Cattle Feeding & Environmental Air Quality

Some Research Highlights from the 2002-2013 USDA-NIFA Special Research Project:

“Air Quality: Reducing Emissions from Cattle Feedlots & Dairies (TX & KS)”

Reported by
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Amarillo TX

Presented to:
USDA-Agricultural Air Quality Task Force
College Station, TX
August 21, 2014
Significant multi-year funding has included:

**Federal, State & Private**

- **Primary Funding:**
  - Other NIFA-AFRI & NSF spinoff grants: n~10

- **Important co-funding has included:**
  - TX A&M AgriLife Research—State Air Quality Legislative exceptional item, 1999-present.
  - KSU— similar parallel State funding.
  - USDA- ARS: Distillers Grains cattle feeding research program, ~2005-present. Included Cooperative Agreements with TX A&M AgriLife Research & WTAMU.
  - TX A&M AgriLife: WDG/Cattle Feeding, State Legislative exceptional item, 2007-present.
  - Private industry & commodity assn. grants (several): TX, CA, NM.
  - Regulatory agencies: TCEQ, others.
USDA-NIFA Federal Air Quality Initiative (FAQI):
“Air Quality: Reducing Emissions from Cattle Feedlots & Dairies (TX & KS)”

- **Objectives (4):**
  A. Abatement measures & receptor impacts.
  B. Process-based emission models.
  C. Dispersion modeling, regulation & emission factors.
  D. Technology transfer to stakeholders.

- **Research Partnering agencies/universities:**
  TX A&M AgriLife Research *(lead agency)*; TX A&M AgriLife Extension; KSU; WTAMU; USDA-ARS. **Collaborator:** UN-L Extension.

- **Industry Partners: **Stakeholder Advisory Committee
  - TCFA, KLA, NCBA, TFB, TAD, USDA-NRCS, TCEQ, USEPA Reg. 6&7.
USDA-NIFA Federal Air Quality Initiative (FAQI):

Project team

Texas A&M AgriLife Research/Extension

- Amarillo/Vernon faculty:
  - Brent Auvermann
  - Steve Amosson
  - Ken Casey
  - Kay Ledbetter
  - Jim McDonald (AgriLife & WT)
  - Ted McCollum
  - Seong Park (Vernon & AMA)
  - Bill Pinchak (Vernon)
  - J. Osterstock/Pablo Pinedo

- BAEN College Station faculty:
  - Calvin Parnell
  - Brock Faulkner
  - Sergio Capareda
  - Saqib Mukhtar
  - Bryan Shaw
  - Ron Lacey
  - Russell McGee

Subcontractors:

- Kansas State University
  - Ronaldo Maghirang
  - J. Pat Murphy
  - Joe Harner

- USDA-ARS/Bushland:
  - Andy Cole
  - Richard Todd

- West Texas A&M University:
  - Mike Brown (WT & AgriLife)
  - David Parker
  - Marty Rhoades

- Univ. of Nebraska-Lincoln:
  - Richard Stowell

- Administrative Advisors
  - Ray Knighton, USDA-NIFA
  - Ron Lacewell, TX A&M AgriLife
Approaches to Emission Sampling

**Source-specific:**

**Examples:**
- Flux chambers
- Wind tunnels
- Calorimetry chambers.

**Comment:**
- Multiple, indiv. sources.
- Semi-invasive;
- Important for *relative or short-term* comparisons;
- Fairly high precision;
- Accuracy *depends* on: protocols & instrumentation for sampling & analysis, frequency, intensity, scale, etc.

**Source-integrated:**

**Examples--**
- PM$_{10}$ sampler array.
- Open path lasers, TDLAS
- Open path FTIR.

**Comment:**
- Integrates across multiple sources.
- Non-invasive.
- Seeks *absolute* values.
- Accounts for spatial & temporal variability.
- Ambient air or open paths.
Common Emission Expressions

• **Emission concentrations:**
  – mass/volume (µg/m³)
  – Volume/volume, ppmv or ppbv.

