



United States Department of Agriculture

# Conservation Innovation Grants: CIG Insights Webinar Series

## *Innovations in Air Quality*

*April 2, 2020*



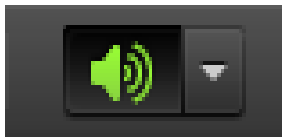
Natural  
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[nrcs.usda.gov/](https://nrcs.usda.gov/)

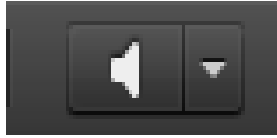


# Logistics

## Computer Speaker Status



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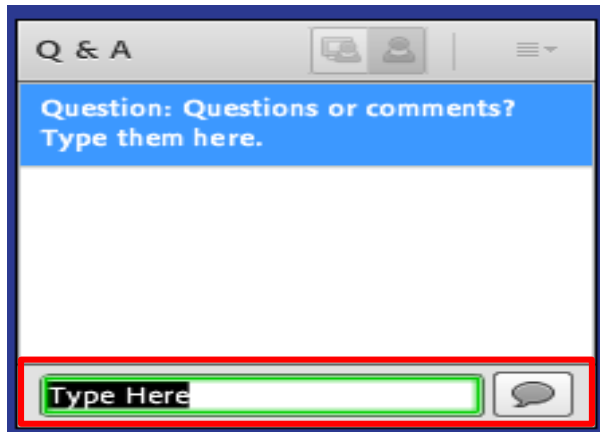
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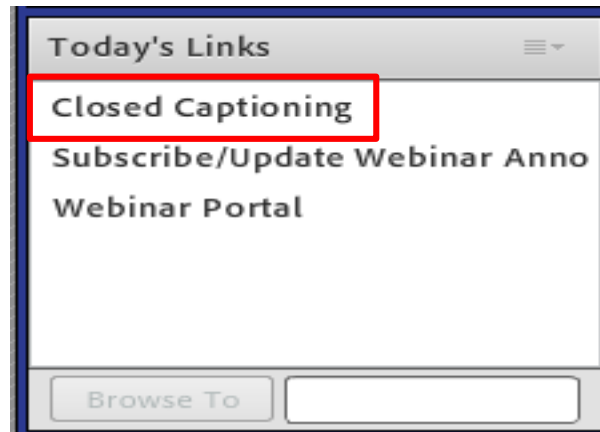
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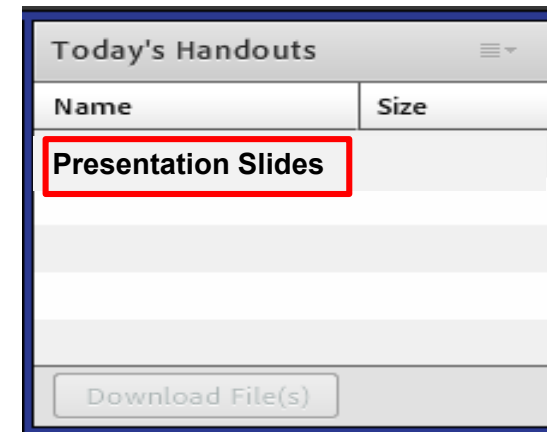
## Q&A Pod



## Today's Links



## Today's Handouts



# Agenda



- Opening Remarks
- Overview of the Air Quality innovation landscape
- CIG project
  - Windbreak Wall-Vegetative Strip System to Reduce Pollutant Emissions from Fan-Ventilated Livestock Barns
- Closing Perspectives
- Questions and Answers



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# CIG Overview



- **Purpose—to stimulate the development and adoption of innovative conservation approaches and technologies on farms, ranches and forest lands.**
- **CIG projects are expected to lead to the transfer of conservation technologies, management systems, and innovative approaches (such as market-based systems) to agricultural producers, into NRCS technical manuals and guides, or to the private sector.**
- **CIG generally funds pilot projects, field demonstrations, and on-farm conservation research. On-farm conservation research is defined as an investigation conducted to answer a specific applied conservation question using a statistically valid design while employing farm-scale equipment on farms, ranches or private forest lands.**





# **USDA-NRCS Air Quality Conservation Innovation Grants**

**April 2, 2020**

**Greg Zwicke, Air Quality Engineer  
NRCS National Air Quality & Atmospheric Change Team**

# Animal Air Quality CIGs

- Queried the USDA-NRCS CIG Project Search Tool for both National and State projects
  - <https://www.nrcs.usda.gov/wps/portal/nrcs/ciglanding/national/programs/financial/cig/cigsearch/>
- Used General Text Search feature for the following key words:
  - Air, ammonia, animal, beef, carbon, dairy, digester, digestion, livestock, manure, poultry, swine
- Manually refined identified projects to ensure there was some relevancy to animal air quality

# Animal Air Quality CIGs

- 1299 total CIG projects in the database
  - 49 (3.8%) have relevance to animal air quality
    - 9 State CIGs
    - 40 National CIGs
  - \$20,323,335 total project funding
    - \$545,756 State
    - \$19,777,579 National
  - At a 1:1 match, approximately \$40 million has been invested in animal air quality CIGs in the past 15 years

# Project Examples

- Innovative Approaches to Capture Nitrogen and Air Pollutant Emissions from Poultry Operations
  - University of Delaware (2012)
- Vegetative and Riparian Buffers for Environmental Stewardship and Renewable Fuels on Poultry Farms
  - Penn State University (2014)
- Engineered Windbreak Wall-Vegetative Strip System to Reduce Pollutant and Odor Emissions from Mechanically-Ventilated Broiler and Swine Barns
  - North Carolina State University (2014)



# ENVIRONMENTAL VEGETATIVE BUFFERS FOR POULTRY PRODUCTION

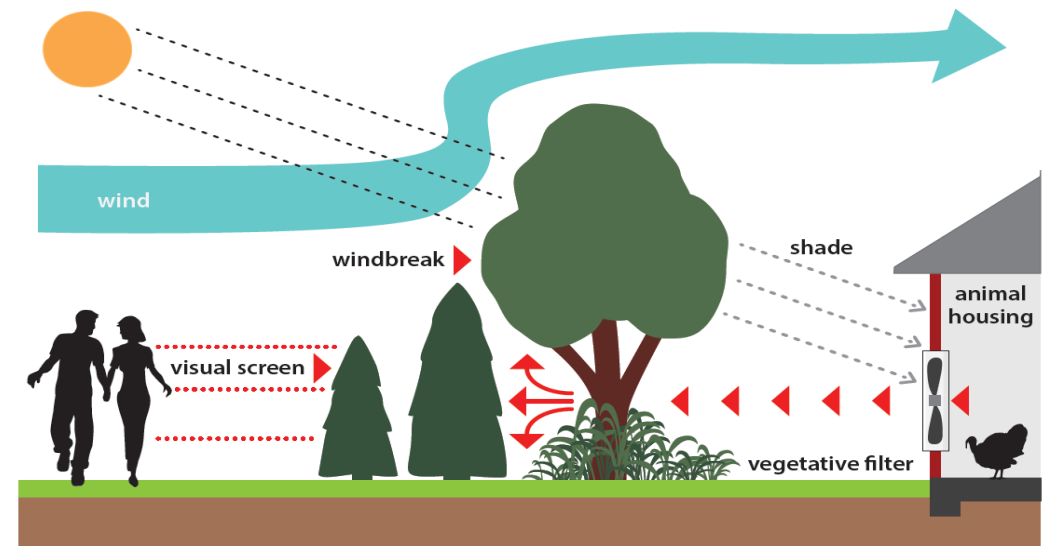
Paul Patterson, Penn State University  
Department of Animal Science



Penn State **Extension**

## Outline

- **Vegetative Buffers:**
  - Landscaping/Screening
  - Air Quality
  - Water Quality
  - Bedding & Biomass
  - Energy Conservation

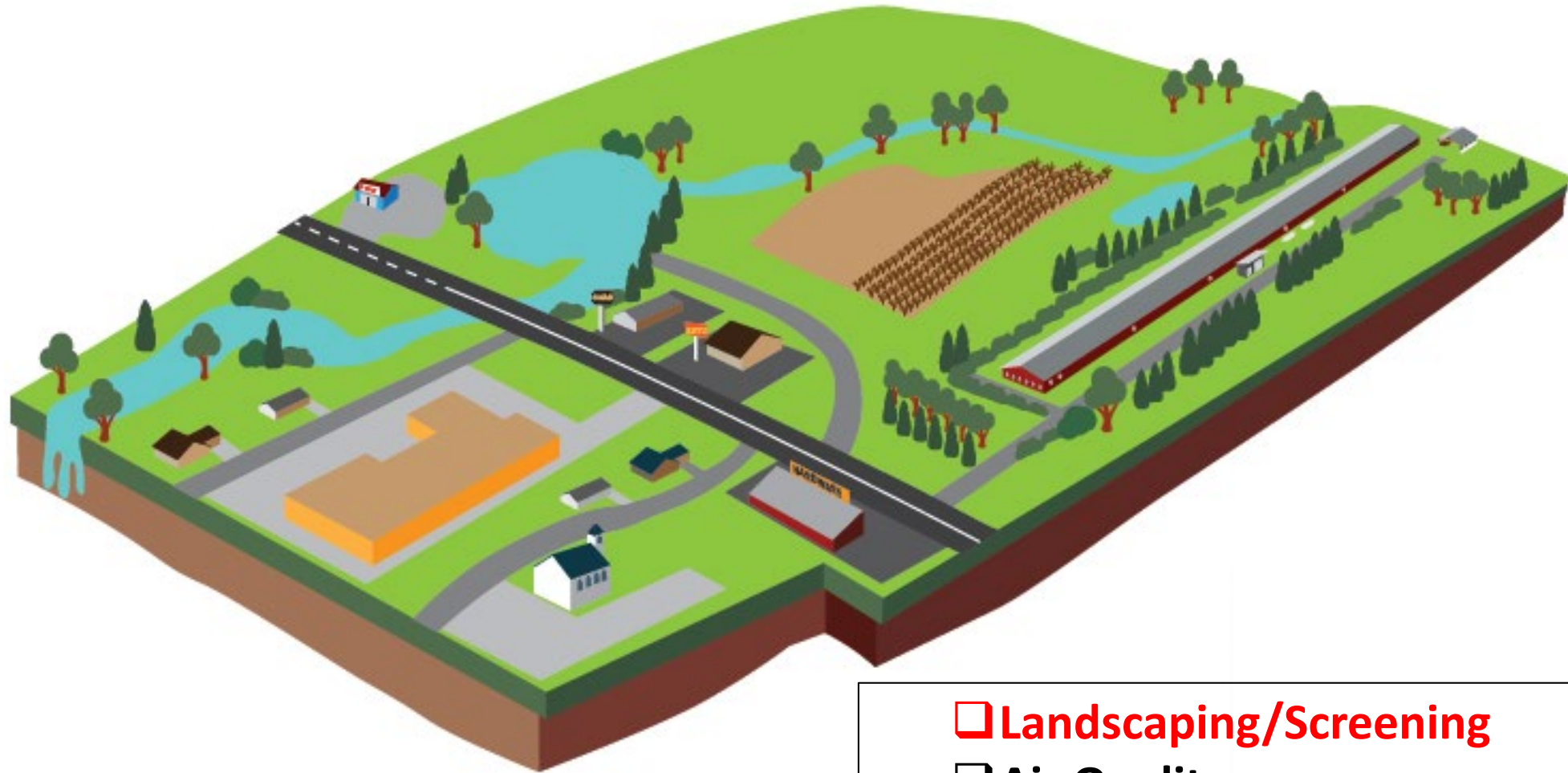


## Challenge at the Urban/Rural Interface

- We have a lot of people in Pennsylvania
- And a lot of poultry & animals too
- Manure, odors, gases
- Dust, feathers
- Insects: flies, beetles etc.
- Rodents, predators
- Dead birds
- Noise, lights
- Water use and quality



# Penn State **Extension**



Landscaping/Screening

Air Quality

Water Quality

Bedding and Biomass Production

Energy Conservation

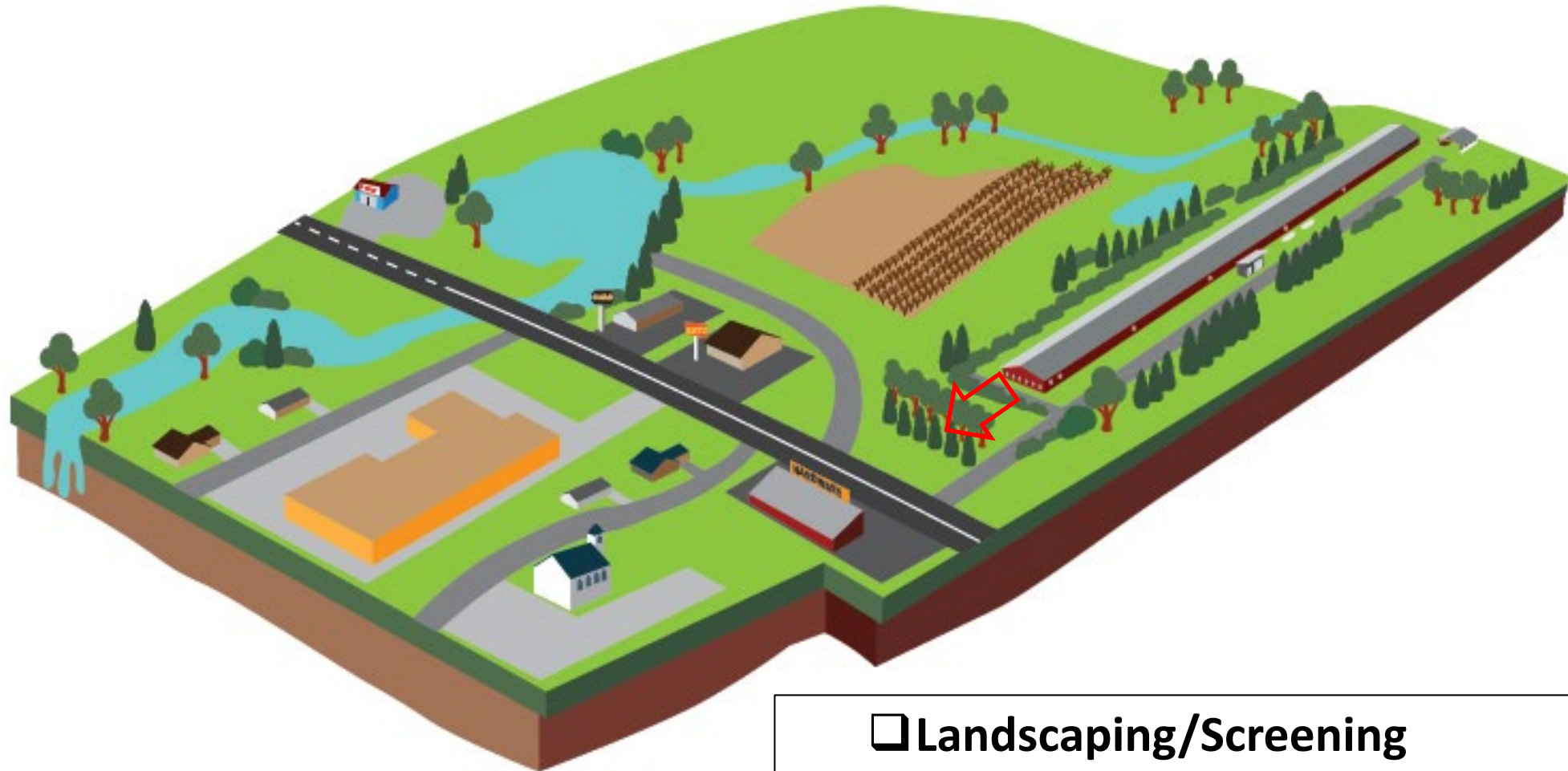
## Landscaping or Screening



# Screening & Beautification at the Urban/Rural Interface



# Penn State **Extension**



- Landscaping/Screening
- Air Quality: dust, ammonia, odor**
- Water Quality
- Bedding and Biomass Production
- Energy Conservation

