THE EGG INDUSTRY CENTER

ADVANCING SCIENCE FOR A THRIVING INDUSTRY

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Egg Industry Center
ADMINISTERED BY
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POULTRY AMMONIA EMISSIONS PRODUCTION TRENDS

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- ✓Emissions Factors: pros and cons
- ✓General Trends
- ✓Recent Published Information
  - o Emission Factors - Broilers
- ✓How to measure emissions?
  - o Ventilation rate
  - o Concentration in exhaust stream
  - o Dynamics
  - o Recent technology updates

Reference summary for daily ammonia emission factor

Potential variables influencing broiler ammonia emission factor:

- inventory
- live animal weight
- flock age
- exhaust temperature
- exhaust relative humidity
- Airflow
- ambient temperature
- ambient relative humidity
- litter age and status
- litter moisture
- litter pH
- litter total ammoniacal nitrogen
- litter total Kjeldahl nitrogen

Selected variables based on EPA emission models (EPA, 2021):

- inventory
- bird weight
- ambient temperature
- ambient relative humidity

EPA. 2021. Development of Emissions Estimating Methodologies for Broiler Operations. Available at: https://www.epa.gov/system/files/documents/2021-08/development_of_emissions_estimating_methodologies_for_broilers.pdf.

Site location	Bird inventory	Grow-out weight (kg)	Measurement period: market age (days)	Ambient Temperature (°C)	Ambient RH (%)	Emission factor (g d^{-1} $bird^{-1}$)	Reference
			USA				
Alabama	NA	3.0	28-55: 55	21.1-32.2	NA	0.14-0.74	W Worley et al. (2002)
Kentucky	20,000-25,000	NA	11-57: NA	-12.0-16.0	NA	0.02-1.29	Casey et al. (2003)
Pennsylvania	31,965	NA	13-15: NA	-0.6-14.4	NA	0.31-0.34	F. Wheeler et al. (2003)
	30,652		20-22:NA	-1.7-11.1		0.63-0.92	
	31,272-32,269		1-3: NA	-16.1-0.0		0.0	
	30,350		13-15: NA	-10.6 to -6.1		0.02-0.07	
Kentucky	25,000		11-13: NA	-1.5-6.6		0.08-0.12	
	19,441		21-23:NA	3.7-16.0		0.02-0.27	
Texas	27,500	2.4	8-47: 49	NA	NA	0.63	E. Lacey et al. (2003)
Delmarva	11,500	NA	29-37: 42	23.6-31.5	54.0-96.0	1.18	Siefert et al. (2004)
Kentucky	NA	NA	≤10: 48	NA	NA	0-0.57	Pescatore et al. (2005)
			15-30: 48			0.10-0.97	
			30-42: 48			0.32-1.71	
			≥48: 48			0.71-2.34	
Kentucky, Pennsylvania	25,000-32,700	2.2	1-45: 42	NA	NA	0.47	F. Wheeler et al. (2006)
		2.2	2-42: 42	NA	NA	0.65	
		2.5	1-53: 49	NA	NA	0.76	
		3.3	1-55: 63	NA	NA	0.98	
Kentucky	25,800 (winter); 24,400 (summer)	NA	365: 50-54	-10.0-30.0	NA	0.49-0.62	R Burns et al. (2007)
California	21,000	2.65	365: 46	3.3-31.1	NA	0.50±0.44	J. Lin et al. (2012)
Arkansas	100,000-122,800	1.91-3.04	42-57	NA	NA	0.77-0.92	Moore Jr et al. (2011)
Georgia	23,500	NA	31-52: 56	3.9-29.7	NA	0.44-2.05	Harper et al. (2021)
			Foreign countries				
France	5,086	1.8-1.9	0-40: 40	NA	NA	0-0.29	Guiziou and Béline (2005)
San Joaquin Valley, Canada	19,295	2.7	0-49: 47	22.5-25.0	41.0-67.5	0-0.8	Harper et al. (2010)
				7.5-14.0	34.0-67.5	0-0.7	
Slovak Republic/Germany	25,000	2.0	1-40: 42	20-35	NA	0.52-0.78	Knížatová et al. (2010)
Shandong province, China	12,240	NA	35-42: 42	-6.72-26.75	26.75-94.74	0.05-0.30	Zhu et al. (2010)
São Paulo, Brazil	23,000	NA	0-42: 42-49	NA	NA	0.25	Lima et al. (2011)
	30.000					0.45	
	20,000					0.10	
	20,200					0.25	
	34,000					0.40	
	33,500					0.50	
Minas Gerais, Brazil	23,100	NA	15-45: 43	-4.0-40.0	15.0-90.0	0.24-0.52	Mendes et al. (2014)

