PRINCIPLE #3. METHODOLOGIES AND PROTOCOLS FOR ANALYSIS OF RAW DATA TO MINIMIZE UNCERTAINTY OF RESULTANT AERIAL EMISSIONS ESTIMATION

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Original Task

- To describe procedures and techniques for processing emissions-related raw data that will lead to reduced uncertainty of resultant emissions data. Specific objectives:
  - To describe procedures and protocols for determining instantaneous and daily emissions from raw data;
  - To describe backup checks of source ventilation rate to enhance quality on resultant emissions;
  - To illustrate the procedure of assessing uncertainty through error analysis.

Paper Outline

0. Governing equations for emissions rate (ER)
1. Determining ER from multiple locations in single (large) building
2. Daily ER from instantaneous ER vs. from daily mean ventilation rate (VR) x daily mean concentration
3. Daily & cumulative ER per animal or per animal marketed
4. Handling methodology for missing within-day data
5. Use of CO2 balance as indirect check of VR
6. Use of mass balance for ER data quality check
7. ER estimates from dynamic flux chamber
8. Uncertainty analysis for ER estimates
9. Continuous vs strategic periodic measurements

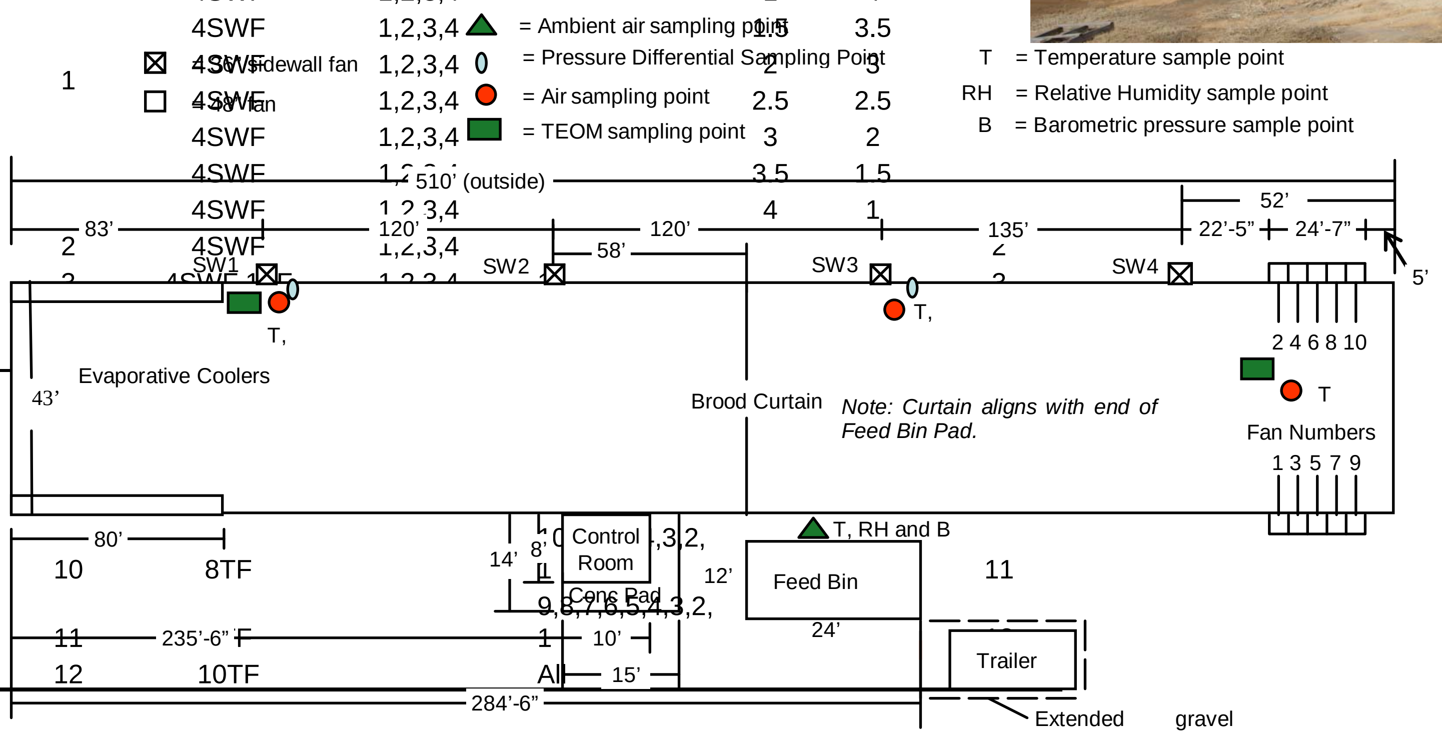
Emissions Rate Equation

$$[ER_G]_t = \sum_{e=1}^{n} [Q_e]_t \left([G]_e - \frac{\rho_e}{\rho_i} [G]_i \right) \times 10^{-6} \times \frac{w_m}{V_m} \times \frac{T_{std}}{T_a} \times \frac{P_a}{P_{std}} \quad [1]$$

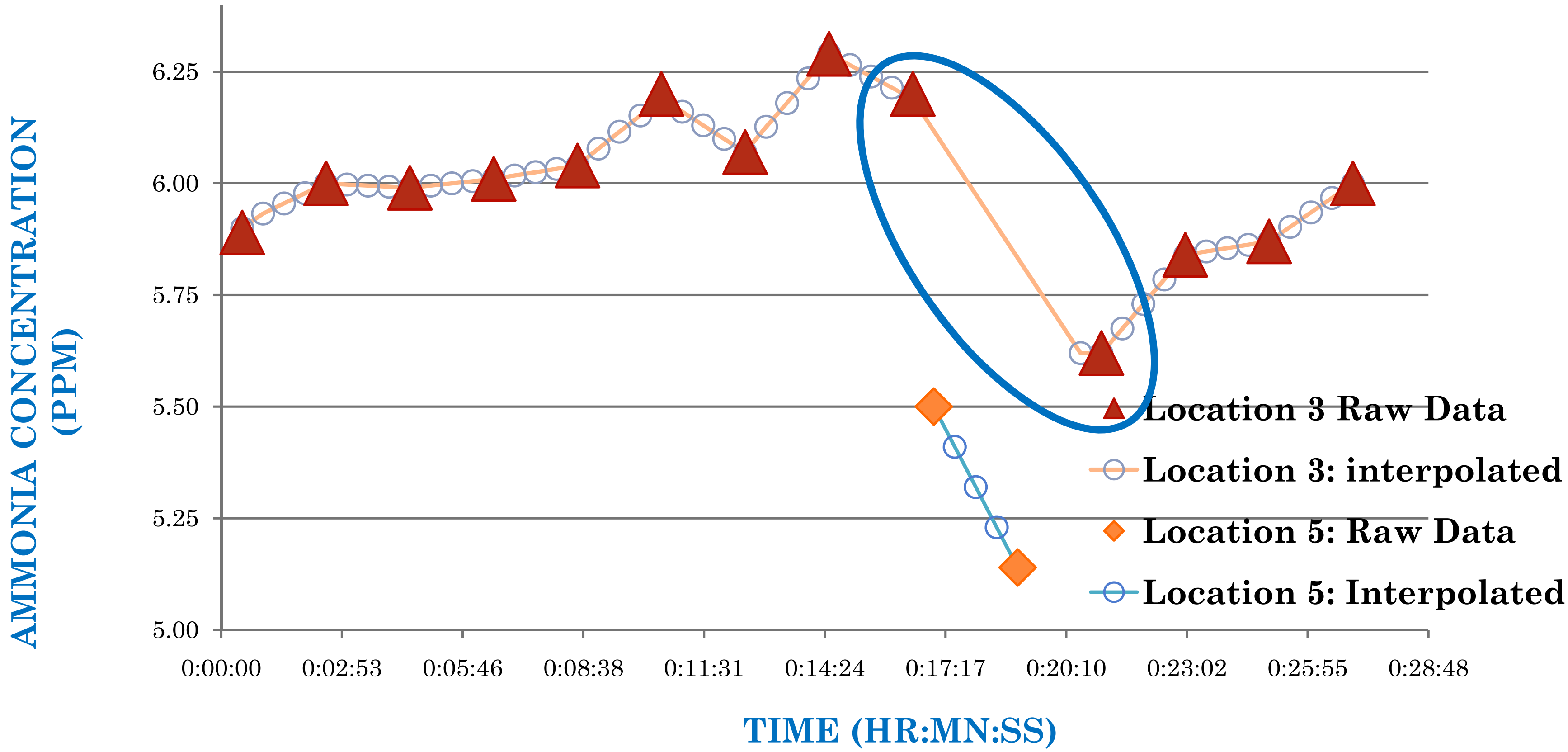
$$[ER_{PM}]_t = \sum_{e=1}^{n} [Q_e]_t \left([PM]_e - \frac{\rho_e}{\rho_i} [PM]_i \right) \times 10^{-6} \times \frac{T_{std}}{T_a} \times \frac{P_a}{P_{std}} \quad [2]$$