# Potential Importance of AFO Emissions

## NRC Committee on Air Emissions from AFO

Emission	Global, Natl & Regional	Local	Effect of Concern
<b>NH<sub>3</sub></b>	<b>Major</b>	<b>Minor</b>	<b>Atm depo, haze</b>
N <sub>2</sub> O	Significant	Insignificant	Globe climate change
NO <sub>x</sub>	Significant	Minor	Haze, atm depo, smog
CH <sub>4</sub>	Significant	Insignificant	Globe climate change
VOCs	Insignificant	Minor	Quality of human life
H <sub>2</sub> S	Insignificant	Significant	Quality of human life
<b>PM<sub>2.5</sub> PM<sub>10</sub></b>	<b>Insignificant</b>	<b>Significant</b>	<b>Health and haze</b>
<b>Odor</b>	<b>Insignificant</b>	<b>Major</b>	<b>Quality of life</b>

## NH<sub>3</sub> Research in PSU Chambers



- Honey locust, poplar, red cedar, reed canary grass
- Some plants can tolerate NH<sub>3</sub> some can not
- Plants deposited N in leaves
  - **Poplar: 4.04 to 10.20%**
  - **Locust: 5.32 to 8.99%**
  - **Grass: 2.86 to 6.36%**
- Plant dry matter increased

