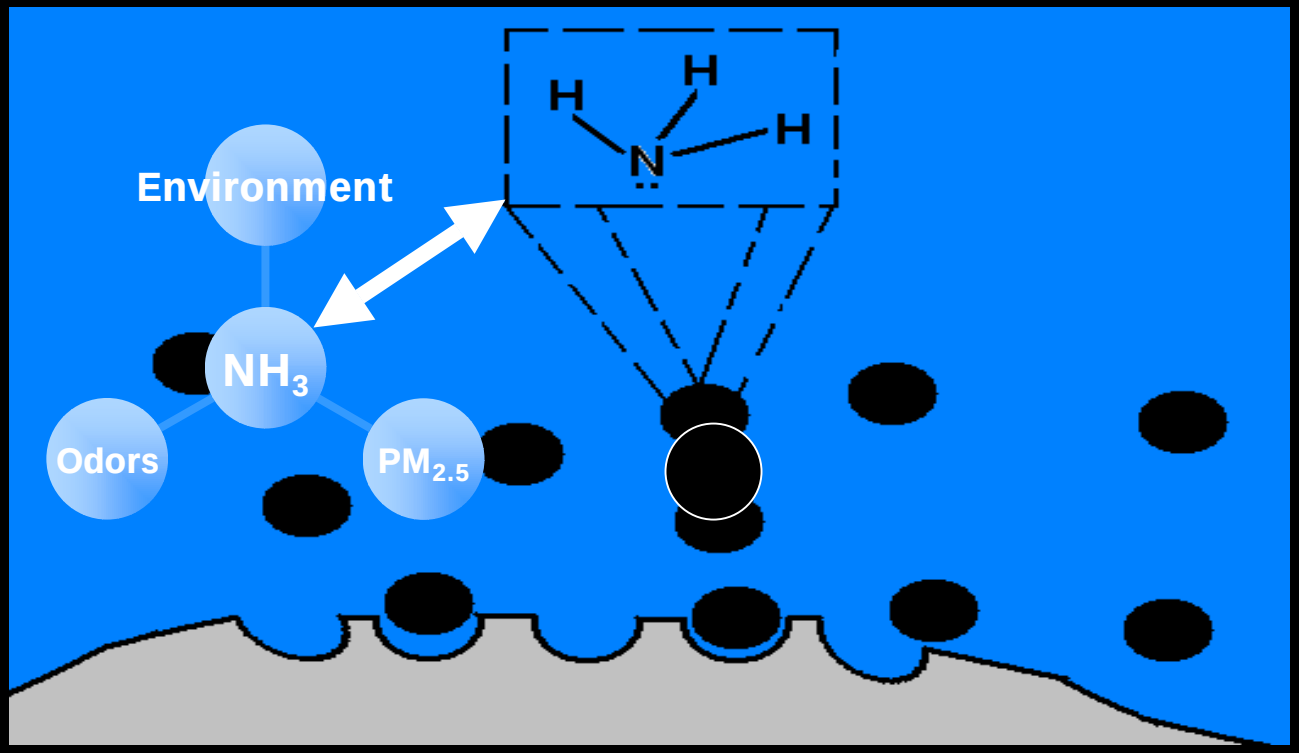
A Processes-Based Approach to Measure Ammonia from Dairy Operations Using a Flux Chamber Protocol



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Process Based?

- Laboratory studies:
  - Assess ammonia interaction with materials
  - Effects of source depletion
  - Consequences of different air flow rates, humidity and temperatures within chamber
  - Uncertainty analysis

- Field studies to assess relative contribution of ammonia from handling, storage and treatment of dairy manure (winter/summer snap shots)

Goal: Develop science-based ammonia emission factors for dairy operations

Methodology

- Stabilization of instruments
- Calibration of gases
- Optimization of analyzers
- Experimental runs
- Replications
- Flushing of chamber with clean air
- Re-calibration

