Air Quality: Odor, Dust & Gaseous Emissions from CAFOs in the Southern Great Plains—

A Project Overview

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April 13, 2005

Research Project Funding

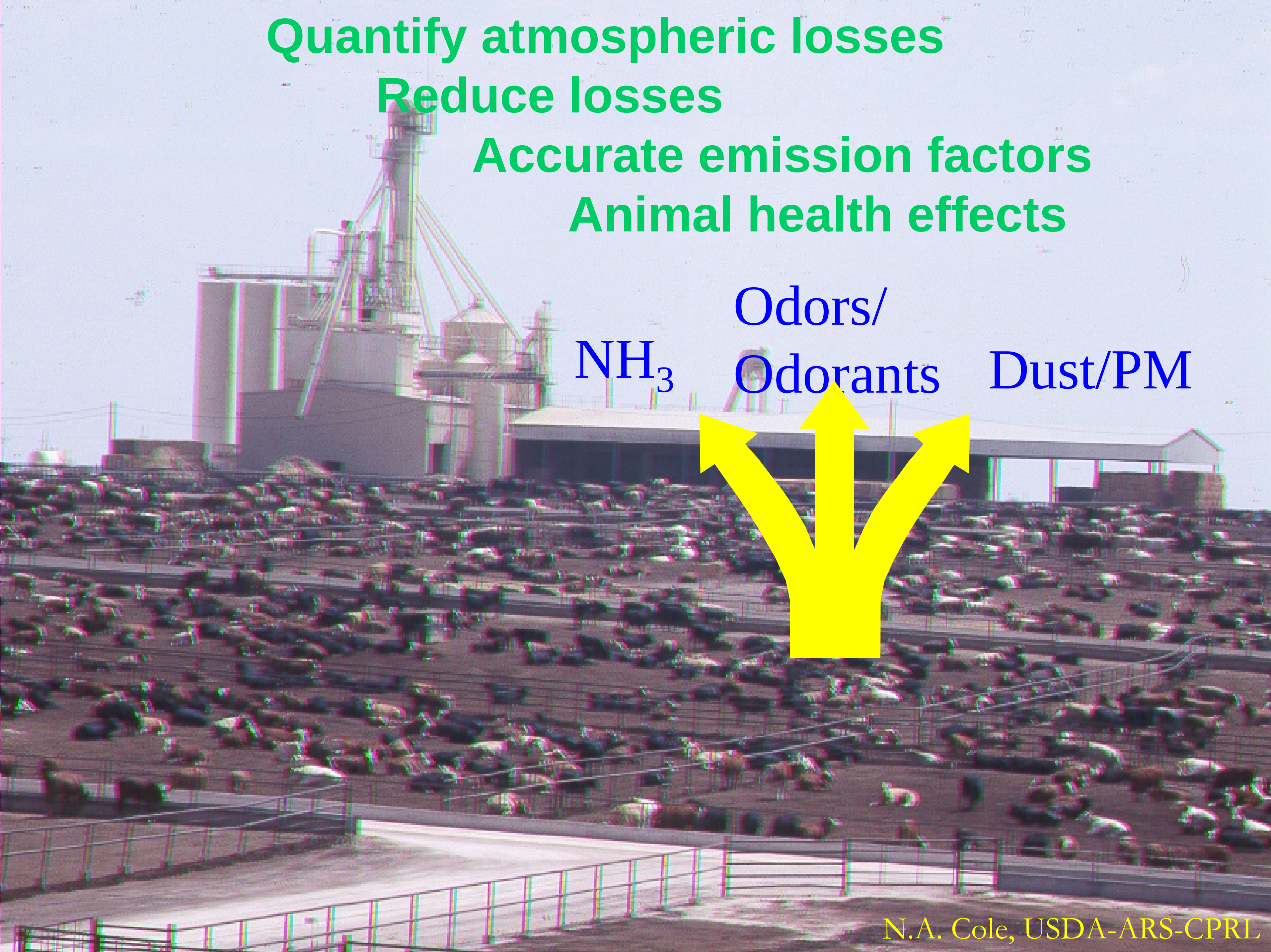
- **Grantor--USDA-CSREES**
- **Funding (net):**
  - **Year 1-- $ 612,500 --completed**
  - **Year 2—$ 812,631 --completed**
  - **Year 3-- $ 835,770 --underway**
  - **Year 4-- $ 994,511 —proposed work plan.**
  - **Year 5--?**

Participants

- **Research Partners**
  - **23 investigators, 5 univ./agencies**
  - **Texas A&M University System**
    - **Texas Agricultural Experiment Station—Amarillo & College Station**
    - **West Texas A&M University**
    - **Texas Cooperative Extension**
  - **Kansas State University**
  - **USDA-ARS—Bushland TX**
- **Cooperators:**
  - **Texas Cattle Feeders Association**
  - **Kansas Livestock Association**

Objectives & Coordinators

1. **Emissions characterization** —
   David Parker, WTAMU, Canyon TX
2. **Effective abatement measures** —
   Brent Auvermann, TCE/TAES, Amarillo
3. **Accurate emission factors** —
   Calvin Parnell, BAEN/TAMU, College Station
4. **Animal health effects** —
   Andy Cole, USDA-ARS
5. **Technology transfer** —
   J. M. Sweeten, TAES; Bill Hargrove, KSU.


Quantify atmospheric losses
Reduce losses
Accurate emission factors
Animal health effects
NH3
Odors/
Odorants
Dust/PM
N.A. Cole, USDA-ARS-CPRL

Experimental Facilities & Personnel

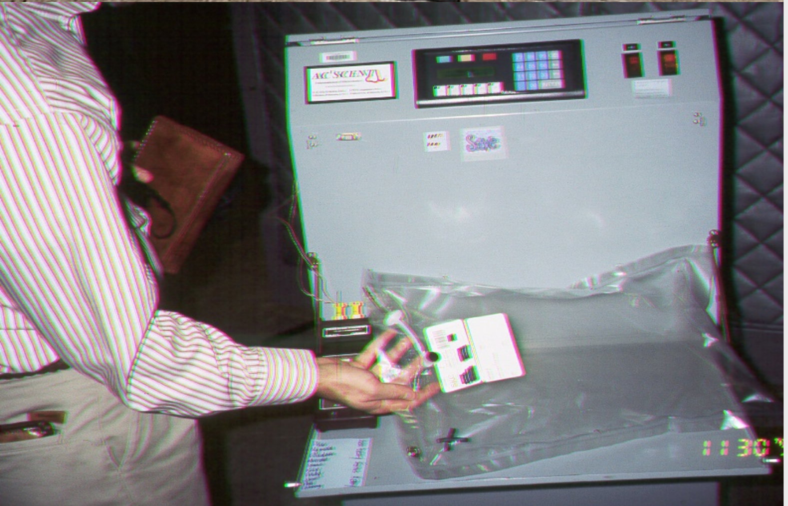
- **Air quality parameters involved:**
  - **Particulate matter (PM)** *—TAES/Amarillo, BAEN/Texas A&M, BAEN/Kansas State.*
  - **Odor/olfactometry** *—WTAMU*
  - **Odorous gases** *—TAES/Amarillo*
  - **Ammonia** *—USDA-ARS/Bushland & Watkinsville GA; TAES-AMA; BAEN/CLL.*
  - **Hydrogen Sulfide** *—TAES/AMA; WTAMU; BAEN/CLL.*
  - ***VOCs****—TAES/AMA;*
  - **R-VOCs** *--BAEN/CLL.*

Experimental Facilities

- **Experimental feedlots**
  - TAES/ARS, Bushland—385 head capacity
  - WTAMU—600 head capacity
- **Commercial feedyards— 40,000+ hd**
  - Texas Panhandle (3)
  - SW Kansas
- Commercial dairies –2,000 hd. capacity
  - N. Central Texas (2)

Objective 1 – Emissions Measurement/Odor

Characterize ambient odor concentrations & odor emissions from open-lot feedyards (Parker & Rhoades, WTAMU)



Dynamic Olfactometry--Summary

Odor Concentrations, ODT (OU/m^3 or OU)

3 beef cattle feedyards, 12-month period

(Parker & Rhoades, WTAMU)

Location	n	Mean ODT	Range ODT	Median ODT	
Upwind	136	40	7 - 362	23	
Downwind Feed Pens	136	59	8 – 665	25	
Downwind Holding Pond	136	78	8 - 1223	25	

Obj. 1 – Emissions Measurement--H_2S

(Parker & Rhoades, WTAMU)

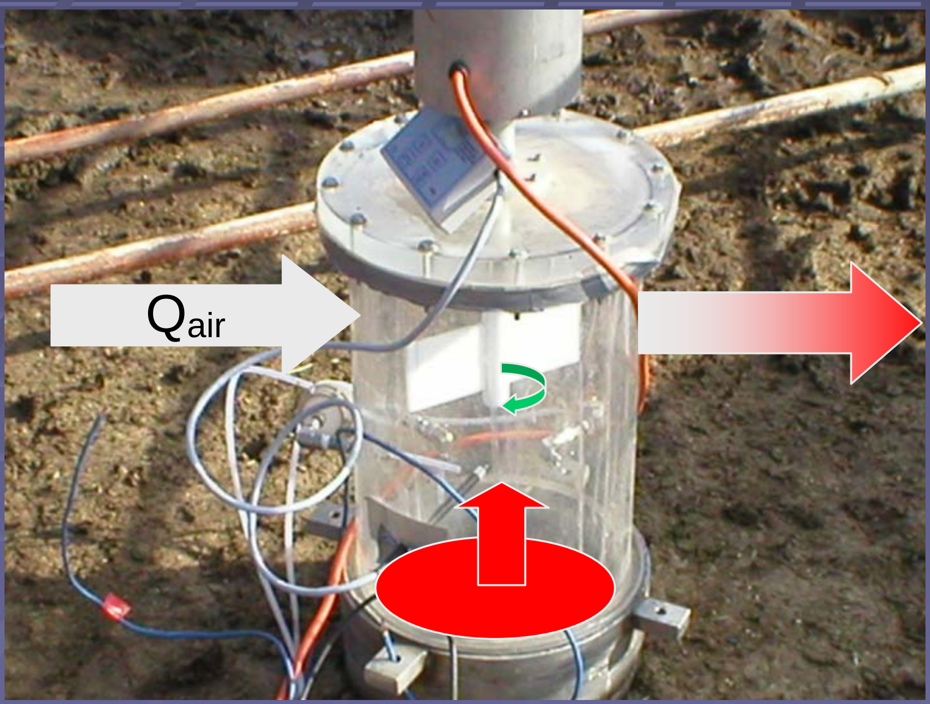
Ambient H_2S Concentrations (ppm) Immediately Downwind of Feed Pens and Runoff Holding Ponds, Feedyards A, B, C (n=3).