# Foliar Injury, Exp. 1

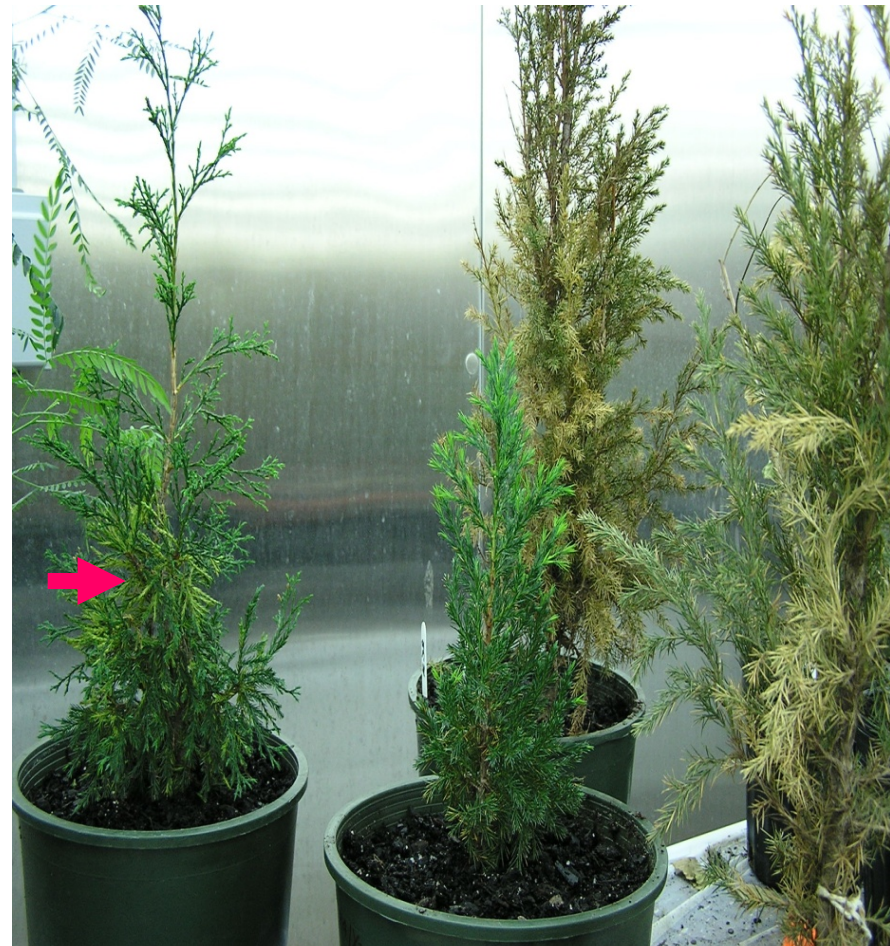
Red cedar



0 Wk

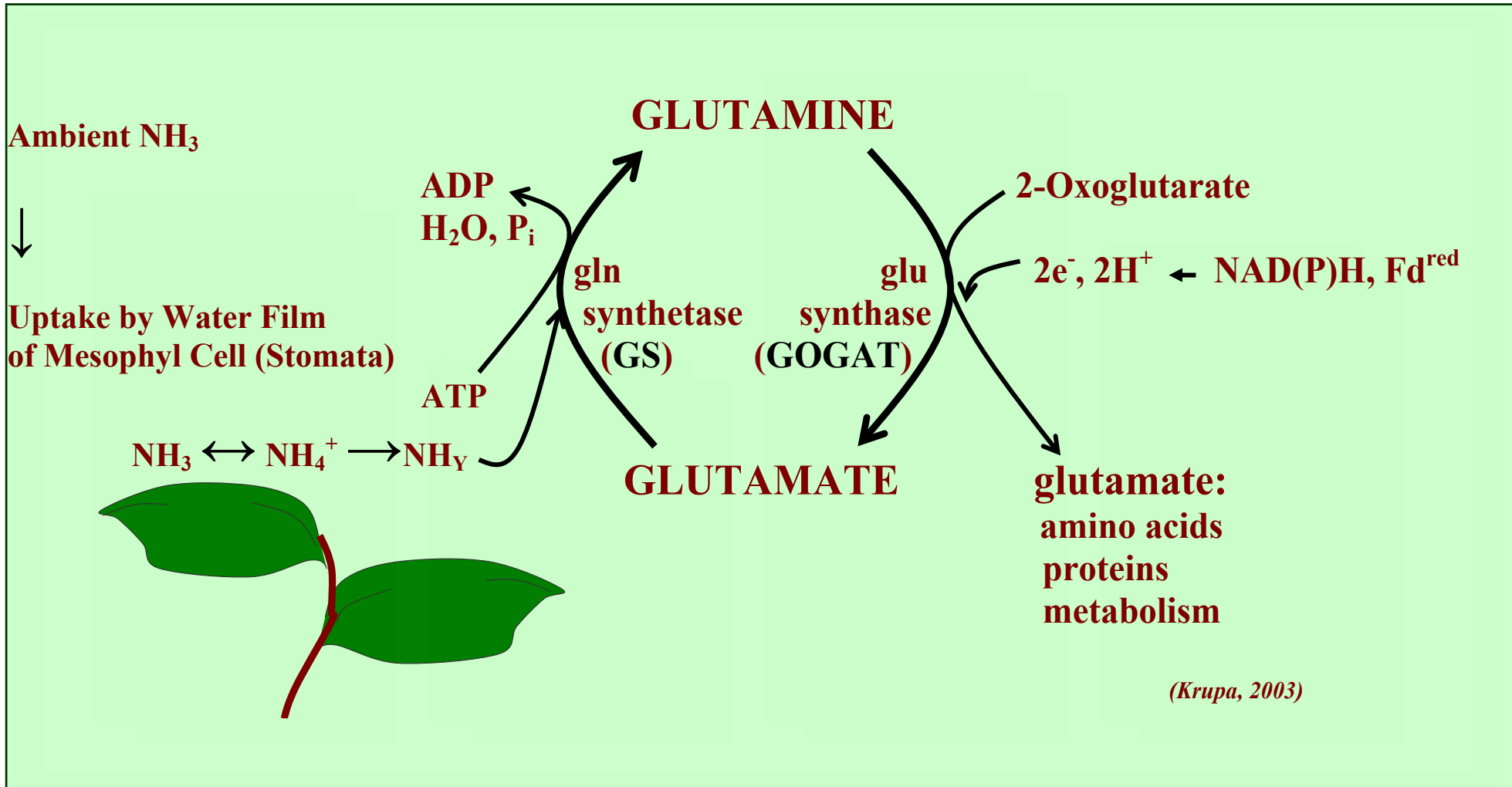


6 Wk



12 Wk

# NH<sub>3</sub> Research in PSU Chambers

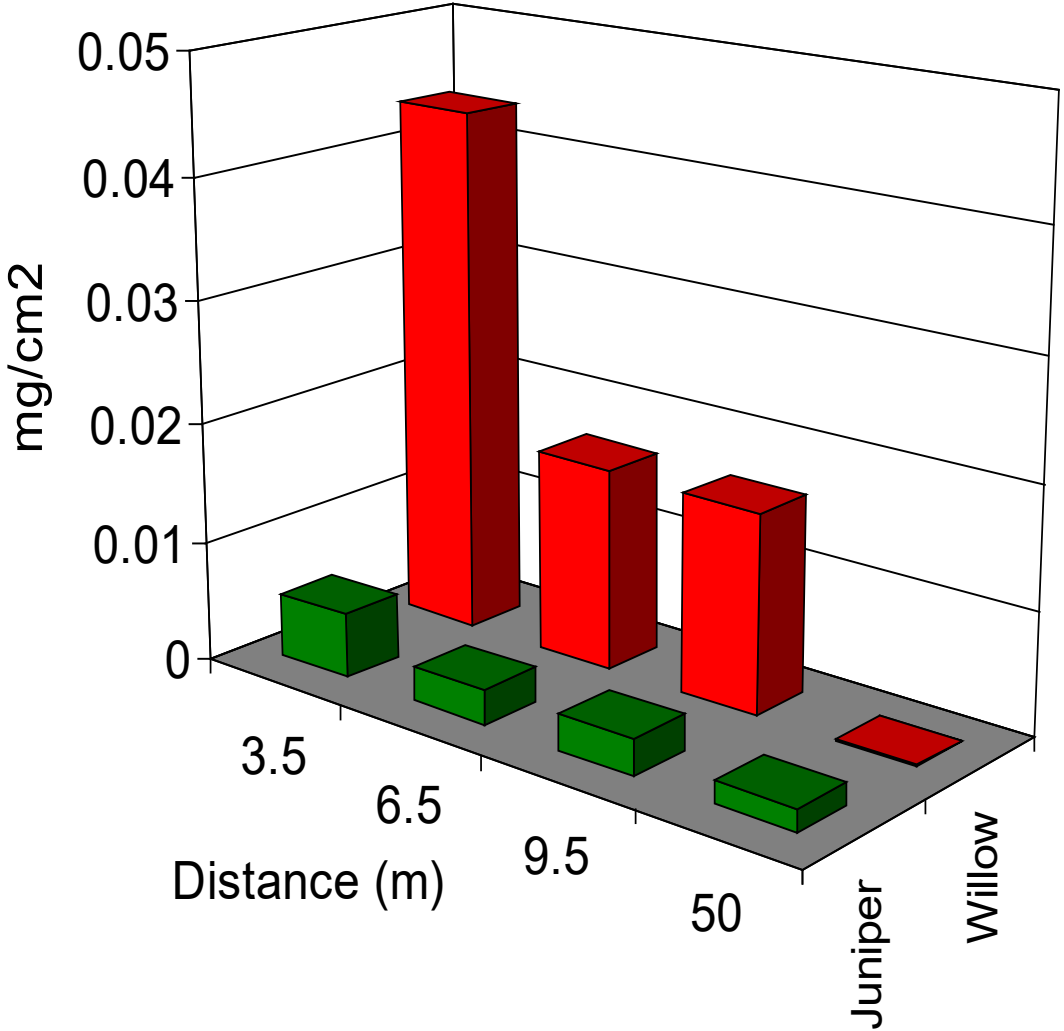




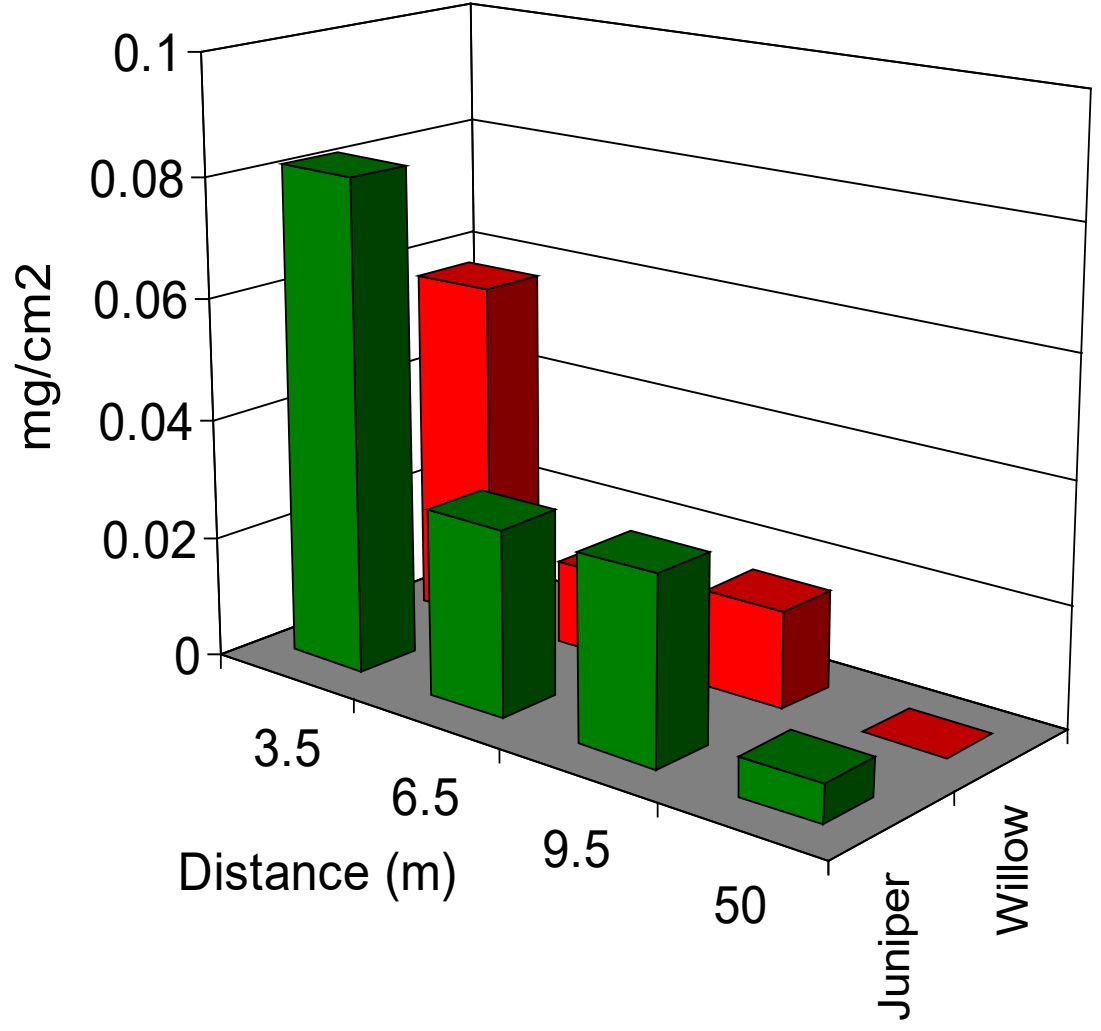
# Penn State Extension



# Foliar-PM<sub>2.5</sub> μm



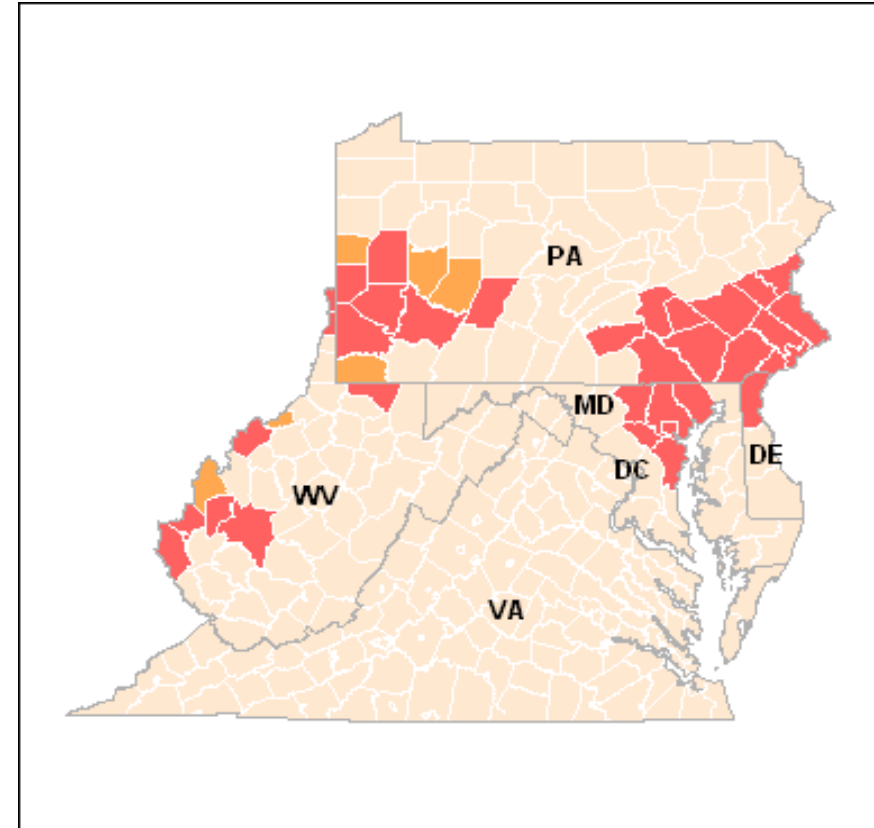
# Foliar-PM<sub>10</sub> μm



## Odor

- *Filtering exhaust air dust can reduce odors up to 65% (Hartung, 1989)*

## EPA PM Non-Attainment Zones



### EPA Designation

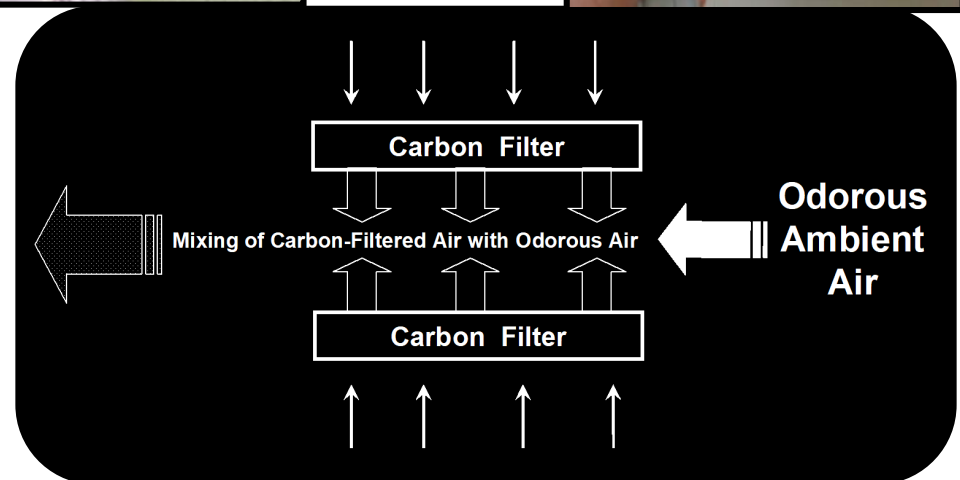
- Attainment/Unclassifiable
- Nonattainment - Whole County
- Nonattainment - Partial County

## Odor Threshold Concentration

- Dynamic Olfactometer



- Field Olfactometer  
*Nasal Ranger*



## Odor (detectable threshold) from PSU Hen House

Treatment	9/15/08	9/22/08
No Trees	33.7	44.7
Trees	21.7	20.7
P-value	0.3999	0.3431

Dynamic olfactometer and AC'SENT data sense olfactometry software.

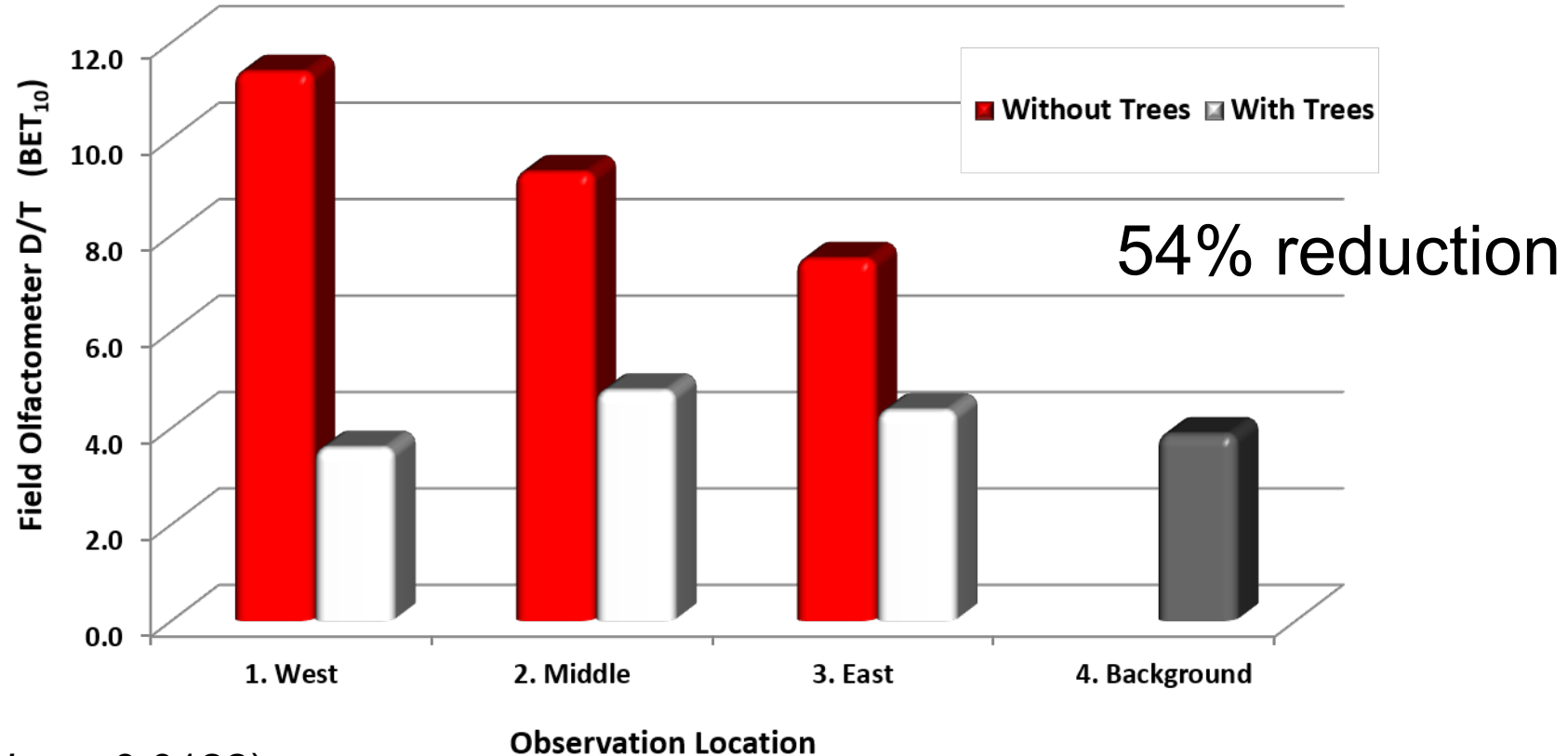


45% reduction



## Odor (Nasal Ranger, detectable threshold) from PSU Hen House

Poultry Housing Shelterbelt Odor Emissions



(*P*-value = 0.0122)

# Around litter/manure storage



## BUFFER PLANT MATERIALS

- Shrubs:
  - Willow
  - Red & Grey Dogwood
  - Holley
  - Lilac
  - Forsythia



- Grasses:
  - Panicum (switchgrass)
  - Big bluestem
  - Miscanthus

## BUFFER PLANT MATERIALS

- Native species, adapted to climate and soil
- Evergreens:
  - Eastern Red Cedar
  - Norway Spruce
  - Hemlock
  - Arborvitae
  - Pine
- Deciduous Trees:
  - Hickory
  - Oak
  - Hackberry
  - Maple
  - Hybrid Poplar
  - Honey Locust
  - Sycamore

## Deciduous



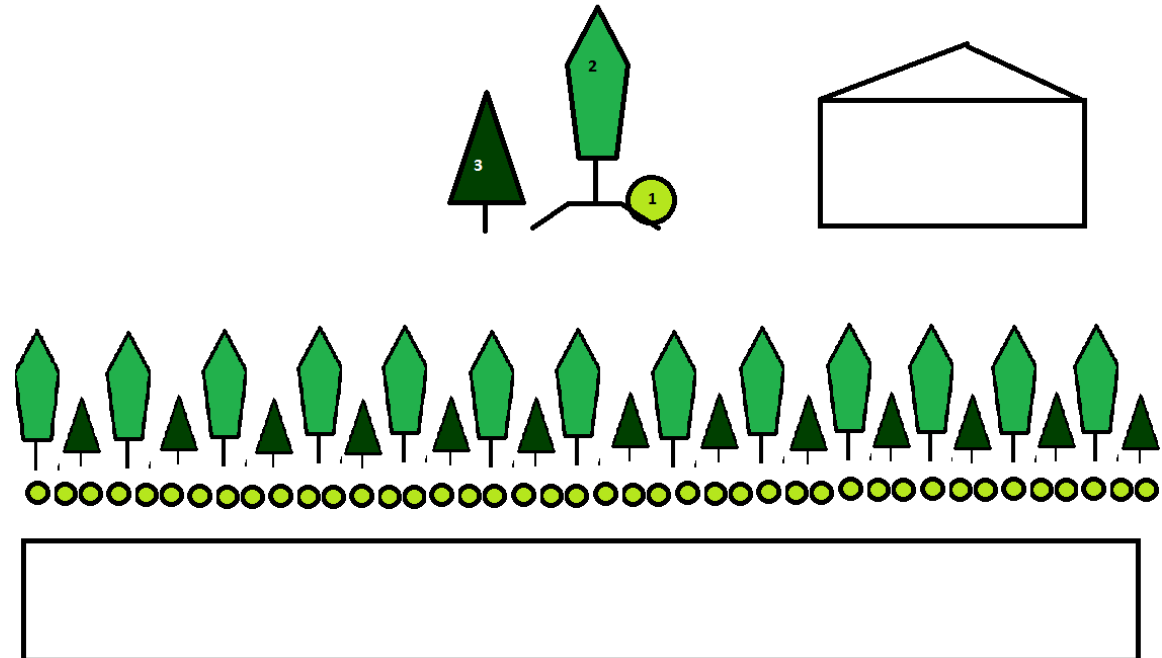
## Evergreen



## Establishing a Buffer

- Soil analysis (fertilizer)
- Weed control:
  - Chemical
  - Mechanical
  - Mats & Mulch
- Contractors/Nursery for plant materials & installation