• *With inverse dispersion modeling*, measured concentrations are used to produce calculated values for:
  – **Emission rate**, mass/time, µg/sec, or kg/day.
  – **Emission flux**, mass/area/time: µg/m²/sec, or kg/m²/yr.
  – **Emission factor**, mass/time/unit of production or throughput: e.g. lbs/day/1,000 hd cattle.
Objective A. Abatement Measures & Receptor Impacts

- Particulate matter, PM$_{10}$
  - Average daily concentrations
  - Peak concentrations
  - Effects of: moisture content, surface manure depth, water sprinkling, manure harvesting, surface mulches, etc.
- Ammonia – effects of ration & manure mgmt.
- Hydrogen sulfide — holding ponds & surface manure
- Volatile organic compounds (VOCs)
- Greenhouse gases (GHGs)
PM10 MASS Concentration vs. Time of Day

PM$_{10}$ Mass Concentrations - Feedyard A Upwind and Downwind
March 20, 2007

Time of Day

PM$_{10}$ Downwind
PM$_{10}$ Upwind
PM$_{10}$ Net Downwind
24-hr Avg Net Downwind
Increased Cattle Activity

Driest Pen Surfaces

Critical threshold is 20% moisture, Auvermann & Maghirang

Transient Inversion

Evening Dust (PM) Peak (EDP)

“Perfect storm” conditions:
- Lowest daily moisture;
- Cattle hoof stirring;
- Developing inversion condition.
Cattle hoof energy, elevates surface particles

**Conceptual model (Auvermann):**

Emission Factor, EF (g/hd/d) =

Pen Surface Dustiness, S (g/kJ) × Animal Activity, AA (kJ/hd/d)

Evening Dust (PM) Peak (EDP)
Evening Dust Peak, EDP

(Auvermann, Texas A&M AgriLife)
Abatement Measures: PM$_{10}$

- **Critical moisture threshold** is 20% surface manure moisture (Auvermann & Maghirang)
- **Abatement measures:**
  - **Solid-set sprinklers** (Auvermann & Maghirang)
    - 50-80% measured effectiveness
    - Cost/benefit, depending on assumed EF ~ $0.75-1.00/lb PM$_{10}$
      - Higher EF yields improved cost/benefit, and vice versa.
  - **Manure harvesting**
    - Including increased harvest frequency.
  - **Stocking density manipulation**
    - Reduces water requirements
    - Extends rainfall effects
    - Must preserve bunk space per head, re: cattle performance.
Obj. A-- Abatement Measures & Receptor Impacts

- **Solid-set sprinklers:**
  - **PM$_{10}$ control efficiency (24-hr values):** *(Maghirang, KSU)*
  - Sprinkled feedyard (KS1):
    - PM$_{10}$ concentration reductions: mean = 53% (range = 32-80% ).
    - PM$_{10}$ emission rates 24-hr reduced: mean = 49% (range=12-92%)
    - PM$_{10}$ emission rates for EDP reduced: mean = 61% (range = 21-93%).
    - Sprinkler effect lasted one day. Improved w/higher application.
  - Rainfall effect for sprinkled vs. unsprinkled (KS2) feedyards:
    - means --KS1 = 77%; KS2 = 76%;
    - range = 60 - ~100% both feedyards.
    - Rainfall effect lasted 3-7 days, per amount & intensity.
  - Cost/benefit of sprinkling, EF-dependent~ $0.75-1.00/lb PM$_{10}$

*(B. W. Auvermann & S. Park, TX A&M AgriLife)*
Sprinkler Water Application, per head

(Auvermann, TX A&M AgriLife)

Fyd Water Use, gal./day

Total water use
~32 gpd/hd
~19 gpd/hd

Cattle Drinking water

Sprinkler

Day of Year
Water Application for Feedyard Dust Control

**Suggestions:**

- Don’t rely on water ALONE if uncompacted manure is deeper than ½”-1”
- Longer sprinkler sets rather than more numerous, IF POSSIBLE
- The last set of the day should be the downwind set, if layout permits.
  - B. W. Auvermann
Obj. A. Abatement Measures & Receptor Impacts

- **Frequent pen scraping/manure harvest:**
  - **PM$_{10}$ control efficiency (24-hr values):** (Maghirang, KSU; Auvermann, TX AgriLife)
    - PM$_{10}$ concentrations, before vs. after scraping
    - Reductions: mean = 40%; range = 11-61%.

