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Amendments for improving air quality

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Bio&Ag⁺
ENGINEERING

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Overview

- Why we are here
- Ammonia formation and drivers
- Amendments to improve air quality
- PPE and sensors for air quality
- Take-home messages



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Why we are here?

Chickens produce billions of pounds of waste in NC. No one tracks where it goes.

BY ADAM BRADY, GARDNER FAY AND KALAMANDER
APRIL 10, 2022 10:00 AM

BAY JOURNAL

Delmarva chicken ammonia debate remains up in the air

Justice
Pollution from N.C.'s Commercial Poultry Farms Disproportionately Harms Communities of Color
The state's massive poultry industry is largely unregulated, leaving the state to guess about the number and location of giant production facilities producing millions of chickens.

ENVIRONMENT FEBRUARY 17, 2022
North Carolina Poultry Frenzy: 500 Million Birds and "Zero Transparency"
First came vast lagoons of hog waste—now unregulated mountains of chicken poop.

MELBA NEWSOME
Feb. 17, 2022

Lawsuit targets air pollution from Maryland chicken industry


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Air pollution

- Presence of chemical, physical, biological agents that modify atmosphere characteristics.
- Linked to human health issues, animal and plant impacts, aquatic system degradation
- Global consequences: climate change



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Air quality

- As part of the Clean Air Act (CCA), EPA sets ambient air quality standards (NAAQS).

Two types of standards are established:

- **Primary standard:** to protect human health, and
- **Secondary standard:** to protect visibility, animals, vegetation, etc.

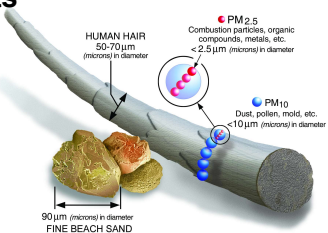
Online at: <https://www.epa.gov/criteria-air-pollutants/naaqs-table>

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NAAQS air pollutants

- Particulate matter (PM)
 - Fine Particulate (PM_{2.5})
 - Particulate PM₁₀
- Nitrogen oxide (NO₂)
- Sulfur oxide (SO₂)
- Carbon monoxide (CO)
- Ozone (O₃), and
- Lead (Pb)



Size comparisons for PM particles
(Source: EPA, Particulate Matter (PM) Basics)₅

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Air pollutants inside broiler houses

- Carbon dioxide (CO₂)*
- **Ammonia**
- Reduced sulfur (sulfides)
- Volatile organic compounds (VOCs)
 - Carboxylic acids, alcohols, and ketones
- **Dust**
 - Particulate matter (PM),
 - Airborne fungi and bacteria
 - Endotoxins

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Ammonia (NH₃)

- Colorless, pungent gas with high alkalinity.


REL: 25 ppm



respiratory complications,
bacterial/fungal infections,
footpad dermatitis,
blindness



respiratory complications,
bacterial/fungal infections,




PM formation,
eutrophication,
acidification,
climate change

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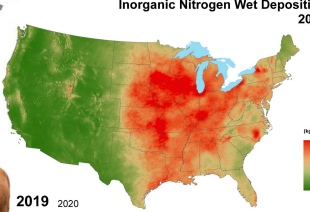
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Ammonia in agriculture