- Irrigation
- Planting
- Spacing
- Orientation



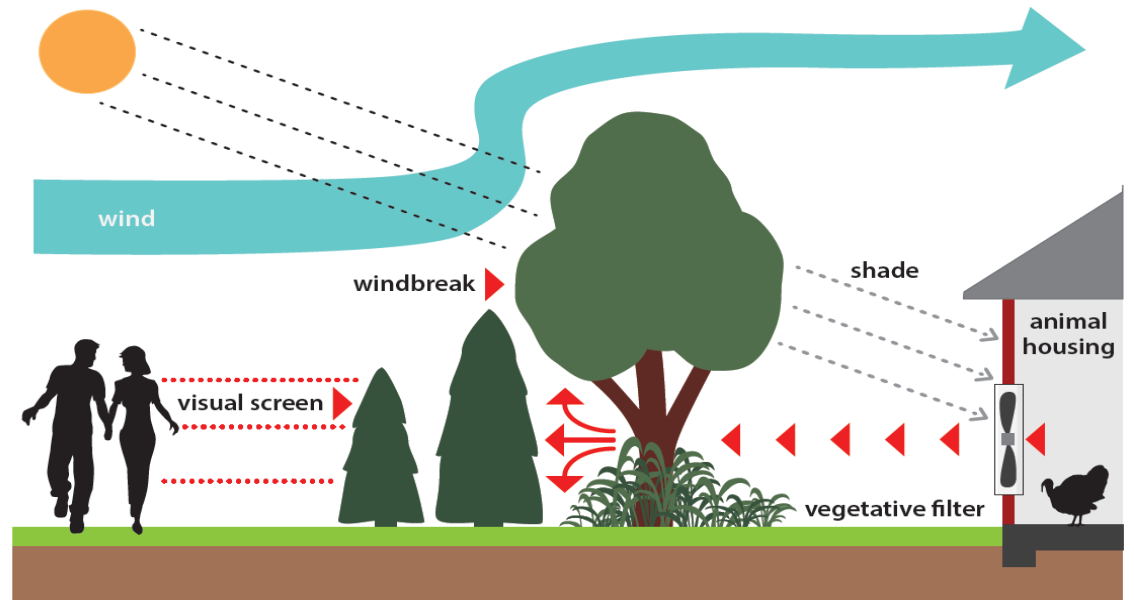
## Cost Share Programs

- EQIP  
<http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip/>
- Windbreak
- Hedge Rows
- Riparian Buffers
- Biomass Crops
- DEP Growing Greener
- PA Conservation Districts: tree programs
- PA Bureau of Forestry



## Summary

- **Vegetative Buffers:**
  - Landscaping/Screening
  - Air Quality
  - Water Quality
  - Bedding & Biomass
  - Energy Conservation
  - **Cover: Outdoor Birds**
  - **Silvopasture**



# Questions

- Paul Patterson  
Penn State University  
Department of Animal Science  
[php1@psu.edu](mailto:php1@psu.edu)  
(814) 865-3414



United States Department of Agriculture

Natural Resources Conservation Service



College of Agriculture  
& Natural Resources

PENNSYLVANIA STATE UNIVERSITY



College of  
Agricultural Sciences



# Innovative Approaches to Capture Nitrogen and Air Pollutant Emissions from Poultry Operations

Hong Li, Associate Professor  
Department of Animal and Food Sciences  
College of Agriculture and Natural Resources  
University of Delaware

# Key Team Members

## University of Delaware

Hong Li

Eric Benson

William Brown

## Penn State University

Paul Patterson

Gregory Martin

## Oklahoma State University

Mike Buser

## University of Maryland

Alba Torrents

Marybeth Shea

Laura McConnell

## USDA Agricultural Research Service

Cathleen Hapeman

Gregory Holt

Philip Moore

John Prueger \*\*

Kyoung Ro \*\*

Steven Trabue

## University of Iowa

William Eichinger \*\*

## University of Georgia

Lowry Harper \*\*

## University of Alberta

Tom Flesch \*\*

*\*\* Leveraged Collaborators*

# Managing Poultry House Emissions

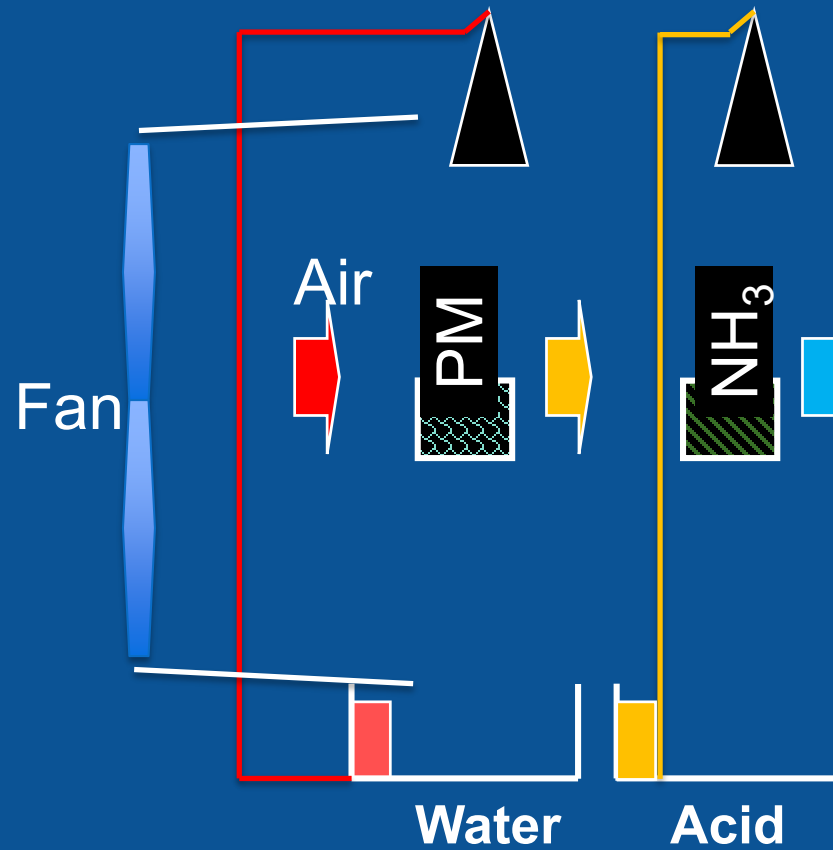
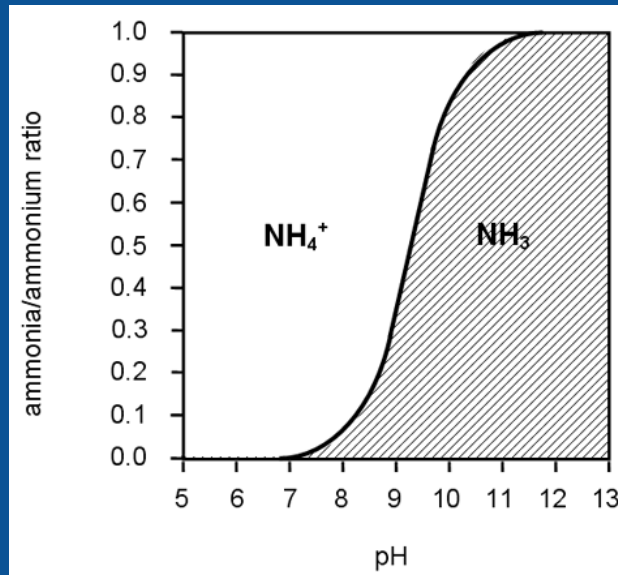
- **Emission sources**
  - Minimum fans in cold seasons
  - Tunnel fans in warm seasons
- **Solution**
  - Acid scrubbers
  - Vegetative environmental buffers (VEBs)

## VEBs and Acid Scrubbers

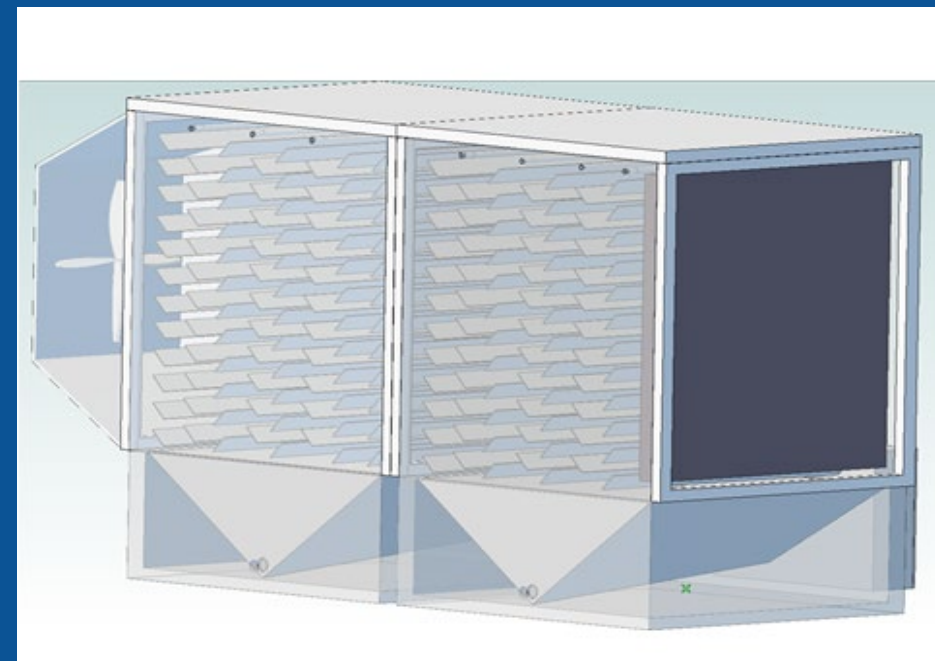
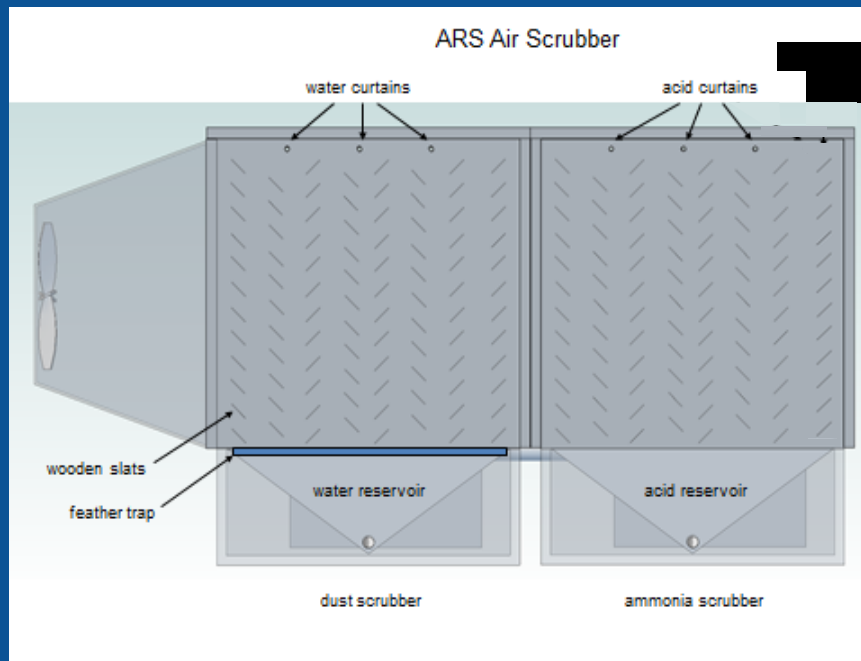


- Three farms for quantifying the reduction efficiency of VEBs in warm seasons
- Four farms for testing five low-cost two-stage acid scrubbers in AR, DE, and PA.