Location	Mean	SD	No. obs.
Upwind, background	0.007	0.014	120
Downwind:			
* pens	0.025	0.023	118
* holding pond	0.038	0.109	114

NH_3, H_2S & VOCs flux measurements, Feedyard C

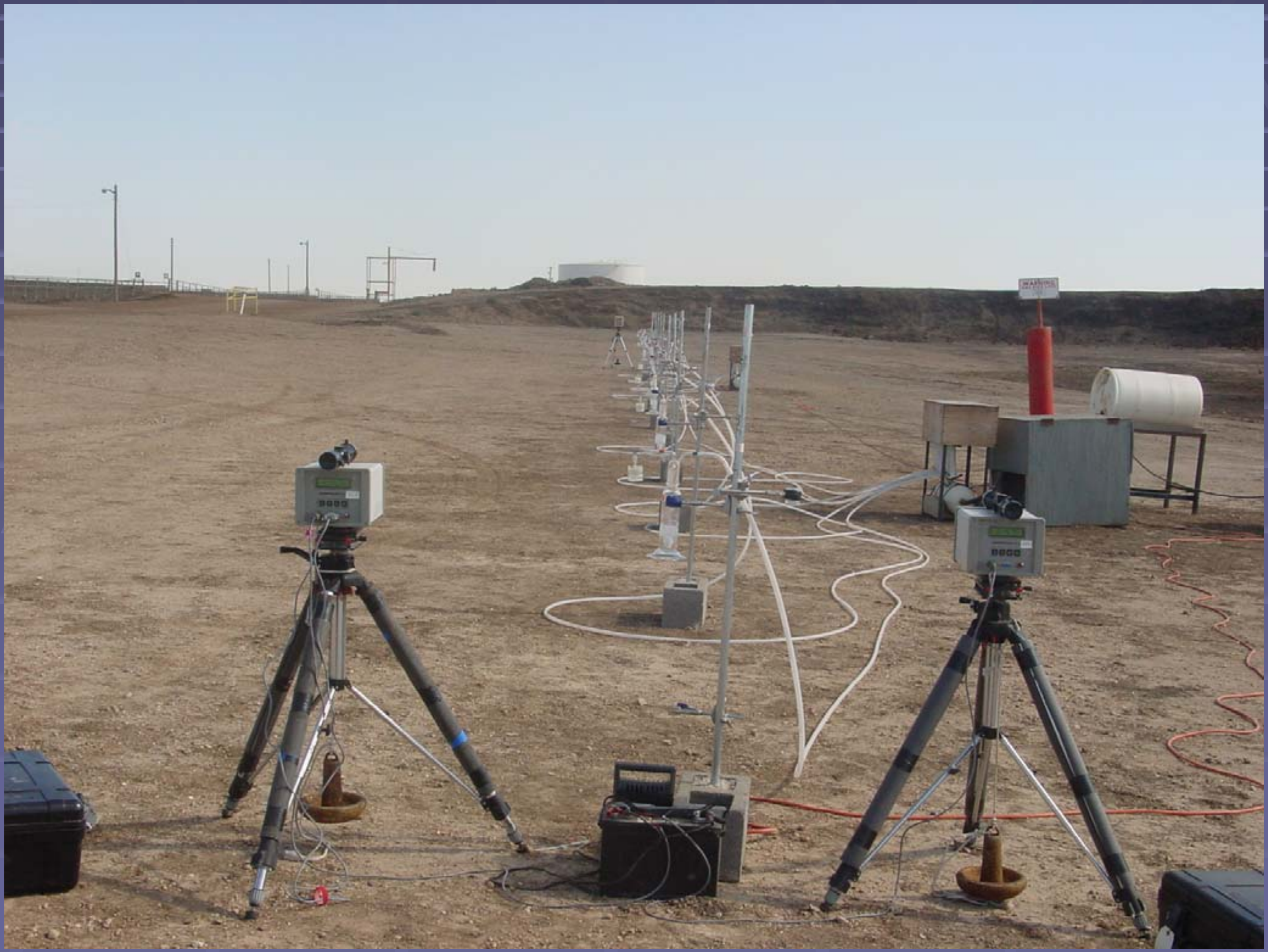
(Koziel, Baek, Spinhirne, TAES-AMA; Todd & Cole, USDA-ARS)

Flux-Chamber methods vs. Micromet.-based methods



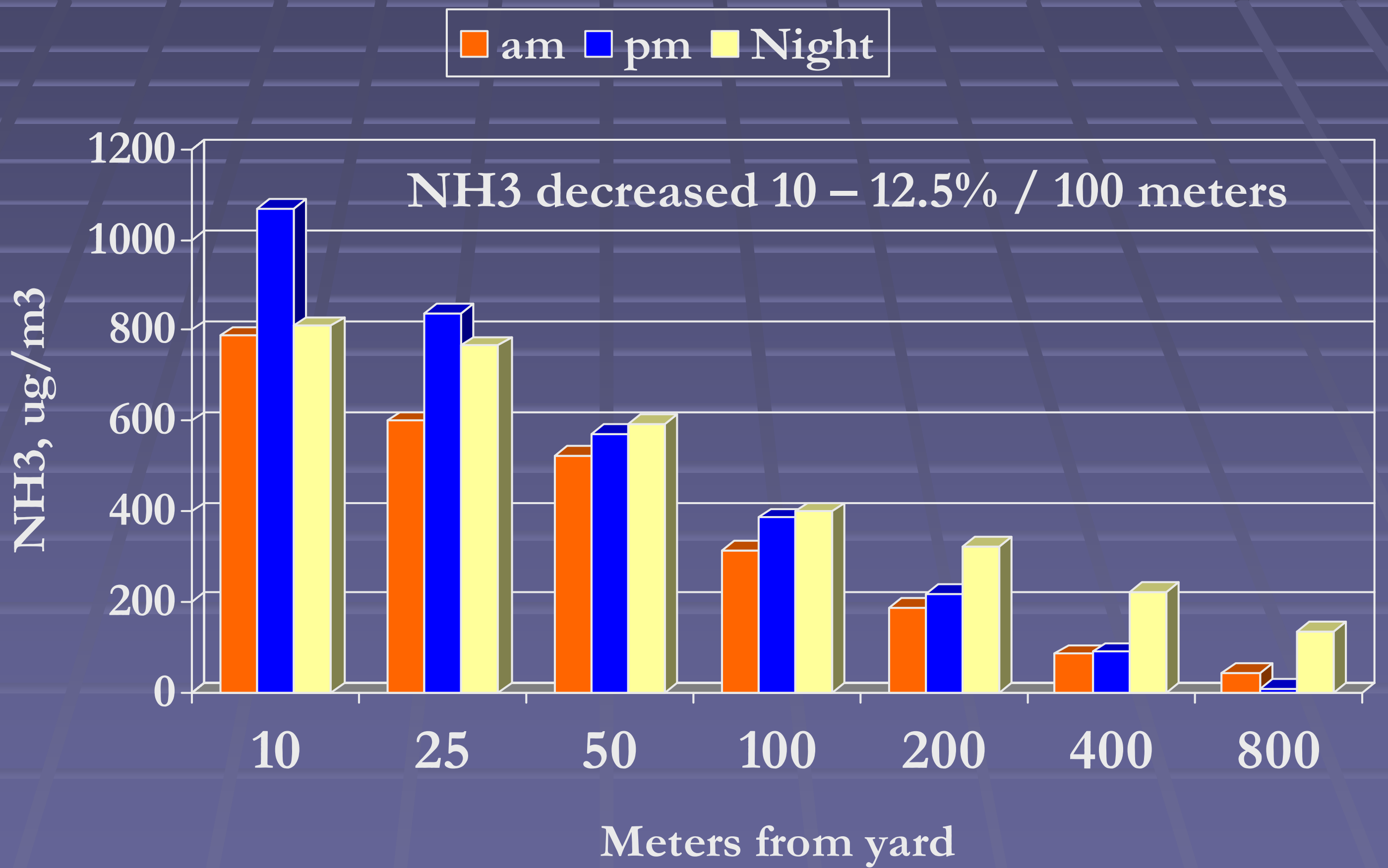
Ammonia Lasers at Feedyard C

(Todd & Cole, USDA-ARS)



Summer Downwind NH_3

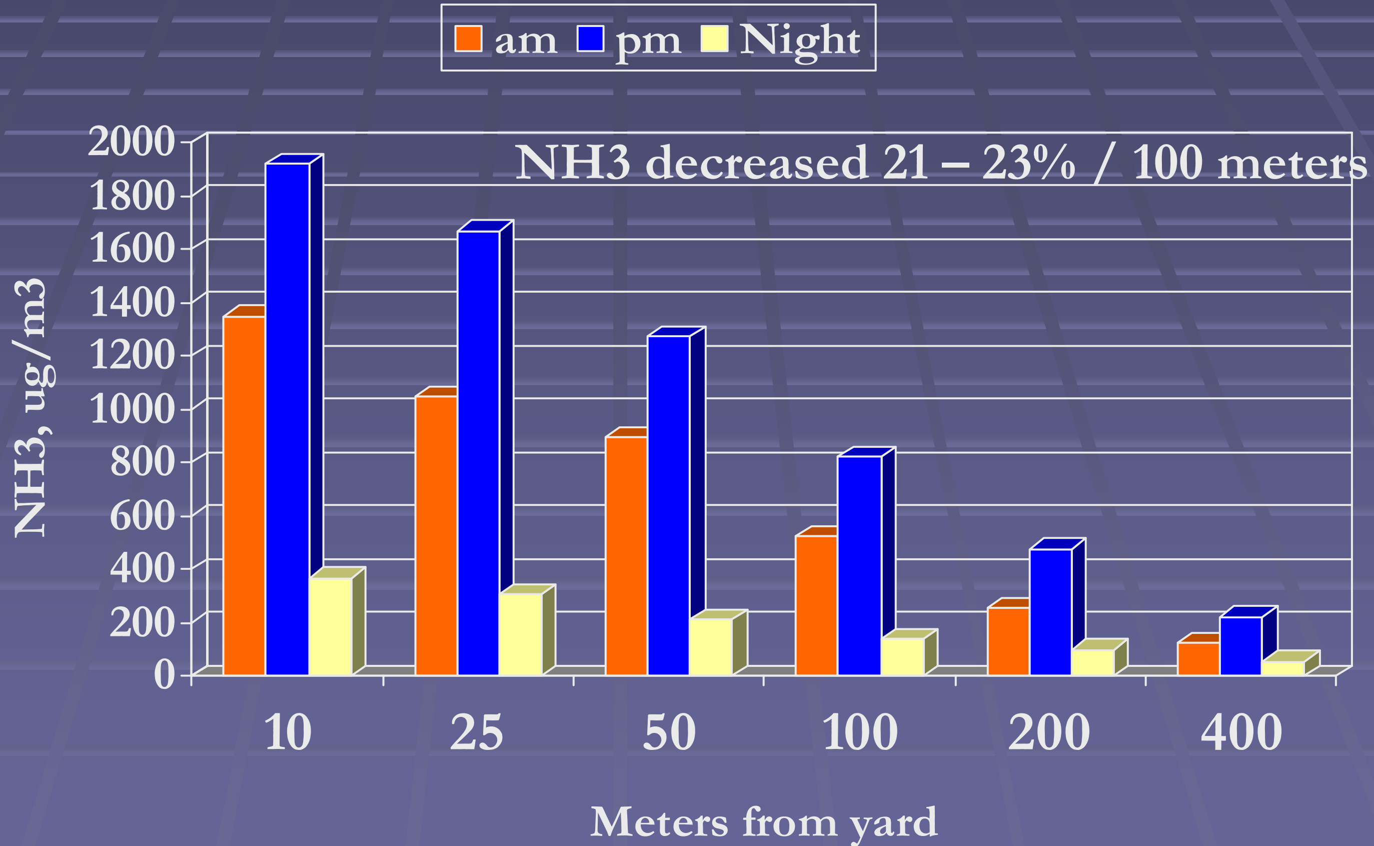
(Todd & Cole, USDA-ARS, Bushland TX)



Ammonia concentrations decreased approximately 72-134 ug per 100 meters

Winter Downwind NH_3

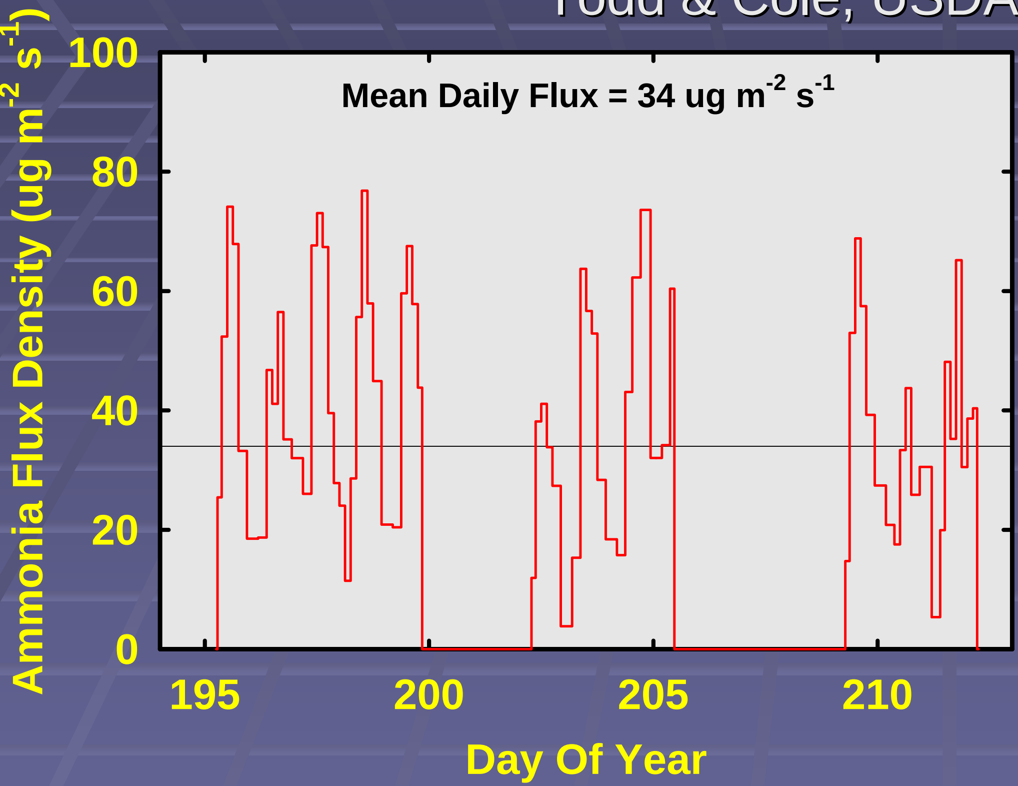
(Todd & Cole, USDA-ARS, Bushland TX)

