Vegetative Environmental Buffers to Mitigate Odor and Aerosol Pollutants Emitted from Poultry Production Sites

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Abstract
In Iowa at a commercial poultry facility, we are assessing the ability of a multi-row vegetative environmental buffer (VEB) to mitigate odor, ammonia, and particulates. In 2004 and 2005 Eastern redcedar (Juniperus virginiana), hybrid willow (Salix X) and limber pine (Pinus flexilis) were planted in rows parallel to a pullet facility. Monitoring of microclimate conditions and ammonia, odor, and particulates (PM$_{10}$ and PM$_{2.5}$) in perpendicular transects from the facility exhaust fans through the VEB is providing detailed data on flow, dispersion, capture, and throughput of the emissions. Tree species health is also being monitored. The expected impact is adoption of VEB systems as air quality best management practices to mitigate the air pollutant risks and to sustain the poultry industry, communities, and the environment.

Introduction
The poultry industry of today is facing environmental challenges relating to air and water quality. Kliebenstein (1998) suggests that the sustainability of industries within agriculture will be shaped by their collective ability to improve environmental impact technologies. Whereas odors from animal production are ubiquitous with agriculture and historically tolerated by rural communities, structural changes in the US poultry industry such as increased farm size and increased concentration of animal manure have caused more pervasive and offensive odor problems. With urban developments pushing into rural areas more people continue to be significantly affected by odor. Poultry odor nuisance may prove to be the most damaging to both rural communities, the poultry industry, and to state economies. Innovative best management practices to mitigate odor problems are needed.

The central thesis of this study is that vegetative environmental buffers (VEBs) can play significant roles in biophysically mitigating odor in a socio-economically responsible way thereby reducing social conflict from odor and dust nuisance (Malone and Van Wicklen, 2001; Malone and Abbot-Donnelly, 2001; Tyndall and Colletti, 2000).

Several recent important livestock producer outreach sources (MWPS, 2002; NPPC, 1995; Lorimer, 1998; OCTF, 1998; Jacobson et al., 1998) list tree systems (VEBs) as odor control practices but provide little physical, chemical, biological, or economic quantification as to their effectiveness.

A multi-state (Iowa, Delaware, and Pennsylvania) project is underway to quantify the efficacy of vegetative environmental buffers (VEBs), which are tree and shrub shelterbelts arranged in specific designs near and within poultry facilities, to provide cost-effective best management practice to facilitate the mitigation of odor, particulates, and ammonia, associated with intensive poultry production. Farm level monitoring and assessment of VEBs in these three states is backstopped by laboratory studies of tree/ammonia and tree/particulate interactions to lead to selection of effective and tolerant species. The farm level data will be used to simulate odor, particulate, and ammonia flow and dispersion with and without VEBs. Outreach activities will occur with collaboration of researchers, state poultry associations and government agencies. Integration of results including costs will guide producer best management decisions and inform policy decisions.

Methods

VEB Establishment
A multi-row VEB was established in two phases on a commercial poultry (pullet) farm in Northcentral Iowa. In the late summer 2004, 6 to 7 ft tall balled and burlapped Eastern redcedar (Juniperus virginiana),
and a few test limber pine (*Pinus flexilis*) were planted in rows parallel to a pullet facility. The closest row, 25 ft from the exhaust fans, was only a partial row planted entirely with Eastern redcedar. All rows were spaced 10 ft apart and all conifers were planted 10 ft apart. Because of the limited supply of Eastern redcedar and hybrid willow (*Salix X*) in 2004 an additional planting occurred in the spring of 2005 to complete the VEB. The first three rows of the VEB closest to the building and fans (25 ft, 35 ft, and 45 ft) contain Eastern redcedar. The third row (45 ft) was planted to hybrid willow (1 ft cuttings) and Eastern redcedar and the most distant row (55 ft from the fans) was planted entirely to hybrid willow. The willows were planted 6 ft apart. The limber pine were included because of their drought tolerance capabilities, but because of the high cost per tree only a few test trees were planted in the conifer rows.

