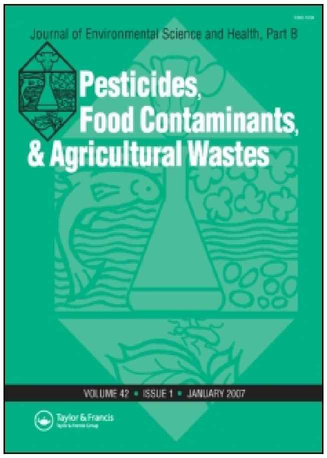


Journal of Environmental Science and Health, Part B
Pesticides, Food Contaminants, and Agricultural Wastes
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713597269

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Online Publication Date: 01 February 2008

To cite this Article: Patterson, P. H., Adrizal, A., Hulet, R. M., Bates, R. M., Myers, C. A. B., Martin, G. P., Shockey, R. L. and van der Grinten, M. (2008) 'Vegetative buffers for fan emissions from poultry farms: 1. temperature and foliar nitrogen', Journal of Environmental Science and Health, Part B, 43:2, 199 — 204

To link to this article: DOI: 10.1080/03601230801890179
URL: http://dx.doi.org/10.1080/03601230801890179

*Journal of Environmental Science and Health Part B* (2008) **43**, 199–204

ISSN: 0360-1234 (Print); 1532-4109 (Online)
DOI: 10.1080/03601230801890179

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# Vegetative buffers for fan emissions from poultry farms: 1. temperature and foliar nitrogen

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This study sought to evaluate the potential of trees planted around commercial poultry farms to trap ammonia ($NH_3$), the gas of greatest environmental concern to the poultry industry. Four plant species (Norway spruce, Spike hybrid poplar, Streamco willow, and hybrid willow) were planted on eight commercial farms from 2003 to 2004. Because temperature (T) can be a stressor for trees, T was monitored in 2005 with data loggers among the trees in front of the exhaust fans (11.4 to 17.7 m) and at a control distance away from the fans (48 m) during all four seasons in Pennsylvania. Norway spruce (*Picea abies*) foliage samples were taken in August 2005 from one turkey and two layer farms for dry matter (DM) and nitrogen (N) analysis. The two layer farms had both Norway spruce and Spike hybrid poplar (*Populus deltoides* × *Populus nigra*) plantings sampled as well allowing comparisons of species and the effect of plant location near the fans versus a control distance away. Proximity to the fans had a clear effect on spruce foliar N with greater concentrations downwind of the fans than at control distances (3.03 vs. 1.88%; $P \leq 0.0005$). Plant location was again a significant factor for foliar N of both poplar and spruce on the two farms with both species showing greater N adjacent to the fans compared to the controls (3.75 vs. 2.32%; $P \leq 0.0001$). Pooled foliar DM of both plants was also greater among those near the fans (56.17, fan vs. 44.67%, control; $P \leq 0.005$). Species differences were also significant showing the potential of poplar to retain greater foliar N than spruce (3.52 vs. 2.55%; $P \leq 0.001$) with less DM (46.00 vs. 54.83%; $P \leq 0.05$) in a vegetative buffer setting. The results indicated plants were not stressed by the T near exhaust fans with mean seasonal T (13.04 vs. 13.03°C, respectively) not significantly different from controls. This suggested poultry house exhaust air among the trees near the fans would not result in dormancy stressors on the plants compared to controls away from the fans.

**Keywords:** *Picea abies*; *Populus deltoides* × *Populus nigra*; leaf nitrogen; leaf dry matter; commercial poultry farms; seasonal temperature.

## Introduction

Air emissions from poultry and livestock production are numerous and may include dust or particulate matter, odors, and nitrogenous compounds including ammonia. Ammonia ($NH_3$) emissions can be significant, and according to the 2005 April-revised report of The United States Environmental Protection Agency (USEPA), [1] poultry feeding operations are the major contributor to atmospheric $NH_3$ from animal agricultural activities with potential environmental impacts. Our mass balance data on commercial pullet, laying hen, broiler, and turkey farms indicated that between 18 to 40% of feed nitrogen (N) is lost to the atmosphere, mostly as ammonia-nitrogen ($NH_3$–N).[2–5] Liang et al. [6] measured $NH_3$ emission rate in high-rise and manure-belt type hen houses in Iowa and Pennsylvania. The results indicated annual emission rates of $NH_3$ were 0.81 to 0.90 and 0.054 to 0.094 g hen$^{-1}$ d$^{-1}$ for high-rise and manure-belt type hen houses, respectively. In their reviews of literature, Liu et al. [7] reported that $NH_3$ emissions from poultry houses could range from 0.24 to 12.5 g

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Received February 26, 2007.