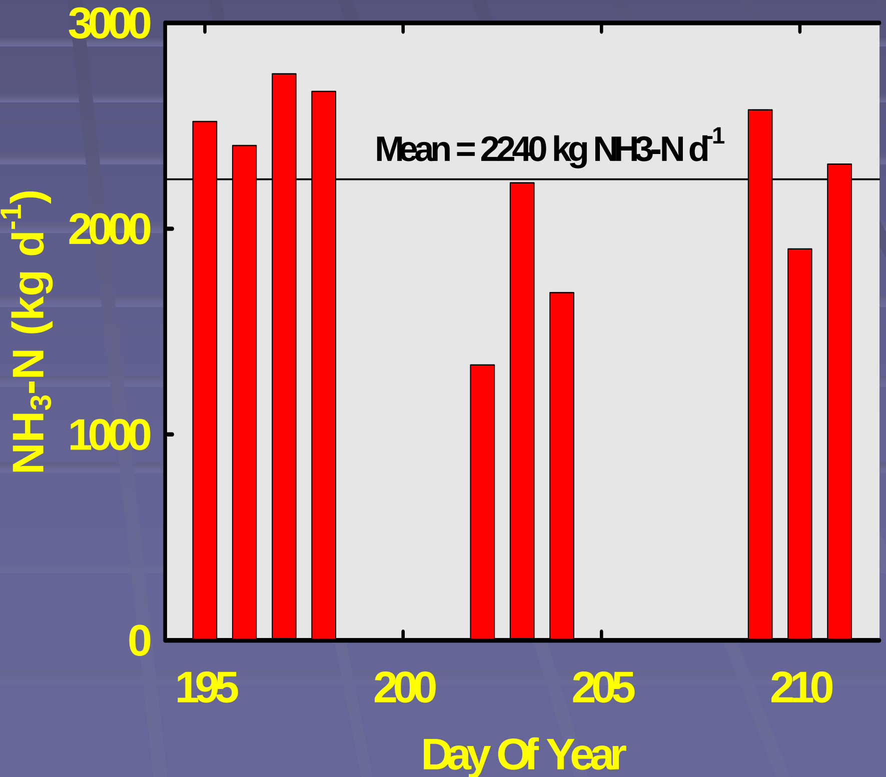


Ammonia concentrations decreased approximately 71-436 ug per 100 meters

Daily Ammonia Flux, Feedyard C, Summer 2003

Todd & Cole, USDA-ARS/Bushland





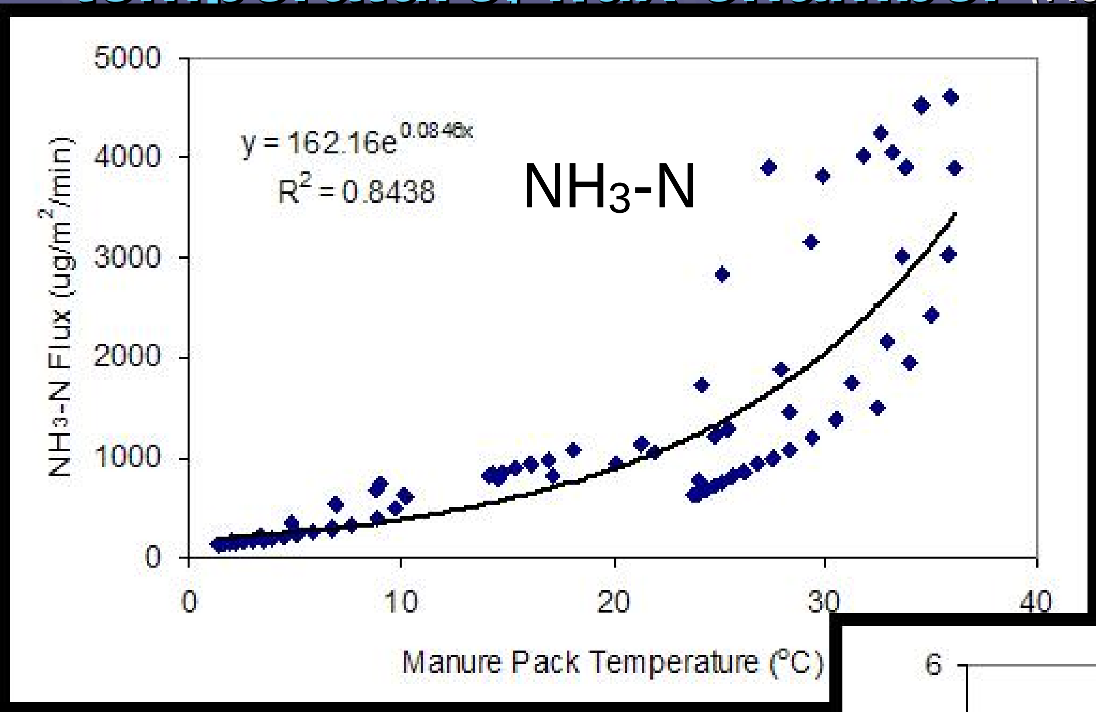
Ammonia Emissions,

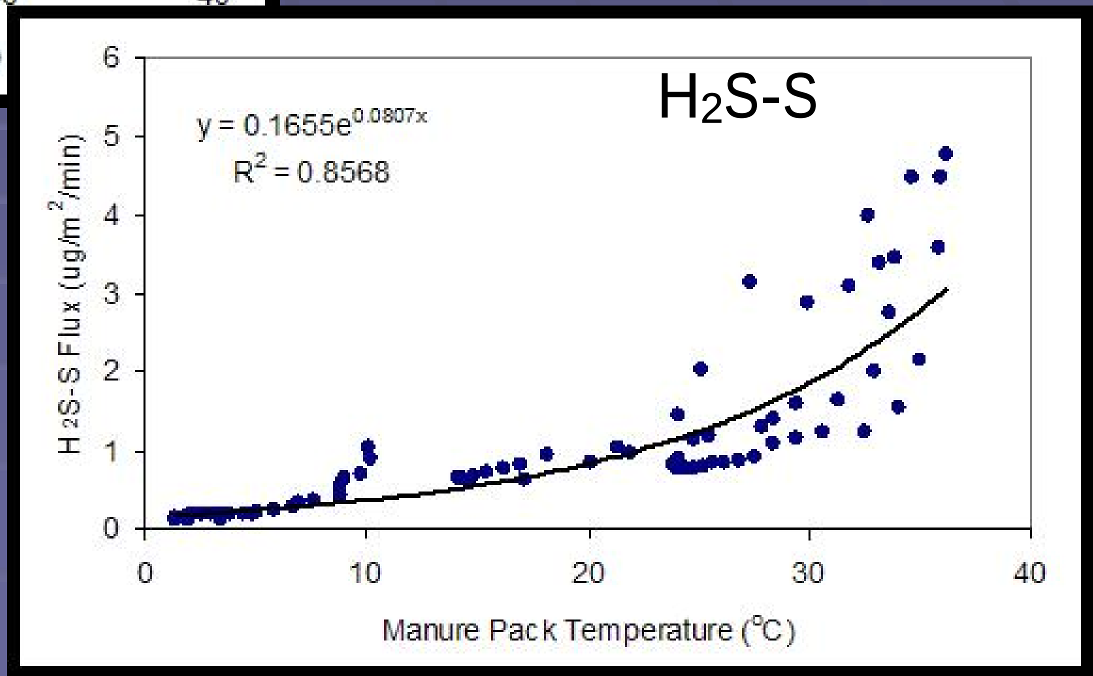
Flux-Gradient Method, Feedyard C

(Todd & Cole, USDA-ARS, Bushland TX)

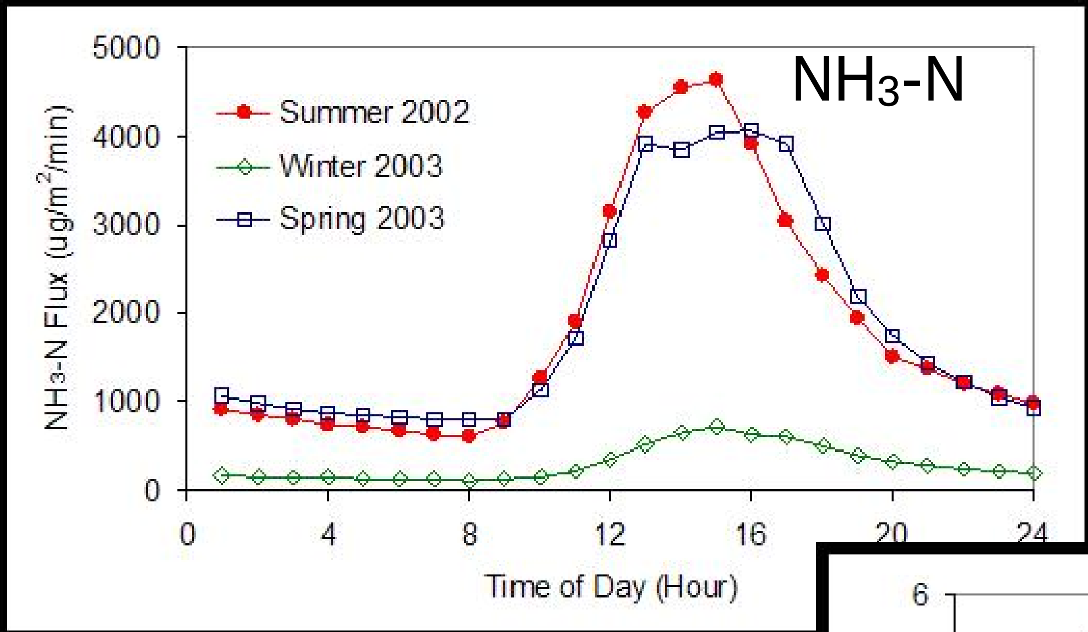
Trial	No. Days	Daily Flux	NH_3-N Loss
		$\mu g\ m^{-2}\ s^{-1}$	$kg\ d^{-1}$
Summer '02	4	16	1030
Winter '03	7	8	520
Summer '03	10	34	2240