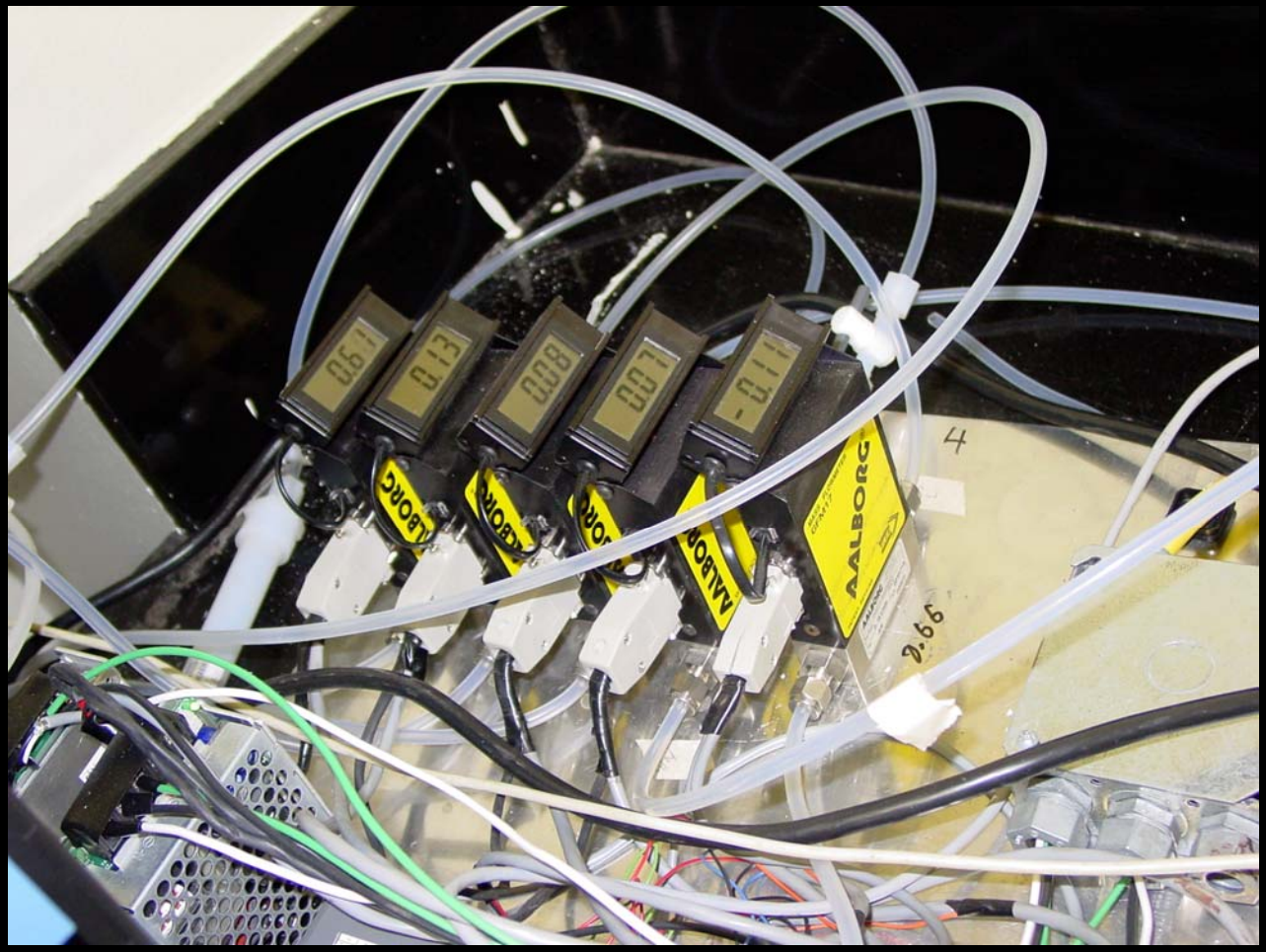
Sampling Protocol

Flux Chamber

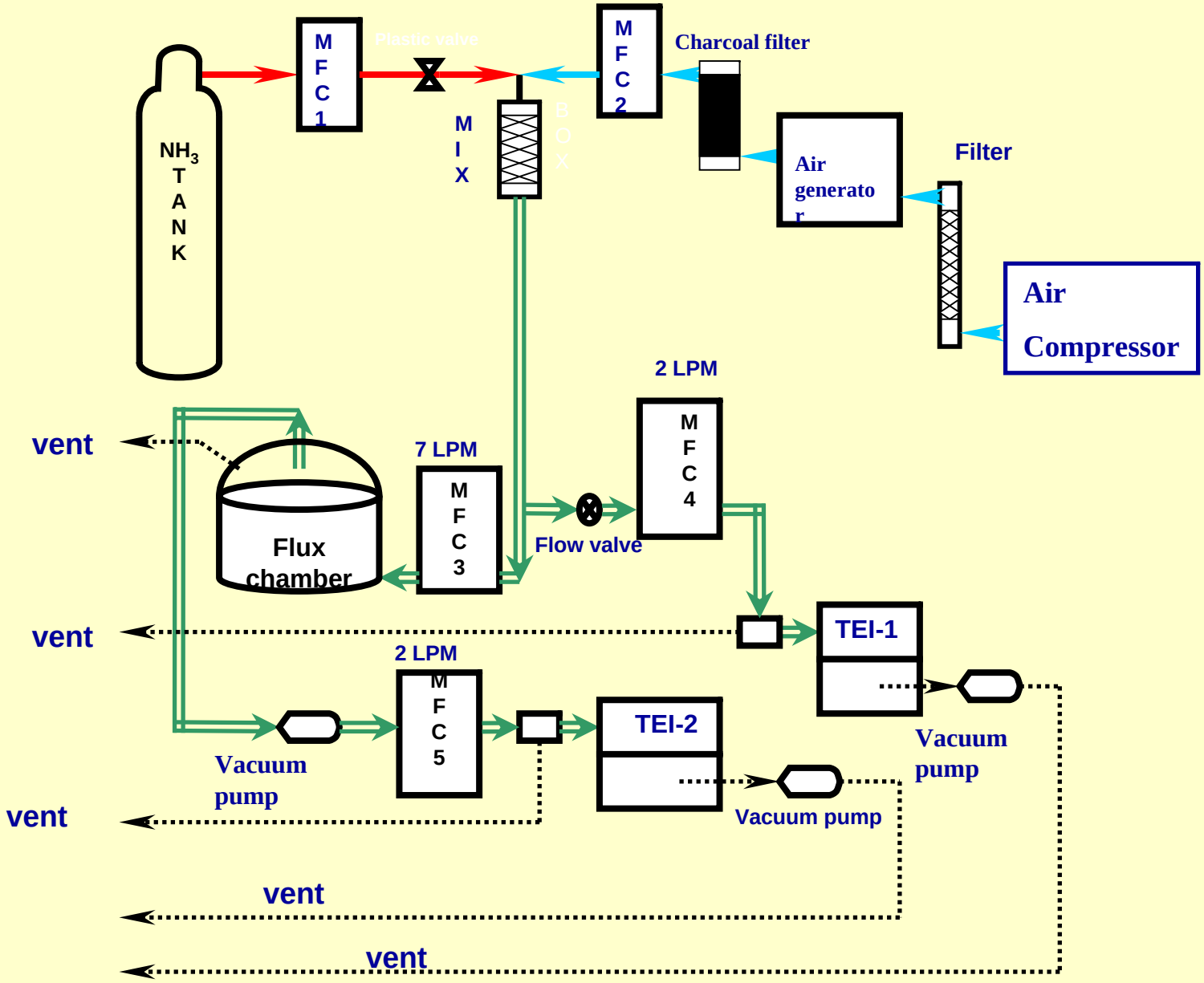
Flux Chamber, Zero Air Generator and NH_3 Analyzers

Ultra-High Purity Calibration Gases

Mass Flow Controllers



SCHEMATIC For Lab Studies



Parameters Tested In the Lab

- Response Time (60 min sampling)