$NH_3$ per animal unit $h^{-1}$ with an average of 5.5 g $NH_3$ reported by Phillips and Chamber [8] in a deep-pit (high-rise) house or manure-belt laying hen house. The $NH_3$ emission factors for broiler, layer, and turkey reported by Lau et al. [9] were 0.21, 0.27, and 0.73 kg of $NH_3$ per bird per year. Using animal unit conversions proposed by the National Research Council [10] these values were equivalent with 2.40, 3.08, and 4.58 g $NH_3$ per animal unit $h^{-1}$ showing that laying hens are an intermediate $NH_3$ contributor between broilers and turkeys.

Planting trees around poultry farms has been utilized for wind breaks and for shade. Recently vegetative environmental buffers have been planted as a visual screen, a filter for air-borne pathogens, and to filter emissions (odors, noises, dust, and gases) discharged by the exhaust fans from poultry farms.[11,12] Plants have the capacity to absorb aerial $NH_3$ via foliar stomata with cellular assimilation through the glutamine synthetase and glutamate synthase pathways.[13] Van deer Eerden et al.[14] suggested that at the right concentrations, $NH_y$ ($NH_3$+ $NH_4^+$) would favor plant growth, but at a critical threshold it would cause tissue necrosis, reduced growth, and greater frost sensitivity.

In chamber studies we determined that multiple plant species including evergreens (red cedar, white spruce, and arborvitae), deciduous trees (honey locust, hybrid poplar, and streamco willow), and reed canary grass deposited almost two-fold greater N in their leaves when exposed to continuous $NH_3$ at 4 to 8 ppm, compared to control chamber plants without atmospheric $NH_3$.[15] However, only honey locust consistently grew well and showed little foliar injury compared to the other species at these concentrations; indicating its capacity to tolerate and utilize aerial $NH_3$-N.

Malone [11] planted three plant species (4.9 m high bald cypress, 4.3 m high Leyland cypress, and 2.4 m high red cedar, 9 m wide) at 9, 12.2, and 14.6 m from the tunnel fans on a farm housing roaster chickens. Measurements made downwind of the trees during summer showed air velocity was reduced by 99%, dust by 50 to 53%, and $NH_3$ by 29 to 67% by the combined effect of distance and the buffering of the trees. One concern of agriculture extension personnel recommending trees for poultry farms is heat from the poultry barns in fall or winter may interfere with plants' dormancy, or result in temperature (T) and/or dehydration stress on the plants.

This study was designed to evaluate the potential of trees planted around poultry house exhaust fans to trap $NH_3$ and the impact of fan exhaust on environmental T among the trees and its associated stressors.

## Materials and methods

There were eight commercial poultry farms involved in this study including three broiler, three layer, one pullet, and one turkey farm. More than 2000 plants from four species (Norway spruce [*Picea abies*], Spike hybrid poplar [*Populus deltoides* × *Populus nigra*], hybrid willow [*Salix matsudana* × *Salix alba*], and Streamco purpleosier willow [*Salix purpurea*]) were planted in one to 12 rows downwind of the exhausted fans on farms from 2003 to 2004 (Table 1). The closest distance of the trees to the fans ranged from 11.4 to 17.7 m and the distance between the rows was approximately 3.0 m. Cox tracer data loggers (Model CT-1E-D-16, Sensitech, Inc. MA, USA) were used to monitor T at two locations on all farms. One T logger was placed at a control distance (48 m) away from the buildings and exhausted fans, whereas the second was placed near the fans (11.4 to 17.7 m) among the trees. Each logger was hung inside a propylene shield and secured to a metal post at 1.5 m from the

