Progress Report Summary

Reporting Period: September 1, 2012 – February 28, 2013

Award Identifying Number: 65-7442-12-350

Title: Demonstrating the Effect of Trees for Controlling Particulate Matter, Ammonia, and Odor from Poultry Buildings
Investigators: Drs. Sheryll Jerez and Joey Bray
Institution: Stephen F. Austin State University
Project Period: September 1, 2012 – September 30, 2015

Objectives: The objectives of this project are three-fold: (1) Evaluate the effectiveness of various tree species in particulate matter and ammonia uptake, and in reducing odor; (2) Assess the ability of trees to tolerate building emissions; and (3) Examine management and costs requirements of using vegetative shelterbelts.

Progress Summary/Accomplishment:
The first six months of the project were spent on the following activities: (1) hiring a graduate research assistant and a student assistant, (2) preparing and submitting a project plan, (3) design of shelterbelt, (4) purchase of equipment for sampling, and (5) preparation for background sampling. One graduate student, Damika Thomas, was hired to work on the project and she was assisted by one undergraduate student assistant, Elaine Harris. A more detailed project plan outlining the sampling and evaluation strategy was submitted in November 2012. Included in the project plan was the design of the shelterbelt. Several equipment for sampling were purchased from different vendors and they include among others (1) EPAM 5000 for sampling different sizes of particulate matter, (2) Nasal Ranger for detecting the odor threshold, (3) ammonia detector tubes for measuring the concentration of ammonia, and (4) Hobo dataloggers for recording the status of fan motors. Attached in this document is the project plan.

Project Plan

Demonstrating the Effect of Trees for Controlling Particulate Matter, Ammonia, and Odor from Poultry Buildings

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Investigators:

Sheryll B. Jerez, Ph.D., Division of Environmental Science
Joey Bray, Ph.D., Department of Agriculture

Organization:

Stephen F. Austin State University (SFASU)
College of Forestry and Agriculture
419 E. College St
Nacogdoches, TX 75962

(Revised April 22, 2013)

Abstract

A variety of strategies and control technologies are available for reducing emissions of particulate matter (PM) and gaseous emissions from poultry buildings. One of these control strategies that is natural and is receiving increasing attention is the use of vegetative shelterbelts. Shelterbelts are rows of trees and other vegetation planted around poultry building or strategically located directly opposite of exhaust fans. Vegetations that are correctly placed will not only create visual barrier but also provide filtration surfaces for PM and gases. This project will utilize six different plant species that will be established in the zone directly opposite of the exhaust fans of four poultry buildings at SFASU's Broiler Research Center. The concentrations of PM, ammonia (NH_3), and odor will be measured at 16 sampling locations in front of the exhaust fans and at the property lines. In year 1 of the project, baseline data will be collected during the last week of two production cycles prior to shelterbelt establishment. In years 2 and 3, measurements will be conducted during the last week of each of the five production cycles. The data will be used to evaluate the effectiveness of the various tree species in filtering out PM and NH_3 from the exhaust air, and in reducing odor. This project will also assess the ability of trees to tolerate building emission by inspecting the trees at the end of each monitored production cycle. An economic analysis will also be done to help poultry producers and government agencies make informed decisions on using shelterbelts as a Best Management Practice.

Objectives

(1) Evaluate the effectiveness of various tree species in particulate matter and ammonia uptake, and in reducing odor;
(2) Assess the ability of trees to tolerate building emissions; and
(3) Examine management and costs requirements of using vegetative shelterbelts.

Study Area and Shelterbelt Design

The study will be carried out at SFASU's Broiler Research Center (BRC) that has four tunnel-ventilated broiler houses (Figure 1). Each house has 11 exhaust fans; six 52-in fans are located on one end wall, two 52-in fans each are on the adjoining sidewalls and one 36-in fan is on the other end wall. The exhaust fans of buildings 1 and 2 are fitted with wind diverters while those of the other two buildings had cones. Shelterbelt will only be established in the zone that will be directly opposite of the 10 52-in exhaust fans (fan impact area in Figure 1). The fan impact area will be determined by visually inspecting the plume of air leaving the fans. The visual inspection will be performed by generating smokes using smoke gun or fogger.