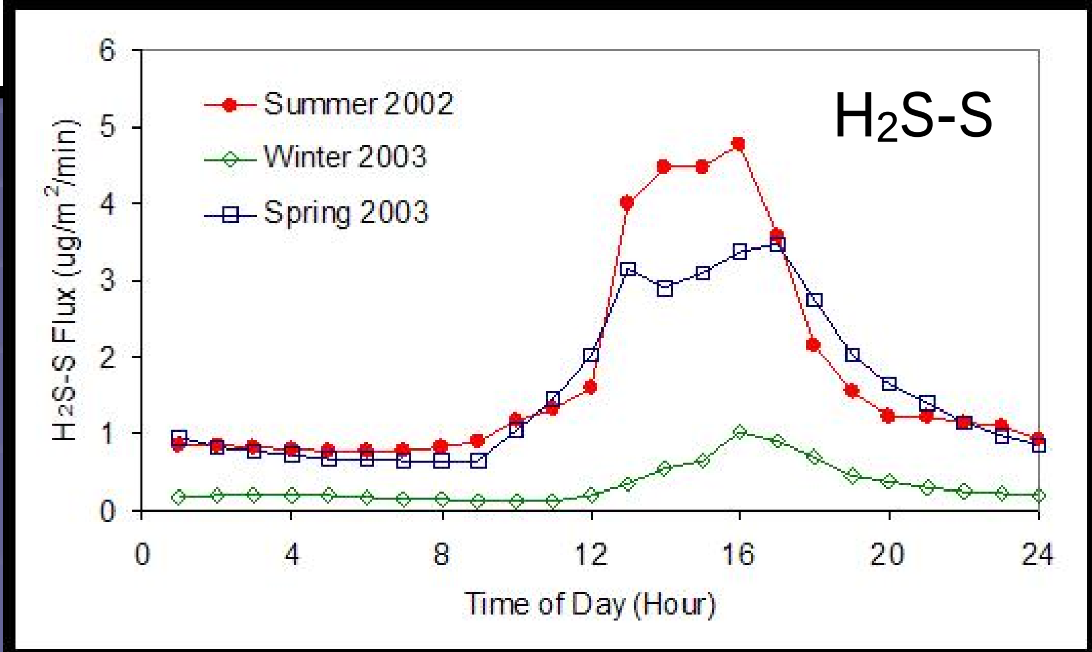
NH_3-N and H_2S-S flux vs. manure pack temperature, flux chamber *(Koziel, Baek, Spinhirne, TAES-AMA)*





Diurnal variations of NH_3-N and H_2S-S flux from cattle pens *(Koziel, Baek, et al., TAES-AMA)*





NH_3-N & H_2S-S : Conc. & Emission Rates

Feedyard C (NCSU flux chamber; one cattle pen)

(Koziel, Baek, Spinhirne, TAES-AMA)

	Concen-trations	Concen-trations	Emission Rates	Emission Rates
Period	NH_3, ppm	H_2S, ppb	NH_3-N g/hd/day	H_2S-S g/hd/day
Summer, 2002	16 (1.3-97.0)	10 (1.1-77.6)	35	0.027
Winter, 2002	3 (0.6-15.8)	2 (0.1-34.5)	9	0.006
Spring, 2003	20 (1.2-99.0)	9 (0.5-50.4)	31	0.026

Mean NH_3-N and H_2S-S flux (µg/m2/sec)
NCSU Flux Chamber, Feedyard C

(Koziel, Baek, Spinhirne, TAES-AMA)

Period Phase I	NH_3-N flux		H_2S-S flux	
	Mean	(SD)	Mean	(SD)
Summer 2002*	28	(27)	0.021	(0.02)
Winter 2003	5	(4)	0.005	(0.01)
Spring 2003	30	(25)	0.025	(0.03)

* Flux, as % of N and S fed in cattle ration:

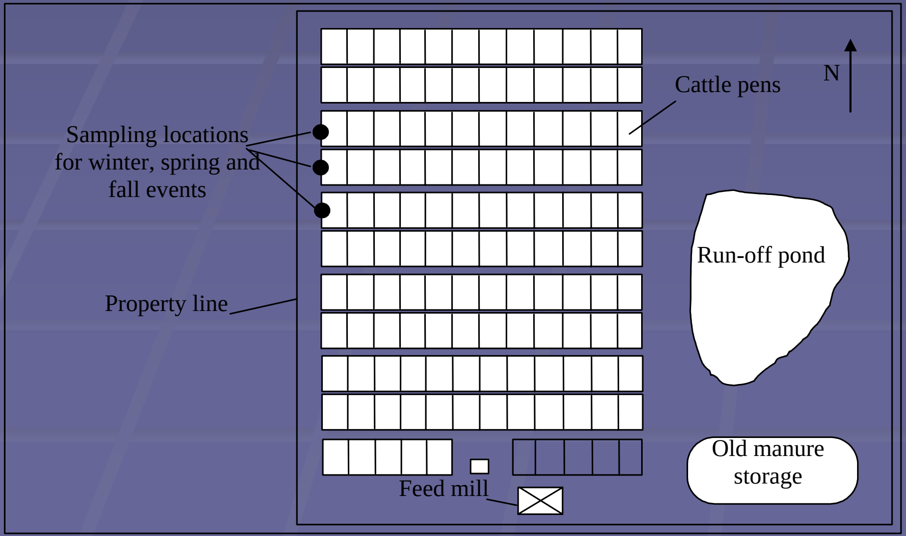
NH_3-N ~16%

H_2S-S ~ 0.14%

Ambient Concentrations of H_2S and NH_3 -- Feedyard C, Texas Panhandle

(Koziel, Baek, Spinhirne, TAES-AMA)

- **1.5 m above ground level, ~fence-rail height.**
- 3 measurements / hr (10 min each), used last 3 min. data
- Continuous NH_3 and H_2S analyzers
- On-site laboratory
- EPA grade calibration gases.



Ambient NH_3 and H_2S Concentrations (ppbv), Feedyard C *(Koziel, Baek, Spinhirne, TAES-AMA)*

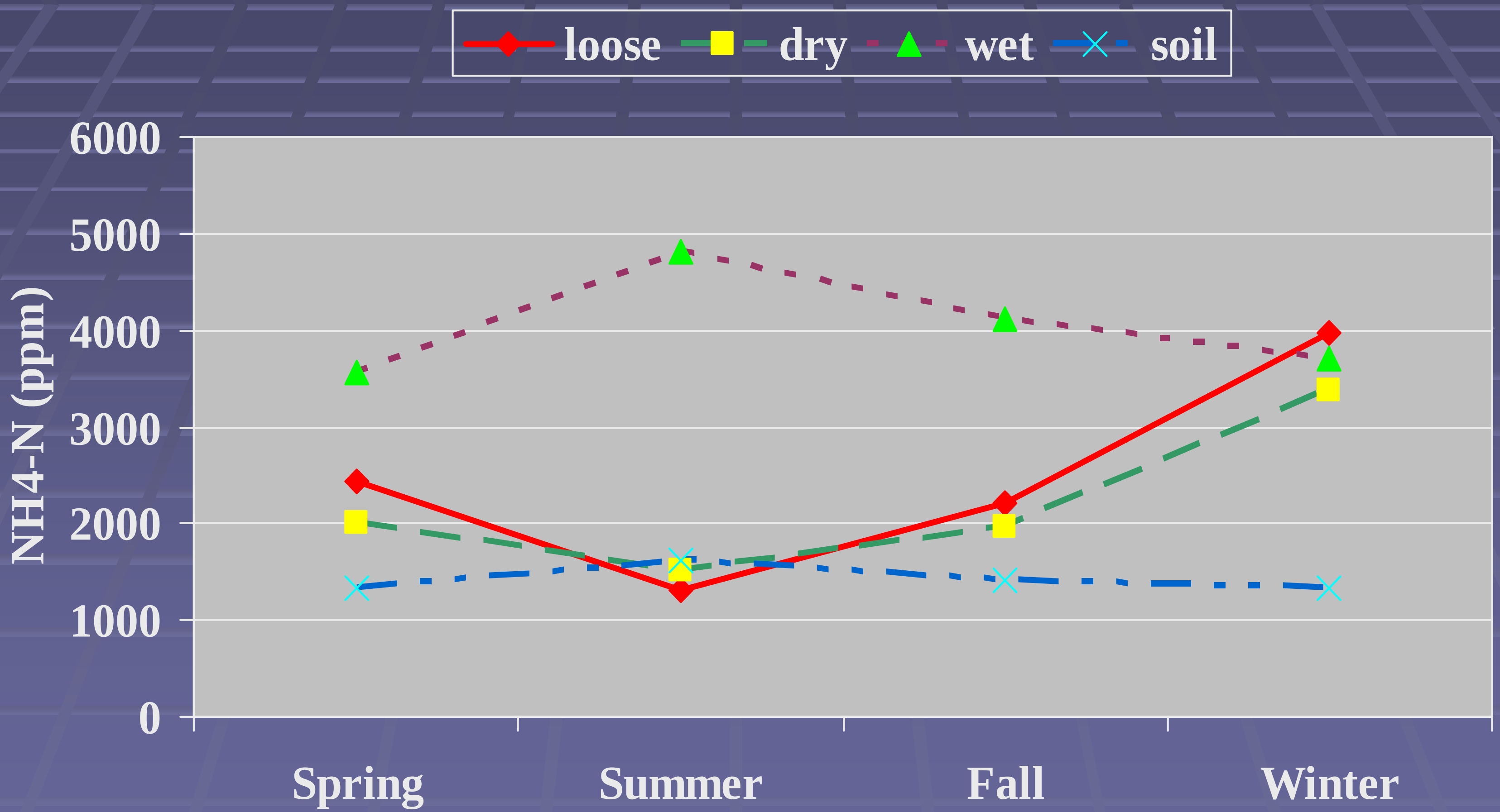
		Hourly averaged NH_3 concentrations (ppb)		Hourly averaged H_2S concentrations (ppb)	
Season	Number of Measurement Days	Mean (st. dev.)	Min - Max	Mean (st. dev.)	Min - Max
Fall 2002	10	429 (507)	106 - 2,890	7.73 (4.36)	2.19 - 29.6
Winter 2003	14	475 (409)	108 – 2,280	0.73 (0.63)	0.12 – 3.50
Spring 2003	15	712 (686)	2 – 5,270	2.45 (3.18)	0.15 – 34.9

Obj. 1--Significant Findings, Years 1 & 2

- **Odor concentrations**
  - ODT varied widely;
  - Wet weather increased ODT.
- **Ammonia flux from cattle feedyard-**
  - **NH_3 & H_2S emissions increased with temperature.**
    - Diurnal patterns—winter & summer;
  - NH_3 ~1000 X H_2S emissions.
  - Similar values for flux gradient (ARS) vs. flux chamber (TAES) methods @ Feedyard C.
  - Flux chamber methods were improved.

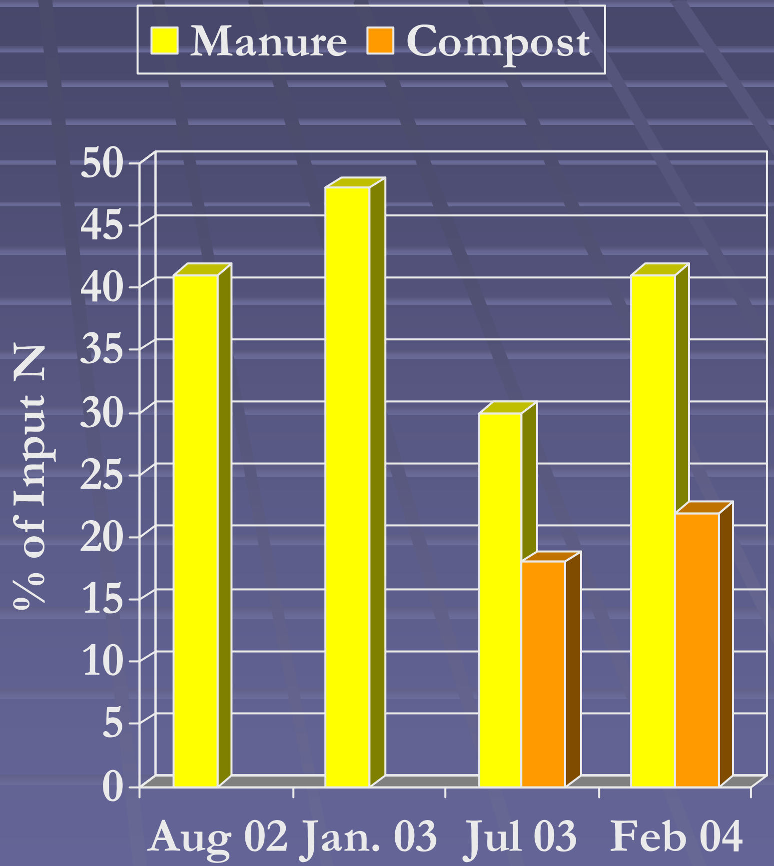
Season vs. Manure Layer Effect on NHx

(Todd & Cole, USDA-ARS, Bushland TX)



Estimating Maximum N Volatilization Using N:P Ratios

- **The lower N:P ratio of pen surface manure, compared to the diet, is a measure of maximum N volatilization losses**
- **Change from pen surface to compost – estimate of compost losses**