**Table 1.** Characteristics of commercial poultry farms and trees

| *Farm* | *House type* | *Bird capacity and number of houses* | *Farm issues* | *Trees* |
|---|---|---|---|---|
| Broiler 1 | Litter | 21,000/house | Visual screen, snow load, odors and dust | 2 rows Norway spruce<br>1 row hybrid willow<br>1 row Streamco willow |
| Broiler 2 | Litter | 50,000/2 houses | Dust, odors and snow load | 1 row Norway spruce<br>1 row hybrid willow<br>1 row Streamco willow |
| Broiler 3 | Litter | 20,000/house | Dust and odors | 1 row Streamco willow |
| Layer 1 | High-rise | 125,000/house | Dust, odors, flies, and visual screen | 2 rows Norway spruce<br>2 rows Spike hybrid poplar |
| Layer 2 | High-rise | 475,000/3 houses | Dust, odors and flies | 2 rows Norway spruce<br>1 row Spike hybrid poplar<br>1 row Streamco willow |
| Layer 3 | High-rise | 1,000,000/8 houses | Visual screen, dust and odors | 2 rows Norway spruce |
| Pullet | High-rise | 83,000/house | Visual screen, snow load, energy conservation, and urban encroachment | 2 rows Norway spruce<br>1 row hybrid willow |
| Turkey | Litter | 40,000/2 houses | Dust, odors, water quality, feathers and truck traffic | 2 rows hybrid willow<br>10 rows Norway spruce |

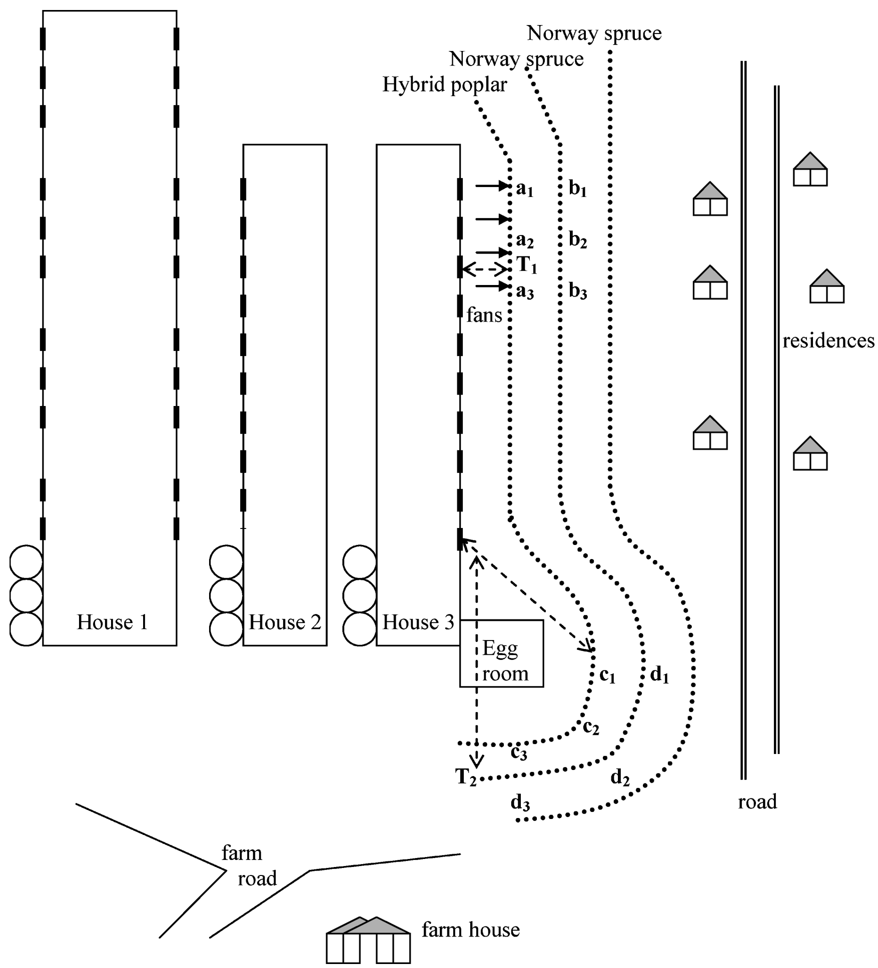


**Fig. 1.** Example trees planted downwind of the exhaust fans on a layer farm with vegetative filters. $\mathbf{a}_1 = \mathbf{a}_3$ and $\mathbf{b}_1 = \mathbf{b}_3$ are sampling locations for Spike hybrid poplar and Norway spruce, respectively, downwind of the fans whereas $\mathbf{c}_1 = \mathbf{c}_3$ and $\mathbf{d}_1 = \mathbf{d}_3$ are sampling locations of the respective species at control distances from the fans. The distance from the fans to $\mathbf{a}_{1-3}$ or the temperature data logger ($\mathbf{T}_1$) is 13.5 m. The closest control foliage sampling point ($\mathbf{c}_1$) is 40 m and 48 m for data logger $\mathbf{T}_2$. The three circles adjacent to the hen houses represent feed bins.

ground, matching the height of the facing fan. In 2005, all the loggers were programmed to record the T every 30 min (n = 48 per day) continuously for two consecutive months in each season (winter: January to February; spring: April to May; summer: July to August; fall: October to November).