- **Prioritize & focus harvesting operations:**
  - Begin downwind side, work upwind.
  - Cattle nearest slaughter weight
  - Operate when sun is highest
  - Remove manure immediately or compact to reduce redistribution.
### Stocking Density Treatments (Auvermann)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Control</th>
<th>TRT 1</th>
<th>TRT 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>J-Row Block</td>
<td>Pens J11-J19</td>
<td>Pens J6-J10</td>
<td>Pens J1-J5</td>
</tr>
<tr>
<td>K-Row Block</td>
<td>Pens K11-K19</td>
<td>Pens K6-K10</td>
<td>Pens K1-K5</td>
</tr>
<tr>
<td>Cattle Spacing</td>
<td>150 sq. ft./hd.</td>
<td>75 sq. ft./hd.</td>
<td>75 sq.ft./hd.</td>
</tr>
<tr>
<td>Method</td>
<td>Industry standard</td>
<td>Pen Area Reduced 50% by fence</td>
<td>Doubled Cattle Numbers per Pen</td>
</tr>
</tbody>
</table>

#### Mobile Monitoring Platforms

- PM10 (OPS)
- Empty Pens
- Control Pens
- Treatment 1 Pens
- Treatment 2 Pens

- Southernly Wind
- August 23, 2012, Loop 2
Effect of Stocking Density on PM$_{10}$ Concentrations, µg/m$^3$

Auvermann, TX A&M AgriLife Research.

- **Control**
- **Treatment 1**
- **Treatment 2**

Downwind PM$_{10}$ Concentration

- **J Row**
- **K+J Rows**
Effect of Stocking Density on PM10 Emission Factor, lbs/day/1,000 hd

Auvermann, TX A&M AgriLife Research.

- **Control**
- **Treatment 1**
- **Treatment 2**

**J Row**

**K+J Rows**
Objective B. 
**Process-based emission models.**

- **Process-based modeling:**
  - Mathematical expressions based on good understanding of emission source(s) & causal mechanisms.

- **Hypothetically:**
  - *Modeling* prediction/evaluation is generally *cheaper* than in-field *monitoring*; but it requires *robust* models.

- **Major recent focus:**
  - Particulate matter, PM$_{10}$ (dust) (*Maghirang & Auvermann*)
  - Ammonia (*Todd, Cole & Waldrip*)
  - Hydrogen sulfide (*Casey*)
  - Greenhouse gases: N$_2$O, CH$_4$, CO$_2$ (*Casey, Faulkner, Cole, Todd, Waldrip, Capareda, Mukhtar, Maghirang*).
PM$_{10}$ Conceptual Model, an example (Auvermann)

PM$_{10}$ Emission Factor, EF (g/hd/d) =

Pen Surface Dustiness, S (g/kJ)

$\times$ Animal Activity, AA (kJ/hd/d)

In which:

• S = “[Intrinsic] dust susceptibility”

• Key Factors Affecting S: Varies spatially & temporally through 3 surface layer properties:
  – Moisture content
  – Bulk density
  – Depth

• USDA-NRCS Standard 375 addresses all three.

• Pen surface assessment tool,
  – Condition A, B, C, ...
  – Descriptors.
Obj. B. Process-based emission models.

- Measurement of **GHG Fluxes from Feedyard Pens** using non-flow-through/non-steady-state (NFT-NSS) chamber techniques *(K.D. Casey, TX A&M AgriLife Research)*

- Objectives:
  - Develop understanding of spatial, temporal and seasonal variations in $\text{N}_2\text{O}$ and $\text{CH}_4$ fluxes from feedyard pen surfaces
  - Collaborate with modelling community and **contribute to improving models** of GHGs from CAFOs.
    - Working with Heidi Waldrip USDA-ARS et al.
Non-Flow-Through (NFT)/Non-Steady-State (NSS) Flux Chambers

Advantages:
• Dominant technique used by scientists for measurement of GHG fluxes from other land and crop systems.
• Well developed methodology and well supported in the scientific literature
• Very useful for developing an understanding of the emission processes

Disadvantages:
• Small area measured by each chamber may not be representative of a large highly spatially-varied area for determining overall emission rates
  • Integrative techniques such as eddy correlation (EC) and open path measurement:
    • face significant operational challenges in the feedlot environment
    • Instrumentation to continuously measure N\(_2\)O at required speed and resolution is very expensive, has limited field deployment potential and is only just becoming available
    • Provides limited information for developing an understanding of the emission processes because the spatial variability masks the response of individual areas
GHG Sample Collection and Analysis

NFT-NSS chamber with top installed and sealing skirt rolled up.