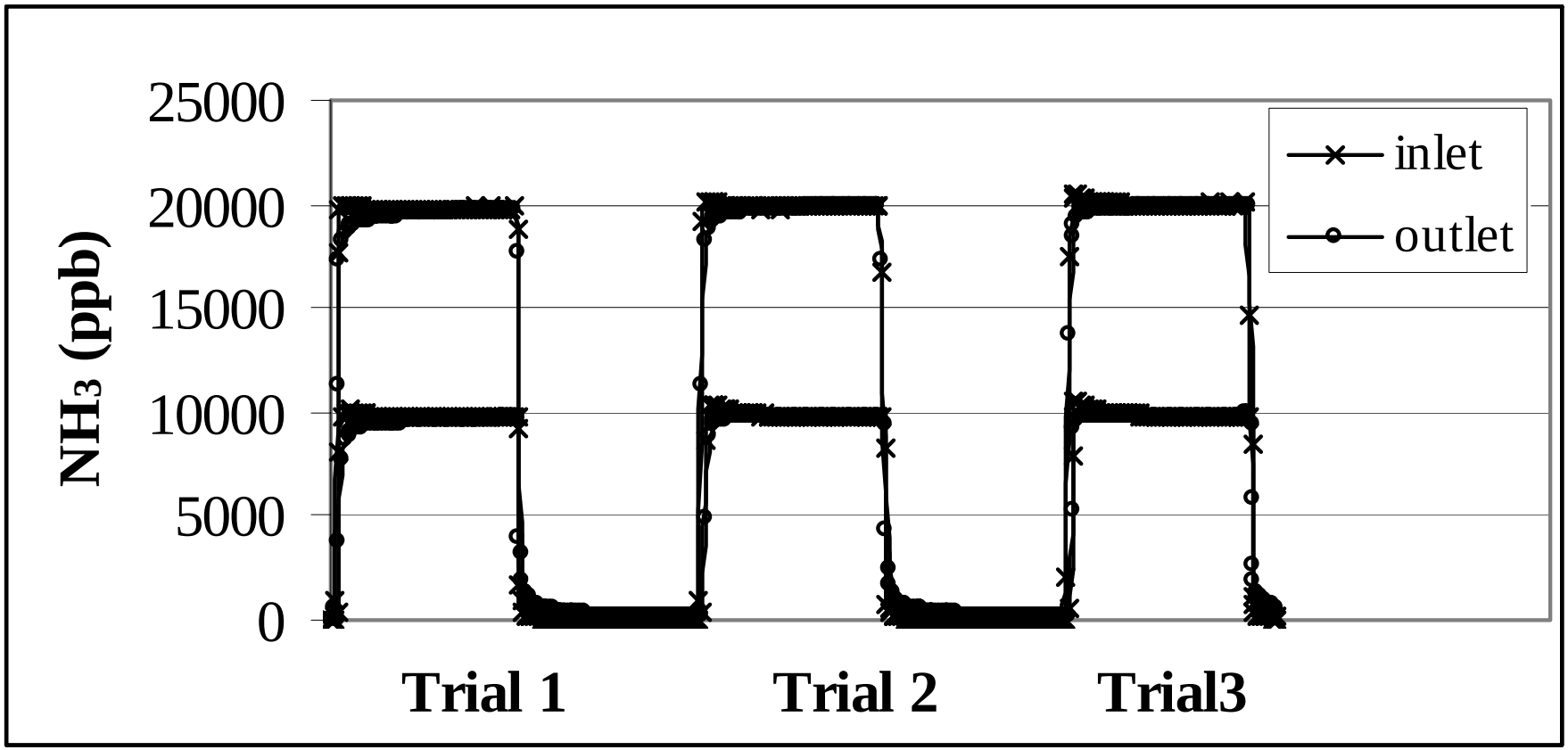
  = F (C_{in}, flow rates, material used, etc)
- Gas Emissions Recovery

  = F (varying C_{in} and flow rate at 7 lpm)
- Materials Used
  - Teflon tubing (150-300 ft, acrylic dome, stainless steel skirt)
- External factors (fixed T, RH and P)

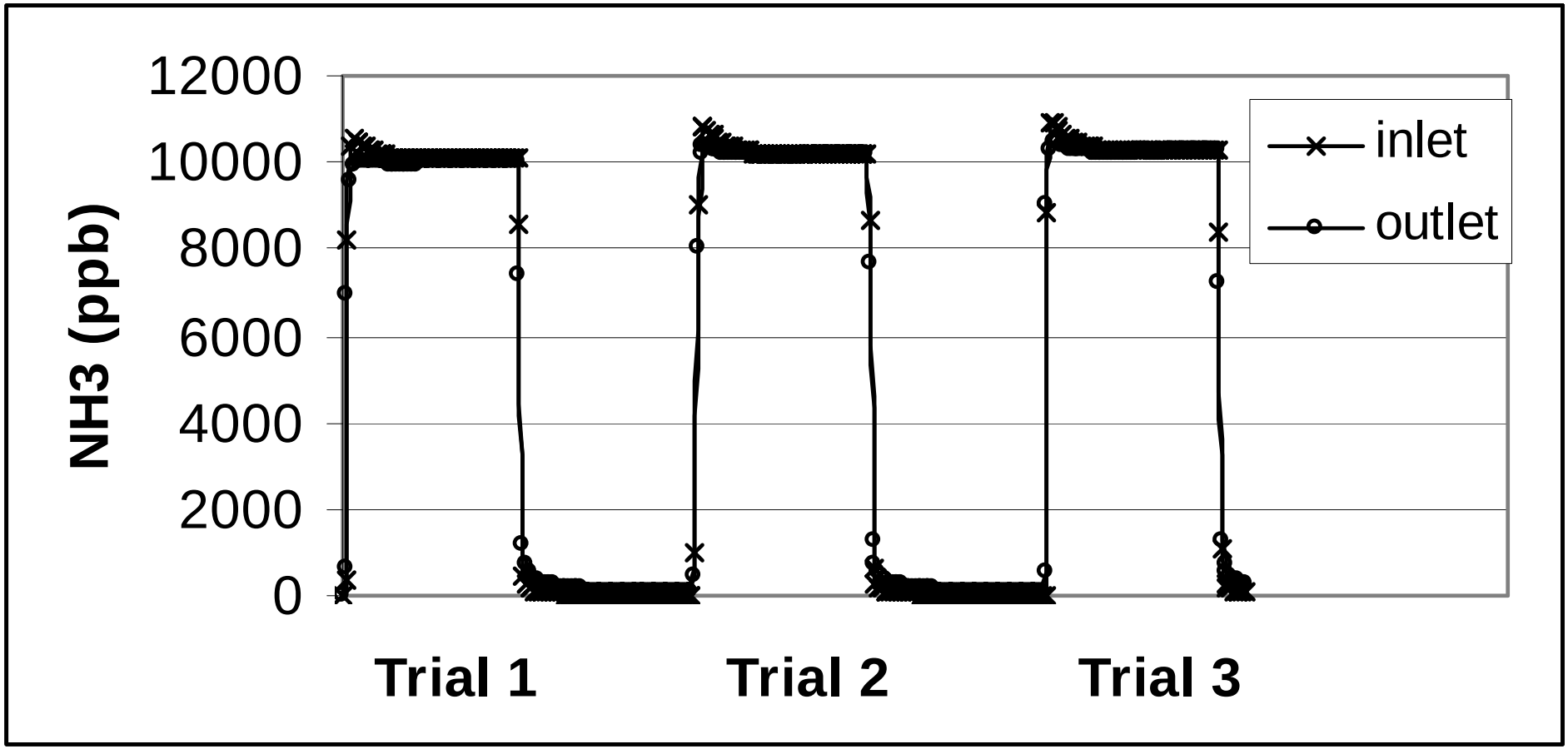
Average NH_3 adsorption and recovery for different inlet concentrations (Flux Chamber)