Example Estimates

Daily ammonia emission factor (g d^{-1} $bird^{-1}$): 0-2.34 as function of age

Examples for estimating annual emissions based on daily emission factor of a broiler house:

- Given conditions:
  - daily emission factor during production ≈ 0.50 g d^{-1} $bird^{-1}$
  - hourly emission factor during downtime ≈ 250 g h^{-1} (A. Topper et al., 2008)
  - bird inventory = 25,000 birds/house
- Example 1
  - Production cycle = 49 days
  - Downtime = 14 days
  - 6 flocks and 5 downtime periods in a year
  - **Annual emission** = 4.51 US tons per house per year
- Example 2
  - Production cycle = 56 days
  - Downtime = 14 days
  - 5 flocks, 5 downtime periods, and additional 10-d downtime in a year
  - **Annual emission** = 4.39 US tons per house per year

A. Topper, E. F. Wheeler, J. S. Zajaczkowski, R. S. Gates, H. Xin, Y. Liang, and K. D. Casey. 2008. Ammonia Emissions from Two Empty Broiler Houses with Built-Up Litter. *Transactions of the ASABE* 51(1):219-225.

Example Estimates

Delmarva region produced 567 million broilers in 2021

- 567 million birds/(25,000 birds house x 6 turns/yr) = 3,780 houses

- From example 1 of previous slide:
  - (Production cycle = 49 days; Downtime = 14 days; 6 flocks and 5 downtime periods in a year)
  - **Annual emission** = 4.51 US tons per house per year x 22,680 houses = 17 kT/yr

- Is this an accurate estimate??

- Why or why not???

- Factors that influence that number include:
  - Number of houses, turns/year, use of litter amendment, downtime btwn flocks
  - Improvements to diet
  - Dated estimate of "emission factor"
  - Market weight of each flock
  - etc.

NH3 INVENTORY FROM 2008

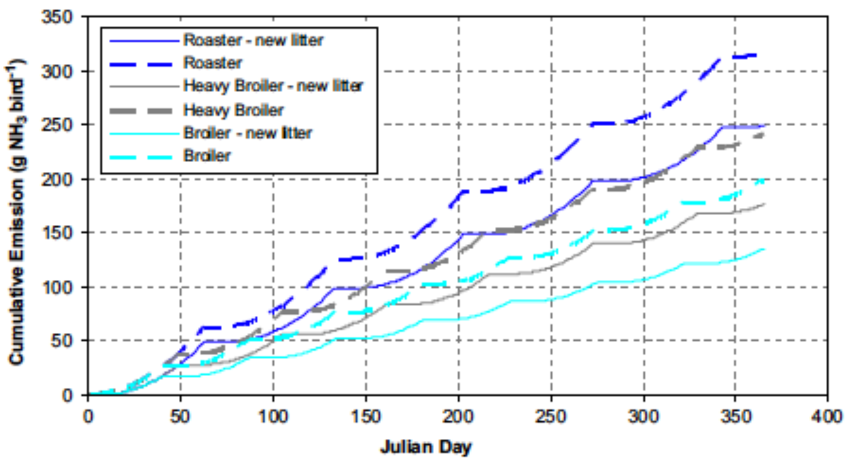

Fig. 1. Cumulative ammonia emission over a year, from multiple flocks, for different bird market weights (roaster, heavy broiler o. broiler) and litter conditions (new litter or built-up litter), using mean ER as per Eq. (1).

