Bunker Silage Storage Leachate and Runoff Management

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Bunker Silage Storage

Silage
- Fermented forage
- Forage examples
  - Corn
  - Hay
  - Sorghum
  - Other grasses
  - Legumes
  - Other forages
WI Standards

- Collection
  - Based on potential silage volume
- Filter strips
  - Based on feed storage area
  - Based on amount collected
- Certain conditions/situations may involve additional measures.

Harvest and Ensilage

Loading and Compaction
Loading and Compaction

Compaction

Ensiling Process

- 4 phases
  1. Aerobic
  2. Fermentation
  3. Stable
  4. Feed-out
1. Aerobic
• Plant and microbial respiration
• Uses sugars and oxygen
• Releases carbon dioxide, water, and heat
• Nutrient and dry matter losses
• Minimize this phase
  • Shorten filling time
  • Good compaction
  • Cover and seal quickly

2. Fermentation
• Anaerobic process
• Microbial competition for resources
• Protein breakdown
• Want lactic acid bacteria – lactic acid
  • Lowers pH
    • Limits other microbial activity
    • Reduces protein breakdown
    • Want rapid decrease in pH
• Preserves feed

3. Stable
• All sugars used up, little microbial activity
• Must remain anaerobic
  • Supports desired microbes
  • Air reactivates/supports undesired microbes
• Desired microbes
  • Preserves/stabilizes feed
  • Lactic acid bacteria
3. Stable cont.

- Undesired microbes
  - Acetic acid bacteria
  - Clostridia
  - Enterobacteria
  - Yeasts
  - Bacilli
  - Listeria
  - Molds
- Compete with desired microbes
- Causes spoilage
- Create health risks (animals and humans)

4. Feed-out

- Aerobic spoilage
  - Degradation of preserving organic acids
  - Heat – increases spoilage microorganism
- Limit exposure
- Feed-out rate should be greater than spoilage rate

Dry Weather Leachate
Leachate Production Based on Dry Matter Content

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

Timing Leachate Production

Dry Weather Leachate

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Leachate</th>
<th>Liq. Dairy Manure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Matter</td>
<td>2-10%</td>
<td>5%</td>
</tr>
<tr>
<td>Total N (mg/L)</td>
<td>1,500-4,400</td>
<td>2,600</td>
</tr>
<tr>
<td>P (mg/L)</td>
<td>300-600</td>
<td>1,100</td>
</tr>
<tr>
<td>K (mg/L)</td>
<td>3,400-5,200</td>
<td>2,500</td>
</tr>
<tr>
<td>pH</td>
<td>3.6-5.5</td>
<td>7.4</td>
</tr>
<tr>
<td>BOD (mg/L)</td>
<td>12,000-90,000</td>
<td>5,000-10,000</td>
</tr>
</tbody>
</table>

1Cornell 1994
2Clarke and Stone 1995
### Seepage

![Image of seepage](Image)

### Litter and Spoilage

![Image of litter and spoilage](Image)

### Runoff Concentrations

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Leachate&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Liq. Dairy Manure&lt;sup&gt;2&lt;/sup&gt;</th>
<th>Runoff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Matter</td>
<td>5% (2-10%)</td>
<td>5%</td>
<td>0-4.6%</td>
</tr>
<tr>
<td>Total N (mg/L)</td>
<td>1,500-4,400</td>
<td>2,600</td>
<td>20-1,356</td>
</tr>
<tr>
<td></td>
<td>300-600</td>
<td>1,100</td>
<td>8-659</td>
</tr>
<tr>
<td>P (mg/L)</td>
<td>3,400-5,200</td>
<td>2,500</td>
<td>n/a</td>
</tr>
<tr>
<td>K (mg/L)</td>
<td>3.6-5.5</td>
<td>7.4</td>
<td>4-7</td>
</tr>
<tr>
<td>BOD (mg/L)</td>
<td>12,000-90,000</td>
<td>5,000-10,000</td>
<td>500-61,210</td>
</tr>
</tbody>
</table>