NH_3 Inlet Conc. (ppm)	Adsorption (%)				Standard Deviation (%)	NH_3 Recovery (%)
	Trial 1	Trial 2	Trial 3	Mean		
5	8.79	7.02	6.33	7.38	1.27	92.62
10	4.98	4.20	3.64	4.27	0.67	95.73
20	4.00	3.44	3.64	3.69	0.28	96.31
30	2.91	2.40	2.35	2.55	0.31	97.45
40	2.36	2.04	1.23	1.88	0.58	98.11

Adsorption–desorption curves of NH_3 on 90 m (300')Teflon tubing at conc. of 10 and 20 ppm

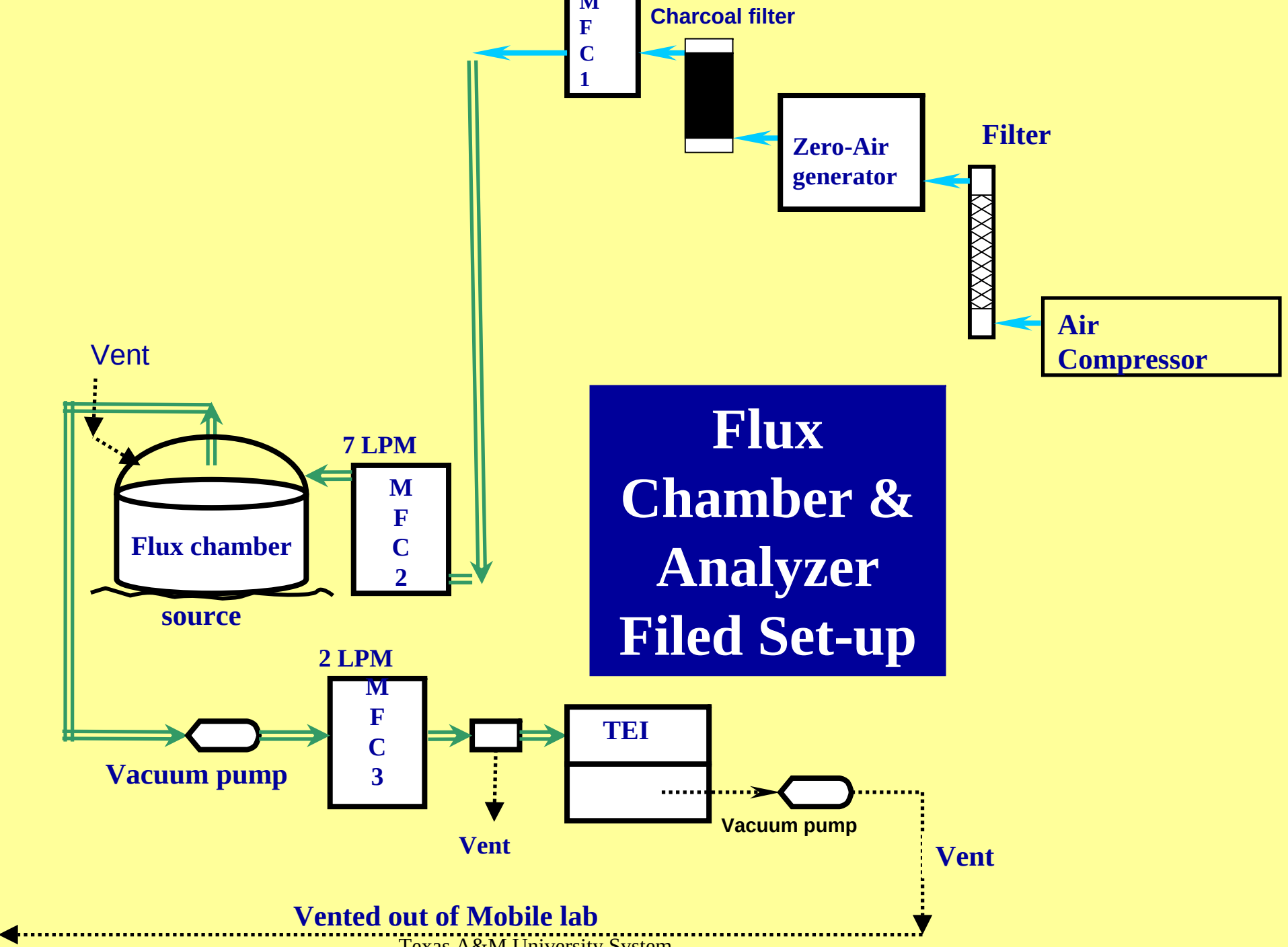


Adsorption – desorption curves of NH_3 on 46 m (150') Teflon Tubing at conc. of 10 ppm