1. Determination of Source ER from Multiple-Location Measurements

house 1-5	STAGE	# FANs	SIDE WALL FAN #'s	Tunnel Fan #'s	ON (min)	OFF (min)	TEMP. DIFF., ºF
Cross Ventilation Mode		4SWF	1,2,3,4		0.5	4.5	
		4SWF	1,2,3,4		1	4	
		4SWF	1,2,3,4		1.5	3.5	
	1	4SWF	1,2,3,4		2	3	
		4SWF	1,2,3,4		2.5	2.5	
		4SWF	1,2,3,4		3	2	
		4SWF	1,2,3,4		3.5	1.5	
		4SWF	1,2,3,4		4	1	
	2	4SWF	1,2,3,4				2
	3	4SWF + 1TF	1,2,3,4				2
Tunnel Ventilation Mode	10	8TF		10,9,8,7,6,5,4,3,2,			11
	11			9,8,7,6,5,4,3,2,1			
	12	10TF		All			

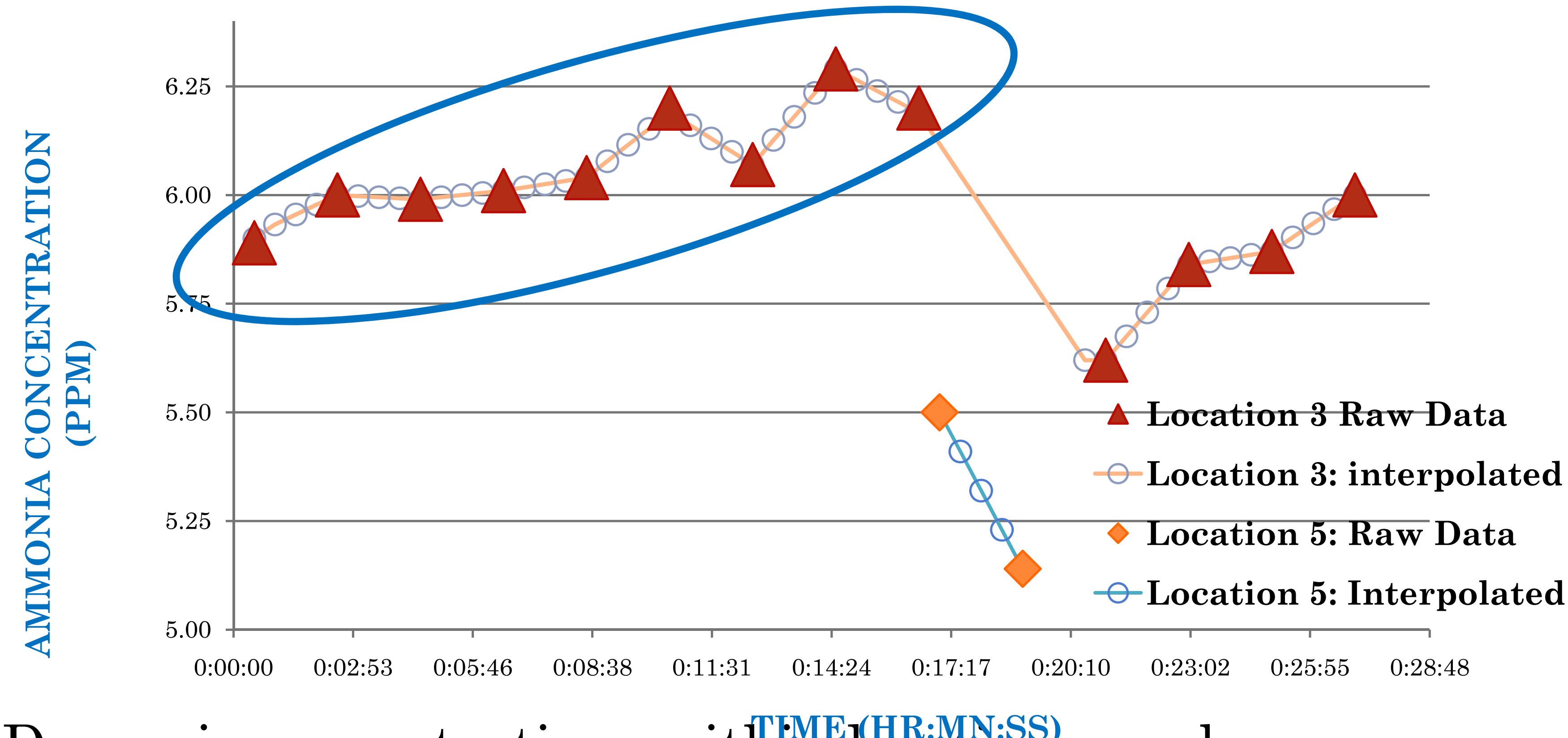


MULTIPLE-LOCATION SAMPLING: INTERPOLATION



Dynamic concentrations between multiple locations over time may be obtained through interpolation.

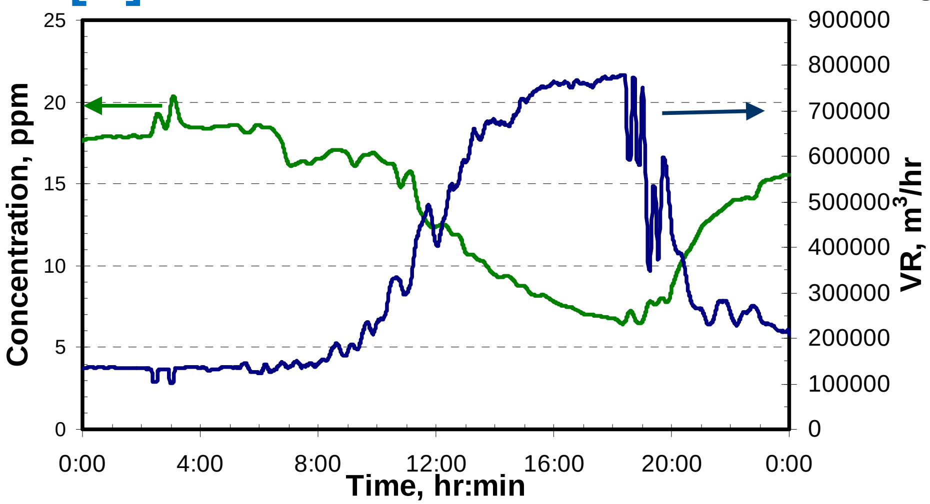
MULTIPLE-LOCATION SAMPLING: WITHIN SAMPLE INTERPOLATION ALIGN WITH VR

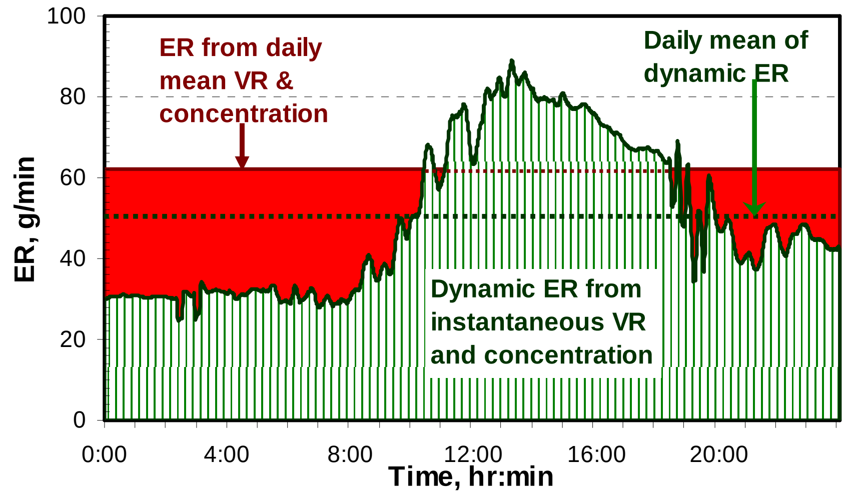


Dynamic concentrations within location may be interpolated to align with Ventilation Rate sampling frequency. Dynamic concentrations and VR then are multplied to get ER.