Synthetic fertilizer




Inorganic Nitrogen Wet Deposition
2019



Poultry



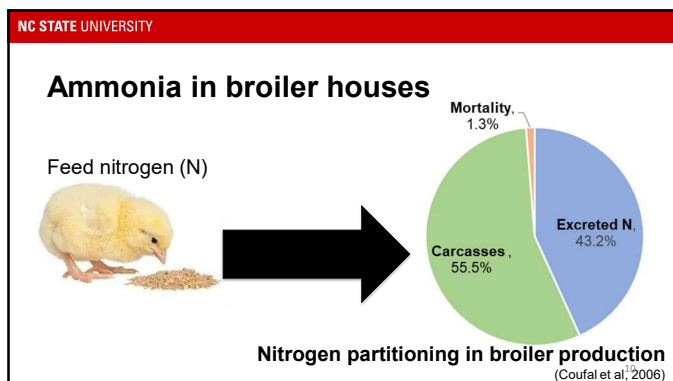
Ruminants



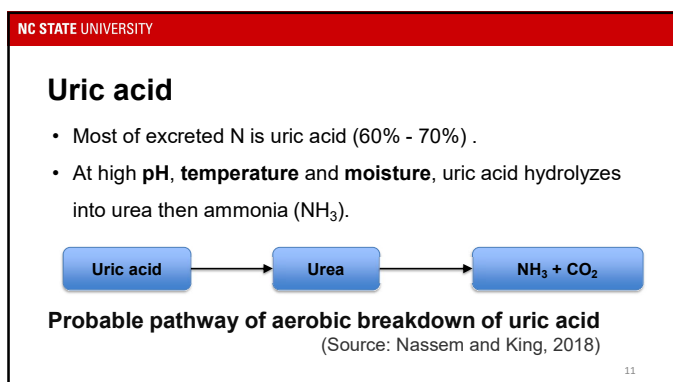
Swine

(Sources: NADP Network, 2021; Behera et al, 2013)⁹

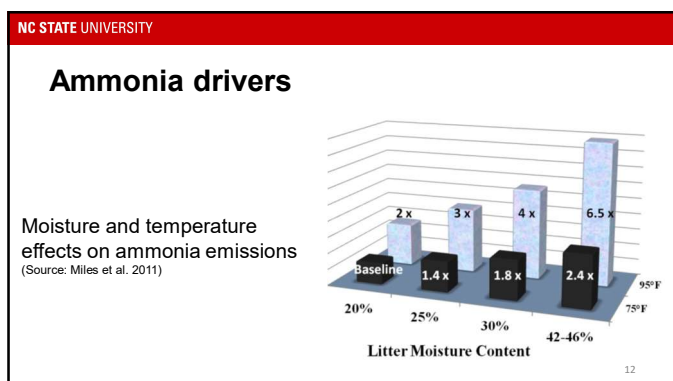
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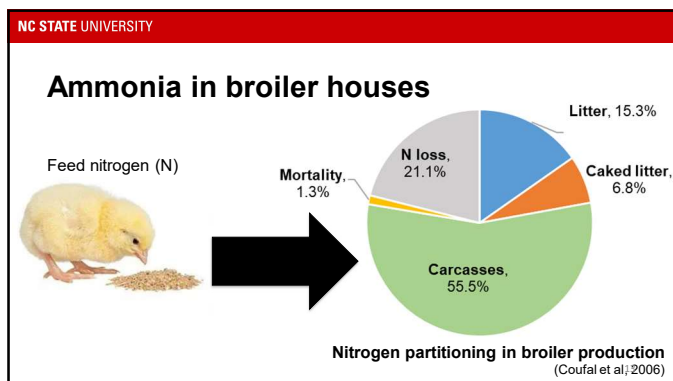
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Interventions for NH₃ control

Bird	Feed & water	Litter
Genetics, enzymes	Low crude protein, Additives (plant extracts) Prebiotics, probiotics, synbiotics	Amendments, Bedding materials, Floor type (litter-free)
Barn		
Ventilation & heating Misting (oil, water) Electrostatic space charge system (ESCS)		

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Amendments for NH₃ control

Acidifiers	Adsorbents (absorbers)	Inhibitors
Lowers pH to shift NH ₃ to NH ₄ ⁺	High water holding capacity (adsorption), binds ammonia	Enzyme inhibitors stop uric acid and/or urea breakdown to form ammonia

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Amendments for NH₃ control

Acidifiers

- Lowering pH to shift NH₃ towards NH₄⁺
- Inhibit uric acid decomposers

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Amendments for NH₃ control

Acidifiers

- Alum -- $Al_2(SO_4)_3 \cdot 14H_2O$
- Sodium bisulfate -- $NaHSO_4$
- Sulfuric acid + clay -- H_2SO_4
- Ferric sulfate -- $Fe_2(SO_4)_3$
- Zinc sulfate -- $ZnSO_4$
- Aluminum chloride -- $AlCl_3$
- Phosphoric acid -- H_3PO_4
- Citric acid -- $C_6H_8O_7$
- Lignite (low-grade coal)

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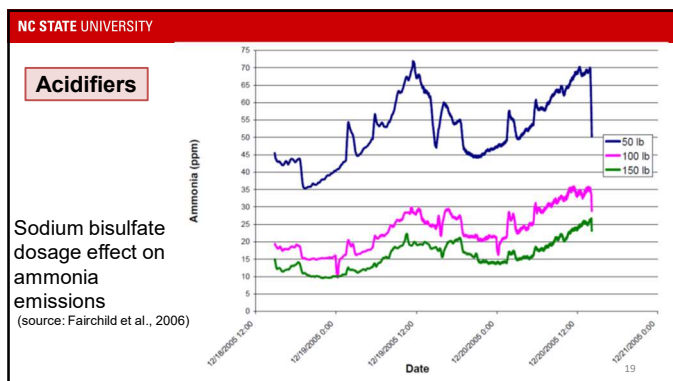
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Amendments for NH₃ control