Monitoring for T began in January 2005 on all eight farms. Foliage samples from three replicate Norway spruce were taken from three farms (Layer 1, Layer 2, and Turkey; Table 1) and another three samples of Spike hybrid poplar were taken from the two layer farms. All foliage sampling was conducted in August 2005 at two locations, near the fans, or at a control distance away (Fig. 1; example farm). Farms selected for foliar tissue analysis were based on the availability of the same plant species on multiple farms. Layer farm 1 with one high-rise house had 15–122 cm diameter pit fans and 7–91 cm diameter pit fans facing the tree rows. On layer farm 2 the high-rise house near the trees had 14–22 cm, and 3–91 cm pit fans facing the trees. On the turkey farm a bank of 4–22 cm tunnel fans faced the tree sampling and T area. The foliage sampled downwind of the exhaust fans was at a similar distance as the T logger. Control T monitoring and distances for foliage sampling was at least 40 m away from the fans as illustrated in Figure 1. The foliage samples were sent to the The Pennsylvania State University Agricultural Analytical Services Laboratory for total nitrogen (N) and dry weight analysis. The dry matter (DM) of foliage was calculated from the difference of fresh and dry weight over the fresh weight and presented as a percentage value.

Two mathematical models were used to analyze the data, with farms as replicates in each model. The effect of plant location (control vs. fan) on foliar DM and N of Norway spruce from three farms was analyzed using Model 1. On the two layer farms a 2 × 2 factorial design using Model 2 was applied to analyze the effects of plant location (control vs. fan) and species (Norway spruce vs. Spike hybrid poplar) on foliar DM and N. Model 2 was also employed to analyze seasonal T at two locations (control vs. fan) on all eight farms using 2 × 8 factorial design. All analyses of variance (ANOVA) were performed using Proc GLM of SAS followed by a Tukey-Kramer test to differentiate means that showed significance at $P \leq 0.05$.[16] The two mathematical models are described below:

$$X_{ij} = \mu + L_i + \varepsilon_{ij} \quad (1)$$

$$X_{ijk} = \mu + L_i + S_j + (L_i \times S_j) + \varepsilon_{ijk} \quad (2)$$

where $X_{ij}$ or $X_{ijk}$ is the observed value, $\mu$ is the overall mean, $L_i$ is the i-th location, $S_j$ is the j-th plant species or season, $(L_i \times S_j)$ is the interaction effect of location by species or location by season at i-th and j-th level, respectively, $\varepsilon_{ij}$ or $\varepsilon_{ijk}$ is the residual error for Models 1 and 2, respectively.

## Results

The data presented in Table 2 shows the effect of plant location on foliar DM and N of Norway spruce. Proximity to the fans had no effect on foliar DM from the three farms (48.78, control vs. 51.44%, fan). However, spruce N levels near the fans (3.03%) were greater than trees at a control distance (1.88%; $P = 0.0002$). On the two layer farms that had Spike hybrid poplar and Norway spruce the impact of plant species and proximity to the fans on foliar N and DM could be compared (Table 3). Dry matter and foliar N were both significantly higher among plants near the exhaust fans compared to the controls. Spike hybrid poplar had significantly greater foliar N (3.52 vs. 2.55%) but less DM than Norway spruce (46.00 vs. 54.83%). The location by species interactions were not significant ($P \geq 0.05$), however there were trends within both species suggesting close proximity to poultry fans would increase foliar N and plant DM ($P \leq 0.10$).

Temperature measurements from the eight commercial poultry farms indicated neither the location nor the location by season effect influenced T, however, T differences were realized in all seasons ($P \leq 0.0001$). The highest T were recorded in summer (25.53°C) followed by spring, fall, and winter (Table 4). Statistical analysis of T on the three farms where Norway spruce was sampled and on the two farms where Spike hybrid poplar was sampled (data not shown) indicated the same seasonal trend with no location or interaction effect. The seasonal average T were 12.48 and 12.47°C near the fans and in the control areas, respectively on the three Norway spruce farms, whereas, the corresponding T on the two farms with Spike hybrid poplar were 12.50 and 12.82°C, respectively. In addition, the average summer T at the control and fans locations were not significantly different on the three farms with Norway spruce (25.29 vs. 25.55°C) or the two farms with Spike hybrid poplar (25.28 vs. 25.72°C).