Cole & Todd. USDA-ARS-CPRL

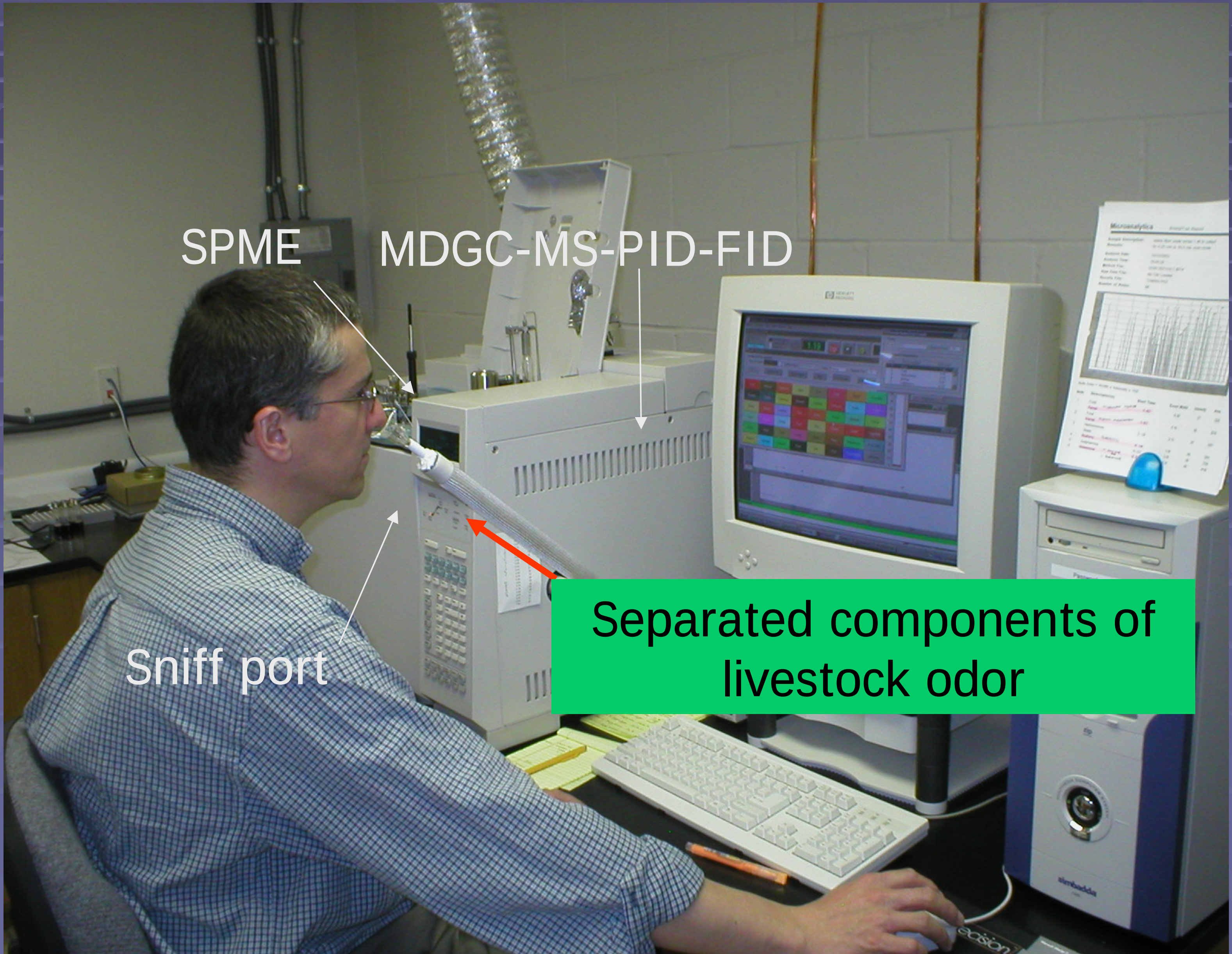
Summertime VFA flux from cattle pens

NCSU Flux Chamber *(Koziel, Baek, Spinhirne, TAES-AMA)*

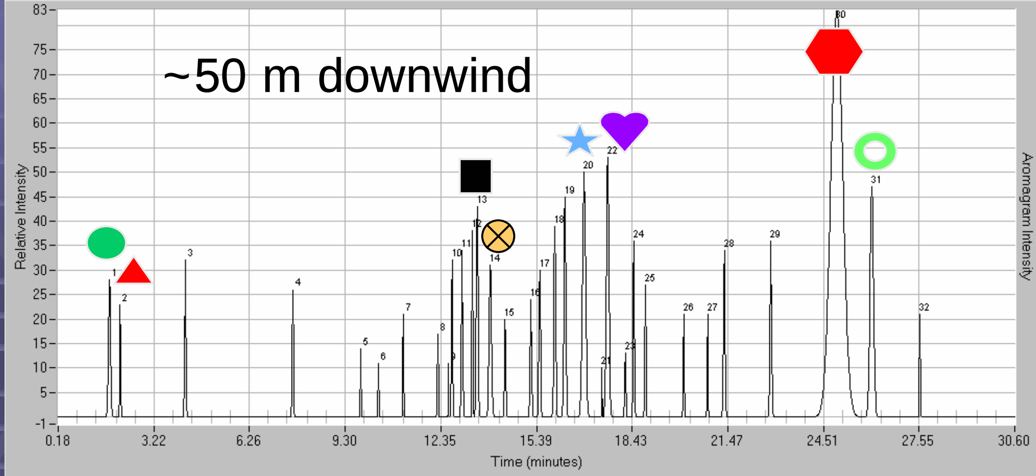
Volatile Fatty Acids (VFA)	Concentration Mean, ppb	Concentration Range, ppb	Mean flux ($\mu g/m^2/min$) (+/-Std)
Acetic acid	47	35 – 55	12.1 (2.3)
Propionic acid	23	17 – 26	7.2 (1.3)
Isobutyric acid	10	7 – 13	3.8 (1.0)
Butyric acid	13	10 – 15	5.0 (0.9)
Isovaleric acid	5.6	3.9 – 6.5	2.5 (0.5)
Valeric acid	6.2	3.8 – 8.4	1.7 (0.6)
Hexanoic acid	0.66	0.43 – 0.81	0.3 (0.1)

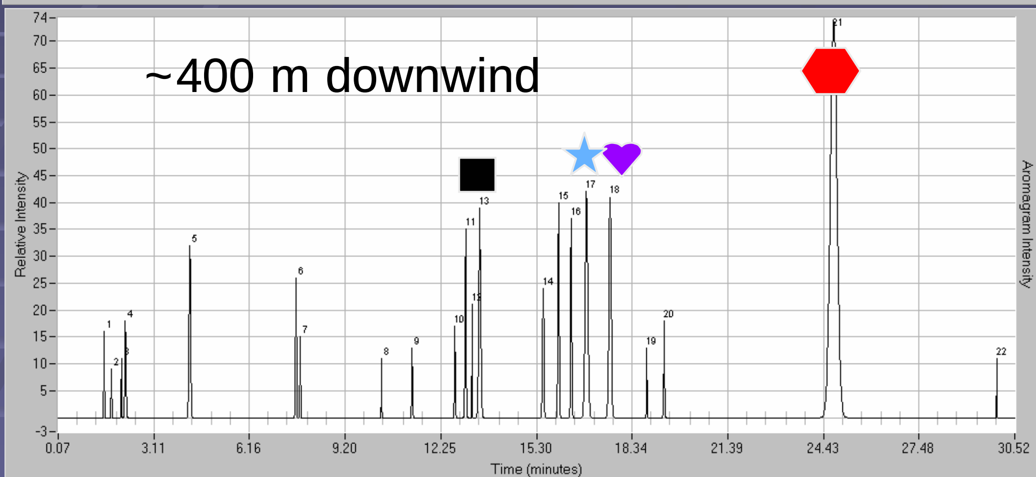
Flux comparison: Hydrogen sulfide = 1.28 (+/- 1.06)
Ammonia = 1,666 (+/- 1,642)

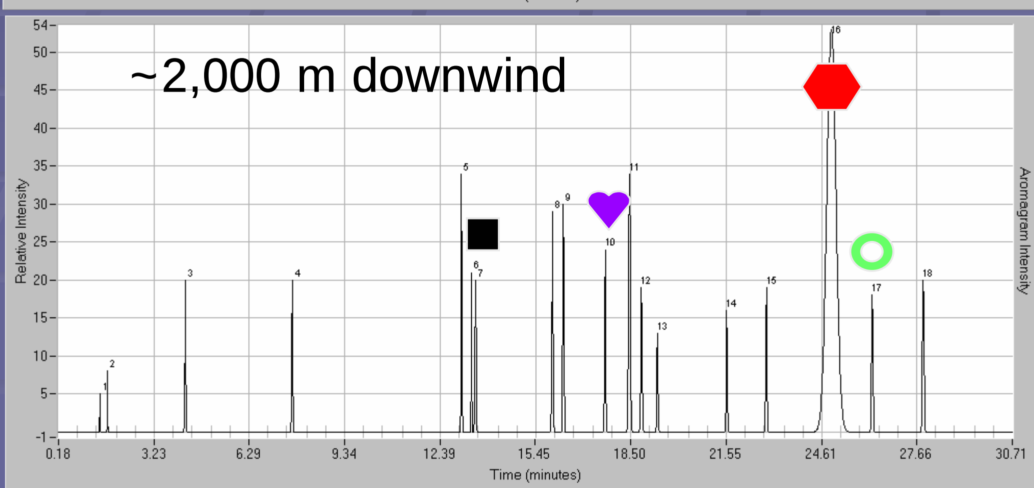
MDGC-MS-O analysis of odor samples collected with SPME (Koziel, TAES-AMA)



Analysis of beef cattle odor (Aromagrams)







- p-ethyl-phenol
- p-cresol
- isovaleric acid
- butyric acid
- DMTS
- acetic acid
- methyl mercaptan
- trimethyl amine

Obj. 1--Significant Findings, Years 1 & 2

- VOC's–GC/MS/SPME
  - 30+ detected
  - including VFA's.

- Multidimensional olfactometry vs. GC/MS—"Aromagrams"
  - Odorants changed with distance downwind of feedyard.
  - Major constituents of downwind odor—
    - p-cresol
    - p-ethyl phenol
    - Isovaleric acid.

- Ammonia reduction w/ surface-applied urease inhibitor:

  ~50+ % in vitro/lab;

  ~ 0 % in preliminary field tests.