**VEB Monitoring**

VEB monitoring began in May 2005. In general, a Mobile Emissions Laboratory (MEL) was used to monitor semi-continuous ammonia and continuous PM10 data and this monitoring was supplemented with portable monitoring towers (PMT) installed every two weeks to capture odor, ammonia, hydrogen sulfide, and wind profiles upwind, within, and downwind of the installed VEB. The measurement methods along with some preliminary results are described below. Additionally, the effectiveness of the VEB to capture particulates was assessed by destructive sampling of tree foliage on the same schedule as the MEL/PMT sampling.

**Mobile Emissions Laboratory (MEL)**

A Mobile Emissions Laboratory (MEL) was installed on-site to monitor fan operation, PM10 inside the barn, ammonia concentration inside the barn, upwind, within, and downwind of the VEB. The MEL is a self-contained laboratory housing all data acquisition and gas/PM10 sampling hardware. Ammonia (NH₃) was measured using a chemiluminescence-based analyzer (Model 17C, TEI, Inc). Ammonia was measured semi-continuously at five locations including inside the barn, 1 m away from the exhaust fan, 1 m in front of the VEB, in the center of the VEB, and 1 m downwind of the VEB. These locations relative to the installed VEB are shown in Figure 1 with the MEL shown in Figure 2. Gas samples at each of these locations were sampled sequentially in 10-minute sampling blocks. A gas sampling system consisting of solenoids and relays routed gas samples from each location to the NH₃ analyzer for a total of 10-minutes each. Within this 10-minute sampling interval, the first 7-minutes were allowed for analyzer stabilization with the final 3-minutes used for analysis.

Dust sampling was conducted inside the pullet house at approximately 2m from the exhaust fan location using a Tapered Element Oscillating Microbalance (TEOM) Method (Model 1400a; Rupprecht & Patashnick Company, Inc). An installed pre-treatment head allowed particulates at and below 10 um to be sampled. PM10 sampling was continuous.

**Portable Monitoring Towers (PMT)**

The semi-continuous gas monitoring was supplemented with measurements conducted using three Portable Monitoring Towers (PMT) designed to capture velocity, gas, and odor profiles upwind, within, and downwind of the VEB. When installed, the PMTs were positioned at the locations shown in Figure 1. Each PMT consisted of a 9 m retractable tower with a 3-cup anemometer and a Teflon lined gas sampling tube at 1, 3, and 8 m from the ground surface. A typical PMT set-up is shown in Figure 3. For each sampling line, a vacuum box and sampling pump were used to pull sampled air into 10-L Tedlar bags, with duplicates sampled at each PMT location and within each PMT elevation. The Tedlar samples were then transported immediately to the Iowa State University Olfactometry Laboratory where odor concentration was assessed using the triangular forced-choice method (Model AC'Scent; St Croix Sensory, Inc). The PMT sampling was conducted to quantify the dispersion characteristics upwind and downwind of the VEB in an attempt to discretize between true VEB scrubbing performance and natural dilution of exhausted odorous air with downwind position. To help as well with this effort, two 6m tall diversion curtains (Figure 3) were raised during PMT sampling to minimize cross-wind effects and channel exhausted air through the VEB test section. A view as seen from the exhaust fan bank of the PMT set-up with the diversion curtains deployed is shown in Figure 4.
Figure 1. Pullet house monitored with the MEL, NH$_3$, PM10, and PMT sampling locations (x) relative to installed VEB

Figure 2. MEL shown installed on-site
Assessing VEB Effectiveness

To assess effectiveness of the “young” VEB in trapping particulates, samples of species included in the VEB (Eastern redcedar and limber pine) as well as control specimens located at some distance from the VEB were collected 12 times on a biweekly schedule May-October 2005 (coordinated with the air quality MEL sampling regime). In the VEB, foliage samples were collected from the top and bottom halves of 2 sample trees located 35 feet from building fans and 3 sample trees located 45 feet from the building on each sample date.

