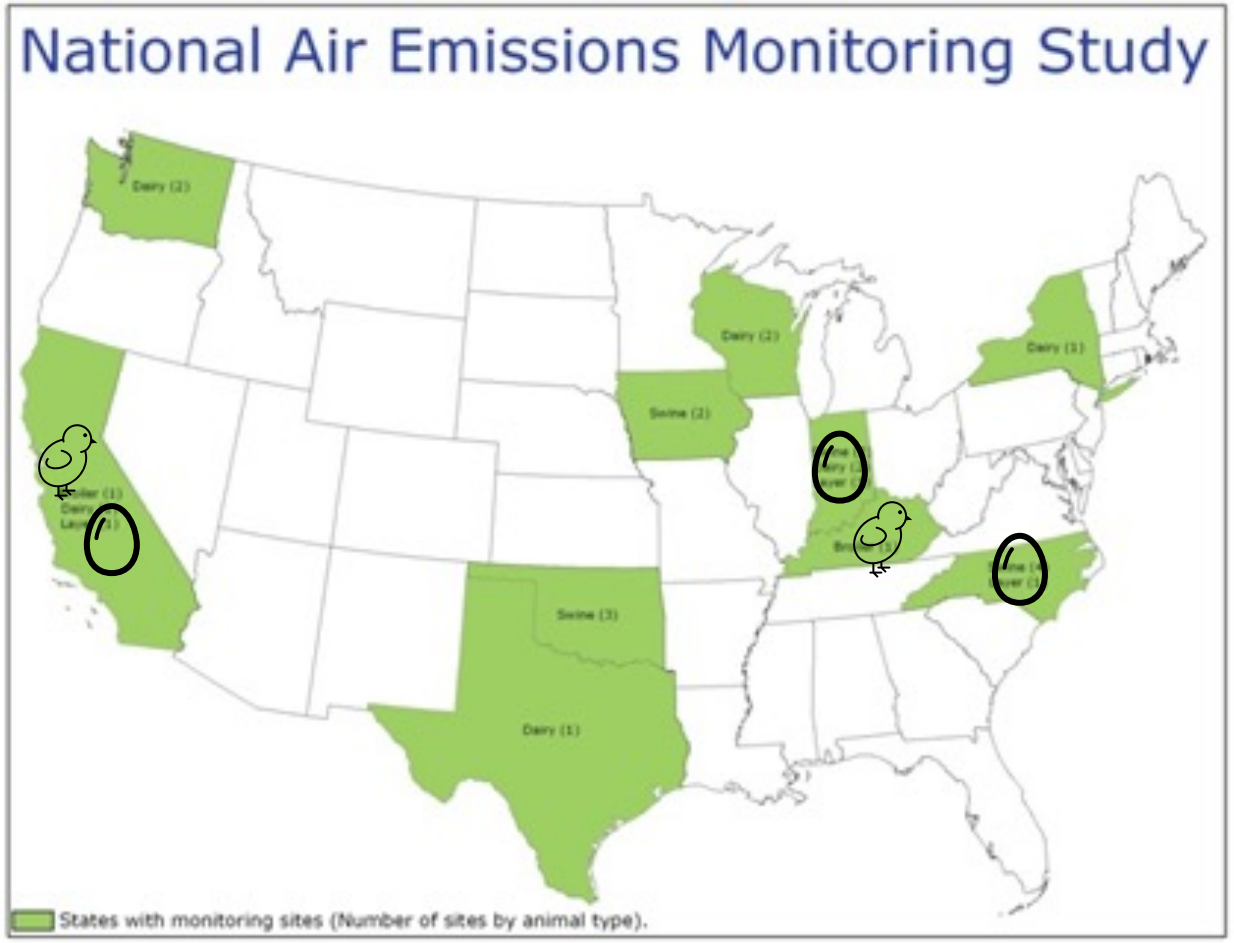
Draft Emissions Estimating Methodologies for Poultry Animal Feeding Operations

September 2021

NAEMS Overview

- Two-year, industry-funded study resulting from the AFO Air Compliance Agreement.
- Monitored 25 sites (e.g., barns and lagoons) for H_2S, NH_3, PM and VOCs.
- Species: Swine, dairy, egg-layers and broilers; beef cattle and turkey were not included in this study.
- Sites selected based on representation of animal species and geographic location.