Two rows of five NFT-NSS chambers installed in a pen at Feedyard-C.
GHG Sample Collection and Analysis

K.D. Casey

Air sample collected from NFT-NSS chamber being injected into an evacuated vial.

Gas chromatograph used for analysis of GHG samples.
Methane and nitrous oxide flux rates for different pen areas *(K.D. Casey)*

*Oct.-Dec, 2012*

<table>
<thead>
<tr>
<th>Feedlot</th>
<th>Overall</th>
<th>Near Feed Bunk</th>
<th>On Mound</th>
<th>Near Water Trough</th>
<th>Mound Edge</th>
<th>Visually Wetter Area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CH₄</td>
<td>N₂O</td>
<td>CH₄</td>
<td>N₂O</td>
<td>CH₄</td>
<td>N₂O</td>
</tr>
<tr>
<td>Fyd-C – Oct 12</td>
<td>10.96</td>
<td>0.03</td>
<td>17.80</td>
<td>0.03</td>
<td>5.98</td>
<td>0.04</td>
</tr>
<tr>
<td>Fyd-A – Nov 12</td>
<td>4.85</td>
<td>9.85</td>
<td>7.66</td>
<td>46.57</td>
<td>2.95</td>
<td>4.05</td>
</tr>
<tr>
<td>Fyd-C – Nov 12</td>
<td>1.40</td>
<td>0.15</td>
<td>1.82</td>
<td>0.01</td>
<td>0.10</td>
<td>0.45</td>
</tr>
<tr>
<td>Fyd-C – Dec 12</td>
<td>2.03</td>
<td>0.13</td>
<td>0.90</td>
<td>0.02</td>
<td>0.08</td>
<td>0.05</td>
</tr>
</tbody>
</table>
Average methane and nitrous oxide flux rates for Fyds. A & C, mg m\(^{-2}\) h\(^{-1}\)

\((K.D.\ Casey)\)

<table>
<thead>
<tr>
<th></th>
<th>Feedyard-A</th>
<th>Feedyard-C</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH(_4) Flux</td>
<td>4.85</td>
<td>10.96</td>
</tr>
<tr>
<td>N(_2)O Flux</td>
<td>9.85</td>
<td>0.03</td>
</tr>
<tr>
<td>(s.d.)</td>
<td>3.26</td>
<td>11.96</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.04)</td>
</tr>
</tbody>
</table>
Tentative Observations, CH4 & N2O flux rates (K.D. Casey)

• **Methane flux rates:**
  - Reduced with the seasonal decline in ambient temperature.
  - Highest from areas where the manure pack was visually more moist, including near the feed bunk and wet patches.

• **Nitrous oxide flux rates** were much higher at Feedyard-A than at Feedyard-C.
  - This variation could result from the different manure management practices at the feedyards, with Feedyard-A harvesting manure from the pens twice per year whereas manure removal was performed annually at Feedyard-C.
  - Highest at sampling positions on a manure mound, on the edges of manure mounds and near the water trough.

• **Manure pack temperature** at 50 mm (2 inches) depth generally follows ambient temperature for the same interval.
  - Flux rates respond quickly to changes in temperature
  - Implying the generation process is in the surface layer of the manure pack

• **Overall**—Considerable **spatial variability** in emission fluxes within each pen.
Open-Path FTIR, Methane & Nitrous oxide emissions (W.B. Faulkner & K.D. Casey)

- **Goal** - develop baseline greenhouse gas (GHG) emissions data from a Texas cattle feeding operations

- **Issues**
  - Dust obscured optics
  - Alignment issues
  - Inter-instrument bias
OP-FTIR Installation at Feedyard C

Path Length = 510 m

PL = 290 m

1120 m

810 m
Spatially Averaged Greenhouse Gas Emissions

- **Premise:** Different areas of feedyard pen emit at different rates: near feed-bunk, near water trough, mounds, drains, other pen area
- Emissions vary seasonally, temporally, with management activities and with episodic weather events
- **Promise:** Open-path FTIR systems offer potential to obtain spatially integrated measurements over significant time periods suitable for determining emission factors.

