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.

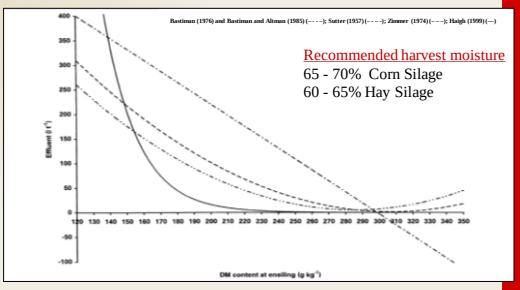
- Undesired microbes
  - Acetic acid bacteria
  - Clostridia
  - Enterobacteria
  - Yeasts
  - Bacilli
  - Listeria
  - Molds
- Compete with desired microbes
- Causes spoilage
- Create health risks (animals and humans)

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

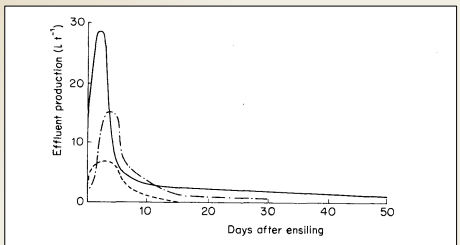
Dry Weather Leachate

Leachate Production Based on Dry Matter Content



(Haigh, 1999)

Timing Leachate Production



igure 8.4. Patterns of effluent production.[49] Silage DM content (g kg⁻¹): ——— 158; —·—·— 182; – – – – 219

Mc Donald 1981, Referencing Bastiman 1976

Dry Weather Leachate

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

[1]Cornell 1994
[2]Clarke and Stone 1995

Dry Weather Leachate

Dry Weather Leachate

Dry Weather Leachate

Corrosive - Concrete Erosion

Runoff

Snowmelt Runoff

Seepage

Litter and Spoilage

Runoff Concentrations

Constituent	Leachate[1]	Liq. Dairy Manure[2]	Runoff
Dry Matter	5% (2-10%)	5%	0 - 4.6%
Total N (mg/L)	1,500-4,400	2,600	20 - 1,356
P (mg/L)	300-600	1,100	8 - 659
K (mg/L)	3,400-5,200	2,500	n/a
pH	3.6-5.5	7.4	4 - 7
BOD (mg/L)	12,000-90,000	5,000-10,000	500 - 61,210

[1]Cornell 1994
[2]Clarke and Stone 1995

Sample Concentrations

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

Impacts of Runoff

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

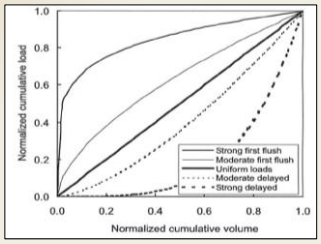
Collection Designs

Collection Designs

Collection Designs

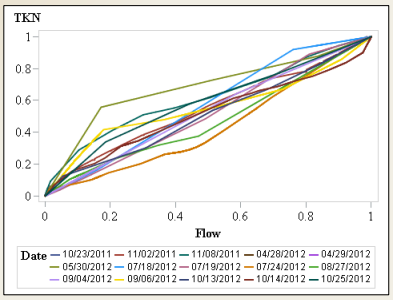
Treatment Using Filter Strips

Does a First-Flush Exist?

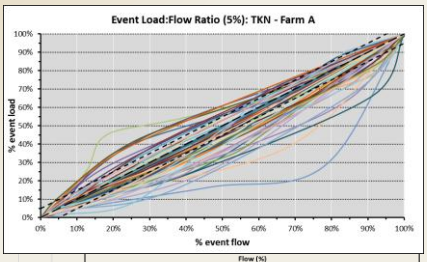


(Taebi & Droste, 2004)

Normalized Nitrogen Data

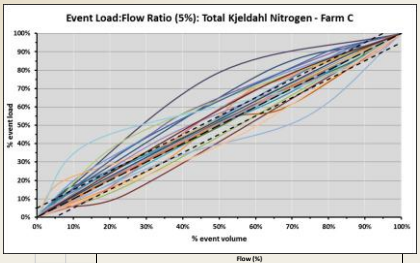


Normalized TKN Data – Farm A



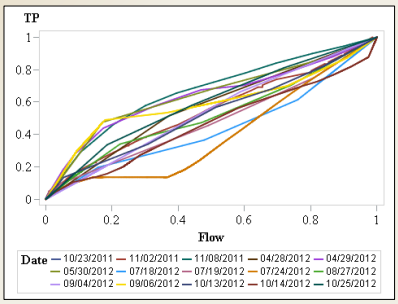
TKN - Farm A		Flow (%)									
		10		20		50		80		90	
		#	%	#	%	#	%	#	%	#	%
10%	Above	0	0%	5	10%	2	4%	0	0%	---	---
	W/in	50	100%	41	82%	36	72%	41	82%	42	84%
	Below	---	---	4	8%	12	24%	9	18%	8	16%
5%	Above	6	12%	7	14%	5	10%	2	4%	0	0%
	W/in	40	80%	25	50%	19	38%	28	56%	36	72%
	Below	4	8%	18	36%	26	52%	20	40%	14	28%