Six different plant species (Table 1), arranged in three rows will be placed in an arc configuration from the outlet of the exhaust fans. The plant species in Table 1 can be found in East Texas. Eastern red cedar in particular has proven to be effective in passive ammonia absorption (NRCS, 2007). Selecting different species of plants will prevent loss of the entire shelterbelt when disease occurs. The first row (R1 in figure 1) will be planted at least 13 m (about ten fan diameters) from the outlet of the exhaust fan. Malone and Abbot-Donnelly (2001)

suggest that a minimum distance of five times the diameter of the fans is sufficient to prevent trees from affecting the fan efficiency. However, to avoid plants from becoming desiccated due to high wind speed from the fans, NRCS (2007) recommended a distance of at least 10 times the exhaust fan diameter. Thus, distance of at least 13 m should be sufficient to deflect fan air flow without creating back pressures and will also ensure the livability of plants.

The plant spacing both between and within rows will be determined based on the expected diameter of matured trees. In addition, trees between rows will be spaced wide enough to allow more pollutant-plant foliage contact. Staggered plant spacing will also enhance the air movement through the shelterbelt allowing pollutants to make contact with tree surfaces. The spacing will be designed to allow an optical porosity of between 35 to 50%. Lin et al. (2006) concluded that windbreaks with low optical porosity of about 35% effectively reduced the odor concentration downwind of the source. Dorr et al. (1998), however, suggested a theoretical optical porosity of 40 to 50% to better capture particles.

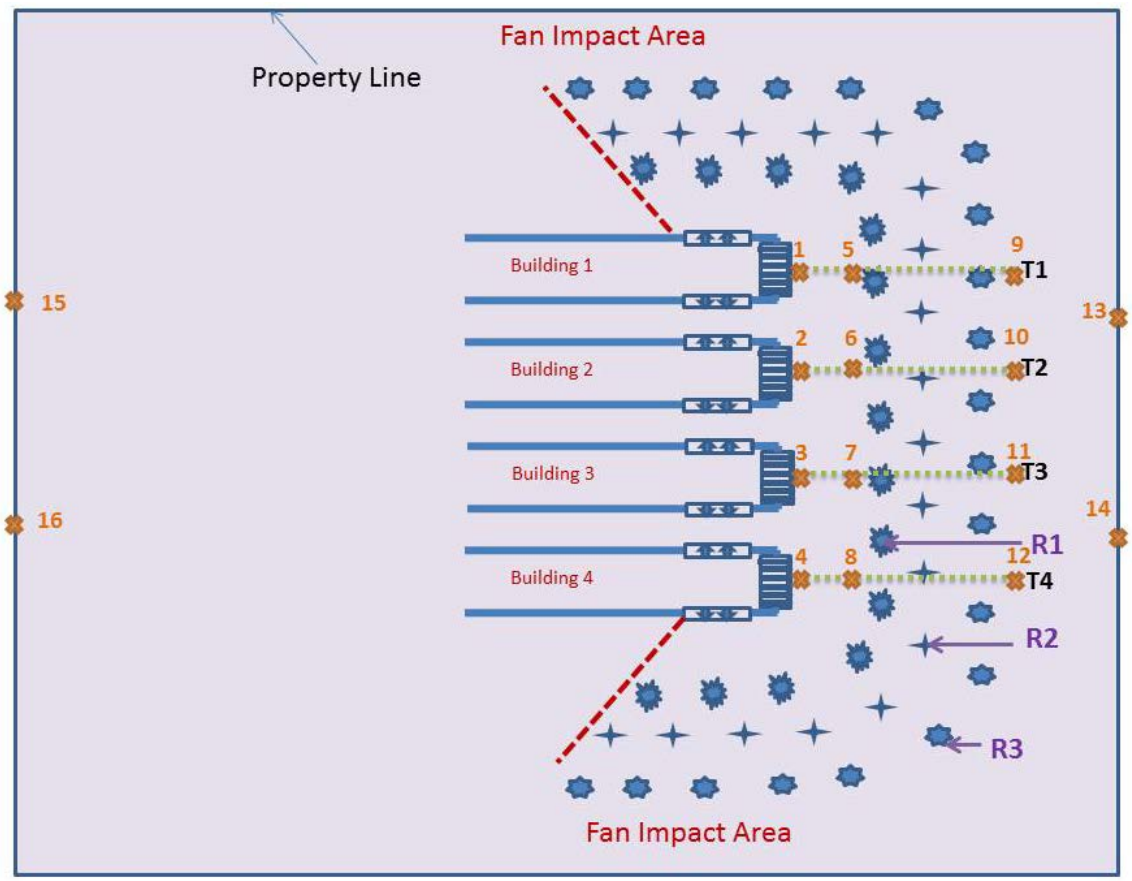

Figure 1. Schematic diagram of the location of shelterbelt relative to the exhaust fans of the four tunnel-ventilated broiler houses at the broiler research center of SFASU. Three rows of plants of different species will be planted (R1 = row 1, R2 = row 2, R3 = row 3). T1, T2, T3, and T4 are the transects where PM, NH_3, and odor will be measured. ✖ = measurement points. Not drawn to scale.