# Air Scrubber on Exhaust Fans

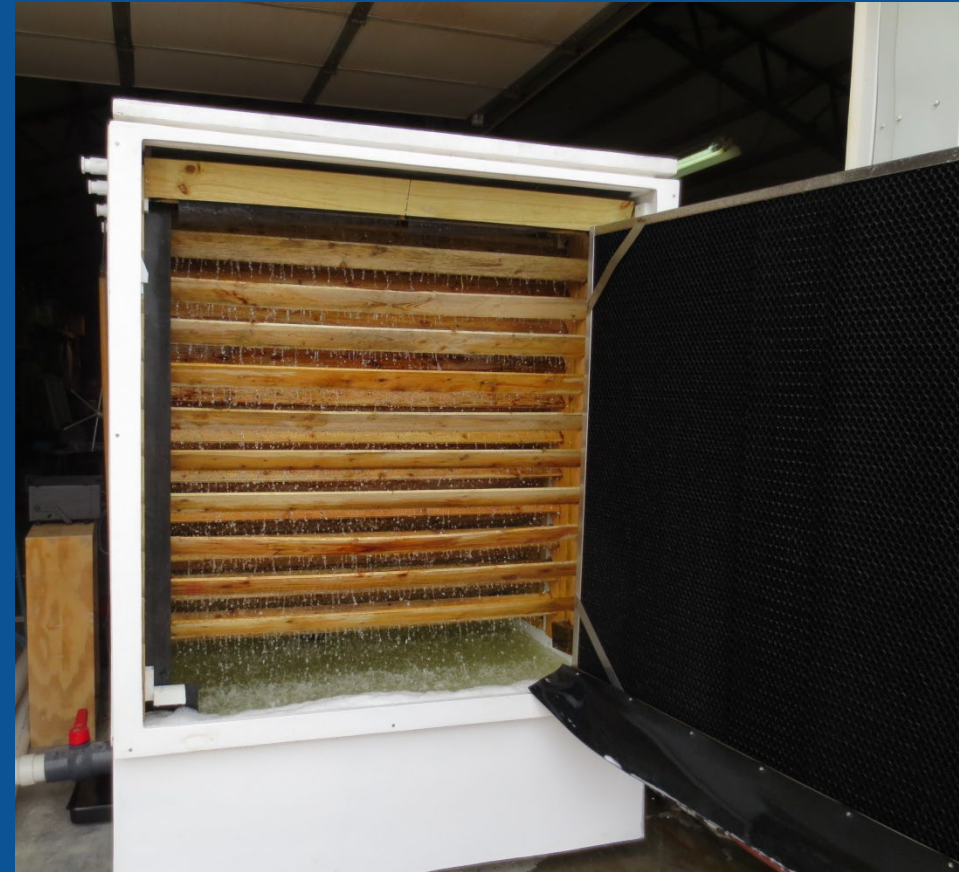


# USDA ARS Scrubber



5 x 5 x 6.5 ft

# USDA ARS Scrubber



# Acid Scrubber Field Demonstration



DE site 1

- Commercial farm
- 36" sidewall fan
- 5,669 cfm
- Built-up litter



DE site 2



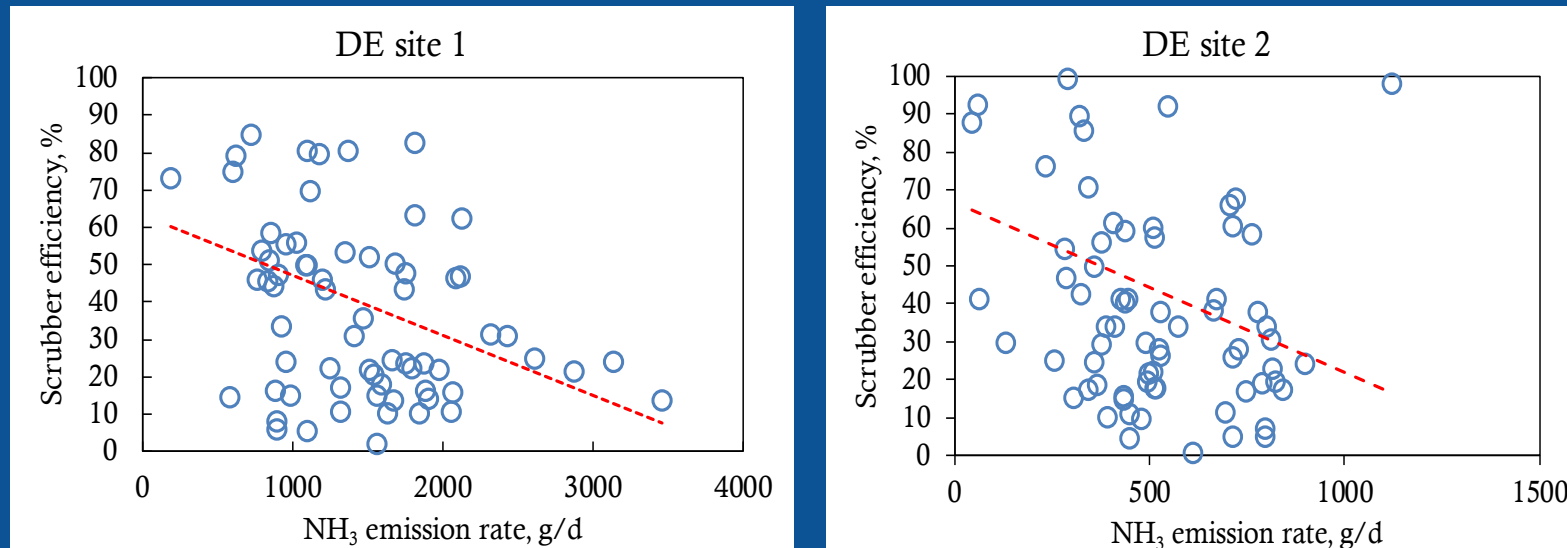
PA site

- Organic farm
- 36" sidewall fan
- 4,768 cfm
- 0.12 in. pressure
- 90° angle
- New bedding

- Experimental house
- 24" fan
- 2,062 cfm

NaHSO<sub>4</sub> used as acid

## USDA ARS Scrubber

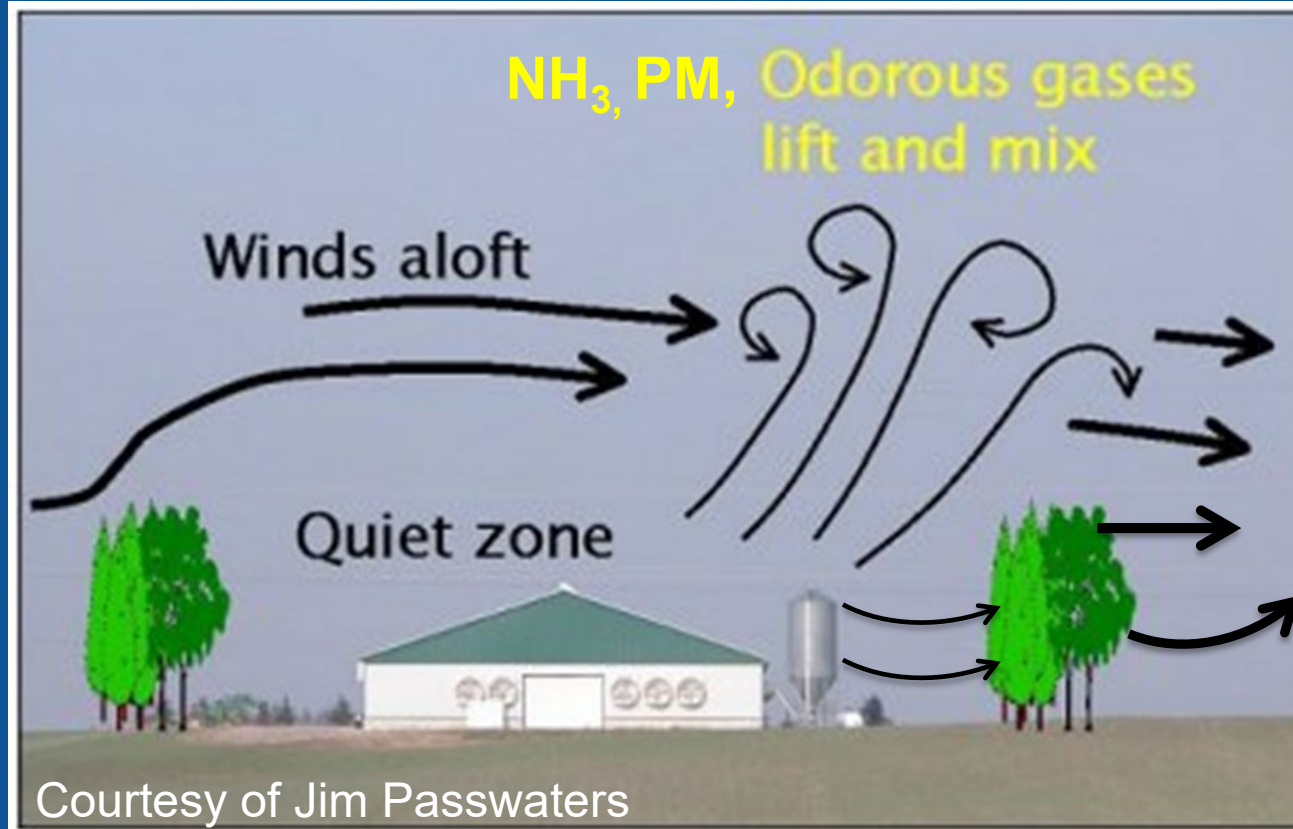


- The average NH<sub>3</sub> removal efficiency was up to 44%, depending on the maintenance schedule, air flow rate, fan control strategies, and litter management.

## Acid Scrubber Recommendations

- Increase fan runtime to compensate air flow loss due to high pressure drop.
- Heat fresh water line and add heater in pump boxes.
- Clean dust scrubber at least twice per flock for used litter.
- Replace acid water frequently toward end of the flock for best performance.
- Automatic dosing system to control pH.
- Need storage tank for spent liquid if the growers don't have crops or pasture to apply.

# Vegetative Environmental Buffers (VEBs)



# Vegetative Environmental Buffers (VEBs)

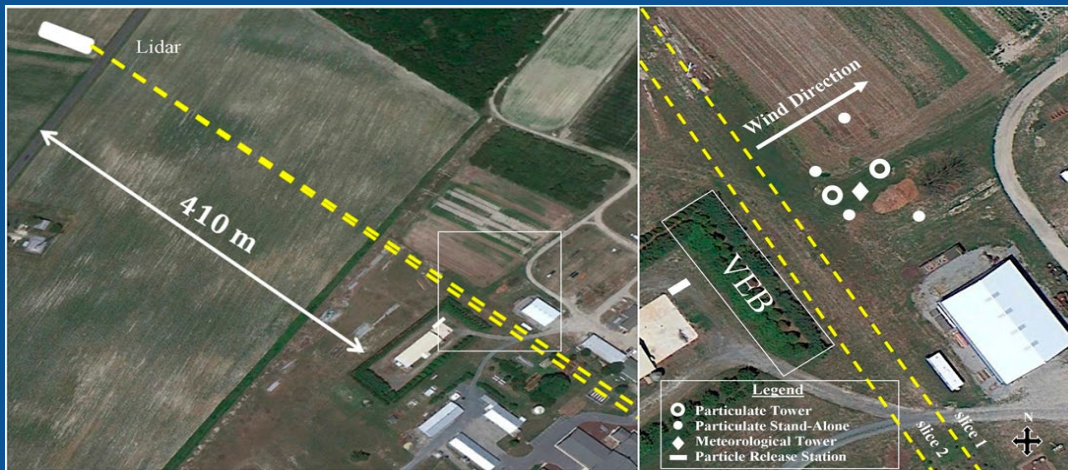
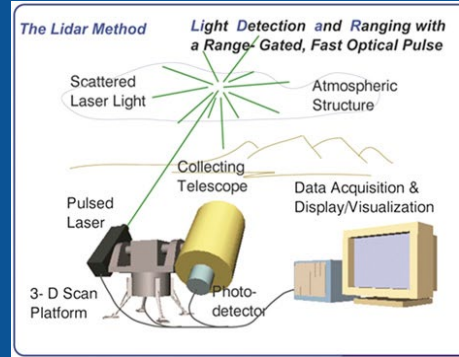