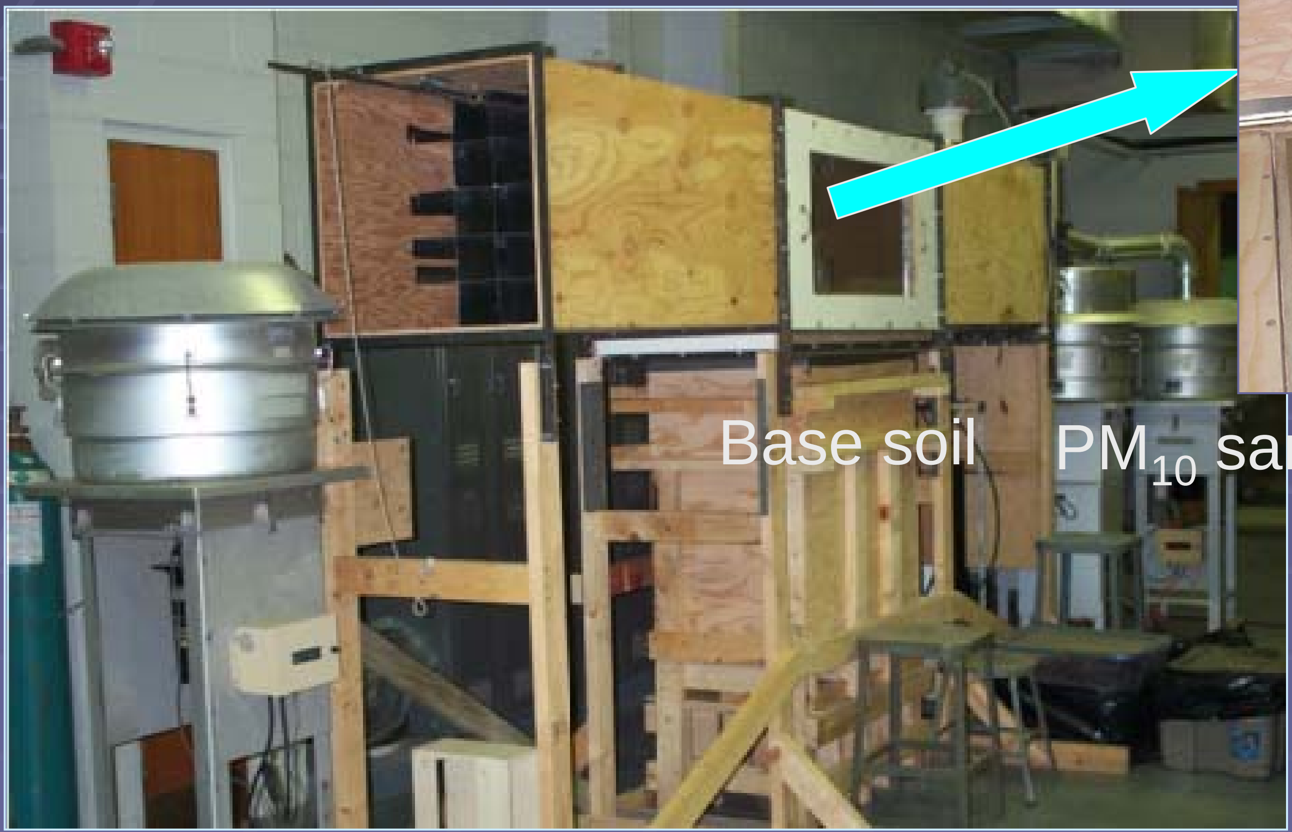
Objective 2. Cattle Feedlot Dust (PM) Emissions

- Diurnal pattern, PM.
- Hot dry weather; evening/night cooling.
- Cattle aggressive activity ~2 hrs sunset.
- Inversion conditions.

Objective 2: Abatement Measures

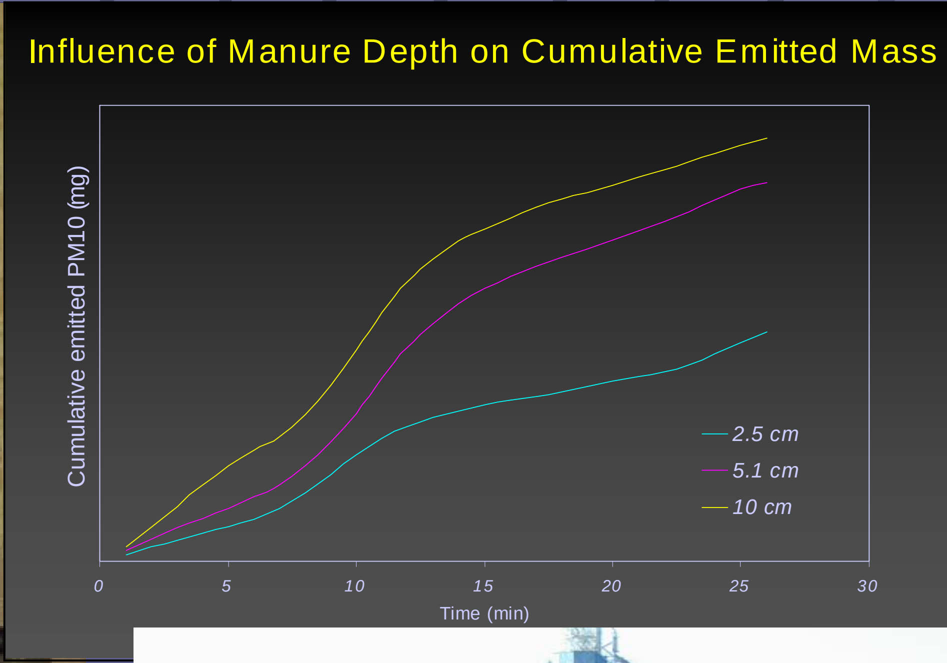
Maghirang, KSU; Auvermann, TAES/TAMU

Weight Drop Test Chamber



Objective 2--Abatement Measures/PM

Weight Drop Test Chambers (TAES/TAMUS & KSU)



WDTC results:

* Loose, **dry manure @ 1, 2 or 4" depth**
* At given impact energy & moisture:
  * **PM_{10} increased with depth.**

Recommendation—>frequent scraping!!

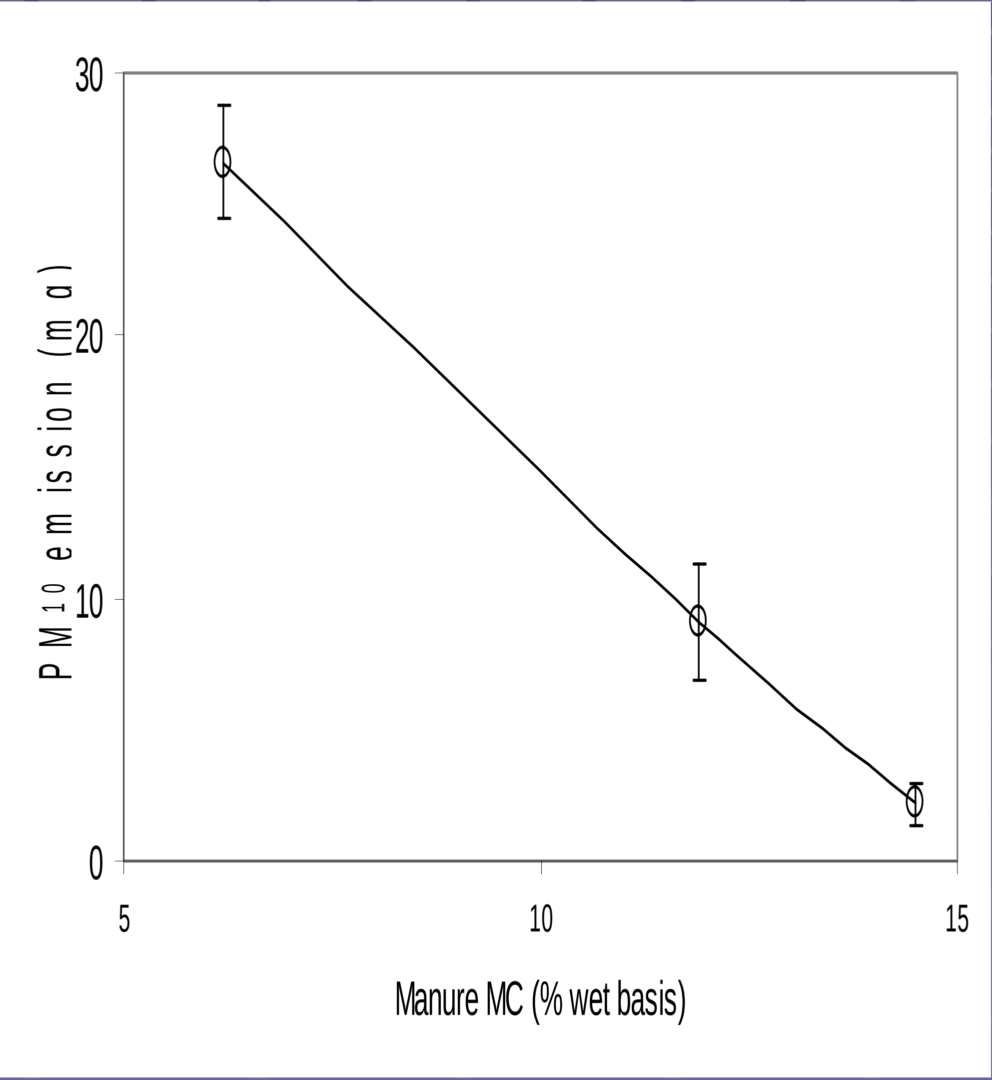
* Greatest benefit: 2" → 1"
* Marginal benefit: 4 " → 2

Objective 2 --Abatement Measures/PM

Weight Drop Test Chambers

(Auvermann,TAES/TAMUS; Maghirang & Murphy, KSU)

- Moisture content vs. PM_{10} emission, mg.
- Test conditions:
  - 3 reps.
  - 10 cm depth
  - Drop energy = 54 J
  - 95% C.I.
- Results:
  - moisture is critical
  - ~10 x increase in PM_{10} from 20 % → 6% MC.



Objective 2—PM Abatement Measures

(Auvermann & Marek, TAES/TAMUS-AMA)

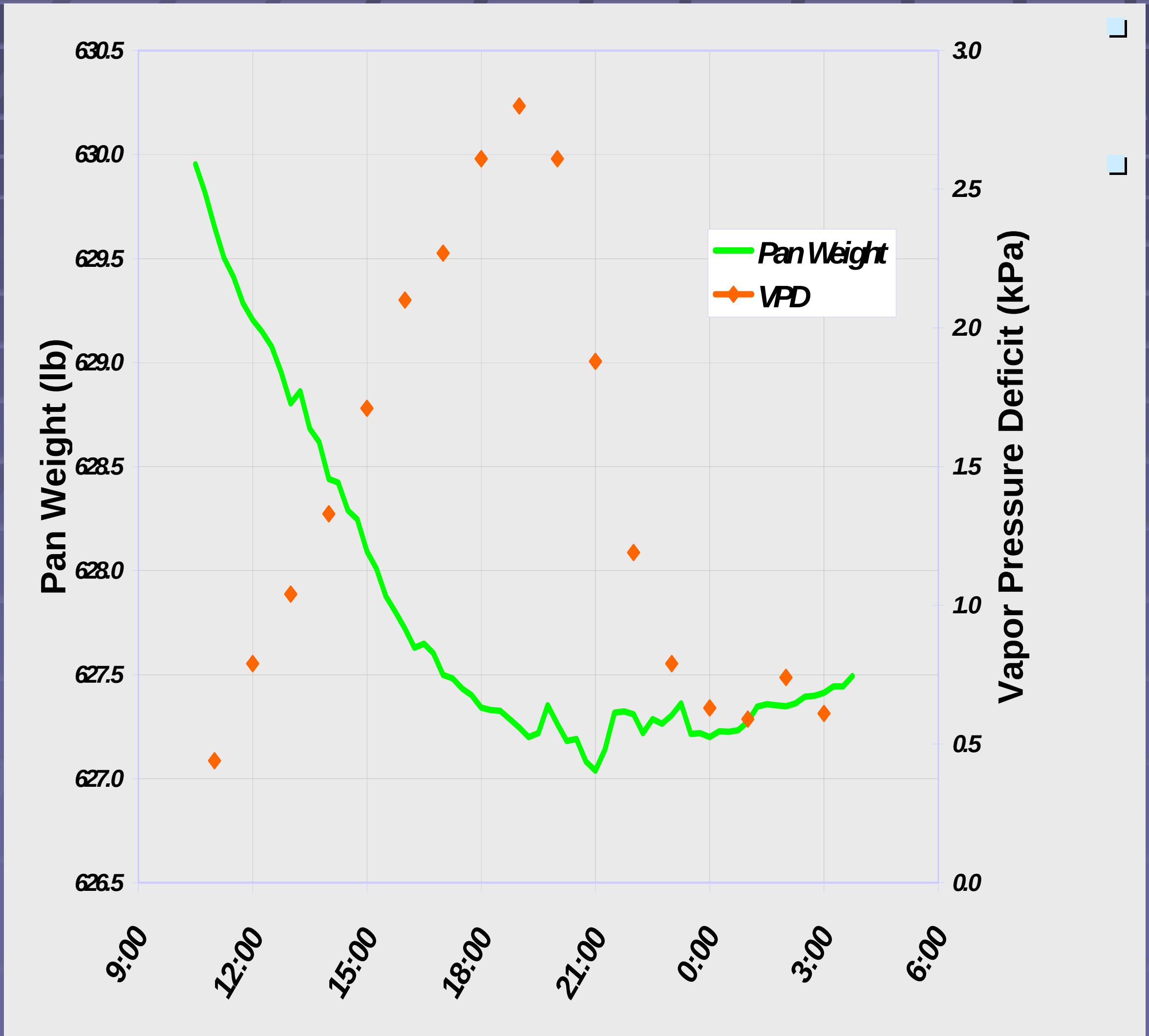
How Much Water?