A linear relation has been recently reported between NH_3 emission rate, bird age and litter condition (Casey et al., 2004a,b; Wheeler et al., 2004, 2006). The slope on Eq. (1) has a standard error (SE_{ER}) of 1.1 mg NH_3 $bird^{-1}$ d^{-1}.

$$ER = 0.031 \cdot x, \quad (1)$$

where

ER = emission rate, g NH_3 $bird^{-1}$ d^{-1},

$$x = \begin{cases} \text{bird age}(d) & \text{if used litter,} \\ 0 & \text{if new litter and bird age} < 7, \\ \text{bird age} - 6 & \text{if new litter and bird age} \geqslant 7. \end{cases}$$

Table 2
Total single flock emission[a] expressed per bird (g NH_3 bird-marketed^{-1}) by production category of roaster (3.25 kg), heavy broiler (2.45 kg) and broiler (2.1 kg), and type of litter used during grow out

Basis of NH_3 emissions	Roaster		Heavy broiler		Broiler	
	New litter	Built-up litter	New litter	Built-up litter	New litter	Built-up litter
Mean	49.5	62.5	28.0	38.0	17.4	25.4
-3 SE_{ER}	44.7	56.4	25.3	34.3	15.7	23.0
$+3$ SE_{ER}	54.3	68.5	30.7	41.7	19.1	27.9
Mean, adjusted	44.4	56.5	27.0	37.1	17.6	25.8

The "Mean, adjusted" row is obtained by integrating over an entire year, and dividing by the number of flocks per each category.
[a]USEPA emission factor is 100 g NH_3 $bird^{-1}$, by contrast.

Source:

Gates et al (2008) Atm Env Vol 42

EPA OVER-ESTIMATED 18+ YEARS AGO…AND MANAGEMENT HAS CONTINUED TO EVOLVE

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Table 3

Annual emission rate (AER) expressed on a per bird-place (g NH_3 bird-place^{-1} yr^{-1}) by production category of roaster (3.25 kg), heavy broiler (2.45 kg) and broiler (2.10 kg), and type of litter used during grow out

Basis of emission rate estimation	Roaster		Heavy broiler		Broiler	
	New litter	Built-up litter	New litter	Built-up litter	New litter	Built-up litter
Mean	248.5	316.2	175.8	241.3	135.2	198.6
$-3\ SE_{ER}$	224.4	285.6	158.8	218.0	122.1	179.4
$+3\ SE_{ER}$	272.5	346.8	192.8	264.7	148.3	217.8

For comparison purposes, USEPA prediction is: 100g NH_3 bird^{-1} × 5.5 flocks yr^{-1} = 550 g NH_3 bird-place^{-1}yr^{-1}.

Source:

Gates et al (2008) Atm Env Vol 42

GENERAL TRENDS

- Feed conversion continues to improve – balanced rations reduce excess protein (i.e. Nitrogen) in the feces
- Similarly, use of phytase to reduce excess phosphorus in feces
- Broiler production reliance on litter amendments for NH3 control
- Layer industry moving to cage-free – currently 34% of production
  - Manure belts, promoting feces drying, reduces uric acid ⇨ NH_3
  - No new high-rise housing for about a decade
- Reduced NH3 emissions in past decade from these facility and management efforts

HOW TO MEASURE EMISSIONS

Ventilation Rate…All the time

- No two fans have identical performance
- Affected by:
  - static pressure
  - Maintenance
- Modern controllers can log fan use but still need calibration for each fan

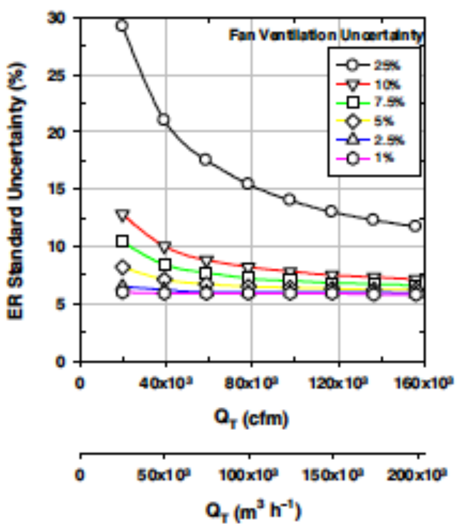
Concentration at Exhaust

- Tendency has been for high-dollar scientific instruments
- PPM, or sub-ppm accuracy