NAEMS Timeline

- 2007 – 2010: NAEMS monitored farm emissions
- 2013: First group of draft emission models reviewed by EPA's Science Advisory Board (SAB)
- 2014 – 2016: Gathered data and conducted analyses per SAB recommendations
- 2017 – 2020: Issued QAPP for data analysis and revised methodology to develop emission models
- **2020 – 2022:** Issue draft models on a rolling basis, by animal species
  - August 2020: Draft swine report
  - August 2021: Egg layers & broilers draft report

Poultry Report Overview

- On August 18, 2021, EPA posted the draft emission estimating methodologies (emission models) for egg-layer and broiler animal feeding operations (AFO).
  - Egg-layer farms: high rise houses, manure belt houses, and manure sheds
  - Broiler farms: broiler houses
- These draft poultry emission models utilize data collected as part of the National Air Emissions Monitoring Study (NAEMS).
  - The broiler modeling dataset was supplemented with data from a Kentucky study.
- The emission models provide methods for estimating air emissions of NH_3, H_2S, and PM (TSP, PM_{10}, $PM_{2.5}$) from houses and manure sheds at poultry operations throughout the country.
- EPA has developed 20 emission models for the various emission source and pollutant combinations at poultry operations.

Model Development Overview

- Select parameters
  - Conduct literature review to identify factors that influence emissions
  - Conduct exploratory data analysis to see trends when comparing individual parameters to monitored emissions
  - Select parameters with strong trends in the literature and/or the exploratory data analysis, while also considering data quantity and potential ease of measurement for a producer
- Create test models for daily emissions with combinations of identified parameters
- Select daily emission model based on subjective evaluation of accuracy and ease of use
- Evaluate model by “jackknife” technique where one barn was removed from the dataset
- Develop annual emission estimates and estimates of uncertainty

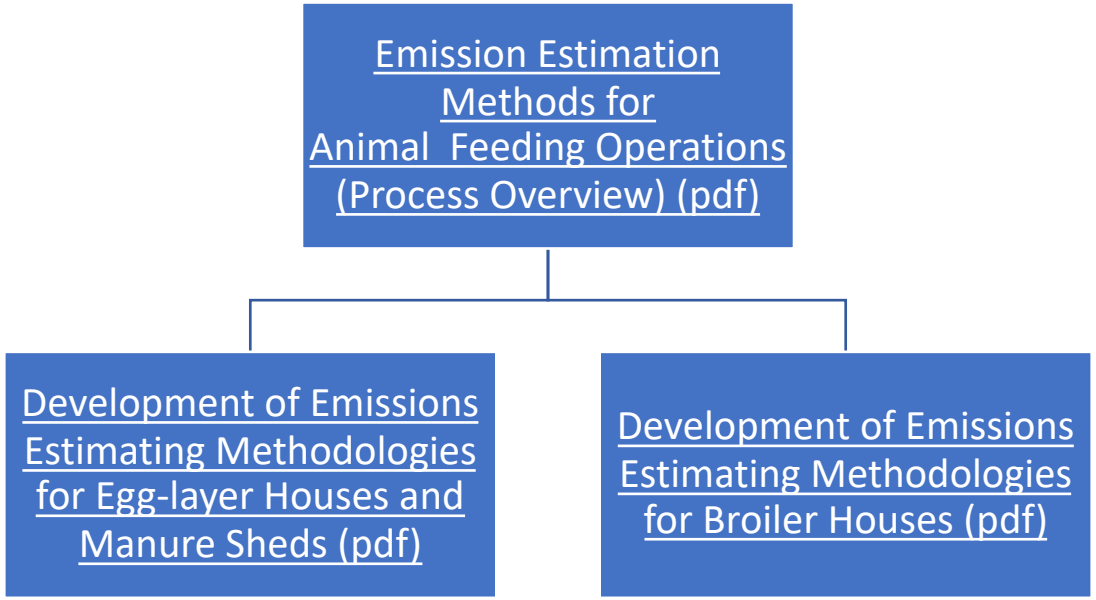
Selection of Parameters

Measured Parameter	
Animals	Inventory
	Weight
Barn conditions	Exhaust temperature
	Exhaust relative humidity
	Ventilation rate/airflow
Meteorological conditions	Ambient temperature
	Ambient relative humidity
	Wind speed