<sup>1</sup> Cornell 1994

<sup>2</sup> Clarke and Stone 1995
### Sample Concentrations

<table>
<thead>
<tr>
<th>Avg.</th>
<th>pH</th>
<th>TS (%)</th>
<th>COD (mg/l)</th>
<th>TP (mg/l)</th>
<th>TDP (mg/l)</th>
<th>Ammonia (mg/l)</th>
<th>TKN (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>5.42</td>
<td>0.70</td>
<td>10,295.14</td>
<td>82.41</td>
<td>76.61</td>
<td>115.20</td>
<td>306.78</td>
</tr>
<tr>
<td>A2</td>
<td>5.29</td>
<td>0.44</td>
<td>6,449.53</td>
<td>47.47</td>
<td>42.04</td>
<td>39.49</td>
<td>182.26</td>
</tr>
<tr>
<td>C1</td>
<td>5.58</td>
<td>0.51</td>
<td>6,444.39</td>
<td>38.64</td>
<td>36.49</td>
<td>72.23</td>
<td>268.67</td>
</tr>
<tr>
<td>C2</td>
<td>5.16</td>
<td>0.37</td>
<td>4,384.90</td>
<td>32.40</td>
<td>29.95</td>
<td>39.62</td>
<td>193.42</td>
</tr>
</tbody>
</table>

### Impacts of Runoff
Impacts of Runoff

Rain Water Infiltration

Spoilage and Health Risks

- Lower quality feed
- Reduced palatability
- Reduced feed intake
- Lung damage, e.g. “silo filler’s disease”
- Allergic reactions, e.g. “farmer’s lung”
- Botulism
- Listeriosis
- Myotoxins
- Toxic gas
- Digestive problems
- Fertility problems
- Reduced immune function
- Ketosis
- Liver and kidney damage
- Abortions
- Impair milk quality
- Death
Management to Minimize Silage Storage Runoff Constituent 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

Silage Storage Collection System Design

Objectives
- Minimize collection volumes
- Reduce storage and hauling requirements
- Reduce environmental impact
  - Collect high strength waste
  - Low strength waste to treatment systems

Current System Design
- Capture the initial volume and send to storage as it has the highest concentrations
- Assumes a first flush scenario, unconfirmed
- First flush exists in urban runoff, why not here

Collection Designs are Numerous
Collection Designs

Treatment Using Filter Strips

Does a First-Flush Exist?
? 1st Flush?

Why is it that only ~10% of the events have characteristics of a 1st flush?

<table>
<thead>
<tr>
<th>% of Events</th>
<th>Linear</th>
<th>Delayed flush</th>
<th>1st flush</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>73%</td>
<td>17%</td>
<td>10%</td>
</tr>
<tr>
<td>P</td>
<td>75%</td>
<td>13%</td>
<td>3%</td>
</tr>
</tbody>
</table>

Relationship of Flow vs. Concentration

![Graph showing the relationship between flow (L/h) and COD (mg/L) over time (min).]

Constituent Correlations

- All constituent data (TKN, TP, TS, COD, BOD) was statistically correlated EXCEPT pH which was negatively correlated.
Annual Loading

- Investigate
  - Timing
  - Load collected vs. load to VTA
  - Volume collected vs. load collected

- Seasonality and a few events
  - Snowmelt
  - Big rains
  - Filling

Total TKN Loading

<table>
<thead>
<tr>
<th>Annual</th>
<th>Volume</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>~2.3 million gal.</td>
<td>3,366 lbs</td>
</tr>
<tr>
<td>Collected (% total)</td>
<td>41%</td>
<td>60%</td>
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<tr>
<th>Annual</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>~2.8 million gal.</td>
<td>5,136 lbs</td>
</tr>
<tr>
<td>Collected (% total)</td>
<td>30%</td>
<td>44%</td>
</tr>
</tbody>
</table>
### Total TKN Loading