Sept 2003

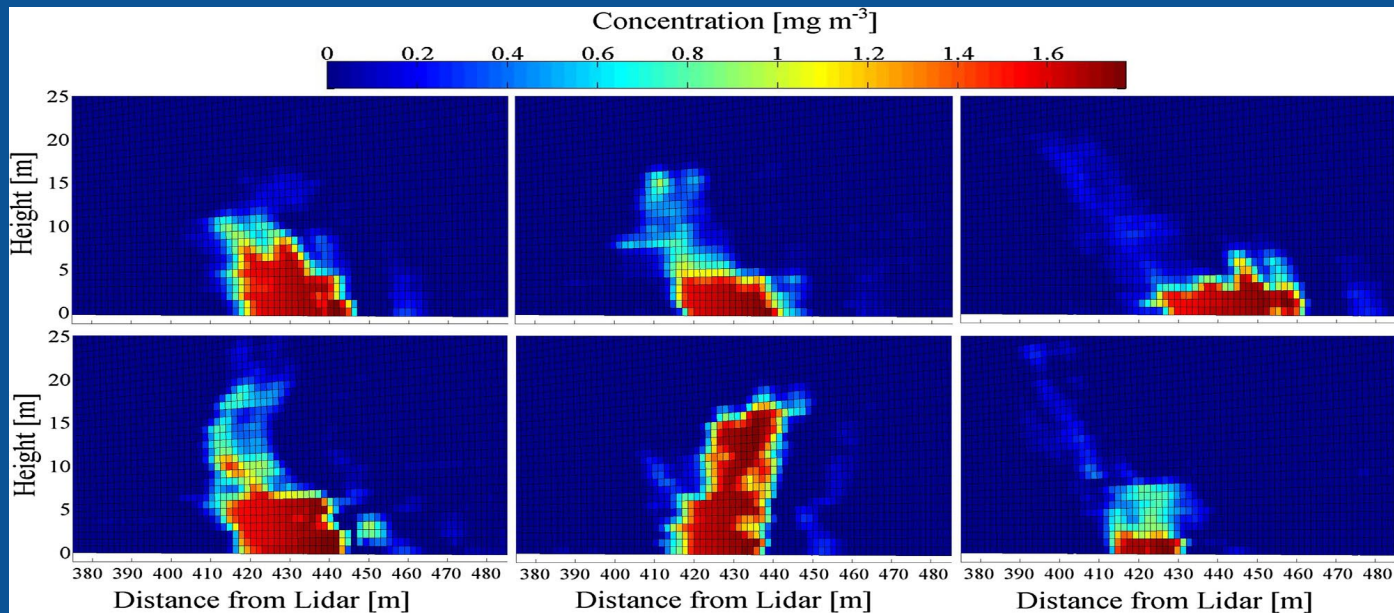


June 2013

# VEBs on PM Reduction with Lidar

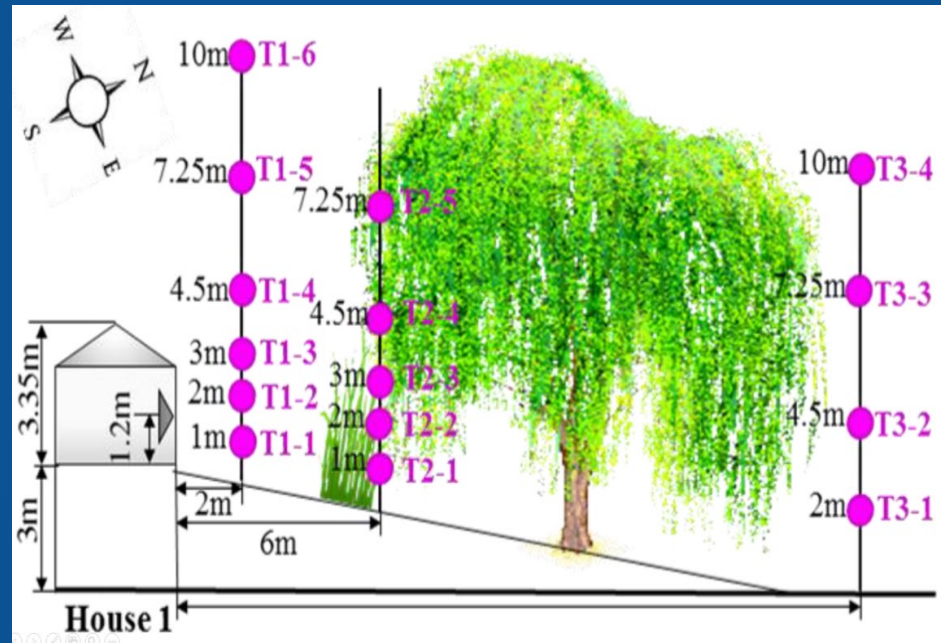


## VEBs on PM Reduction with Lidar



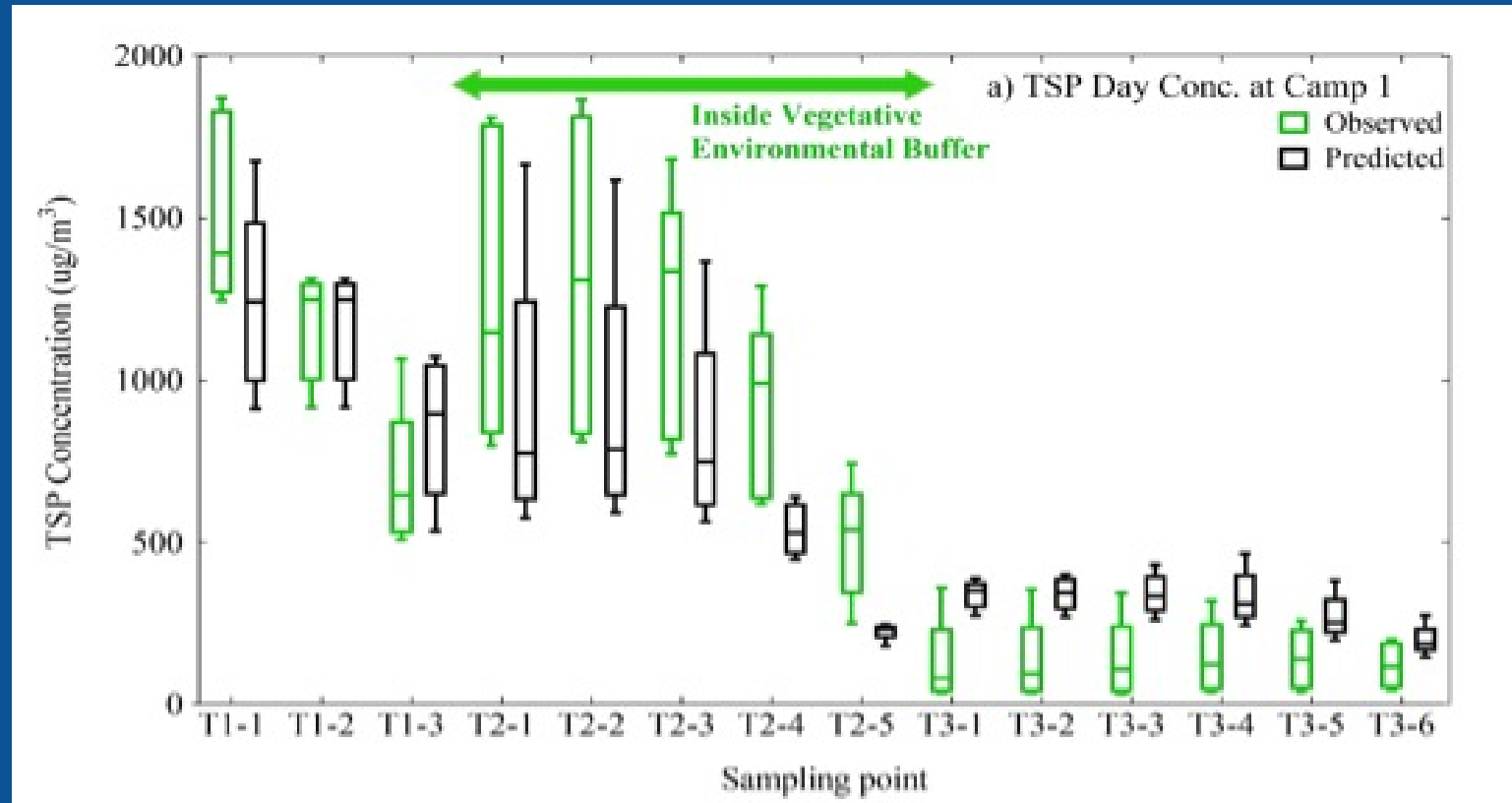
- PM capture efficiency =  $47 \pm 14\%$  during the daytime runs
- PM capture efficiency =  $73 \pm 1.5\%$  during the daytime runs
- VEB therefore performed best during times with less turbulence

# VEBs on Emission Reduction



- Willow trees
- Grasses

# VEBs on Emission Reduction



## VEBs on Emission Reduction

- Observed PM concentrations behind the VEB were all noticeably lower than predicted values
  - Reduction efficiencies of VEB were 17%, 21%, and 25% for TSP, PM10 and PM2.5 respectively.
- NH<sub>3</sub> reduction efficiency of VEB was 15% to 25% during the daytime and 13% to 25% during the nighttime by comparing field-observed and model-predicted data from all campaigns. This result showed the high potential of reducing NH<sub>3</sub> downwind concentration from the poultry houses by VEB.
- Downwind methanol concentration was reduced by 23% during the day and 27% during the night with VEBs.

## Summary

	<b>VEB</b>	<b>Scrubber</b>
Effectiveness on emission reduction	Varies in seasons	High for cold seasons
Initial cost	Low	High
Maintenance	Medium (irrigation, weed&pest control)	High (acid, water, electricity)
Product	Biomass	Fertilizer
Impact on ventilation	Improve fan performance by blocking wind	Lower fan performance



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## Questions?

Website: <http://sites.udel.edu/vebscrubber/>

Contact the Project Director  
Hong Li, University of Delaware  
Phone: (302) 831-1652  
E-mail: [hli@udel.edu](mailto:hli@udel.edu)

# Windbreak Wall-Vegetative Strip System to Reduce Pollutant Emissions from Fan-Ventilated Livestock Barns

Sanjay Shah & Ali Ajami

2 April 2020

*CIG New Innovation Webinar Series*

# Background

- Livestock barns emit many pollutants, e.g., ammonia, hydrogen sulfide, particulate matter (PM)
- Example: A finishing barn with 1,000 pigs could emit 3 tons of ammonia & 200 lb of fine PM annually

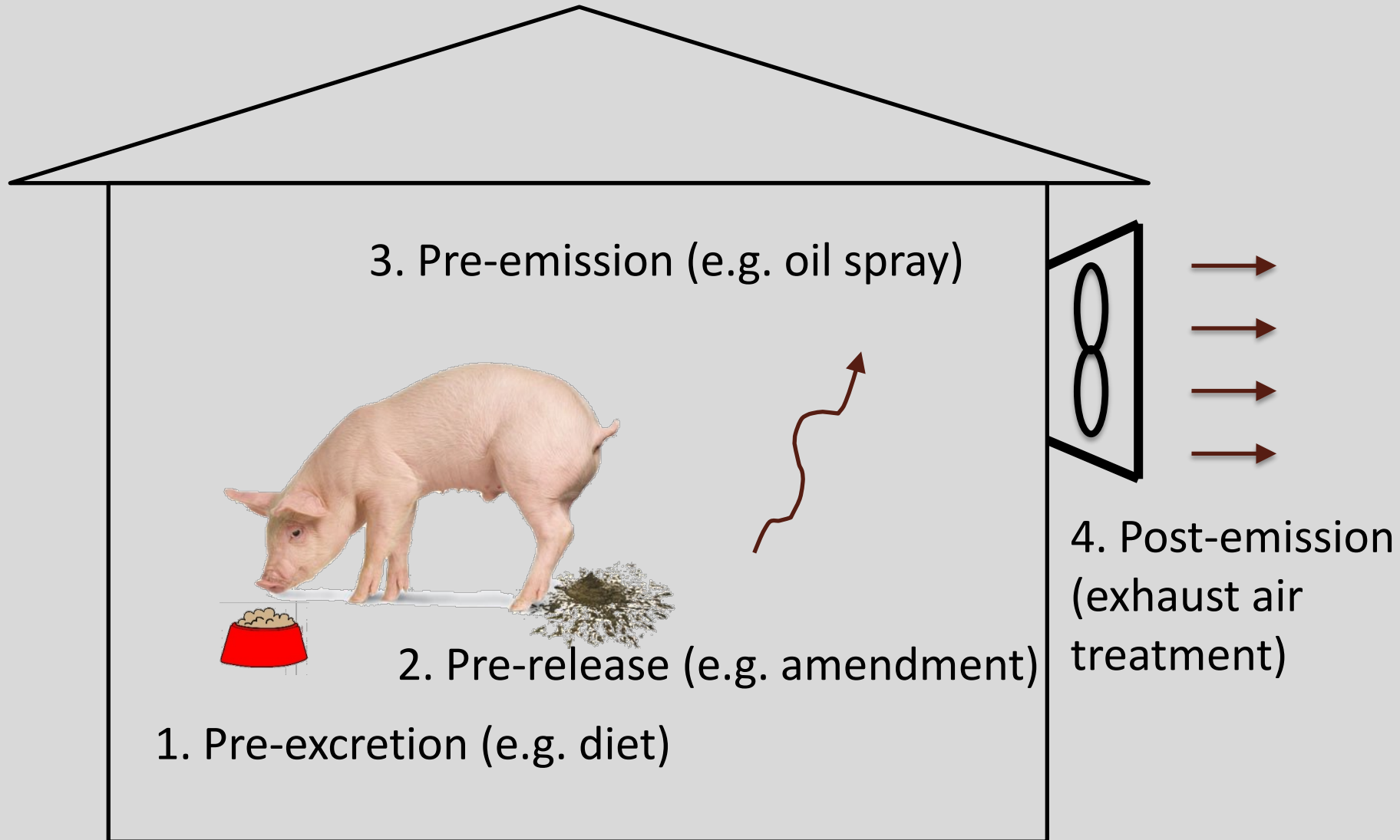
View of finishing barn  
(Photo courtesy of  
National Hog  
Farmer/National Pork  
Board)



# Background (contd.)

- Pollutants emitted from barns affect the environment, public health, and quality-of-life
  - Two NC odor lawsuits led to huge awards against major swine integrator
  - More NC lawsuits in the courts
  - Poultry odor complaints also increasing
- Air quality issues, particularly, odor complaints may affect sustainability of US confined livestock production

# Mitigation Approaches



# Background (contd.)

- All mitigation approaches have advantages and disadvantages
- May need to consider multiple approaches, including post-emission approaches
- Industrial exhaust air treatment systems effective but expensive & impose unacceptable pressure drops
- Since PM transport gases & odor, effective treatment systems should trap PM & cause low pressure drop

# Promising Exhaust Air Treatment Systems for US Barns

## Vegetative Environmental Buffer

- Low pressure
- Variable pollutant removal



## EPI Filter Wall®

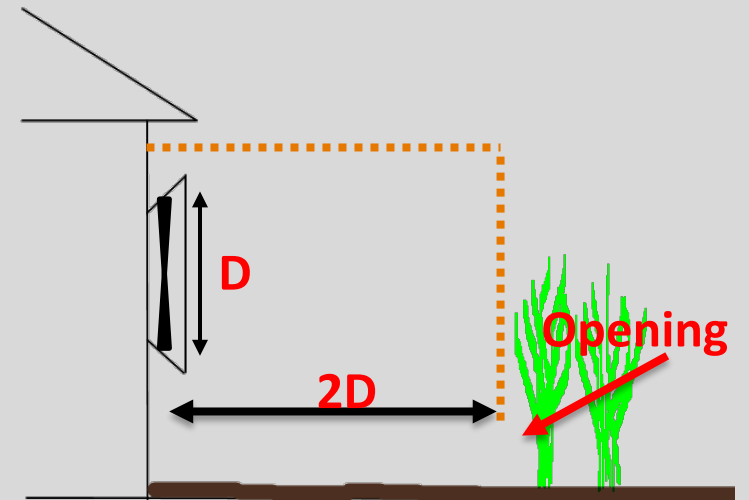
- Electrostatic precipitation used downstream of fans
- 30% odor removal, 50% total suspended particulate removal



(Courtesy: Agriment Services)

# Motivation: Windbreak wall - vegetative strip system

- Porous fabric has minimal impact on airflow rate
- Low-cost system; can be built with on-farm resources
- Mechanisms:
  1. Front screen reduces momentum forcing some air to move through top & sides
  2. Reduced airspeed facilitates dust trapping on screen & ground
  3. Vegetative strip provides physical trapping & N uptake



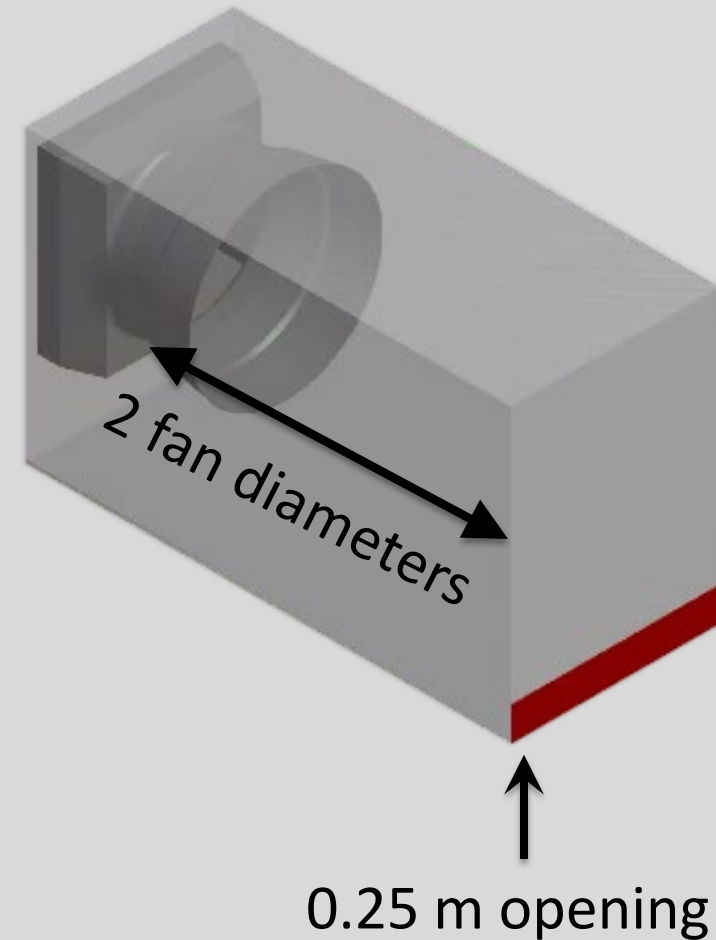
# Objectives

- Overall: Evaluate effectiveness of system for reducing emissions from ventilated livestock barns
  1. Design & fabrication
    - Computational Fluid Dynamic (CFD)
  2. Monitoring
    - Swine barn
    - Layer barn

# Materials & Methods

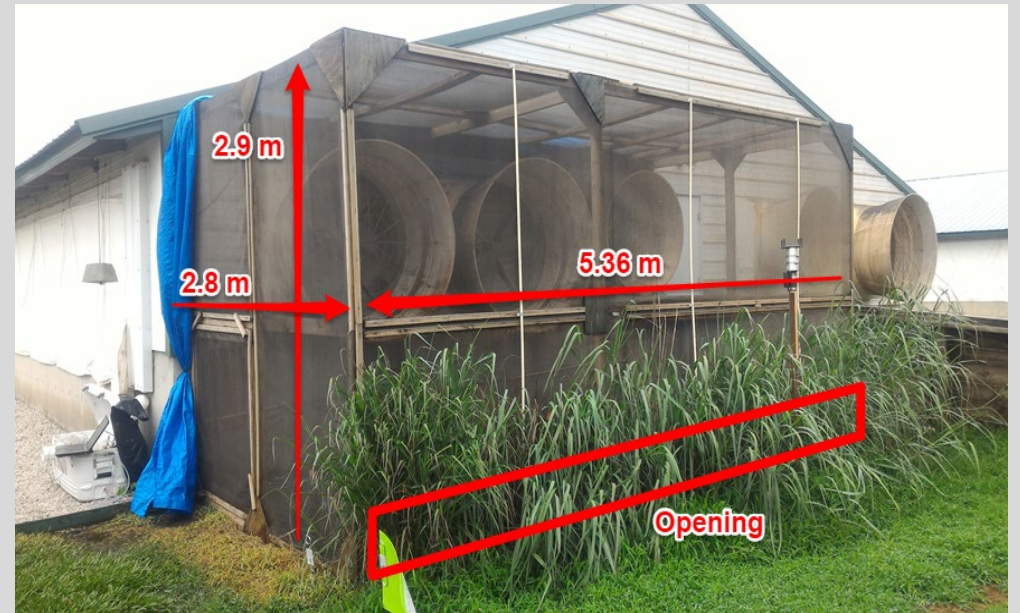
# Design & Fabrication

- Modeled 3 shapes, 3 footprint size, 6 fabrics (porosity & pore type), & opening (to prevent pressure rise)
- Selected low-cost design (two fan diameters length with mosquito screen) with acceptable pressure increase (<12 Pa or 0.05 in)