- For Egg-layers considered:
  - Hen age
  - Management Phase (experimental)
  - Manure Age
- For Broilers also considered:
  - Flock age
  - Litter age
  - Litter status (experimental)
    - Indication of the number of flocks since full clean out
  - Management Phase (experimental)
- For manure sheds, the inventory and live animal weight was lagged by 5 days to reflect the amount of time it takes for the manure to travel to the shed.

Report Overview

- Reports have been restructured
- Created the “process overview” report (“All Sectors” report)
  - Provides the overarching information relevant to all animal types
    - Background information on the consent agreement and NAEMS
    - General process for developing emission models
- Animal specific information in separate reports
  - Any exceptions to the process
  - Animal specific results



Uses of the Emission Models

- These models *estimate* emissions.
- The final models will be used by participants in the Air Compliance Agreement and other AFOs to determine whether their emissions trigger certain Clean Air Act permitting requirements.
- The models may also be useful for general estimates of emissions from poultry operations across the US or comparisons between operations in different regions.
- **The current *draft* models should not be used for these purposes** until they are finalized.
- When the models are final, EPA will provide a tool that will apply the model to estimate emissions for farms from confinement and open sources.

Date	Milestone	Status
September 2019	Call for Information for additional VOC data	Complete
August 2020	Draft models for ammonia, hydrogen sulfide and particulate matter emissions from swine farms	Complete
August 2021	Draft models for ammonia, hydrogen sulfide and particulate matter emissions from poultry (broiler and layer) farms	Complete
March 2022	Draft models for ammonia, hydrogen sulfide and particulate matter emissions from dairy farms	
May 2022	Draft models for volatile organic compound emissions from swine, poultry and dairy farms	
TBD	Stakeholder review period	
TBD	Finalization of all AFO emission models	

Contact Info:

Project website: https://www.epa.gov/afos-air/national-air-emissions-monitoring-study#main-content

If you have questions or informal comments:

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Appendix A

Emission Models

Models Development: Form

$$Y_p(\ln\{pollutant\}) = \beta_0 + \beta_1 \mathrm{X}_1 + \beta_2 \mathrm{X}_2 + \ldots + \beta_k \mathrm{X}_k$$

Where:

Y_p is the log transformed emissions

β_0 is a constant

X_i is a predictive parameter (e.g., ambient temperature, wind speed)

β_i is the coefficient for parameter X_i

Emission Models: High Rise Houses

Pollutant	Intercept	Inventory (thousand head)	Ambient Temperature (°C)	Ambient Relative Humidity (%)
H_2S	2.723104	0.009798	0.020988	0.003752
NH_3	2.659821	0.005890	0.038714	0.001761
PM_{10}	6.870178	0.007684	0.014477	-0.003022
$PM_{2.5}$	4.621874	0.008039	0.051013	-0.018133
TSP	7.599452	0.007927	0.013670	-0.005795

Emission Models: Manure Belt Houses

Pollutant	Intercept	Inventory (thousand head)	Ambient Temperature (°C)	Ambient Relative Humidity (%)
H_2S	3.739100	0.007300	0.022200	0.004800
NH_3	2.439200	0.004700	0.029400	0.001900
PM_{10}	6.631005	0.007205		
$PM_{2.5}$	-127.448900	0.534577		
TSP	6.936206	0.009870		

Emission Models: Manure Sheds

Pollutant	Intercept	Inventory, lagged 5 days (thousand head)	Ambient Temperature (°C)
H_2S	1.295775	0.004976	-0.02416
NH_3	-0.194945	0.003927	-0.01375
PM_{10}	4.5366	0.000732	
$PM_{2.5}$	-30.57734	0.067599	
TSP	4.041666	0.002286	