Table 1. The six different plant species, arranged in three rows (R1, R2, R3), that will be planted in front of four poultry buildings at SFASU's Broiler Research Center.

Building No.	Row 1	Row 2	Row 3
1	Yaupon (*Ilex vomitoria*)	American holly (*Ilex opaca*)	Arizona cypress (*Cupressus arizonica*)
2	Yaupon (*Ilex vomitoria*)	American holly (*Ilex opaca*)	Arizona cypress (*Cupressus arizonica*)
3	Roughleaf dogwood (*Cornus drummondii*)	Eastern red cedar (*Juniperus virginiana*)	Arborvitae (*Thuja plicata* x *standishii*)
4	Roughleaf dogwood (*Cornus drummondii*)	Eastern red cedar (*Juniperus virginiana*)	Arborvitae (*Thuja plicata* x *standishii*)

In addition to the shelterbelt, one row of the six plant varieties will also be planted away from the buildings to use as control for NH_3 uptake measurements. All planting will take place in late March 2013 or after collecting the baseline data and will follow the NRCS Tree/Shrub Establishment Guideline (NRCS, 2011) and Seedling Planting Guidelines (NRCS Texas, n.d.). Drip irrigation will be installed to ensure constant source of moisture especially for the plants that are planted in row 1. Plastic weed barrier with organic mulch or herbicide will be used to control weed. When necessary, plants which will not survive will be replaced during the first two years of the project. The replacement plants will be of the same species, size, and age as the original plants.

Approach and Research Procedures

Experimental Design and Statistical Analysis

One experimental site (SFASU's Broiler Research Center) will be utilized to establish the vegetative shelterbelt consisting of six different plant species. Baseline data for particulate matter (PM), ammonia (NH_3), and odor will be collected during the last week each of two production cycles before planting commences. These data will be used to test if *improvement* in air quality (particularly odor and NH_3) is realized by establishing a shelterbelt. A paired t-test will be used to test the null hypothesis of mean difference between the paired observations being equal to zero. The baseline data will also be used to calculate the potential reduction in the concentrations of air pollutants over time.

A completely randomized block design will be used to test the effectiveness of various tree species in PM and NH_3 uptake, and in reducing odor. The experimental area directly downwind of each of the four poultry buildings will be considered as blocks, thus, there are two blocks for each three plant species combination. All data will be subjected to either one-way ANOVA (with plant species as a factor) or two-way ANOVA (with plant species and day of sampling as factors) using Proc GLM of SAS.

Measurement of PM, NH_3, and Odor

Particulate matter ≤ 10 μm (PM_{10}) and ≤ 2.5 μm ($PM_{2.5}$) in diameters will be measured in real time using Haz-Dust samplers (Model EPAM 5000, Environmental Devices Corp., Plaistow, NH). In addition to real-time measurements of PM_{10} and $PM_{2.5}$, total suspended particulate matter (TSP) will also be collected on Teflon filters and will be sent to a laboratory for particle size distribution (PSD) analysis. Ammonia concentrations will be measured using passive dosimeter tubes. A scentometer (Nasal Ranger, St. Croix Sensory, Lake Elmo, MN) will be used to measure odor intensity expressed in terms of dilution threshold ratio (D/T). PM_{10} and $PM_{2.5}$ will be measured sequentially and in pairs starting at sampling locations 1 and 2 up to locations 11 and 12 (Figure 1). The concentrations of NH_3 will be measured at all 16 sampling locations. Odor will be measured at locations 1 to 4, 9 to 12, and 13 to 16. The TSP that will be analyzed for PSD will be collected at sampling locations 1 to 4 and on foliage samples. The PSD analysis will be useful in comparing the particle capture characteristics of the different plant species.

In order to measure the NH_3 uptake of the plants, foliage samples will be collected from each of the six plant varieties planted directly in front of the exhaust fans. The foliage samples will be sent to the Soils laboratory at SFASU for total nitrogen and dry matter (DM) analysis. Foliage samples will also be collected from the six plant varieties that are planted away from the exhaust fans to use as control.