Normalized TKN Data – Farm C

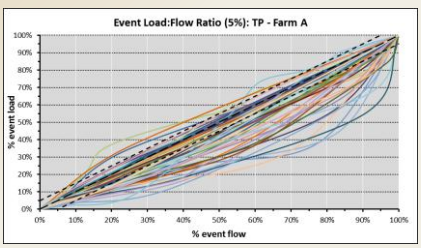


TKN - Farm C		Flow (%)									
		10		20		50		80		90	
		#	%	#	%	#	%	#	%	#	%
10%	Above	2	7%	6	21%	6	21%	3	10%	---	---
	W/in	29	100%	22	76%	22	76%	25	86%	29	100%
	Below	---	---	1	3%	1	3%	1	3%	0	0%
5%	Above	8	28%	10	34%	9	31%	8	28%	2	7%
	W/in	21	72%	17	59%	16	55%	18	62%	26	90%
	Below	0	0%	2	7%	4	14%	3	10%	1	3%

Normalized Phosphorus Data

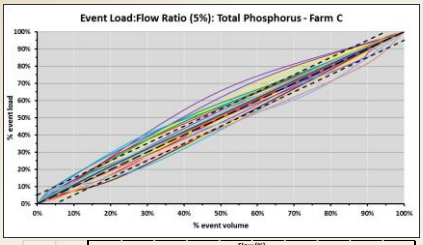


Normalized Phosphorus Data – Farm A



TP - Farm A		Flow (%)									
		10		20		50		80		90	
		#	%	#	%	#	%	#	%	#	%
10%	Above	0	0%	2	4%	0	0%	0	0%	---	---
	W/in	51	100%	44	86%	33	65%	36	71%	39	76%
	Below	---	---	5	10%	18	35%	15	29%	12	24%
5%	Above	2	4%	3	6%	3	6%	0	0%	0	0%
	W/in	46	90%	28	55%	23	45%	26	51%	31	61%
	Below	3	6%	20	39%	25	49%	25	49%	20	39%

Normalized Phosphorus Data – Farm C



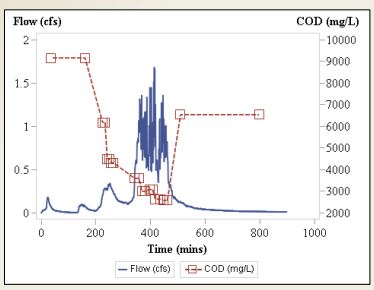
TP - Farm C		Flow (%)									
		10		20		50		80		90	
		#	%	#	%	#	%	#	%	#	%
10%	Above	0	0%	0	0%	2	7%	0	0%	---	---
	W/in	28	100%	28	100%	26	93%	28	100%	28	100%
	Below	---	---	0	0%	0	0%	0	0%	0	0%
5%	Above	2	4%	5	10%	8	16%	3	6%	0	0%
	W/in	26	93%	21	75%	17	61%	23	82%	27	96%
	Below	0	0%	2	4%	3	6%	2	4%	1	2%

? 1st Flush ?

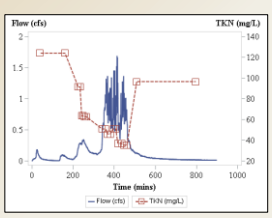
Why is it that only ~10% of the events have characteristics of a 1st flush?

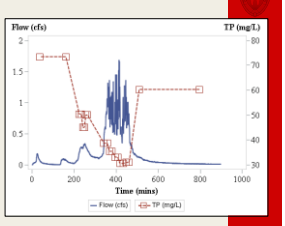
% of Events		
Linear:	73% N	(75% P)
Delayed flush:	17%	(23%)
1st flush:	10%	(3%)

Relationship of Flow vs. Concentration



Constituent Correlations



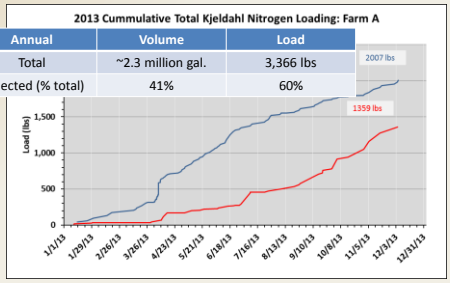


- All constituent data (TKN, TP, TS, COD, BOD) was statistically correlated EXCEPT pH which was negatively correlated

Annual Loading

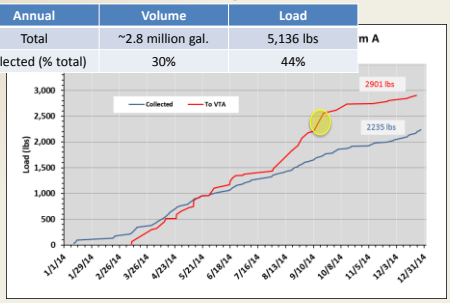
- Investigate
  - Timing
  - Load collected vs. load to VTA
  - Volume collected vs. load collected
- Seasonality and a few events
  - Snowmelt
  - Big rains
  - Filling