Emission Models: Broiler Houses

Pollutant	Intercept	Live animal weight (thousand kg)	Ambient Temperature (°C)	Ambient Relative Humidity (%)
H_2S	2.824278	0.016214	0.015048	0.004429
NH_3	1.60581	0.008532	0.020739	0.004038
PM_{10}	397.28057	40.872002	10.401892	-6.584463
$PM_{2.5}$	15.776704	4.087002	1.308433	-0.464143
TSP	1518.9199	85.598315	22.632906	-21.28833

Appendix B

Consent Agreement Requirements

Background – AFO Air Compliance Agreement (Agreement)

- In 2005, the voluntary Agreement, which includes NAEMS, was initiated in response to a National Academy of Sciences report on the complexity of estimating AFOs' emissions from and industry's concern with ongoing EPA and citizen enforcement activity.
- The Agreement's goals were to:
  - (1) reduce air pollution;
  - (2) monitor AFO emissions;
  - (3) promote a national consensus on emission models; and
  - (4) ensure compliance with requirements of the Clean Air Act (CAA), as well as certain reporting requirements under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), and the Emergency Planning and Community Right-to-Know Act (EPCRA).

Air Compliance Agreement

- EPA approved approximately 2,600 Agreements, representing nearly 14,000 participating AFOs.
- Participants paid a civil penalty of between $200 and $100,000, based on the size and number of facilities covered by their Agreement. They also were responsible for contributing to a fund to cover the cost of NAEMS.
- As part of the Agreement, EPA agreed not to sue participating AFOs for certain past and ongoing violations of the CAA, CERCLA, and EPCRA during NAEMS, provided that the AFOs comply with the Agreement's conditions.
- Once EPA publishes final emission models for an AFO's animal sector, that AFO must apply the final models to determine what actions, if any, it must take to comply with any applicable CAA requirements.

Consent Agreement Requirements

- **Paragraph 28(B):** If the emissions estimating methodologies demonstrate that a source does not trigger any Clean Air Act permitting requirements, the source must certify this outcome to the EPA in writing within 60 days after the EPA publishes the emission estimating methodologies applicable to the emission units at that source or facility.
- **Paragraph 28(C)(i):** If the emissions estimating methodologies demonstrate that a source triggers Clean Air Act permitting requirements, the source must submit all permit applications required by the permitting authority for the source within 120 days.
  - Agreement participants should consult the Agreement for additional specifics related to permitting requirements and control technologies.
  - **Paragraph 28(C)(d):** Farms installing waste-to-energy systems will have an additional 180 days to submit permit applications.
- **Paragraph 28(C)(i)(b):** The annual emissions from a source shall be determined based on current operating methods and on the maximum number of animals housed at the source at any time over the 24 months prior to EPA's publication of the applicable emissions-estimating methodologies.

Appendix C

Model development process

Selection of Parameters: Egg-layers

Measured Parameter	
Animals	Inventory
	Weight
Barn conditions	Exhaust temperature
	Exhaust relative humidity
	Ventilation rate/airflow
Meteorological conditions	Ambient temperature
	Ambient relative humidity
	Wind speed

- Also considered:
  - Hen age
  - Management Phase (experimental)
  - Manure Age
- For manure sheds, the inventory and live animal weight was lagged by 5 days to reflect the amount of time it takes for the manure to travel to the shed.