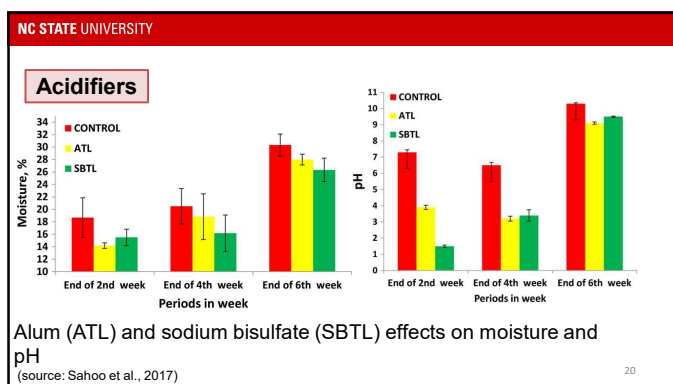
Acidifiers

Week	Alum treated litter (ppm)	Untreated litter (ppm)
0	~10	~45
1	~15	~35
2	~18	~40
3	~22	~30
4	~25	~32
5	~28	~35
6	~20	~25

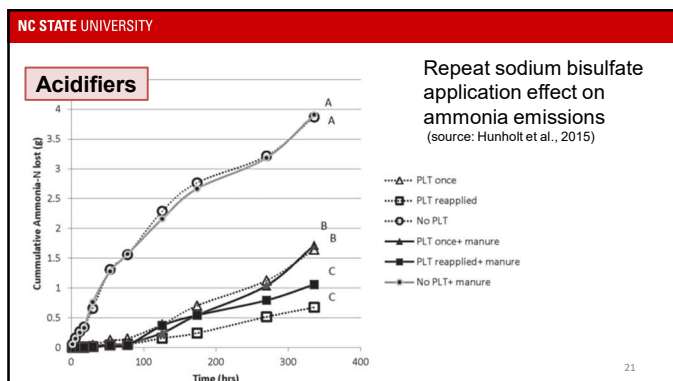
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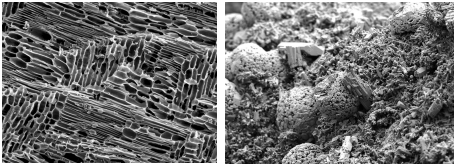
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Amendments for NH₃ control

Absorbers

- Zeolite (clay)
- Biochar



Electron microscope images of (left) biochar, and (right) zeolite

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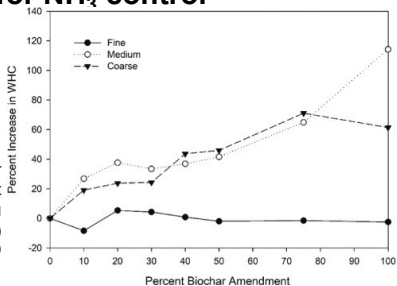
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Amendments for NH₂ control

Absorbers

- Zeolite (clay)
- Biochar

Relationship between biochar (BC) inclusion rate and percent increase in water holding capacity (WHC)
(Source: Linhoss, 2019)



Percent Biochar Amendment	Fine (WHC %)	Medium (WHC %)	Coarse (WHC %)
0	0	0	0
10	-5	20	20
20	5	40	25
30	5	35	25
40	5	40	45
50	5	45	45
75	5	70	70
100	5	110	60

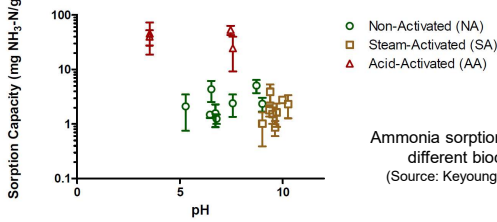
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Amendments for NH₃ control

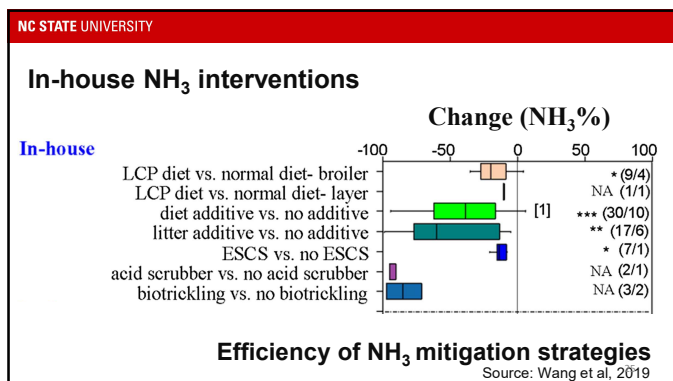
Absorbers



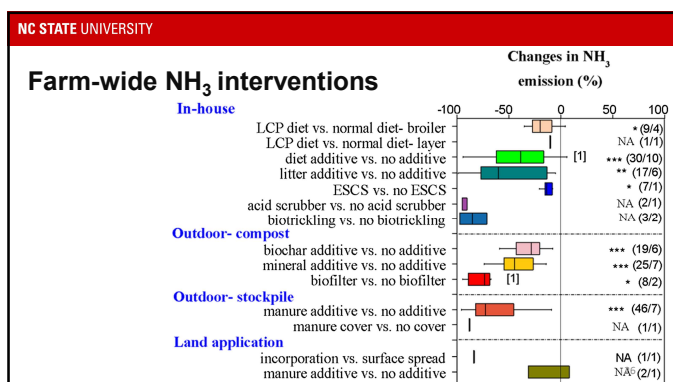
Ammonia sorption vs pH of different biochar types
(Source: Keyoung et al, 2015)