- **Protocol:**
  - Two, open-path FTIR systems deployed at Feedyard C to measure N$_2$O and CH$_4$ emissions.
  - First unit was located on predominant downwind edge of feedyard while the second unit was located on predominant upwind edge of feedyard

- **Realization:**
  - Relatively long path lengths were necessary to obtain sufficient sensitivity as measured concentration were not substantially greater than background concentration.
  - Background concentration (~320 ppb) potentially varied with activities on adjacent land areas.
  - Expected increase across the feedyard was perhaps 10%.
  - Measured increases across the feedyard were too variable to report with confidence/comfort at this time.
  - Simultaneous use of both source-specific & source-integrated sampling, may improve accuracy of determining GHG emission factors. (*Faulkner & Casey*)
OP-FTIR System Experience

• **Installation/set-up challenges**
  – Small foundation/structural movements can significantly affect signal strength over required long paths

• **Technically Challenging**
  – FTIR measurement and spectral processing for N₂O in agricultural environments not well defined
  – Performance differences between two otherwise identical FTIR system posed problems when computing emissions based on the measurements by the two systems. Relatively few hours of co-extensive data collected.

• **Significant learning curve**
  – Instrumentation and processing software

• **Maintenance challenges**
  – **Hostile** monitoring environment
    • Constant dust coating of optics reduces signal strength
    • Atmospheric gases and compounds attached to dust particles corrode the coatings on optical mirrors and lens
  – Maintenance items are very expensive
  – On-going maintenance and reliability issues with downwind FTIR system posed problems when both systems had to operate concurrently for valid measurements

• **Financially Challenging**
  – High capital, operating and maintenance budget requirements

**Summation:** While much has been learnt about making measurement with this system under these conditions, limited useable emissions data has been obtained to date.
Measuring NH$_3$ & CH$_4$ Emissions at Feedyards

Emissions corroborated via total nitrogen balance
How Do We Estimate Emissions?

- Measure gas concentrations (using open path lasers) & micrometeorology variables (sonic anemometers) downwind;
- Use dispersion model (bLS) to calculate emissions.
Respiration Calorimetry System
To Measure GHG from Individual Cattle

- Incoming air
- Outgoing air
- AC
- Feces collection
- Urine collection
- Duplexer
- Gas analyzers
- Air Flow System
Typical Daily Ammonia Emission Rates

Feedyard E
2008

February
April
July
October

Ammonia emission rate (kg min\(^{-1}\))

Hour
0 4 8 12 16 20 24
# Fractional Ammonia Loss, 4-yr data (% of fed N)

<table>
<thead>
<tr>
<th>Feedyard</th>
<th>Summer</th>
<th>Winter</th>
<th>Annual</th>
</tr>
</thead>
<tbody>
<tr>
<td>FYC</td>
<td>68</td>
<td>36</td>
<td>53</td>
</tr>
<tr>
<td>FYA</td>
<td>71</td>
<td>44</td>
<td>58†</td>
</tr>
<tr>
<td>FYE</td>
<td>68</td>
<td>42</td>
<td>52†</td>
</tr>
</tbody>
</table>

† Includes spring and autumn emissions;
$\text{Loss}_{\text{NH}_3-N} = 0.5 \, N_{\text{fed}}$

$\text{EF}_{\text{NH}_3} = 110 \, \text{g head}^{-1} \text{ daily}$
Calculation Worksheet – Ammonia and Hydrogen Sulfide
Beef Cattle Feedyards
January 2009

The following emissions estimates for ammonia and hydrogen sulfide are based on research data collected by Texas AgriLife Research, Texas AgriLife Extension Service, Texas A&M University, USDA-Agricultural Research Service, and West Texas A&M University. Data has been collected as part of the USDA-CSREES-funded project, “Air Quality: Reducing Emissions from Cattle Feedlots and Dairies,” between the years of 2003-2008. Field measurements are on-going and as such these values are a good faith estimate of air emissions based on currently available scientific information.