Samples were washed with purified water and a dispersal agent using a flat-bed rotational shaker, and successively filtered to allow separation of coarse particulates, PM$_{10}$ and PM$_{2.5}$. Quantity of particulate deposition was determined gravimetrically for each size class. Surface area for the foliage was determined for samples that were air-dried following the washing procedure. Samples were scanned using a digital scanner and processed using the ROOTEDGE image analysis program.
Results and Discussion

Emission Monitoring
The monitoring conducted to-date represents data collected from an immature VEB as shown in Figure 4. The monitoring results collected in 2005 will serve as base-line data to be compared as the VEB matures. Monitoring began in May 2005 and continued through December 2005, with monitoring planned again for 2006 and into 2007. To demonstrate the sampling procedures and available data for analysis, one typical monitoring day will be discussed during a day when the PMTs were implemented. Figure 5A&B show a very typical result from the PMT monitoring. The boundary layer wind speed profiles shown in Figure 5A clearly indicate the influence of the exhaust fan (PMT 1). Also, the corresponding odor concentration profiles shown in Figure 5B indicate the dilution effects as downwind distance from the exhaust fan increases. The challenge is to discretize the dilution effect that naturally occurs from entrained ambient air from the dilution or scrubbing influence of the VEB. Work continues in the development of methods to quantify the actual VEB effect.

VEB Particulate Capture
Preliminary data on total quantity of particulates captured by trees in the VEB indicate capture rates that are favorable according to levels reported in the literature (Table 1 shows data for one sample date). Control samples indicate relatively low levels of particulates under nearby ambient conditions away from the tunnel fans.

Additional data processing will allow determination of total leaf area within the VEB and estimation of total particulate capture, as well as information for each particle size fraction.
Figure 5. Boundary layer (A) wind speed and (B) odor concentration profiles measured between the exhaust fan and upwind of the VEB (PMT 1), within the VEB (PMT 2), and 1 m downwind of the VEB (PMT 3). The source odor concentration was 280 OU/m³ and the exhaust ventilation rate from the fans exhausting between the diversion curtains was 37.8 m³/s during this PMT sampling event.
Table 1. Particulate capture (mg/cm²) by Eastern redcedar and limber pine placed at 35 and 45 feet from building fans at a pullet facility for one sample date (October 10, 2005). Foliage was sampled from the top and bottom halves of VEB trees, and from one location on control trees.

<table>
<thead>
<tr>
<th>Sample type</th>
<th>Total particulate matter, VEB samples (mg/cm²)</th>
<th>Total particulate matter, control samples (mg/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree part</td>
<td>Eastern redcedar (35')</td>
<td>Eastern redcedar (45')</td>
</tr>
<tr>
<td>Top</td>
<td>3.06</td>
<td>0.70</td>
</tr>
<tr>
<td>Bottom</td>
<td>4.02</td>
<td>1.49</td>
</tr>
</tbody>
</table>

VEB Health

After one complete growing season in front of the banks of exhaust fans, it is apparent that the Eastern redcedar trees planted only 25 ft from the fans are highly stressed and may only survive and not thrive. Careful assessment of the health of these trees will be made early in the growing season of 2006.

Figure 6. A fall 2004 photo of particulate capture by Eastern redcedar from a three-month old VEB at a pullet facility in Northcentral Iowa. The trees are 25 feet downwind of the exhaust fans. Trees were balled and burlapped 6-7 ft tall trees when planted.

Conclusions

The initial results of the three-row VEB located 25 to 35 ft from the exhaust fans of a pullet facility are encouraging in terms of the ability of the VEB to capture particulates. Both visually (see Figure 6) and quantitatively the particulate capture is evident. The emission data suggest odor concentration dilution effects downstream of the fans. However, the separation of the natural, ambient dilution effect from the efficacy of the VEB to reduce odor by capture and transformation cannot be determined at this time.

Our initial evidence suggests that VEBs can be effective in mitigating poultry odor and other emissions by intercepting and diluting odor and particulates before these pollutants reach people downwind. With time we expect to quantify the efficacy of VEB in terms of retaining and transforming odor, ammonia, and particulates.
References


