Phosphorus
- 1st flush
- Continuous
- Low flow

Nitrogen
- 1st flush
- Continuous
- Low flow

TP Collected

TKN Collected

Farm A  Farm B  Farm C
Farm A  Farm B  Farm C
Conductivity Metering

![Graph showing Conductivity Metering with various data points and lines representing Flow, Conductivity, and Concentration (mg/l).]
Collection Design Recommendations

• First flush rarely exists!
  • Not the greatest load per volume
  • Collect low flow only
  • Or continuous throughout

• Additional collection within 2 weeks of filling
Minimizing Runoff Concentrations

• **Protect** from water
  – Cover when filling if rain is forecast
  – Cover/wrap side walls
  – Cover and seal edges
  – Divert clean water away
  – Minimize exposure when feeding

• **Clean** pad (remove litter) particularly if rain event is forecast

• **Cover** spoilage and litter piles until removal
Litter and Spoilage
Ineffective covering
Key Filter Strip Design Components

• Spreader at point of discharge to filter strip

• Ensure even application across filter strip
  • Irrigation pods
  • Grade evenly (difficult to achieve, need to supervise)
  • Rock checks for spreading
    • Impermeable membrane
    • 2-4 inch round stone
    • Every 100 feet of length
Spreader at Discharge
Ineffective Rock Check
Other analysis being conducted

- Recommended loading: filter strips (Larson)
- Timing and variation of constituent loss
- Effect of feed volume and area covered

Study reports

- Technical report (March)
- Fact sheets (April)
- Extension publications (December)
Thank You!

Questions/Comments

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