Information and Comments, Recommendations (“FWTAW”)

- to NAEMS Science Advisory Board
- by Al Heber, Purdue University
- March 15, 2012

Independent Variables (RH for example)

- ***Function of temperature, "relative"***
- ***Does not directly affect emissions.***
- ***RH is not available information***

For now, use "Simple Sensible Statistical" Prediction

- E' (g/d-m2) = f(LMD, Ti)
  - LMD = # birds x avg wt / area
  - Ti = inside temperature
- So E = A * E'
- So Ti = f(To, LMD, Q', UA, setpoints, etc.)
- Notes:
  - Use hourly data to develop models.
  - Q independent of emissions, per se.
  - Must make physical sense.
- **Use data to validate process-based models.**

Prediction Models – IN3B (based on HOURLY data)

$$E_{PM_{10}} = -0.162277 + 0.001762 * D + 0.010301 * T + 0.000435 * M$$

where:

E_{PM10} = emission rate in g d^{-1} m^{-2}

D = live mass density, kg m^{-2}

T = barn temperature, °C

M = manure depth, cm

Emission rate	**Equations**	**R^2**
NMHC, *kg d^{-1} m^{-2}*	$E_{NMHC} = -0.000030172 + 0.000002162 * D + 0.000008917 * T - 0.000000191 * M$	0.142
H_2S, *g d^{-1} m^{-2}*	$E_{H_2S} = -0.290981 + 0.00523 * D + 0.003924 * T - 0.010019 * M$	0.112
CO_2, kg d^{-1} m^{-2}	$E_{CO_2} = -0.797271 + 0.021896 * D + 0.011926 * T - 0.005058 * M$	0.709
NH_3, kg d^{-1} m^{-2}	$E_{NH_3} = 0.002359 + 0.000061368 * D + 0.000080059 * T$	0.438

D = # animals x average weight / floor area

T = temperature setpoint , default values, thermal model

Sampling times for VOC

- ***"Except for times that canisters were received from multiple sites on same day (rare), <u>we transferred the sample from the canister upon arrival</u>. Several samples had to wait 24 h in the lab, and <u>very very few</u> samples waited more than 48 h before transferring, which was an overnight operation. Analysis would start right after the completion of the sample transfer. Almost no samples waited for more than 48 h before transferring, or analysis after transfer."***

Broiler House VOC Sampling

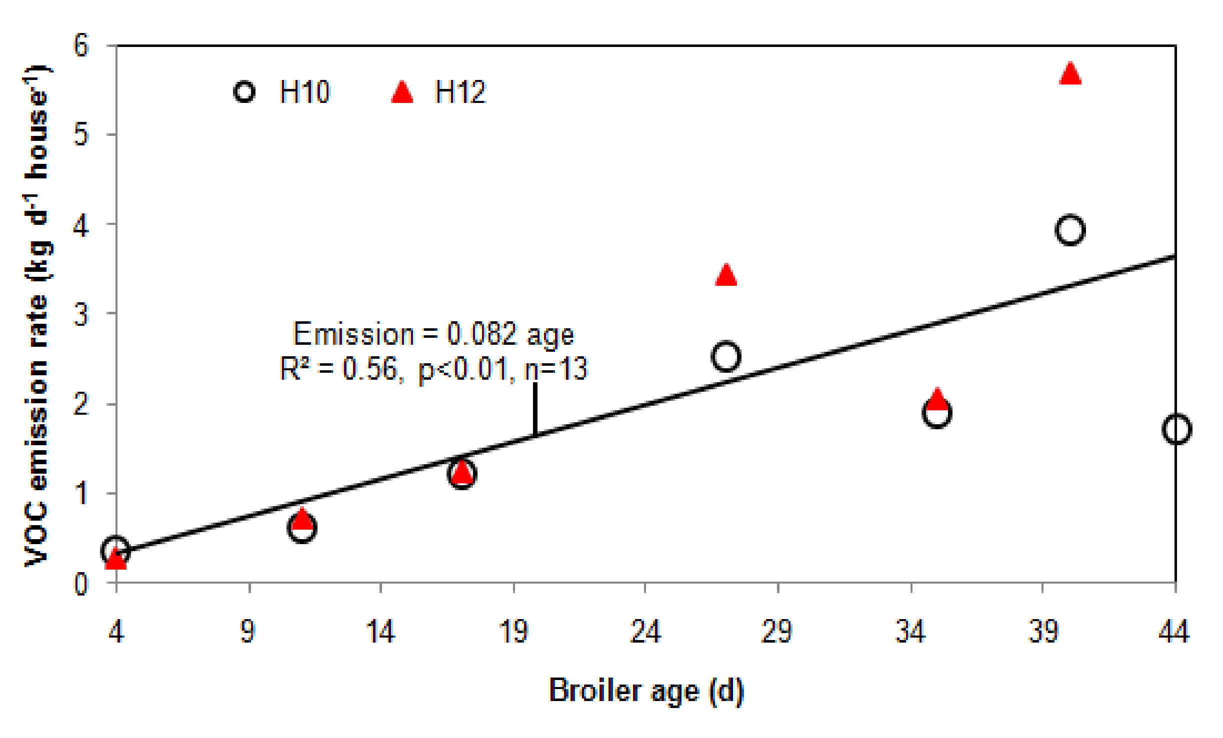
Table 1. Bird and manure age during VOC sampling periods in the broiler houses.