2. Determination of Daily Emissions of a Constituent from Instantaneous ERs vs. from Daily Mean Concentration and Daily Mean VR

[C] x VR $\propto$ ER





Mean VR = x   Mean [C] = y   Mean VR x Mean Y **= 62 g NH3/min**

“Actual” Daily Mean (from integration of instantaneous values) **= 50 g/min**

Care needs to be taken when using daily mean concentration and mean ventilation rate to determine daily emissions. The method is valid only when one or both of the two variables (VR or concentration) remain relatively constant.

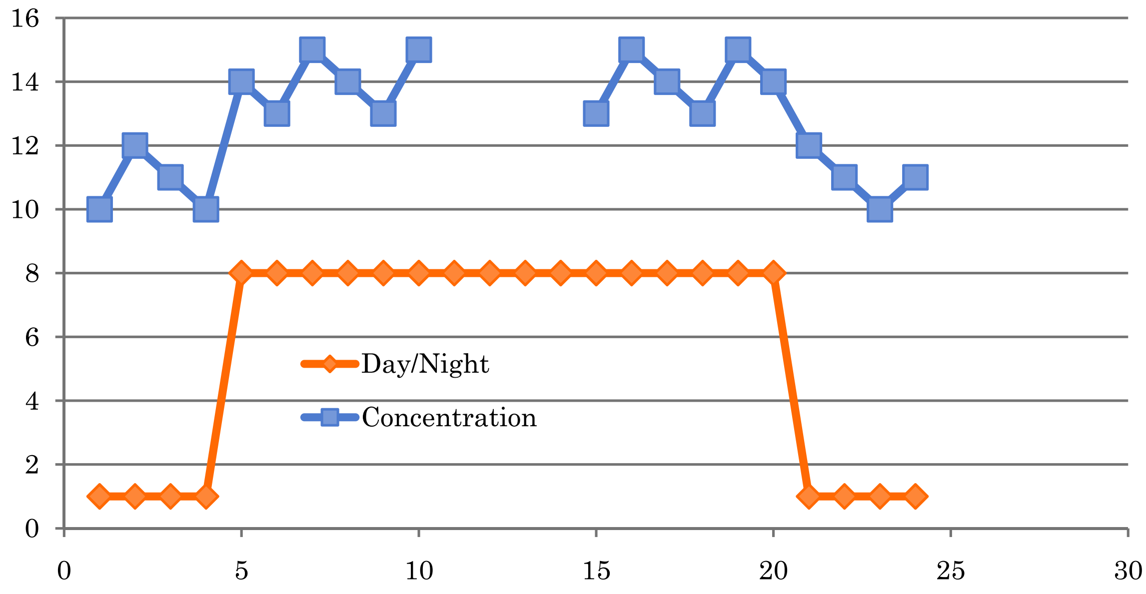
3. Determination of Daily and Cumulative Emissions per Animal or Per Animal Marketed

Bird Age, d	Bird Population	Daily ER, lb/barn-d	Cumulative ER, lb/barn	Cumulative ER, g/bird marketed
1	25695	0.73	0.73	0.01
2	25680	0.93	1.67	0.03
3	25665	1.03	2.69	0.05
4	25646	1.12	3.82	0.07
5	25635	1.36	5.17	0.09
6	25622	1.17	6.34	0.11
7	25610	0.86	7.20	0.13
8	25596	1.20	8.39	0.15
9	25587	2.25	10.6	0.19
10	25578	4.41	15.1	0.27
17	25486	12.5	66.6	1.18
18	25472	18.8	85.3	1.52
19	25449	22.5	107.8	1.92
20	25433	22.7	130.6	2.33
21	25417	23.8	154.4	2.75

When dealing with animals of highly variable body weight (e.g., meat-type animals), use of cumulative emissions per animal or animal unit (500 kg body weight) marketed is more adequate than daily emissions per animal or AU

4. Handling of Missing Within-Day Concentration Data and Daily Emission Data

Time-weighted average, as opposed to arithmetic mean, should be used when estimating daily emissions where there are missing hourly ER data and there exist circadian patterns in the emissions.