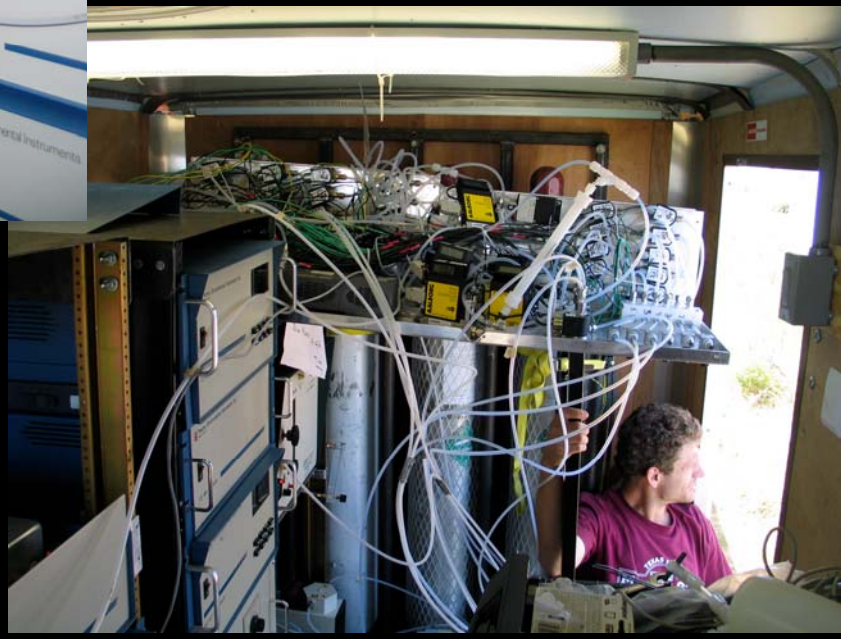


Summary

- Ammonia Recovery Runs (Chamber)
  - No losses at higher concentrations
  - For lower concentrations, equilibrium period is longer to achieve full recovery
  - Perceived loss is a consequence of system response
- Maximum Un-recovered NH_3 = **7.38%**


Flux Chamber & Analyzer Filed Set-up
Charcoal filter
MFC1
Zero-Air generator
Filter
Air Compressor
Vent
7 LPM
MFC2
Flux chamber
source
2 LPM
MFC3
Vacuum pump
TEI
Vent
Vacuum pump
Vent
Vented out of Mobile lab