The final rule on EPCRA reporting issued by EPA on Dec. 18, 2008 and effective Jan. 20, 2009 requires reporting of ammonia or hydrogen sulfide if (1) the feedyard is 1,000 head or larger and (2) the ammonia exceeds 100 lbs/day or the hydrogen sulfide exceeds 100 lbs/day. **DO NOT** report ammonia or hydrogen sulfide values if the “upper bound” is LESS THAN 100 lbs/day.

Feedyard Name: ________________________________

**AMMONIA (NH₃)** EMISSIONS ESTIMATE
The emissions estimates provided below are inclusive of ammonia emissions from the feedyard pen surfaces and the runoff holding pond(s). Ammonia emission rates are generally lower in the winter and higher in the summer.

<table>
<thead>
<tr>
<th>Ammonia (NH₃) Emissions Estimate</th>
<th>Lowest Head Count</th>
<th>NH₃ Emission Rate (pounds/hd/day)</th>
<th>NH₃ Lower Bound (pounds/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NH₃ Lower Bound =</td>
<td>x</td>
<td>0.16ᵃ</td>
<td>=</td>
</tr>
</tbody>
</table>

ᵃwinter emission rate from research data

<table>
<thead>
<tr>
<th>Permitted Head Count</th>
<th>NH₃ Emission Rate (pounds/hd/day)</th>
<th>NH₃ Upper Bound (pounds/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NH₃ Upper Bound =</td>
<td>x 0.48ᵇ</td>
<td>=</td>
</tr>
</tbody>
</table>

ᵇsummer emission rate from research data
Results Summary: USDA-ARS-CPRL

• On an annual basis – about 50% of fed N is lost as ammonia (NH$_3$) from feedyards
• Emissions are about 2x greater in summer than in winter
• NH$_3$ emissions have a diel pattern with lowest emissions at night (cooler, less animal activity)
• NH$_3$ emissions increases with increased dietary N (greater urinary N excretion)
Grain Processing & C-Footprint

Dry Rolled (Cracked) Corn
1.54 Mcal NEg /kg

Steam Flaked Corn
1.68 Mcal NEg /kg

Brown et al., 2008
Enteric Methane, L/day (% of GE)

Hales, Cole, MacDonald, 2012
Distillers Grains and Enteric CH$_4$

g/day (% GEI), Hales & Cole, 2012

0% WDGS  15%  30%  45% WDGS

2.4%  2.5%  2.9%  3.8%

70.6  72.6  85.5  115.6
<table>
<thead>
<tr>
<th>Month</th>
<th>Methane Emission Rate</th>
<th>Methane Conversion Factor ($Y_m$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g animal$^{-1}$ d$^{-1}$</td>
<td>%</td>
</tr>
<tr>
<td>January</td>
<td>84.0</td>
<td>2.7</td>
</tr>
<tr>
<td>February</td>
<td>85.2</td>
<td>2.9</td>
</tr>
<tr>
<td>May</td>
<td>85.9</td>
<td>3.3</td>
</tr>
<tr>
<td>June-July</td>
<td>93.4</td>
<td>3.1</td>
</tr>
</tbody>
</table>

Mean Monthly *Methane* Emissions, Feedyard A, 2010

USDA-ARS-CPRL/Bushland TX

Methane Results Summary
USDA-ARS-CPRL/Bushland TX

- Feeding steam flaked corn (SFC) decreases enteric CH$_4$ emission by 25%, compared to feeding dry rolled corn (DRC).
- Feeding less than 30% wet distillers grain (WDGS) had no effect on CH$_4$.
- Feeding >30% WDGS increased enteric CH$_4$ production.
- CH$_4$ emissions from cattle fed SFC-based finishing diets ranged from 2.5 to 3.0% of GE intake (via both respiration calorimetry and bLS).
Objective C. Dispersion Modeling, Emission Factors, & Regulation
(Parnell, McGee Faulkner et al., TAMU)