Sample date	Cycle	Bird age, d	Manure age[1], d
7/14/09	1	40	95
8/3/09	2	4	115
8/16/09	2	17	128
8/26/09	2	27	138
9/3/09	2	35	146
9/12/09	2	44	155
10/7/09	3	11	11

[1] Day 1 was the first day of a cycle of birds after all manure was loaded out.

- ***EPA apparently did not use this data and judged the VOC data based on the lack of this information.***

VOC Emission vs. Bird Age



Adjustment of Layer Site VOC Emission to Annual Average

- ***Average VOC emission = <u>5.42 kg/d</u>. House temperature and airflow showed a strong correlation with VOC emission. A linear regression of VOC emission (V) and ambient temperature (T) resulted in V = 0.46 T – 4.5 (R^2=80%). Using this equation to predict the annual average VOC emission based on the historical mean ambient temperature of 15.0°C resulted in V = 0.46 (15°C) – 4.5 = <u>2.40 kg/d</u>.***
- ***Similarly, the California VOC was collected during warm weather and should be adjusted downward to annual average T, which would make the average closer to the Kentucky data.***

Two-Year Average Gas Concentrations and Inlet/Outlet Ratios (%)

Site	NH_3			H_2S			CO_2		
	Inlet	Exh.	Ratio	Inlet	Exh.	Ratio	Inlet	Exh.	Ratio
CA1B	0.29	21.8	1.3%	2.10	39.8	5.3%	449	1,556	28.9%
CA2B	1.40	26.6	5.3%	2.40	22.4	10.7%	474	1,030	46.0%
IN2B	0.70	26.1	2.7%	2.00	46.5	4.3%	495	2,290	21.6%
IN2H	1.90	50.4	3.8%	7.00	24.0	29.2%	483	1,780	27.1%
NC2B	0.91	20.8	4.4%	0.87	9.30	9.4%	506	1,657	30.5%
IN3B	0.20	13.3	1.5%	22.0	596	3.7%	495	2,190	22.6%
NC3B	0.25	11.5	2.2%	4.80	176	2.7%	459	1,522	30.2%
NC4B	0.50	5.73	8.7%	6.00	452	1.3%	450	1,694	26.6%
IA4B	0.42	11.7	3.6%	15.0	1,490	1.0%	459	1,648	27.9%
OK4B	0.29	6.13	4.7%	8.00	334	2.4%	479	1,470	32.6%
IN5B	0.14	2.67	5.2%	2.70	27.8	9.7%	459	767	59.8%
WI5B	0.12	1.75	6.6%	5.40	99.6	5.4%	424	872	48.6%
NY5B	0.40	4.25	9.4%	3.00	28.5	10.5%	484	980	49.4%
WA5B	0.90	1.53	58.8%	25.6	30.5	83.9%	657	792	83.0%
CA5B	0.48	0.52	91.3%	18.0	19.0	94.7%	436	450	97.0%
Avg MV	0.58	15.6	4.6%	6.3	257.3	7.4%	470.5	1,496.5	34.8%
Avg NV	0.69	1.0	75.1%	21.8	24.8	89.3%	546.7	621.0	90.0%

Two-Year Average PM Concentrations and Inlet/Outlet Ratios (%)