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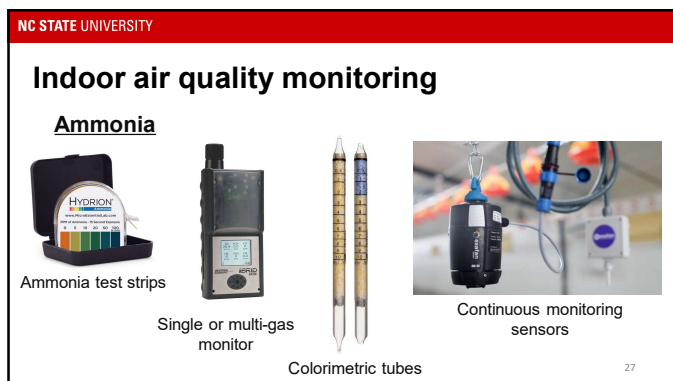
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PPE for respiratory Health

Disposable particulate/dust respirators

Chemical cartridge respirators

Powered air-purifying respirators

SCBA or self-contained breathing apparatus

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Take-home message

- Air quality is a major challenge facing poultry production.
- Ammonia is the largest air quality pollutant in broiler houses.
- Ammonia control require precise management to control pH, water, and temperature inside the barn.
- Acidifiers are most effective but repeat addition needed to maintain levels throughout the cycle.
- Using multiple additives and repeat application can increase ammonia reduction
- Continued data collection are critical to inform management practices.

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Questions..

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REFERENCES

- The impact of ammonia By Kayla Price October 3, 2019 <https://www.canadianpoultrymag.com/be-air-aware-the-impact-of-ammonia-31089/>
- Poultry Industry Pollution in the Chesapeake Region - Ammonia Air Emissions and Nitrogen Load Higher than EPA estimates - Environmental Integrity project. <https://environmentalintegrity.org/wp-content/uploads/2020/04/Chesapeake-Poultry-Report.pdf>
- EPA, Ambient Air Quality Standards (NAQS). <https://www.epa.gov/criteria-air-pollutants/naqs-table>
- Behara, S. N., Sharma, M., Anja, V. P., & Balasubramanian, R. (2013). Ammonia in the atmosphere: a review on emission sources, atmospheric chemistry and deposition on terrestrial bodies. *Environmental Science and Pollution Research*, 20, 8092-8131.
- National Atmospheric Deposition Program (NADP) - Annualized Maps. At: <https://nadp.ch1.wisc.edu/maps-data/annualized-maps/>
- Source: Goulet, C. D., Chavez, C., Nienmeyer, P. R., & Cheney, J. B. (2009). Nitrogen emissions from broilers measured by mass balance over eighteen consecutive flocks. *Poultry science*, 88(3), 384-391.
- Source: Naim, N. H. (2003). Evaluation of the nitrogen content in poultry manure. *World's Poultry Science Journal*, 59(1), 77-88.
- Source: Naseem, S., & King, A. J. (2018). Ammonia production in poultry houses can affect health of humans, birds, and the environment—techniques for its reduction during poultry production. *Environmental Science and Pollution Research*, 25, 15269-15293.
- Miles, D. M., Rows, D. E., & Cathcart, T. C. (2011). High litter moisture content suppresses litter ammonia volatilization. *Poultry Science*, 90(7), 1397-1405.
- Factsheet - Poultry Litter Moisture Management to Reduce Ammonia. https://www.ars.usda.gov/ARSUserFiles/19212/livestock/GRAC/Enred_LitterMoisture.pdf
- Huntot, A. E., Maguire, R. D., Ogajo, J. A., Badgley, B. D., Frame, W. H., & Reiter, M. S. (2015). Multiple applications of sodium bisulfite to broiler litter affect ammonia release and litter properties. *Journal of environmental quality*, 44(6), 1903-1910.
- Source: Wang, Y., Xue, W., Zhu, Z., Yang, J., Li, X., Tian, Z., ... & Zou, G. (2019). Mitigating ammonia emissions from typical broiler and layer manure management-A system analysis. *Waste Management*, 93, 23-33. <https://www.sciencedirect.com/science/article/pii/S0959652619303198#R010>

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