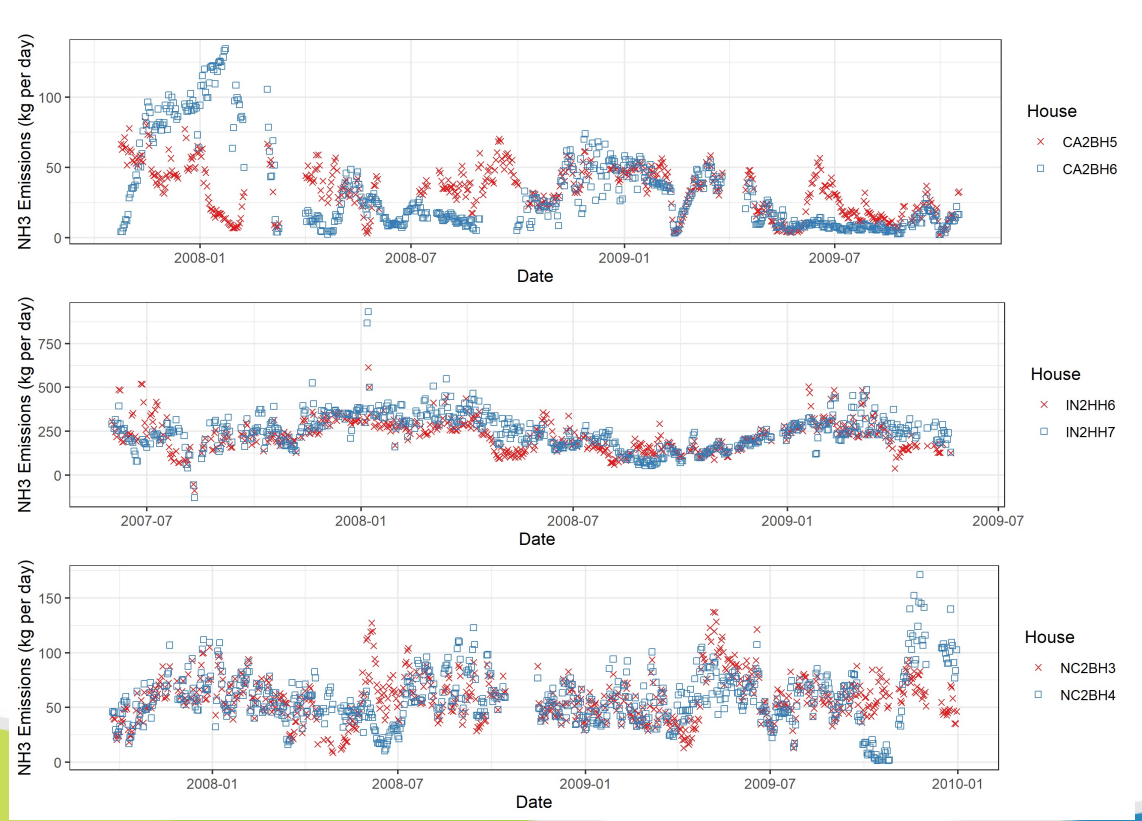
Selection of Parameters: Broiler Houses

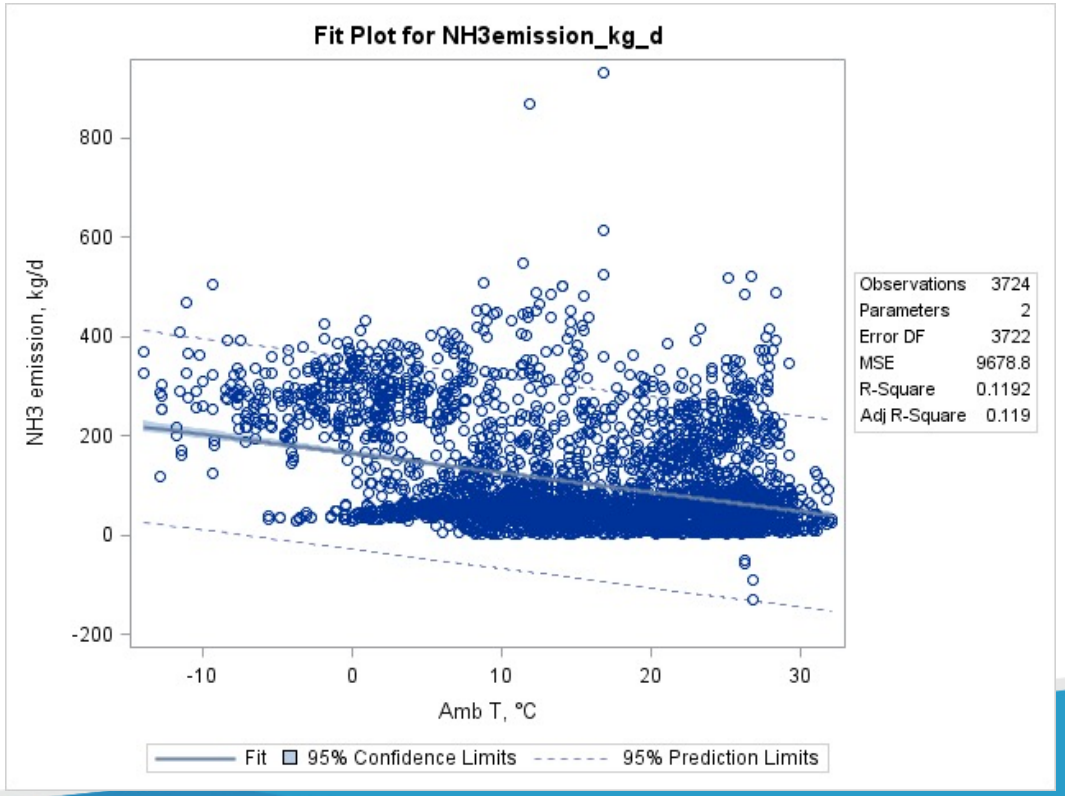
Measured Parameter	
Animals	Inventory
	Weight
Barn conditions	Exhaust temperature
	Exhaust relative humidity
Meteorological conditions	Ambient temperature
	Ambient relative humidity