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<thead>
<tr>
<th>Annual</th>
<th>Volume</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>~277,000 gal.</td>
<td>375 lbs</td>
</tr>
<tr>
<td>Collected (% total)</td>
<td>12%</td>
<td>16%</td>
</tr>
</tbody>
</table>

### Total P Loading

<table>
<thead>
<tr>
<th>Annual</th>
<th>Volume</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>~2.3 million gal.</td>
<td>787 lbs</td>
</tr>
<tr>
<td>Collected (% total)</td>
<td>41%</td>
<td>60%</td>
</tr>
</tbody>
</table>

### Total P Loading

<table>
<thead>
<tr>
<th>Annual</th>
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<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>~2.8 million gal.</td>
<td>1,469 lbs</td>
</tr>
<tr>
<td>Collected (% total)</td>
<td>30%</td>
<td>47%</td>
</tr>
</tbody>
</table>
Total P Loading

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<tr>
<td>Total</td>
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<td>68 lbs</td>
</tr>
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<td>15%</td>
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**Collection Design Recommendations**

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

- Additional collection within 2 weeks of filling.

**Event Loading**

|  | Flow weighted avg. | Max. | Min. | Median |
|  | pH  | TP  | TDP | Ammonia | TKN |
| A1 | 5.43 | 5.1 | 4.8 | 0.5 | 6.5 | 18.5 |
|    | 6.94 | 21.0 | 19.3 | 20.9 | 46.9 |
| Med | 5.43 | 4.1 | 3.6 | 3.2 | 15.0 |
| A2 | 5.43 | 25.8 | 23.1 | 21.9 | 59.1 |
|    | 6.94 | 88.6 | 78.3 | 75.1 | 291.2 |
| Med | 4.35 | 0.1 | 0.0 | 0.0 | 0.2 |
| Med | 5.43 | 6.7 | 5.8 | 6.8 | 27.0 |
| C1 | 5.45 | 0.2 | 0.2 | 0.2 | 1.0 |
|    | 6.77 | 0.5 | 0.4 | 1.0 | 4.9 |
| Med | 5.39 | 0.1 | 0.0 | 0.0 | 0.1 |
| C2 | 5.21 | 2.5 | 2.1 | 2.7 | 12.7 |
|    | 6.24 | 7.9 | 7.4 | 7.8 | 41.7 |
| Med | 4.60 | 0.0 | 0.0 | 0.0 | 0.2 |
| Med | 5.19 | 0.8 | 0.7 | 1.0 | 4.8 |

*Load for TP, TDP, Ammonia, and TKN are in lbs.*
Collection Design Recommendations

- All flow to single collection point
- Provide subsurface drainage
- Inspect and Maintain facilities
  - Feed storage area
  - Collection system
  - Filter strip
  - Address potential issues

Design Concepts

Low Flow Collection

- Calculated greater loading collected when collecting the low flow.
- Calculated using 1% of the peak flowrate from a 2-year 24-hour design storm.
- Peak runoff flowrates can be calculated using one of many methods, e.g. Rational Method.
  - Calculate by hand or with software, e.g. HydroCAD.
Conductivity Meter to Route High Strength Runoff to Storage

Example Event with Conductivity: COD

Key Filter Strip Design Components

- Soil profile provides treatment
- Avoid high groundwater table or shallow depth to bedrock
- Ensure even application across filter strip
  - Irrigation pods
  - Grade evenly (difficult to achieve, need to supervise)
  - Rock checks for spreading
    - Prefer in ground with impermeable membrane
    - 2-4 inch round stone
    - Every 100 feet of length
    - Lip of impermeable membrane even with ground, rocks must be rise above the lip to catch debris

Poor Grading = Little Treatment
To be continued...

- Other analysis being conducted
- Determine recommended loading for filter strips
- Better understand timing & causes of variation
- Effects of feed vol. and surface coverage
- Conductivity as a metering option
- Economics

Thank You!

Questions/Comments

http://www.uwdiscoveryfarms.org