5. Use of CO_2 Balance for Indirect Estimation of VR

- Indirect determination of VR through CO_2 balance can provide a useful backup or check for directly determined building VR, and its use is encouraged when possible.

- Metabolic heat production data reflecting the current animal genetics, nutrition and environment are essential to the success of the method.

- The method may not work well when difference in CO_2 concentration between the exhaust and incoming air streams is less than 200 PPM.

6. Use of Mass Balance to Estimate Emissions or Check Data Quality

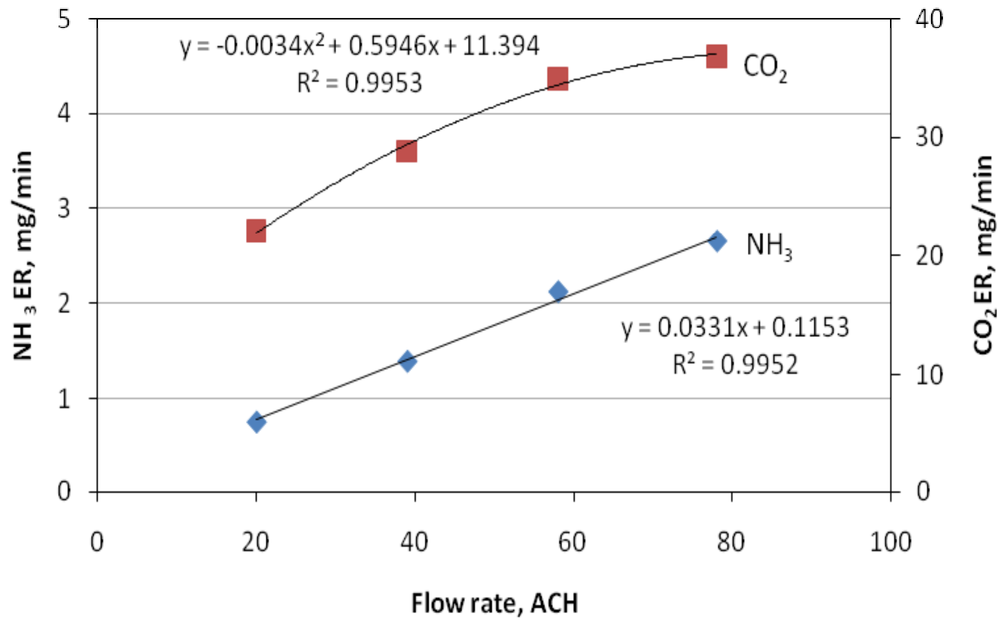
- Mass balance should be considered and included, when possible, as a check to emission values obtained from flow integration method.

- Precise mass balance can be a logistical challenge on commercial facilities.

7. Presentation of Gaseous Emissions Obtained with Dynamic Flux Chambers

- ER measured with DFC can be greatly affected by air exchange rate (ACH) through DFC

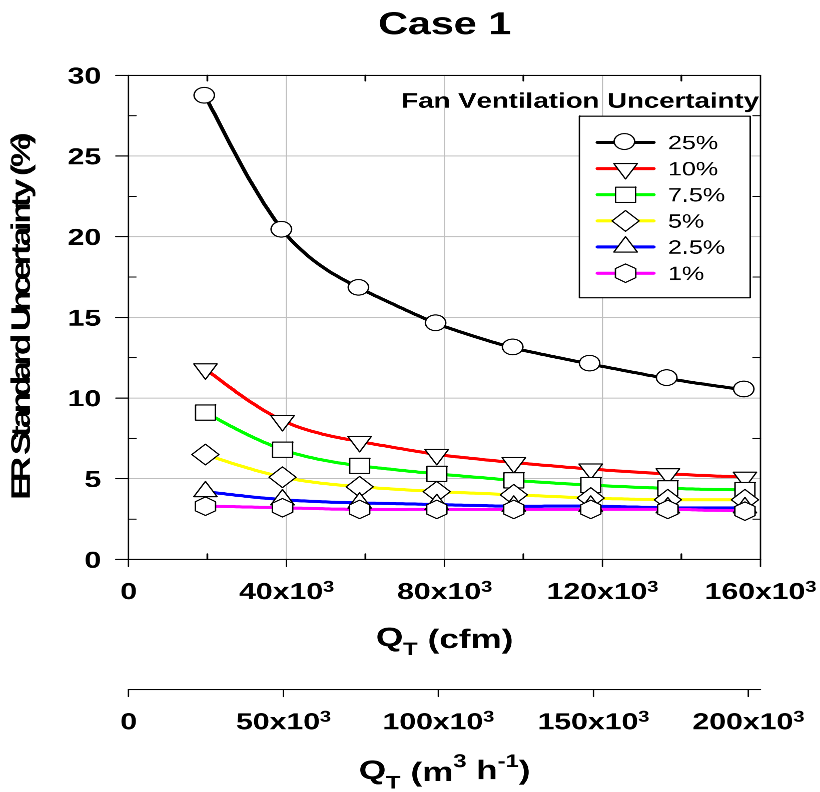
- Recommend that air flow rate(s) through the DFC be specified when reporting emissions data obtained with this method