# Swine Barn System

- Mosquito screen & lumber construction covering two 1.2-m and one 0.9-m fans
- Switchgrass for treatment
- Front screen 2 fan diameters from fan blade plane
- 0.25-m opening behind switchgrass to prevent pressure rise
- Self-cleaning with rain
- Average pressure increase  $\leq 0.05$  in
- Operating since July 2016



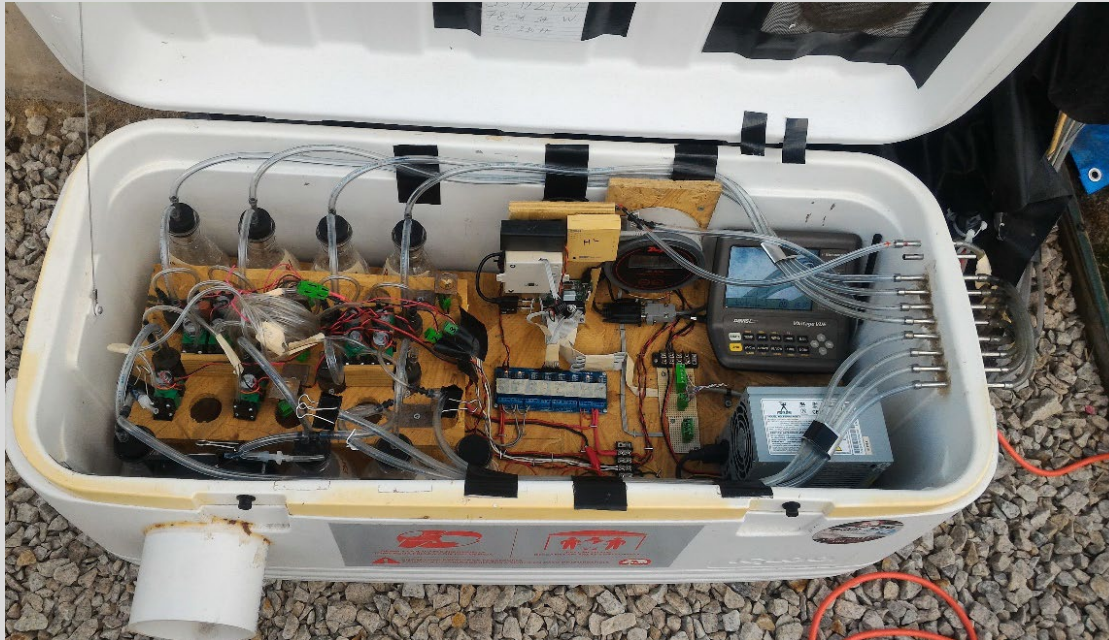
# Layer Barn System

- Earlier designs discarded due to clogging with feathers
- Final chamfered design covering one 0.9-m fan monitored for 4.5 months
  - Chamfered to ease cleaning by rain
- Larger footprint with 3 fan diameters to front screen
- 0.45-m opening behind switchgrass
- Average static pressure  $\sim 5$  Pa



# Monitoring

- Ammonia & H<sub>2</sub>S: scrubbers, manifolds
- Total suspended particulates (TSP): optical sampler, in grid pattern alongside airspeed, image analysis of TSP on screen



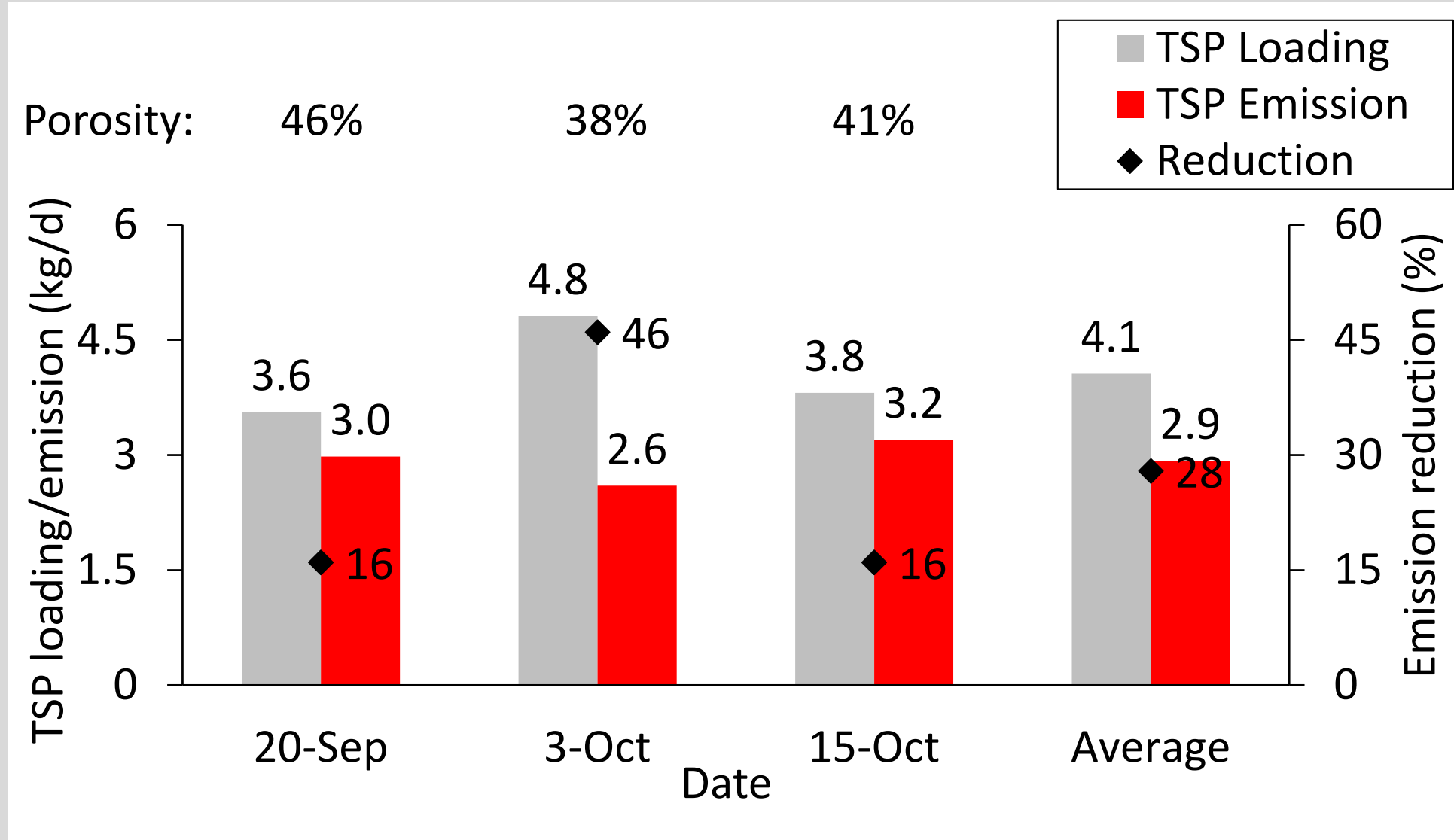
# Monitoring (contd.)

- Odor: Dilution to threshold (D/T) with Nasal Ranger™
  - D/T: Volumes of clean air per volume of odorous air that can be detected by panelist
- Vegetation uptake, interception, & soil samples: N & S