Mobile Lab Views



Freestall Sampling

Open Lot Sampling

Lagoon Sampling

Texas A&M University System

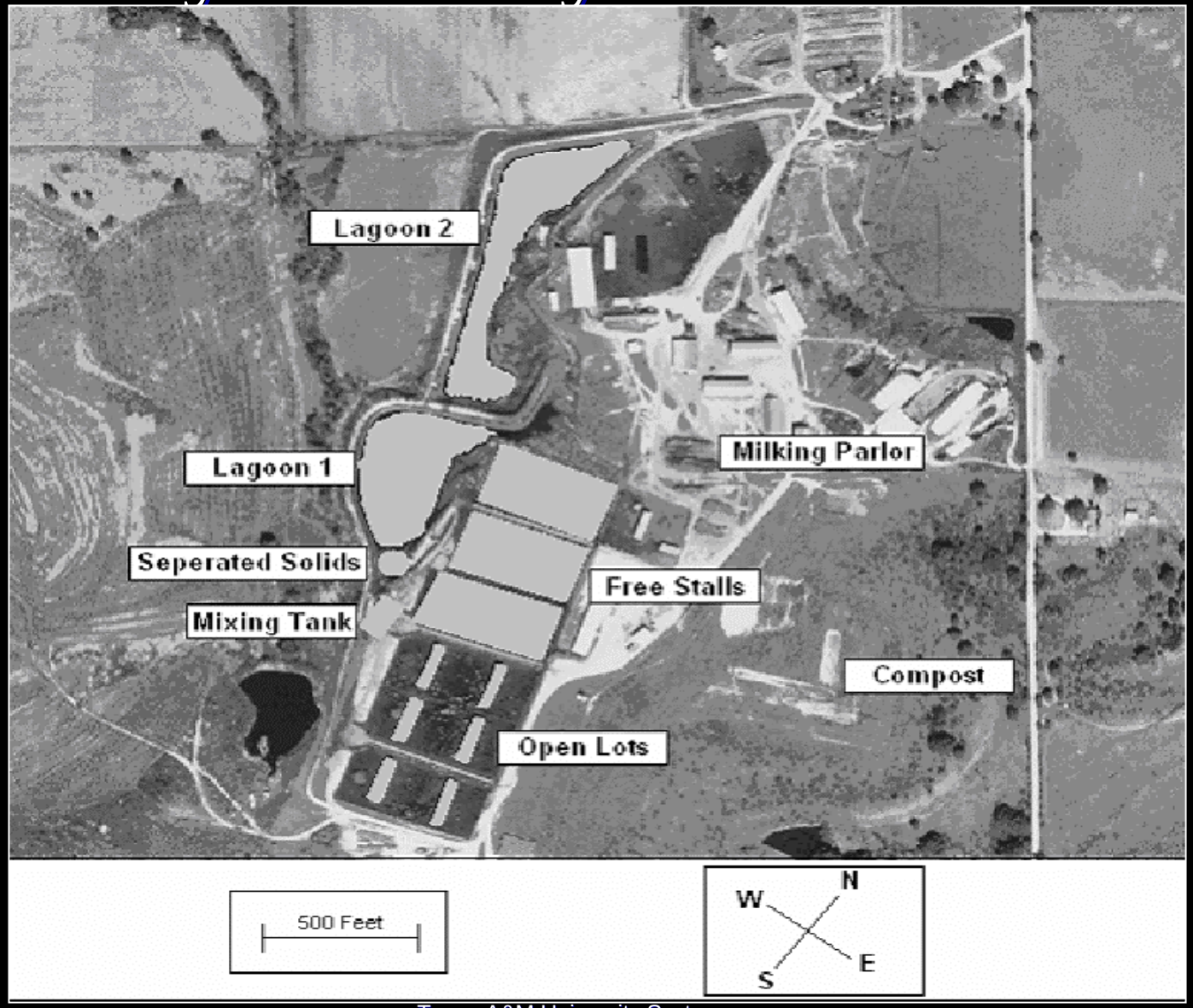
NH_3 Flux & Emission Rate Calculations

$$C_{mass} = 1000 \times \left(\frac{P}{RT} \right) \times C_{ppm} \times MW_p$$

$$EFl_{NH_3} = \frac{C_{mass} \times V_{fc}}{A_{FC}}$$

$$ER = EFlxA_s$$

Hybrid Dairy & GLAS



Hybrid Dairy NH_3 Conc. & Emission Rates for Winter 2003

GLAS	Samples	Conc. (ppm)	Conc. ($\mu g/m^3$)	Flux ($\mu g/ m^2/ s$)	ER (kg/day)	GLAS Temp (°C)	Amb. Temp (°C)
Compost	3	17.4 ±23.5[b]	12120	5.3 ±7.1[b]	9.5 ±12.9[b]	30.1	8.5
Free- Stall	5	36.4 ±23.3	25354	11.0 ±7.0	9.3 ±6.0	6.4	6.3
Dry openlot	3	6.5 ±8.8	4527	2±2.7	4.4 ±6.0	-1.0	-1.0
Wet openlot	4	14.1 ±5.4	9821	4.3±1.6	0.5 ±0.2	-1.0	-1.0
Sep. Solids	2	9.3 ±7.9	6478	2.8 ±2.4	0.03 ±0.02	3.6	3.7
Lagoon 1	6	2.0 ±0.5	1393	0.6 ±0.2	0.7 ±0.2	8.7	16.7
Lagoon 2	6	0.4 ±0.3	279	0.1 ±0.1	0.2 ±0.1	9.5	13.0
Statistics	29[a]						

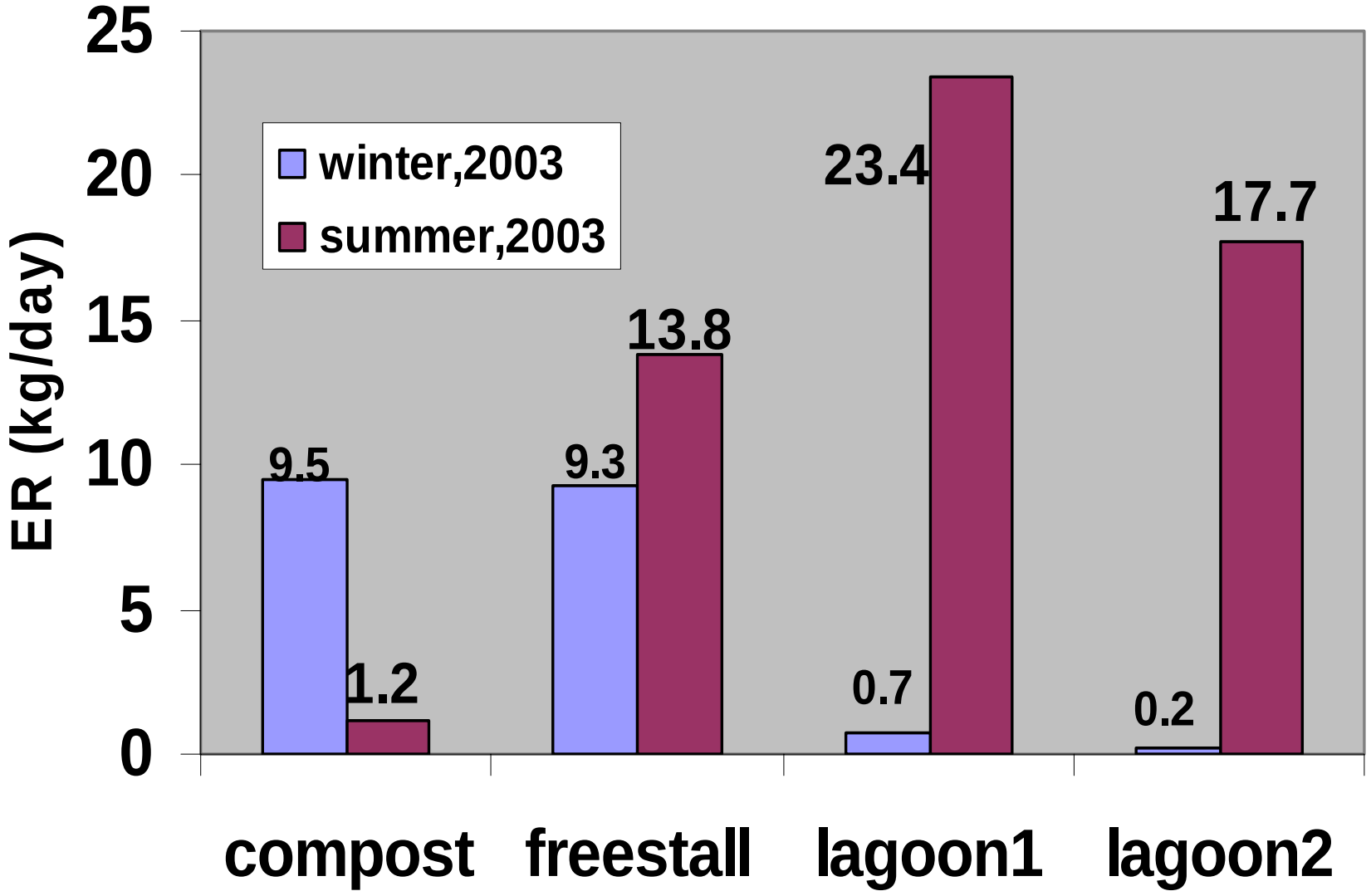
[a] Summation, [b] 95% confidence interval (CI)