Site	PM10, µg/m^3			PM2.5, µg/m^3			TSP, µg/m^3		
	Inlet	Exh.	Ratio	Inlet	Exh.	Ratio	Inlet	Exh.	Ratio
CA1B	58.5	956	6.1%	21.8	104	20.9%	71.2	2,237	3.2%
IN2B	123	663	18.6%	45.0	108	41.6%	350	1,432	24.4%
IN2H	101	556	18.2%	19.0	53.5	35.5%	77.0	1,297	5.9%
NC2B	36.0	464	7.8%	23.0	40.0	57.5%	41.0	885	4.6%
CA2B	58.0	302	19.2%	28.6	53.9	53.1%	56.1	707	7.9%
IN3B	22.0	260	8.5%	13.2	19.3	68.4%	28.0	1,024	2.7%
NC3B	19.2	283	6.8%	11.6	26.2	44.3%	24.4	757	3.2%
IA4B	20.0	324	6.2%	9.0	43.7	20.6%	20.0	753	2.7%
OK4B	29.0	267	10.8%	9.0	30.7	29.3%	27.0	505	5.3%
NC4B	13.0	285	4.6%	1.2	31.3	3.8%	18.0	472	3.8%
IN5B	21.0	24.0	87.5%	13.8	14.5	95.2%	22.0	46.0	47.8%
WI5B	17.7	42.0	42.3%	9.8	19.4	50.5%	21.7	81.3	26.6%
NY5B	13.0	38.5	33.8%	9.3	14.8	63.1%	19.0	65.0	29.2%
WA5B	96.0	182	52.9%	22.8	39.3	58.1%	191	608	31.4%
CA5B	48.0	47.5	101.1%	11.8	6.1	193.4%	65.0	119	54.9%
Avg MV	40.9	343.3	20.8%	16.5	43.0	44.9%	59.6	789.4	12.9%
Avg NV	72.0	114.5	77.0%	17.3	22.7	125.8%	128.0	363.3	43.1%

PM Completeness

- ***PM10 first priority***
  - ***Interrupted only by TSP and PM2.5***
  - ***364/609 = 60%***
- ***TSP second priority***
  - ***Measured 1/8 of the time. 17*7=119 d***
    - ***Completeness = 38/91 = 42%***
- ***PM2.5 third priority***
  - ***2 weeks winter, 2 weeks summer***
    - ***Completeness = 48/28 = 171%***

Table 1. Emissions data completeness (days with >75% valid emission data collection).

Location	NH_3	H_2S	PM_{10}	$PM_{2.5}$	TSP
H10	467	592	352	53	37
H12	466	590	376	43	39

Missing Ammonia Data

Approximately 144 d of NH_3 concentration data were lost or invalidated due to INNOVA-related issues.

Gas concentrations were invalidated between 9/27/08 and 11/9/08, because of a leak in the GSS and high analyte concentrations detected during zero gas checks

See Table of Major Data Invalidations for other losses.

Short term negative emission

- Emission calculations are “noisy” due to:
  - Analyzer noise
  - Wind caused variations in inlet concentrations.
  - Localized activities (mowing, man. hauling, gravel rds, etc.)
  - Location-shared and nonsimultaneous sequential sampling
- Subtracting inlet introduces some negative emissions when inlet concentration > outlet concentrations
    - Low emissions
    - Imperfect representation of inlet air (e.g. 1200 ft of eave inlet).
    - Interpolation of inlet air readings coupled with interpolation of outlet.
- Also introduces unnoticed high biases of emissions.
- Actual negative emissions could result from:
  - Dry scrubbing.
  - PM settling in barn.
  - Ammonia wet deposition and adsorption
  - Also introduces unnoticed high biases of emissions.

Feed samples

- 44 samples (22 each house) were taken. Data resubmitted to EPA today.
- Missing from 2010 EPA Report.
- Meant to submit on 8-2-11.

CO_2 Data

- ***Concentrations submitted early 2010.***
- ***Daily and hourly emissions submitted a few days ago.***