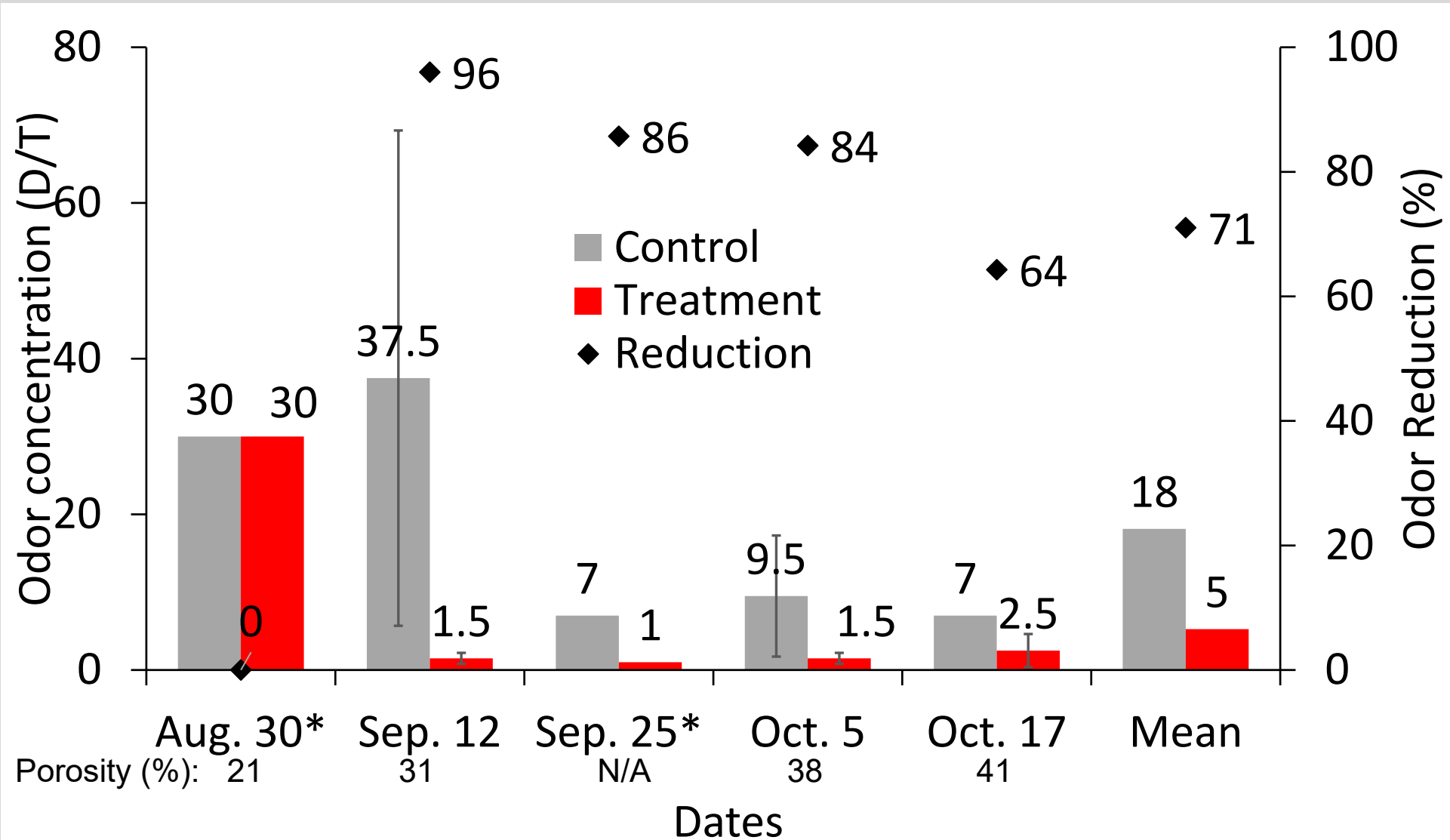


# Results & Discussion

# Swine System TSP Reduction

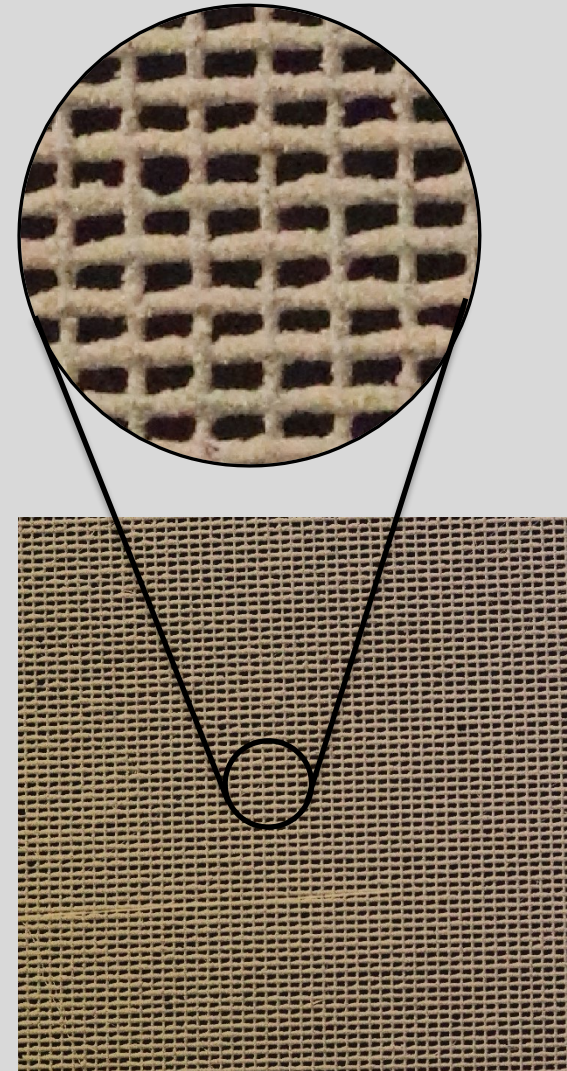


# Swine System Odor Reduction @ 10 m from Fans



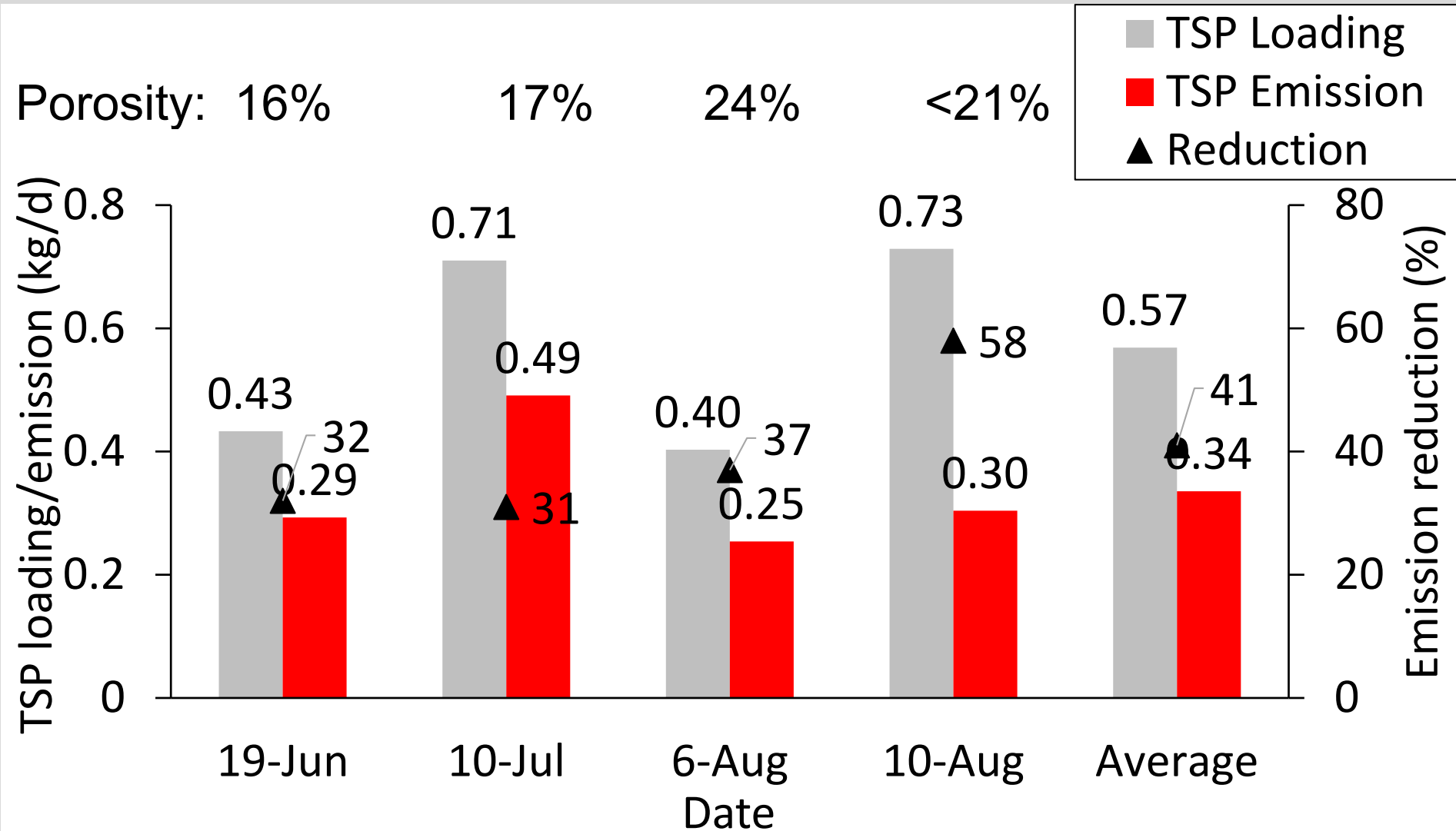
# Swine System Results

- Modest TSP reduction
- Large odor reduction
- No reduction in ammonia or H<sub>2</sub>S
- Test switchgrass had 259% higher N & 49% higher S than control (adjacent) switchgrass (over 15 months)
- Over 10 months, soil inside the system had
  - 132% more nitrate but 17% lower ammonium
  - 167% more sulfur

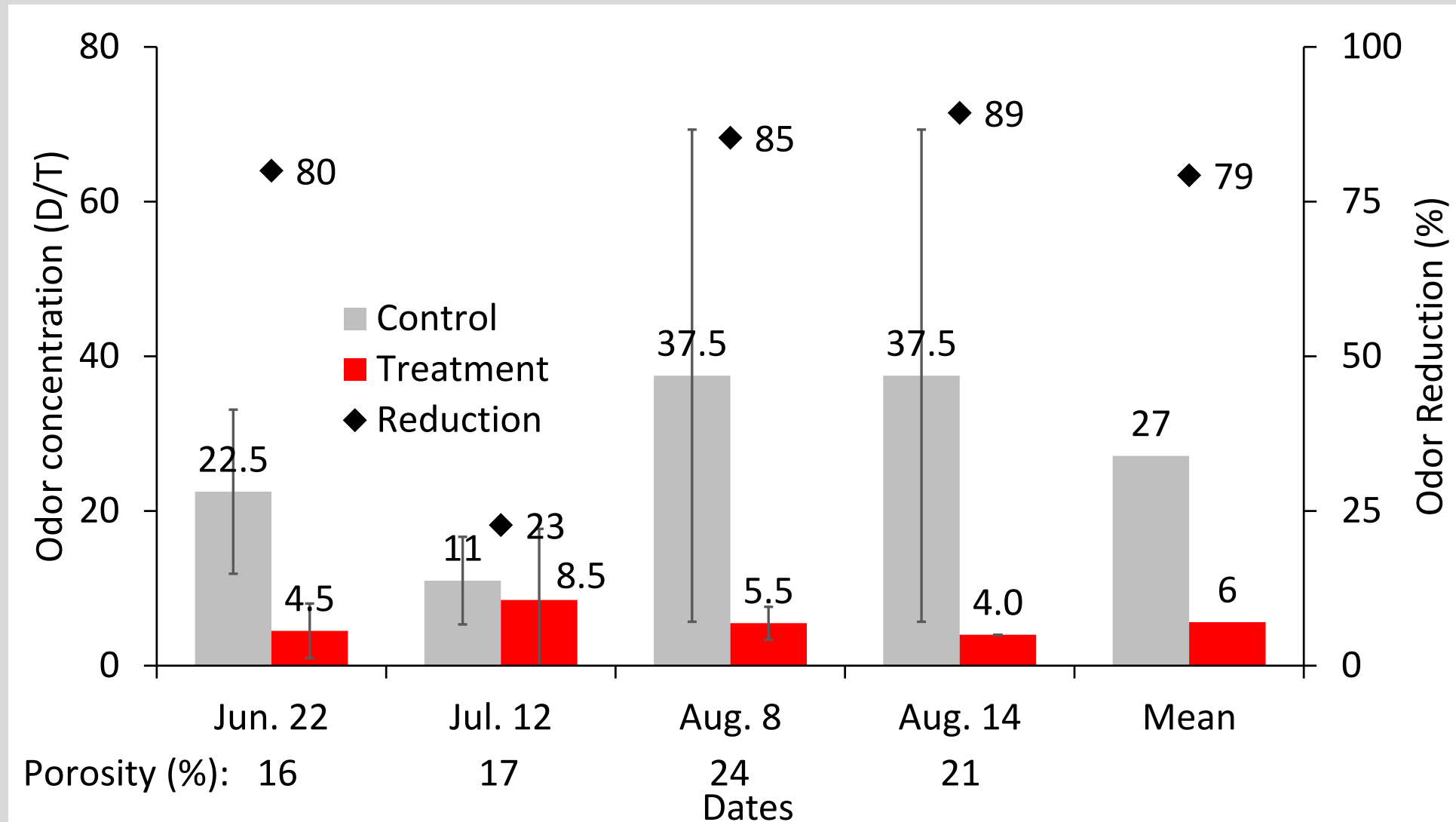


Close-up of dust accumulating on swine system screen

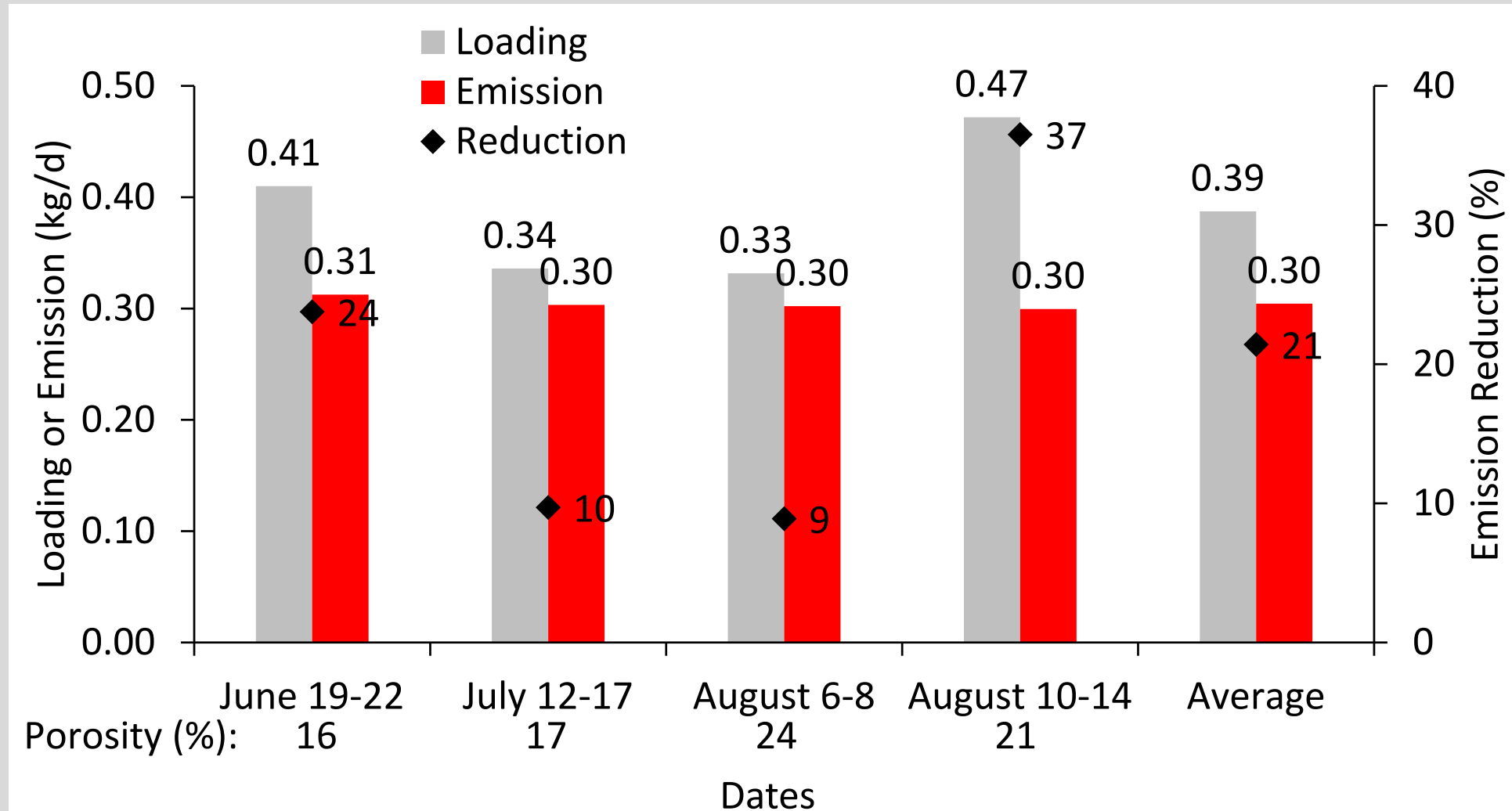
# Layer System TSP Reduction



# Layer System Odor Reduction @ 10 m from Fan



# Layer System Ammonia Reduction



# Layer System Results

- Moderate TSP emission reduction
- Large odor reduction
- Modest ammonia reduction
- Soil inside system had 22% higher N in 3 months
- Test switchgrass had lower N & S than control switchgrass

# Discussion

- Both systems reduced odor more than EPI Filter Wall™
  - Different odor measurement methods used
- Filter Wall had higher TSP reduction
- Ammonia emission reduction similar to Biocurtain™, predecessor of Filter Wall
  - Dust on screen could be source or sink for ammonia
- Inclined fan and chamfered system design in layer barn caused more N & S deposition on ground, reducing loading to switchgrass unlike swine system

# Discussion (contd.)

- Alamo cv. of switchgrass performed better than Shenandoah cv.
- Full potential of vegetative treatment unrealized due to inadequate vegetation height (late planting)
- No vegetative treatment in winter due to dormancy

# Conclusions

- Suitable for swine barn exhaust treatment
  - Compact, low-cost, self-cleaning system
  - Retrofittable & modular
  - Low pressure
- More work needed for use in poultry house
- Large odor reduction
- TSP reductions variable & modest
- Ammonia reduction small
- Evidence of enrichment in vegetation & soil inside system

# Future Work

- Requested funding from NC Ag Foundation to maintain system at swine farm and build new system at broiler farm
- If funded, will be used as demonstration sites
  - More odor data will be collected
  - Fate of volatile organic compounds will be studied
  - Other add-on components might be evaluated

# Additional Resources

1. Ajami, A., Shah, S.B., & Stikeleather, L.F. (2019). Windbreak wall-vegetative strip system to reduce air emissions from mechanically-ventilated livestock barns – Part 1: CFD modeling. *Water, Air, & Soil Pollution*, 230(12). <https://doi.org/10.1007/s11270-019-4333-4>
2. Ajami, A., Shah, S.B., Wang-Li, L., Kolar, P., & Castillo, M.S. (2019). Windbreak wall-vegetative strip system to reduce air emissions from mechanically ventilated livestock barns: Part 2—swine house evaluation. *Water, Air, & Soil Pollution*, 230(12). <https://doi.org/10.1007/s11270-019-4335-2>
3. Ajami, A., Shah, S.B., Wang-Li, L., Kolar, P., & Castillo, M.S. (2019). Windbreak wall-vegetative strip system to reduce air emissions from mechanically ventilated livestock barns—Part 3: layer house evaluation. *Water, Air, & Soil Pollution*, 230(12). <https://doi.org/10.1007/s11270-019-4345-0>

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- Bio. & Ag. Engineering Dept.
- NC State University

Questions/Comments  
Sanjay Shah  
[sanjay\\_shah@ncsu.edu](mailto:sanjay_shah@ncsu.edu)  
919-515-6753



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**"To be effective, our research and programs need to be focused on finding solutions and providing state-of-the-art technologies to improve management decisions on farm and on forest lands."**  
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