"*MEASURING*" EMISSIONS

Putting VR and Concentration together:

$$ER_{[g]} = Q_e\left(\frac{[G]_e}{T_e} - \frac{\upsilon_i}{\upsilon_e} \times \frac{[G]_i}{T_i}\right) \times 10^{-6} \times T_{std} \times \frac{P_a}{P_{std}} \times \frac{w_m}{V_m}$$



A 5% uncertainty in NH_3 is "swamped" by ventilation rate uncertainty.

Sources:

- *Gates et al (2009)*
- *Moody et al (2006)*

Also need:

- Consistency in measurement frequency
- Combine into hourly, daily, and greater intervals
- Effect of growing birds on reporting

DYNAMICS are important

INTELLIGENT PORTABLE MONITORING UNIT (IPMU)

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MICRO-CONTROLLER
Replace w/ Arduino Wireless/IoT Module

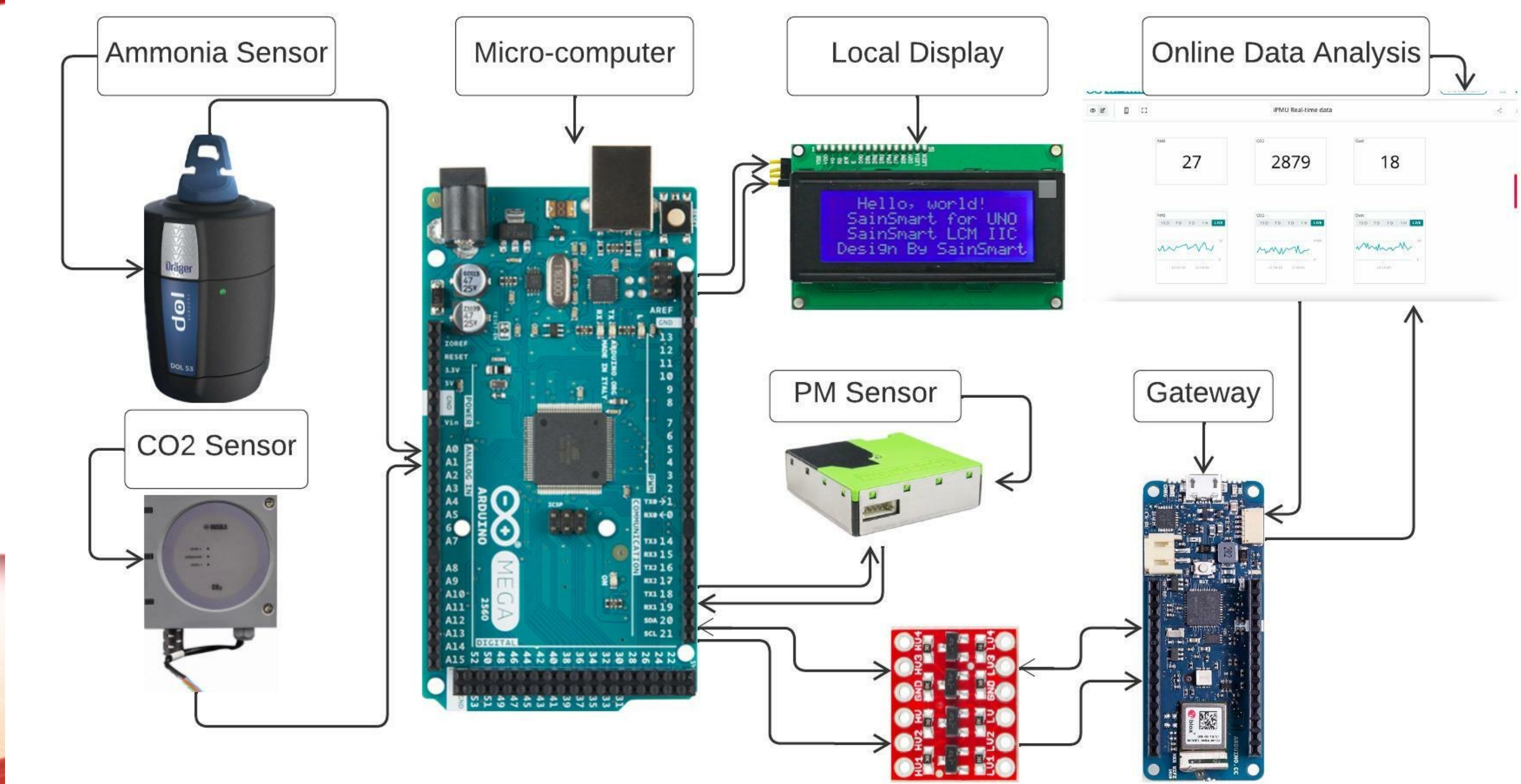
PM MONITOR

NH_3 SENSOR
Replace w/ DOL 53

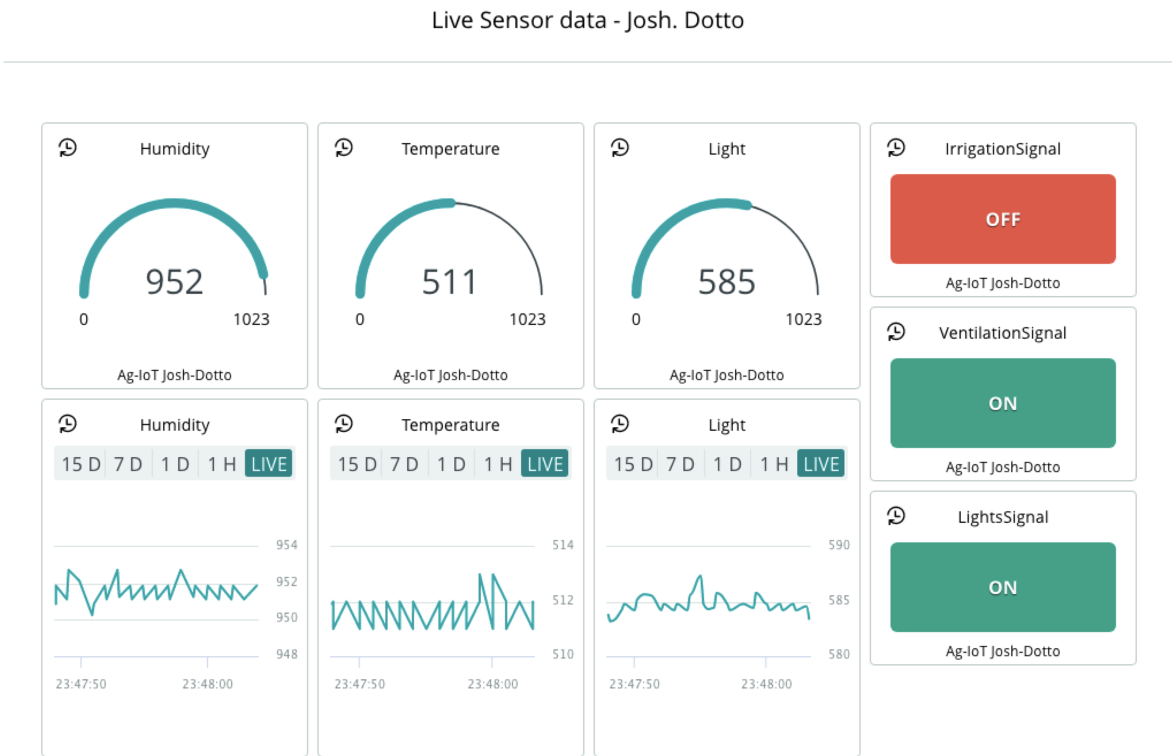
AIR TEMPERATURE

CO_2 SENSOR

IPMU ARCHITECTURE



ONLINE CONTROL DASHBOARD



Cloud-based data storage, retrieval, analytics

MS project, Mr Josh Dotto, University of Nebraska

(Dr. Y. Xiong lab)

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