Broiler Site Publications

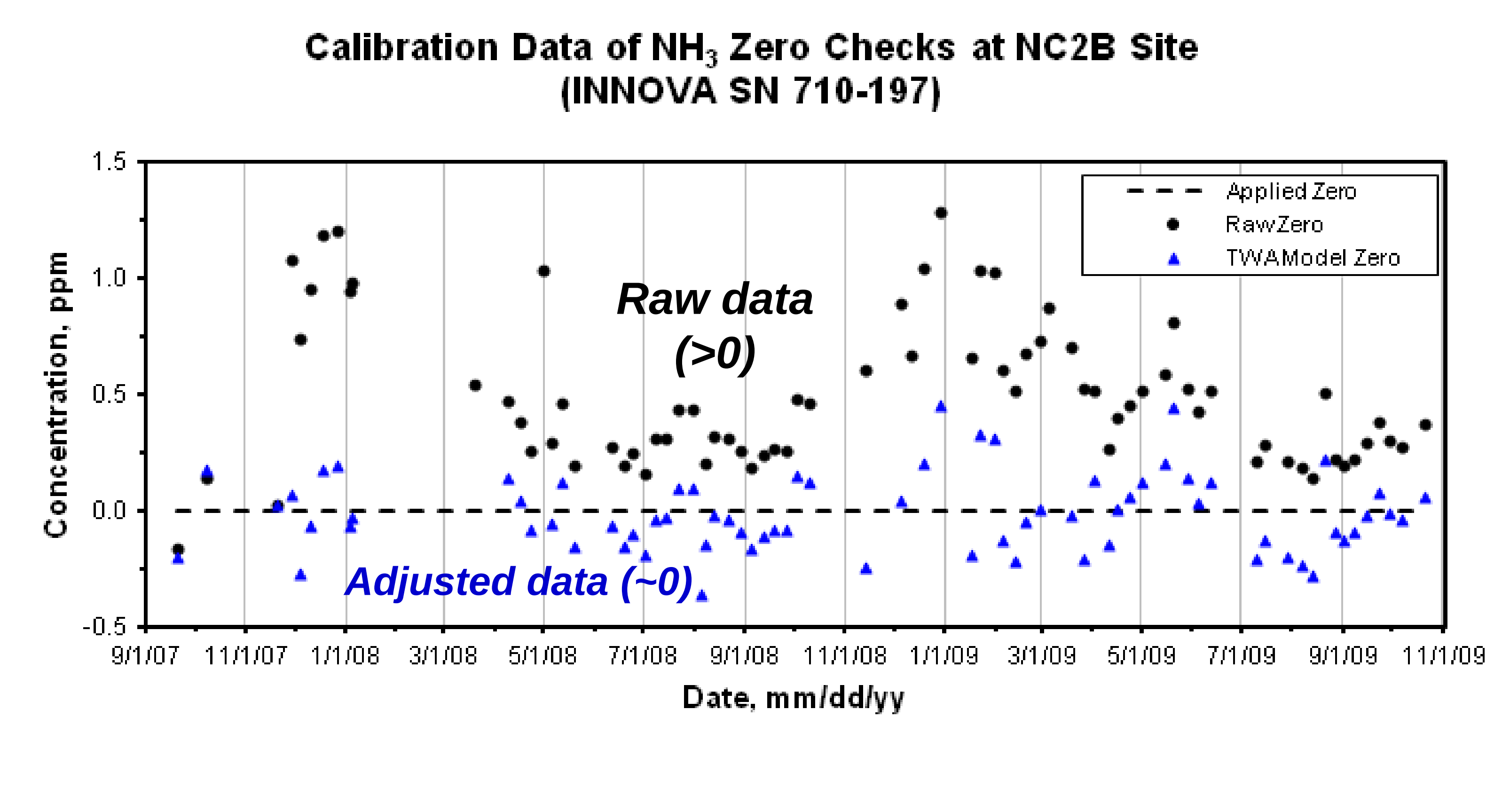
- ***Lin, X-.J., E.L. Cortus, R. Zhang, S. Jiang, and A.J. Heber. 2011. Ventilation monitoring of broiler houses in California. Transactions of ASABE 54(3):1059-1068.***
- ***Lin, X.J., E.L. Cortus, R. Zhang, S. Jiang, and A.J. Heber. (Accepted 2/29/12 pending acceptable revision.). Air emissions from broiler buildings in California. Transactions of ASABE.***

Are negative concentrations are bad data?

- ***Gas analyzers have noise – random up and down variation, even when measuring zero.***
- ***Slightly negative gas concentrations occur with zero or very low concentrations. Negative gas concentrations in the NAEMS were slight.***
- ***Similar but unnoticed noise occurs at high gas levels.***
- ***EPA advised Purdue not to delete noise-related negatives for the emission calculations. "Report the validated data and indicate the MDL rather than arbitrarily modifying the data".***
- ***Slight to large negative PM concentrations can occur at short time scales (minute, hour) due to moisture, but disappear at longer time scales (day, month, year)***
  - ***Negative PM2.5 more frequent than PM10 and TSP.***

- ***Changing the treatment of readings<MDL would require Purdue to recalculate all the data submitted to EPA.***

Calibration Adjustment
Zero Checks for NH3 analyzer



Seven (7) adjustment models (NH_3 NC2B) (2, 1, 7, 2, 2, 4 and 2 months)

Start/end dates	# of checks		Linear model	Accuracy, % of span			
	Zero	Span		Bias		Precision	
				z	s	z	s
9/20/07-11/19/07	3	3	y = 1.14x – 0.06	0.0	0.0	1.0	3.3
11/28/07-1/4/08	7	7	y = 1.10x – 1.15	0.0	0.0	0.2	3.1
3/19/08-10/10/08	26	26	y = 1.05x – 0.39	0.0	0.0	0.2	2.4
11/13/08-1/16/09	6	5	y = 1.04x – 0.87	0.0	0.0	0.3	0.6
1/22/09-3/26/09	8	9	y = 1.04x – 0.78	0.0	0.1	0.3	0.8
4/02/09-8/13/09	15	15	y = 1.09x – 0.44	0.0	0.3	0.5	2.6
8/20/09-10/20/09	9	9	y = 1.11x – 0.34	0.0	0.0	0.3	0.7