Total TKN Loading



Annual	Volume	Load
Total	~2.3 million gal.	3,366 lbs
Collected (% total)	41%	60%

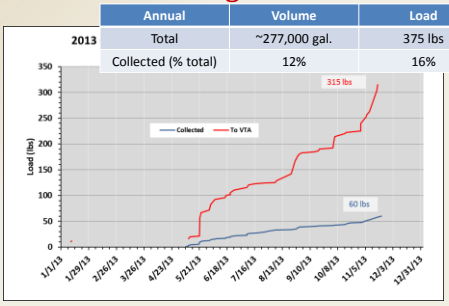
Total TKN Loading



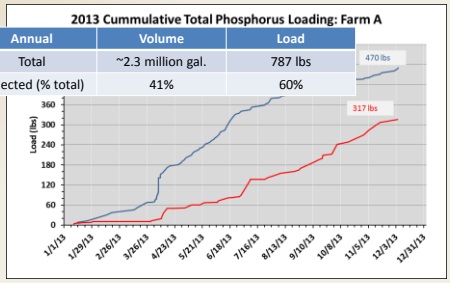
Annual	Volume	Load
Total	~2.8 million gal.	5,136 lbs
Collected (% total)	30%	44%

Total TKN Loading

Annual	Volume	Load
Total	~277,000 gal.	375 lbs
Collected (% total)	12%	16%



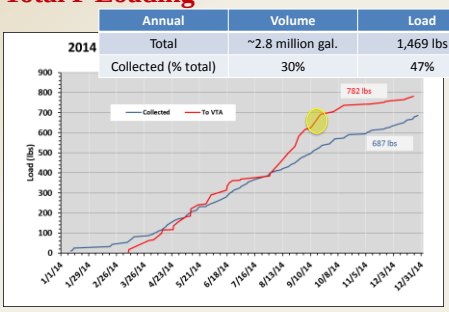
Total P Loading



Annual	Volume	Load
Total	~2.3 million gal.	787 lbs
Collected (% total)	41%	60%

Total P Loading

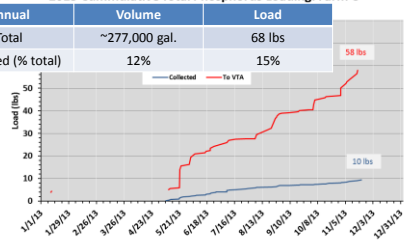
Annual	Volume	Load
Total	~2.8 million gal.	1,469 lbs
Collected (% total)	30%	47%



Total P Loading

2013 Cummulative Total Phosphorus Loading: Farm C

Annual	Volume	Load
Total	~277,000 gal.	68 lbs
Collected (% total)	12%	15%



Event Loading

		pH	TP	TDP	Ammonia	TKN
A1	Flow weighted avg.	5.43	5.1	4.8	6.5	18.5
	Max.	6.94	21.0	19.3	20.9	46.9
	Min.	4.55	0.1	0.1	0.0	0.2
	Median	5.43	4.1	3.6	5.2	15.0
A2	Flow weighted avg.	5.43	25.8	23.1	21.9	99.1
	Max.	6.94	68.6	64.8	75.1	351.2
	Min.	4.55	0.1	0.1	0.0	0.2
	Median	5.43	6.7	5.8	6.8	27.0
C1	Flow weighted avg.	5.45	0.2	0.2	0.2	1.0
	Max.	6.77	0.5	0.4	1.0	4.9
	Min.	4.31	0.0	0.0	0.0	0.1
	Median	5.39	0.1	0.1	0.2	0.8
C2	Flow weighted avg.	5.21	2.5	2.1	2.7	12.7
	Max.	6.24	7.9	7.4	7.8	41.7
	Min.	4.60	0.0	0.0	0.0	0.2
	Median	5.19	0.8	0.7	1.0	4.8

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

Collection Design Recommendations

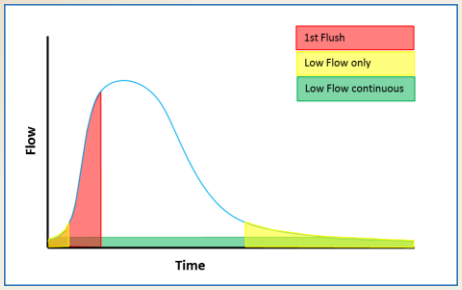
- **First flush rarely exists!**
  - Not the greatest load per volume
  - Collect low flow only
  - Or low flow throughout
- Additional collection within 2 weeks of filling.

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



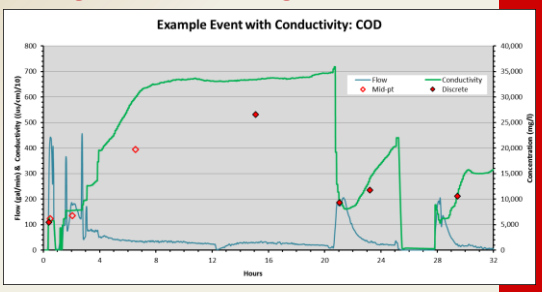
Low Flow Collection

- 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



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

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