- Major upgrade to lysimetry system completed May 2004
- Real-time data
- Data already show diurnal effect of "hygroscopicity"
- Web-based control, datalogging and video monitoring

Objective 2—PM Abatement Measures

Feedlot Evaporation Rate (lysimetry)

(Auvermann et al., TAES-AMA)



- **Surface manure moisture, summer**
- **Diurnal trend, summer.**
  - **Afternoon--**
    - **Rapid evaporation**
    - **Rising vapor pressure**
    - **Minimum ~ 9 pm.**
  - **Night--**
    - **Falling vapor pressure**
    - **Rising humidity**
    - **Hygroscopic adsorption.**

Obj. 2--Significant Findings, Years 1 & 2

- **Particulate matter/"feedlot dust"—**
  - Intrinsic susceptibility increased with:
    - Simulated hoof energy –vertical mode
    - Greater manure depth
    - Decreased moisture content <20% w.b. (10x increase).
- **Evaporation rates (lysimeters) —**
  - Winter ~ 50-70% of ETo.
  - Summer < 30% of ETo;
  - High evaporation rate -- daytime
  - Hygroscopic effects -- night/morning.

Obj. 2—Potential Chemical Mulches: $MgCl_2$ and Organic Polymer (X-hesion).

(Maghirang, KSU)

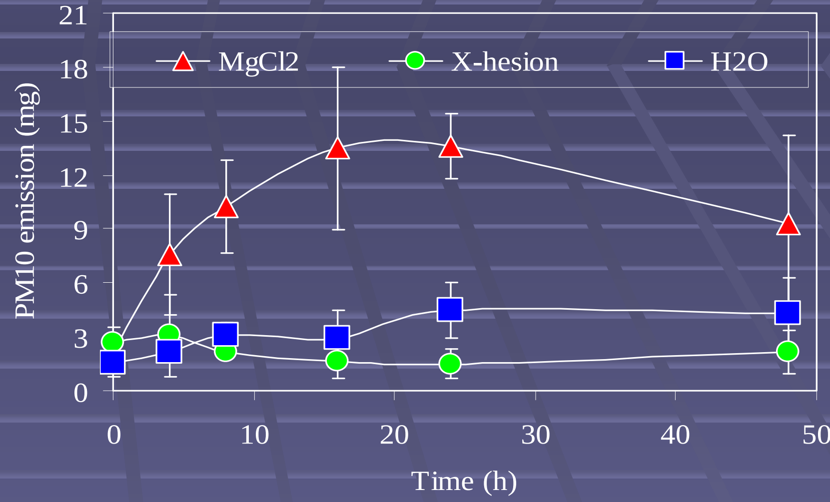
- The effectiveness of $MgCl_2$ and an organic-based polymer (X-hesion) was compared with that of water.
- The two materials were applied in accordance with manufacturers' specifications.
- Drop tests involved 27 J of drop energy and 10 cm manure depth.

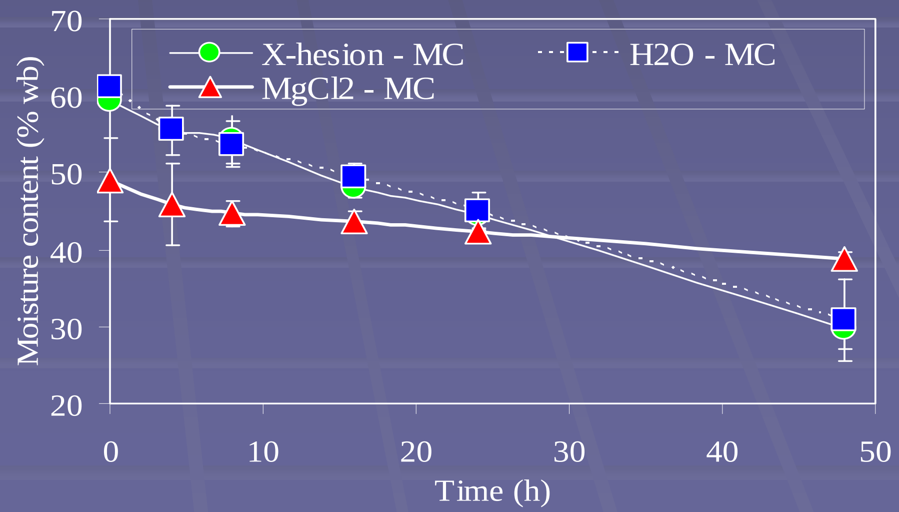
1 h after application

48 h after application

MgCl$_2$ and Organic Polymer (X-hesion), con't.

- Manure treated with MgCl$_2$, X-hesion, & water did not differ in PM$_{10}$ emission immediately after application.
- As the wet surface manure layer dried up, however, the manure with X-hesion had the least PM$_{10}$ emission and the manure with MgCl$_2$ had the greatest emission.





Objective 2—PM Abatement Measures

- **Frequent manure harvesting/scraping** *—reduce depth.
- **Sprinkler irrigation** *–replace evaporative demand.
  - Water requirement ~> cattle drinking water needs.
  - Scheduling vs. moisture balance/ET data.
- **Cattle stocking density** —excreted moisture, smaller area.
- **Water curtain** —Edge-of-feedlot sprinkler/“scrubber”.
- **Mulches**—physical, chemical, etc.?

** Denotes USDA-NRCS- EQIP/TX cost-share practices, 2003-05.*

Objective 3– Scientific Basis for Emission Factors

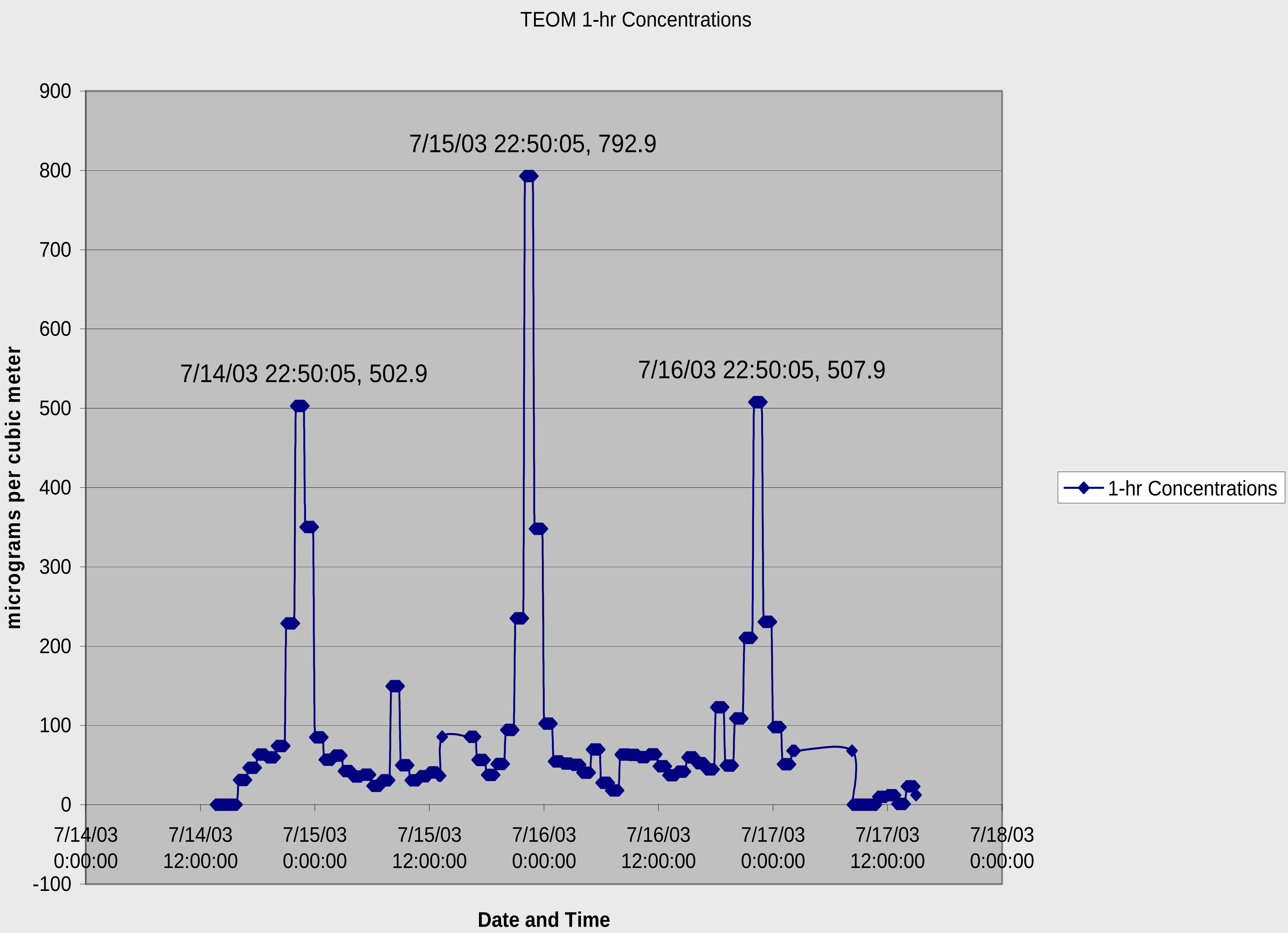
- Biological & Agricultural Engineering Dept., TAMU
  - **Calvin Parnell**
  - **Bryan Shaw**
  - **Ron Lacey**
  - **Saqib Mukhtar**
  - Sergio Capereda.
- Center for Agricultural Air Quality Engineering Science, TAMUS
- Co-located PM_{10} and TSP samplers

Emission Factors

- Development of Cattle Feed Yard Fugitive Dust Emission Factors
  - 280 lbs/1000hd-day (TSP)
    - Peters and Blackwood, 1977
    - Algeo data with infinite line source model
  - 70 lbs/1000hd-day (PM_{10})
    - Sweeten et al, 1988
    - PM_{10}/TSP ratio = 25%
  - 10 lbs/1000hd-day (PM10)
    - Parnell, S. 1994
  - 15 lbs/1000hd-day (PM_{10})
    - Parnell et al, 1999
    - Source sampling

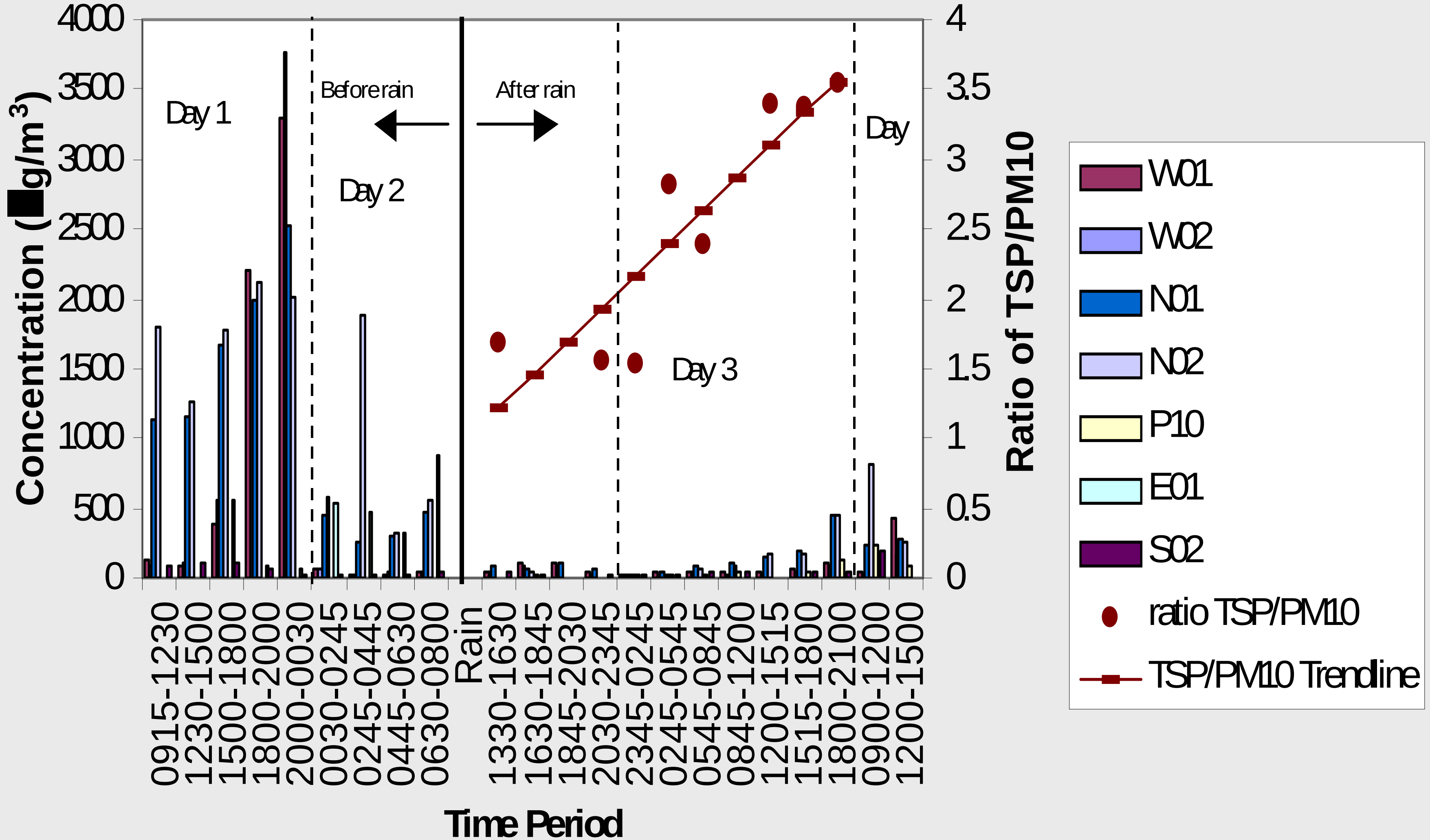
Emission Factor Development Protocol
(Parnell et al., TAMU)