- **PM sampler performance:**
  - PM$_{10}$ samplers were designed for use in urban areas where MMD is <10 um.
  - Rural/ag PM is typically 20-30 um.
  - Penetration of only a few large particles results in oversampling of 2X-5X.
  - Can give misleading results & inaccurate regulatory interpretations.
Objective C. Dispersion Modeling, emission factors, and regulation:
(Parnell, McGee, Faulkner et al., TAMU)

• **PM-coarse (PM$_c$) regulation:**

- Subtraction method to determine coarse PM
- Problematic due to shifting cut points on samplers
- Rural/ag PM has large MMDs, negligible PM$_{2.5}$
- PM coarse NAAQs of 70 µg/m3 would effectively be a new PM$_{10}$ NAAQS that is 50% lower than present.
Objective C. Dispersion modeling, emission factors & regulation.

• **Particulate matter, PM$_{10}$:**

  • Developed *correction factors* for non-EDP conditions; translates measured concentrations from EPA’s FRM vs. TEOM sampler types (*Parnell, Faulkner & Auvermann*).
    
    – For low PM$_{10}$ concentration (<100 µg/m²) & small particles (<10 µg MMD): FRM concentrations = TEOM concentrations.
    
    – For high PM$_{10}$ Conc. (>100 µg/m²) & larger MMD (>10 µm):
      
      • FRM conc. = 0.6 x TEOM results.
    
    – If oversampling bias due to very large PM sizes:
      
      • FRM conc. = 0.5 x TEOM results.

  
  – TEOM concentrations of PM$_{10}$ at Fyd. C, non-EDP conditions (20 hrs/day), averaged: Sept. 169; Oct. 107; Nov. 43; & Dec. 63 µg/m².

• **Derived Emission Factors** (non-EDP conditions) varied 3-36 lbs. PM$_{10}$/1,000 hd/day (11.5 average).
Objective C. Dispersion modeling, emission factors & regulation.

• **Feedyard GHG** *(Capareda et al.)*
  • Flux chamber approach, discrete sources.
  • Emitting surface areas: feedpens (89%), retention ponds (5%), compost windrows/piles (6%).

• **Aggregated GHG Emission Rates** *(ERs) per head:*
  – Methane, CH$_4$ = 3.8 g/hd/day.
  – Nitrous oxide, N$_2$O = 0.52 g/hd/day.
  – Carbon dioxide, CO$_2$ = 1,192 g/hd/day.

• **Relative** contributions:
  – **Methane, CH$_4$** : pen surfaces (51%), retention ponds (48%), composting (1%).
  – **Nitrous oxide, N$_2$O** : pens (81%), retention ponds (2%), composting (17%).

• Feedyard values of ER were lower than dairy ER values.
Objective D- Technology Transfer to Stakeholders

- **2002-2013:**
  - Industry/Stakeholder Advisory Committee, met w/investigators ~annually; added much value.
  - Peer-reviewed journal articles (69);
  - M.S./PhD theses/dissertations (22).
  - Book Chapters (13)
  - Scientific conference papers & abstracts (141);
  - Invited presentations to stakeholders (~20+)
  - Extension, TCFA & KLA feedyard management seminars (7)—So. Tx, So. Plains, Panhandle, SW Kansas.
  - Extension fact sheets (22)— includes *extension*, UN-L/NLPELC & AgriLife Extension.
  - Webinars, webcasts & videos (11)
  - In-depth short courses conducted (8) for state regulators TX, KS, IA, OH, etc.
  - Co-Funding: (0.9:1 leveraging of federal grant dollars).
Closing Comments

- Open-lot emissions not straight forward or especially easy to measure.
- USEPA “standard/reference methods” show breakdowns with feedlots and other agricultural sources of PM.
- Flux chamber methods are useful for relative emission values; results can vary with design/operation; standardization needed.
- Long term PM monitoring data bases have been developed at Feedyards C, A  B.
- Dissimiliarities between open-lot cattle feedyards and open lot dairies; EDP is not a factor in dairies.
- Moisture is a main driver; so are ration and manure management.
- Diurnal effects— PM$_{10}$, NH$_3$, H$_2$S, N$_2$O, etc.
- Process-based emission models still under development.
- So are ER’s and EF’s.