Hybrid Dairy NH_3 Conc. & ER for 2003 Summer

GLAS	Samples	Conc. (ppm)	Flux ($\mu g/m^2/s$)	ER (kg/day)	GLAS Temp. °C	Amb. Temp. °C
Compost	11	1.9 ±1.6[b]	0.81 ±0.7[b]	1.17 ±0.97[b]	43.17 ±7.1[b]	33.34 ±1.6[b]
Freestall	14					
Non-feed	5	57.5 ±50.5	20.53 ±23	4.79 ±5.4	25.79 ±3.16	33.38 ±1.33
Feed	5	74.0 ±72.4	31.75 ±31	8.48 ±8.3	33.91 ±56.1	34.60 ±0.2
Bedding	2	2.4 ±22.2	1.05 ±9.5	0.34 ±3.1	27.02 ±2.78	33.34 ±3.14
Water	2	21.7 ±84.4	9.30 ±36.2	0.16 ±0.63	23.79 ±2.07	34.53 ±2.76
Open Lot	8	4.8 ±3.9	2.05 ±1.7	6.72 ±5.5	30.63 ±3.5	33.27 ±1.43
Crowding	4	9.6 ±8.2	4.06 ±3.4	0.32 ±0.3	21.54 ±1.0	25.62 ±1.0
Sep. Solids	4	3.7 ±7.2	1.50 ±2.9	0.01 ±0.03	34.01 ±5.2	-
Lagoon 1	8	32.8 ±7.1	14.09 ±3.0	23.4 ±5	29.48 ±1.2	29.61 ±2.3
Lagoon 2	6	28.1 ±2.9	12.07 ±1.3	17.72 ±1.9	28.42 ±0.7	26.67 ±1.9
Statistic	55[a]	-	-			

[a] Summation , [b] 95% confidence interval (CI)

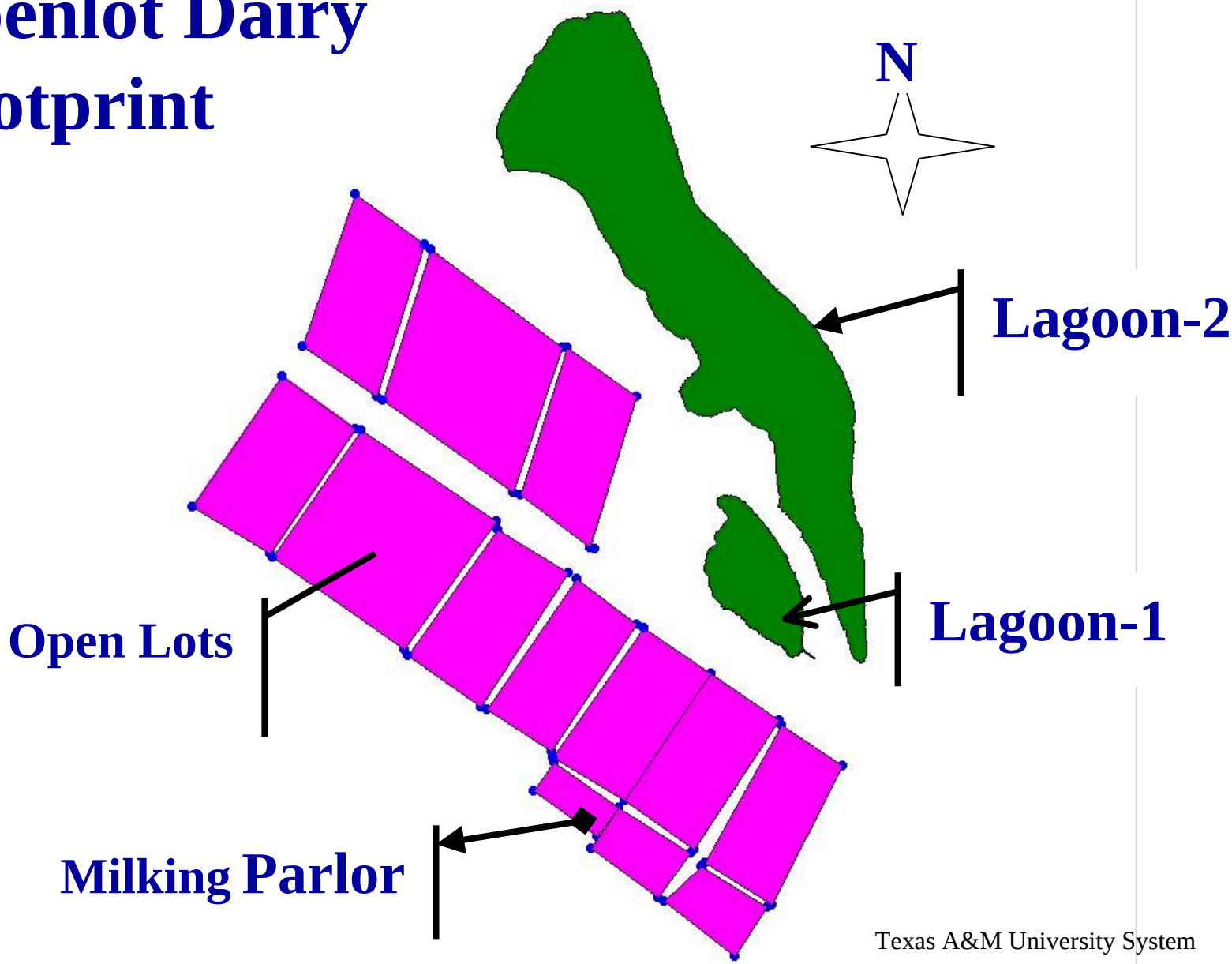
Seasonal NH_3 ER Variations of GLAS



Key Results

- ✓ Winter: Compost and freestalls contributed 77% to overall NH_3 emissions at the dairy.
- ✓ Winter: Lagoons contributed little to the overall emissions.
- ✓ Summer: Lagoons contributed 65% to total NH_3 emissions at the dairy.