- Also considered:
  - Flock age
  - Litter age
  - Litter status
    - Experimental
    - Indication of the number of flocks since full load out
  - Management Phase (experimental)

Selection of Parameters:

- Literature Review
- Exploratory Data Analysis
  - Plots to identify trends
  - Regressions to assess strength of the relationships





Models Development: Poultry Production

- EPA developed separate models for:
  - High rise houses
  - Manure belt houses
  - Manure Shed
  - Broiler houses

Model Development: Statistical Approach

- Linear model
- Performed a natural log transformation on the average daily emissions before fitting a model
- Evaluate the models based on their performance (e.g., error, bias) and their potential ease of use (i.e., how easily could a farmer potentially obtain measurements of the predictor values)

Models Development: Form

$$Y_p(\ln\{pollutant\}) = \beta_0 + \beta_1 \mathrm{X}_1 + \beta_2 \mathrm{X}_2 + \ldots + \beta_k \mathrm{X}_k$$

Where:

Y_p is the log transformed emissions

β_0 is a constant

X_i is a predictive parameter (e.g., ambient temperature, wind speed)

β_i is the coefficient for parameter X_i

Model Development: Evaluation

- “Jackknife”
  - Examines the cumulative effect of multiple “minus-one-house” runs on coefficient estimates
  - Models predict emissions for the subset sample left out
  - The predicted emissions are then evaluated using the observed (measured) data for the subset sample left out
  - Limited data for manure shed prevented this analysis for this source. Exploring alternatives for the final report.

Model Development: Annual Emissions Estimate

- Annual emissions are estimated by summing the daily emissions over the course of a year
- Also developed an estimate of uncertainty for the model
  - Developed based on variation of a predictor variable
  - Ran multiple simulations for each day for each value of the predictor to estimate the residual
  - Percent uncertainty plotted versus annual emission and fitted with a model of uncertainty for the emission estimate
- Developed a method to combine the uncertainty for each component of the farm (e.g., house and manure sheds) for a farm total uncertainty

Improvements from 2012 Draft Emission Models

- Switched to linear regressions, which prevents inconsistent results for extreme values
- Adjusted parameter selection to include more robust literature review
- Expanded the criteria to evaluate model performance
  - Added residual plots (i.e., model fit plots) and calculated model performance statistics
- Refined evaluation approach to the “minus-one-house” technique, which is a more refined statistical approach with temporally correlated data

Uses of the Emission Models

- These models *estimate* emissions.
- The final models will be used by participants in the Air Compliance Agreement and other AFOs to determine whether their emissions trigger certain Clean Air Act permitting requirements.
- The models may also be useful for general estimates of emissions from operations across the US or comparisons between operations in different regions.
- **The current *draft* models should not be used for these purposes** until they are finalized.
- When the models are final, EPA will provide a tool that will apply the model to estimate emissions for farms.

Limitations of the Emission Models

- The models do not estimate emissions for all pollutants, or all emission sources found on poultry operations.
- The models do not incorporate all the site-specific management factors that can affect emissions.
- The models cannot be used to quantify impacts of best management practices on emissions.
- The model estimates uncontrolled emissions and the typical management at the time of data collection.