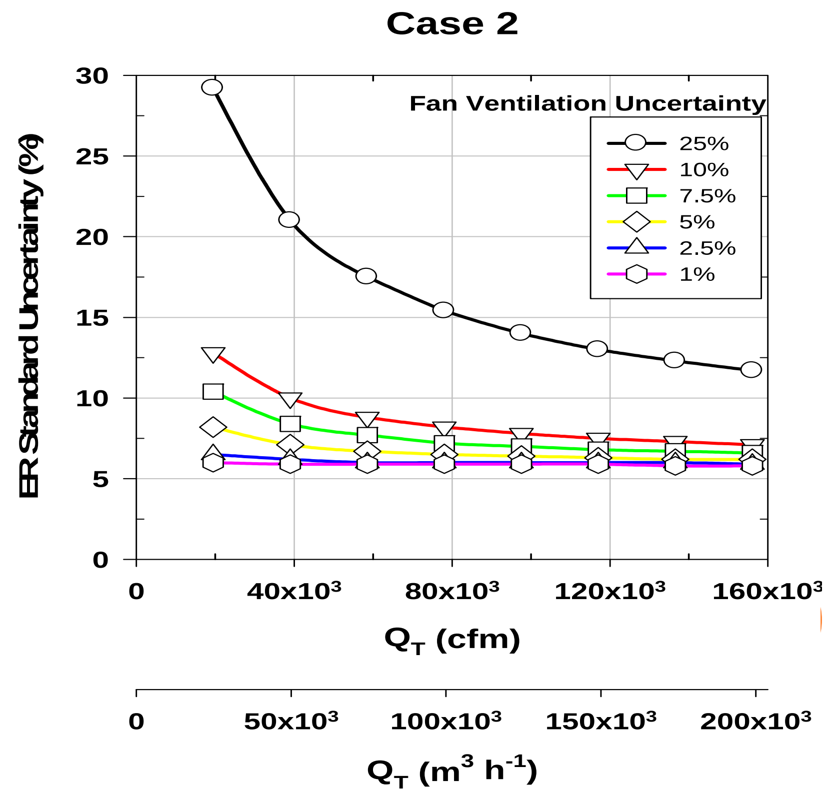


- Recommend that discussion be initiated to standardize air exchange rate(s) (ACH) when using a DFC. Although the measured values may still not reflect the actual ER, at least data from different studies share some common ground for comparison.

8. Uncertainty of Component Measurements and Resultant ER Estimation

Uncertainty of an emission value should be estimated through error analysis and provided when reporting emissions. For recent project we found that unless VR uncertainty can be controlled below 10%, concentration uncertainty of 0.5% vs. 5% makes little difference in the resultant emission rate uncertainty.





9. Continuous vs. Strategic Periodic Measurements

- Strategic, intermittent sampling, as opposed to continuous monitoring, coupled with statistical modeling may provide viable means to significantly reduce time and resource requirements for estimating annual emissions.

- This approach could increase the ability to sample more farms, which in turn enhances representativeness of the data.
- Variance = Var(measurement uncertainty)
  + Var(within house)
  + Var(between houses)

Discussion

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