Openlot Dairy Footprint

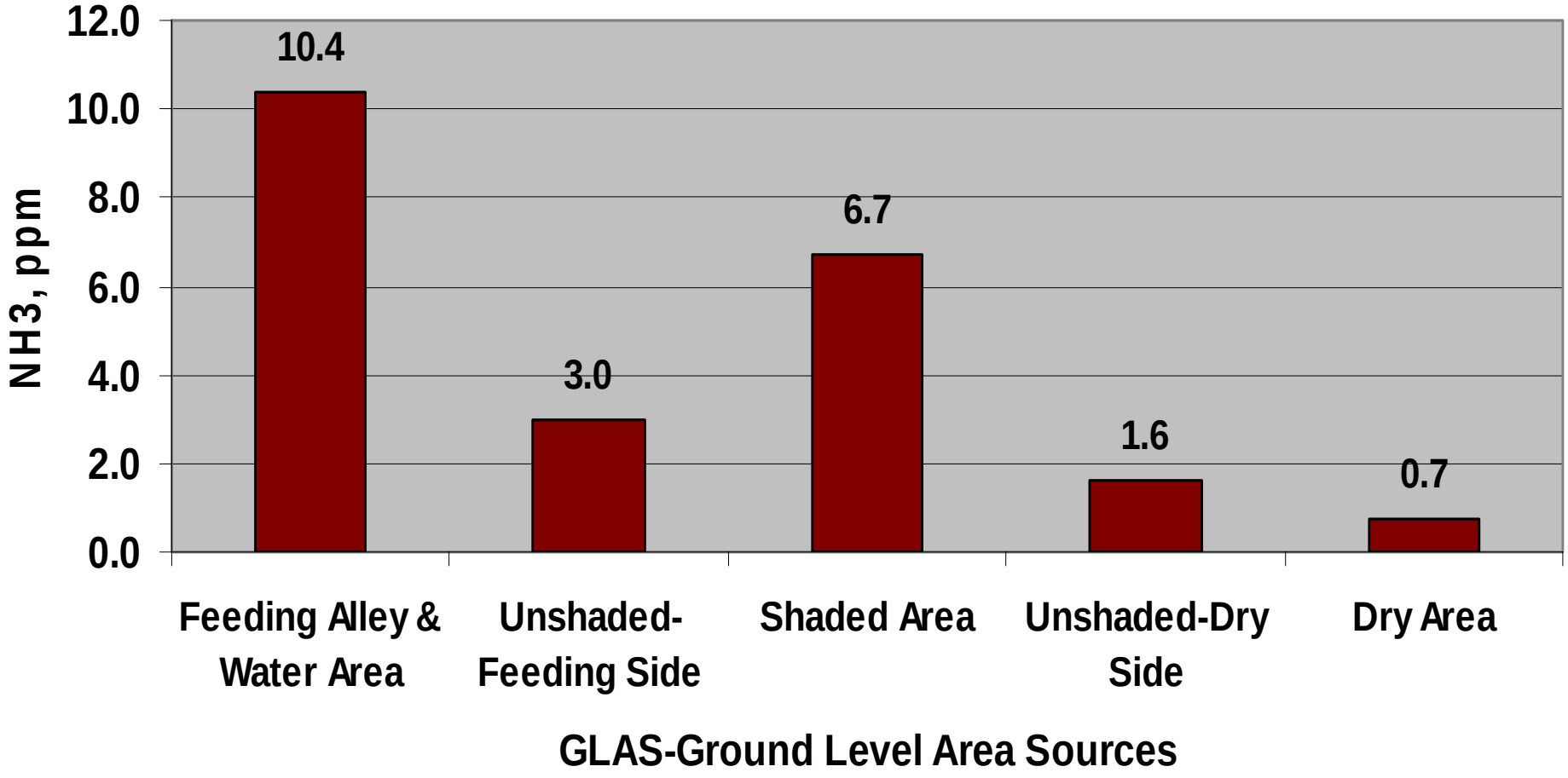


Summer 2004 NH3 Data From Openlot Dairy

GLAS	Samples	Conc. (ppm)	Flux ($\mu g/m^2$-s)	ER Kg/day	Temp (C) GLAS	Temp (C) Amb.
Lagoon-1	8	11.21 [a]	4.81 [a]	2.61 [a]	29.7 [a]	28.9 [a]
		(0.94) [b]	(0.4) [b]	(0.22) [b]	(1.3) [b]	(1.2) [b]
Lagoon-2	35	3.82	1.6	6.5	28.2	25.9
		(0.64)	(0.27)	(1.09)	(0.2)	(0.7)
Open Lot-5	36	3.12	1.4	1.01	28.0	27.2
		(0.78)	(0.3)	(0.2)	(1.4)	(1.01)
Open Lot-11	28	2.91	1.2	0.9	27.0	27.1
		(0.69)	(0.3)	(0.22)	(0.4)	(1.3)
Milking Par.	6	5.60	2.4	0.10	30.3	30.6
		(4.13)	(1.7)	(0.08)	(1.05)	(0.8)
Alley to MP	5	0.82	0.35	0.51	30.2	27.3
		(0.44)	(0.18)	(0.27)	(1.7)	(1.01)
	118 [c]					

[a] Average
[b] 95% (CI)
[c] Summation

NH3 Concentrations from Open Lot-11, Summer of 2004



Conclusions

- ✓ NH_3 emissions may vary due to:
  - 1- Seasonal variations in temperatures
  - 2- Dairy manure loading rates
  - 3- Moisture and biological activity

- ✓ Intensive sampling needed to examine temporal and spatial variability.

Acknowledgement

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Gracias! Questions?