- Source sampling at a Texas feed yard
  - 5 Co-located TSP/PM_{10} Samplers
  - 2 TEOM Samplers
  - Tower with TSP samplers at 5, 7, and 9m
  - Met Station
- ISCST3
  - TSP Measured Concentrations
  - Met Data
- PSD Data to Correct TSP to PM_{10}



TEOM 1-hr Concentrations
900
800
700
600
500
400
300
200
100
0
-100
micrograms per cubic meter
7/14/03 22:50:05, 502.9
7/15/03 22:50:05, 792.9
7/16/03 22:50:05, 507.9
7/14/03 0:00:00
7/14/03 12:00:00
7/15/03 0:00:00
7/15/03 12:00:00
7/16/03 0:00:00
7/16/03 12:00:00
7/17/03 0:00:00
7/17/03 12:00:00
7/18/03 0:00:00
Date and Time
1-hr Concentrations

Measured Feedyard PM Concentration



Obj. 3--Significant Findings—Years 1 & 2

- **Summer PM emissions—**
  - Diurnal patterns
  - Evening/nighttime peaks ~ 10-20 X daytime concentrations.
  - Nighttime PM emission peaks –influenced by inversion conditions (“fanning”).
  - Low moisture + cattle activity + inversions.
  - Rainfall– reduces PM emission & lowers TSP/ PM_{10} ratio.
- **Dispersion model comparison**
  - Compared back-calculated emission flux from concentration data
  - ISC Model (Gaussian) vs. bLS (Euolarean) ~ 10 X differences
  - Cannot mix-and-match methodologies.
- **Development of accurate emission factors**
  - PM, NH_3, H_2S, VOC, odor.
  - continuing for open-lot feedlots & dairies

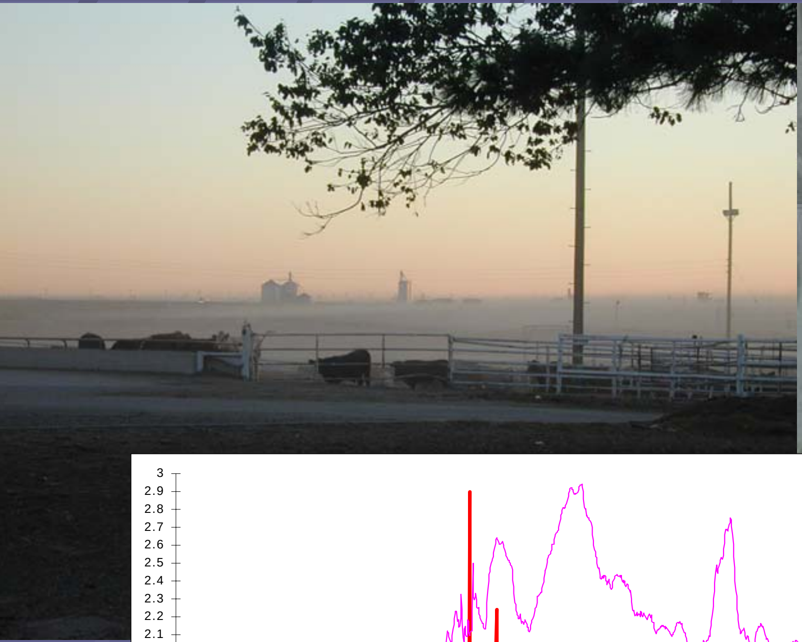
Dairy NH_3 sampling for Emission factor development, Muhktar, BAEN/TAMU

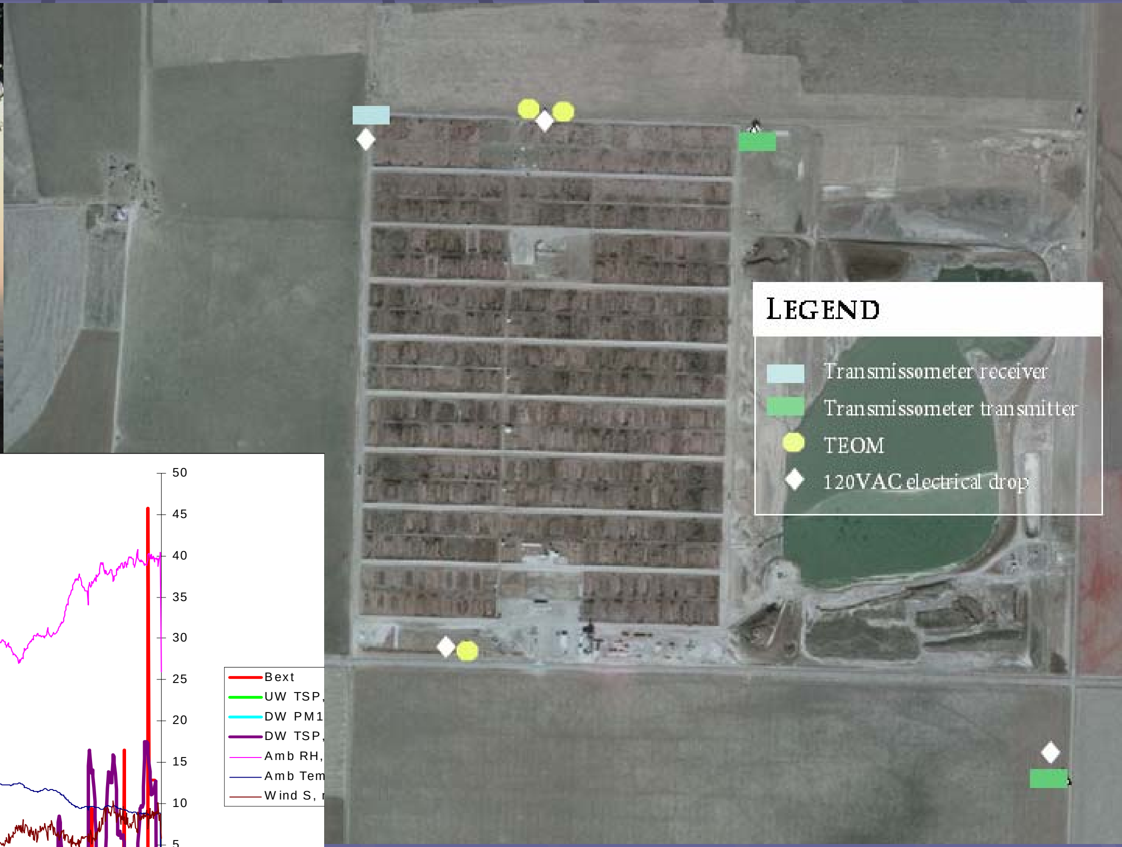
Hybrid Dairy NH_3 Conc. & ER for 2003 Summer, Muhktar, BAEN/TAMU

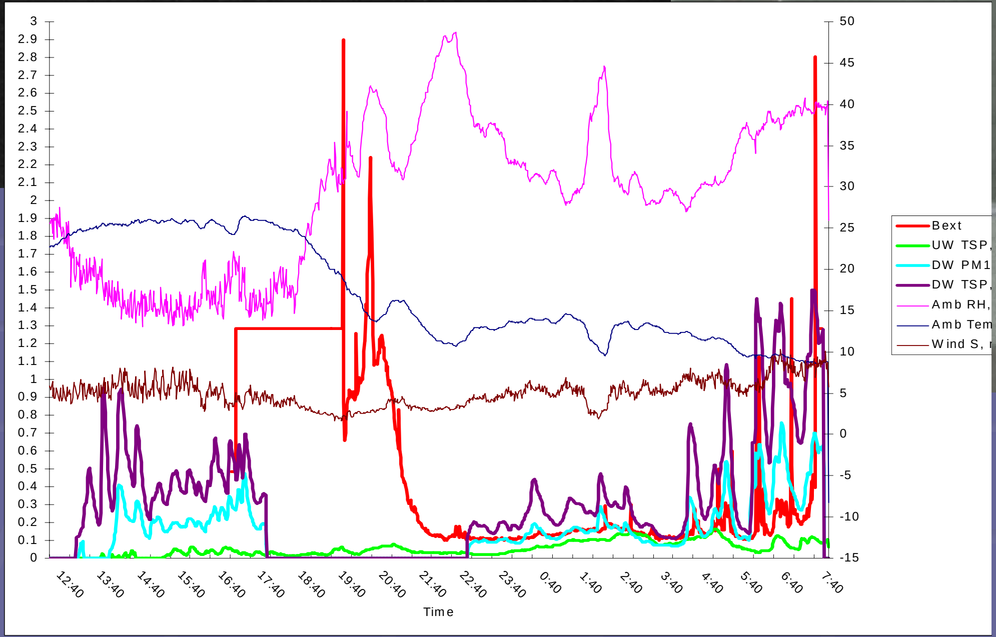
GLAS	Samples	Conc. (ppm)	Flux (μg/m²/s)	ER (kg/day)	GLAS Temp. °C	Amb. Temp. °C
Compost	11	1.9 ±1.6[b]	0.81 ±0.7 [b]	1.17 ±0.97 [b]	43.17 ±7.1[b]	33.34 ±1.6 [b]
Freestall	14					
Non-feed	5	57.5 ±50.5	20.53 ±23	4.79 ±5.4	25.79 ±3.16	33.38 ±1.33
Feed	5	74.0 ±72.4	31.75 ±31	8.48 ±8.3	33.91 ±56.1	34.60 ±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)

Continuous Monitoring of PM
(Auvermann, TAES-AMA)







Objective 4. Animal Health Effects

Dust/PM Exposure Chambers

Objective 4 –Animal Health Effects

(Cole, ARS; Auvermann, TCE/TAES; Brown/Loneragan, WTAMU; Pickrell, KSU)

- **PM exposure chambers for incoming calves**
  - Prototype—designed & built.
  - Calibrated for PM_{20} delivery.
  - Test chambers constructed.
- **Cattle exposure experiments → Year 3**
- **Feeding trials — calf performance & health effects indicators (Brown & Loneragan, WTAMU; Pickrell, KSU).**
- **Health effect indicators** --
  - Blood antioxidant (Chirase, TAES)
  - Lung lavage fluids (Pickrell, KSU)

Objective 5 –Technology Transfer

- **Project Industry Advisory Committee**
  - TCFA & KLA
- **QA/QC plan** developed.
- **Graduate students** ~ 30 involved with project.
- **Scientific outputs**, to August '04:
  - > 60 professional papers.
  - > 10 refereed journal articles, published or subm.
  - > 50 presentations at scientific meetings; etc.
- **Co-funding** recruited > $ 2 million to date.