Particulate load (weight per foliage area) on the plant foliage will be measured by collecting fresh foliage that will be analyzed by following the procedures reported by Adrizal et al., 2007. A leaf area meter will be used to measure the leaf area needed in particulate load calculation. PSD analysis will also be done on the collected foliage by rinsing the samples in a surfactant solution and sending the samples overnight to a laboratory at Texas A&M University for analysis.

Measurement of Environmental Parameters

A weather station will be installed on site to measure wind speed, wind direction, temperature, relative humidity, rainfall, and atmospheric pressure. Hobo dataloggers will be used to continuously measure the temperature and relative humidity at the sampling locations shown in Figure 1. Pocket weather trackers (Model 4500, Nielsen-Kellerman, Boothwyn, PA) will be used to track the wind direction and wind speed during odor measurements. Building flow rates will be determined by measuring the average velocity across each fan using a hot-wire anemometer. The average velocity multiplied by the cross sectional area is the fan flow rate. Building flow/ventilation rate is the sum of the individual fan's flow rates.

Soil chemical properties (e.g. pH, nitrogen, phosphorus, potassium) will also be measured once during the 1-week sampling period per cycle. By measuring the soil properties, the impact of poultry emissions on the soil, hence, the vegetation can be determined. Soil samples will be collected at multiple locations within each row of vegetation.

Plant Growth Analysis

For the growth analysis, the following parameters will be determined: diameters at breast height (measured 4.5 ft above ground on the uphill side on slopes), tree height, crown length and crown width. Diameter will be measured with a caliper and a height pole or clinometer will be used for height measurements. Crown width will be measured by projecting the edges vertically to the ground using a plumb bob or an optical prism or a laser. Crown length, which is the vertical distance from the tip (highest growing point) to the lowest live foliage, will be measured with a hypsometer. The growth of a row of trees planted away from the exhaust fans will also be evaluated using the aforementioned parameters and will be compared with the growth of those that are directly exposed to the pollutants.

In addition to the aforementioned quantitative measurements, the plants will be inspected at the beginning and end of every production cycle. In the inspection, several characteristics will be looked at including the following: (1) changes in color of individual leaves and the crowns, (2) changes in the shape or form, (3) presence of pest infestation, (4) wilting, and (5) dieback. Results of the observations will be recorded in a logbook and documented with photographs and videos.

Quality Assurance/Quality Control (QA/QC)

Quality Control (QC) samples will be collected each time sampling is done. These will include field blanks for PM and NH_3. Field blanks are samples that undergo the full handling and shipping process of an actual sample except sampling. They are collected to detect sampling contamination that can occur during field operation or shipment. For PM, field blanks consist of filters tightly sealed in filter holders. Opened then immediately resealed dosimeter tubes will be used to collect field blanks for NH_3. These field blanks will be used to correct the measured concentrations by subtracting the recorded concentrations by the blanks from those of the actual samples.

All instruments that will be used for sampling will be calibrated either at the Environmental Assessment Lab or will be sent back to manufacturers for factory calibration. The flow rates of the pumps that will be used for PM sampling will be verified using a bubble generator (Model Gilibrator 2, Sensidyne, Clearwater, FL). All filters will be conditioned in a dessicator at a relative humidity of 30 ± 5% and temperature of 20 ± 1°C before and after sampling.

Data collected electronically from the Haz-Dust, weather station, pocket weather tracker, hobo dataloggers, and other instruments will be saved to a flash drive and hard drives of the desktop computers in the Environmental Assessment Laboratory. Electronic and hard copies of all data will also be kept in Dr. Jerez's office computer and filing cabinet. Dr. Jerez is also in charge of supervising the students during the calibration and data collection.

Timeline

Project Activities	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Year 1												
1. Design of shelterbelt and purchase of trees				1								
2. Purchase of instruments			2									
3. Background sampling						3						
4. Establishment of drip irrigation system							4					
5. Tree planting								5				
6. Tree inspection											6	
7. Prepare and submit annual report.												7
Year 2												
1. Prepare instruments for field monitoring	1											
2. Conduct field monitoring for air quality and tree inspection		2		2		2		2		2		
3. Analyze the data			3		3		3		3		3	
4. Prepare and submit annual report.											4	
Year 3												
1. Prepare instruments for field monitoring	1											
2. Conduct field monitoring for air quality and tree inspection		2		2		2		2		2		
3. Analyze the data			3		3		3		3		3	
4. Prepare a paper for presentation to a workshop or conference											4	
5. Prepare information bulletin for producers											5	
6. Prepare and submit annual report.											6	

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