**Table 2.** Foliar dry matter (DM) and nitrogen (N, % DM basis) of Norway spruce (*Picea abies*) sampled at two locations (control vs. downwind of the exhaust fans) on three commercial poultry farms

| *Factors* | *D M (%)* | *N (%, DM basis)* |
|---|---|---|
| Control | 48.78 | $1.88^b$ |
| Fan | 51.44 | $3.03^a$ |
| SEM[1] | 5.06 | 0.29 |
| *P*-value | 0.5302 | 0.0002 |

$^{a-b}$Means in a column with no common superscripts differ significantly ($P \leq 0.05$).
[1]Standard error of the means, mean of three farms with three foliage samples each.

**Table 3.** Foliar dry matter (DM) and nitrogen (N, % DM basis) of Spike hybrid poplar (*Populus deltoides* × *Populus nigra*) and Norway spruce (*Picea abies*) sampled at two locations (control vs. downwind of the exhaust fans) on two commercial poultry (layer) farms

| *Factors* | *D M (%)* | *N (%, DM basis)* |
|---|---|---|
| Location: | | |
| Control | $44.67^b$ | $2.32^b$ |
| Fan | $56.17^a$ | $3.75^a$ |
| Species: | | |
| Poplar | $46.00^b$ | $3.52^a$ |
| Spruce | $54.83^a$ | $2.55^b$ |
| Location Species: | | |
| Control × Poplar | 36.67 | 2.77 |
| Control × Spruce | 52.67 | 1.87 |
| Fan × Poplar | 55.33 | 4.23 |
| Fan × Spruce | 57.00 | 3.22 |
| SEM[1] | 6.20 | 0.43 |
| Sources of variances: | | |
| Location | 0.0044 | 0.0001 |
| Species | 0.0228 | 0.0008 |
| Location × Species | 0.0592 | 0.7510 |

$^{a-b}$Means in a column with no common superscripts differ significantly ($P \leq 0.05$).
[1]Standard error of the means, mean of two farms with three foliage samples each.

## Discussion

Previous studies have calculated $NH_3$ losses from hen, pullet, broiler, and turkey farms. [2–6,17] Recently, Adrizal et al. [15] demonstrated that plants grown in environmental chambers with atmospheric $NH_3$ at 4 to 8 ppm for 12 weeks (wk) deposited almost two-fold more N in their leaves compared to control plants in chambers without $NH_3$. Significantly great tissue DM was also observed in these chamber studies among plants exposed to the $NH_3$. In a second chamber study Adrizal et al.[18] measured tissue N levels of Spike

**Table 4.** Average temperature (°C) recorded at two locations (control vs. downwind of the exhaust fans) from eight commercial poultry farms

| *Factors* | *Temperature (°C)* |
|---|---|
| Location: | |
| Control | 13.04 |
| Fan | 13.03 |
| Season: | |
| Winter | $-0.13^d$ |
| Spring | $15.69^b$ |
| Summer | $25.53^a$ |
| Fall | $11.08^c$ |
| Location × Season: | |
| Control × Winter | −0.21 |
| Control × Spring | 16.10 |
| Control × Summer | 25.49 |
| Control × Fall | 10.84 |
| Fan × Winter | −0.06 |
| Fan × Spring | 15.28 |
| Fan × Summer | 25.61 |
| Fan × Fall | 11.32 |
| SEM[1] | 1.41 |
| Sources of variances: | (*P*-values) |
| Location | 0.9856 |
| Season | 0.0001 |
| Location × Season | 0.7023 |

$^{a-d}$Means in a column with no common superscripts differ significantly ($P \leq 0.05$).
[1]Standard error of the means, mean of eight farms with 3 to 20 30-min measurements each.

hybrid poplar and Norway spruce. Poplar N levels at 6-wk exposure time to 5 to 8 ppm $NH_3$ were more than two-fold greater than spruce, however, both species increased their respective N levels the same amount (1.45 times) compared with levels measured at the start of the study. These are the same plant species and stocks utilized in the field study herein. Some plant tissue damage and discoloration were observed among plants in the chamber studies. [15,18] However, no tissue injury was observed among plants on the poultry farms in the current study. This suggests greater plant tolerance to $NH_3$ exposure under outdoor conditions that may include rain cleansing and lower and variable $NH_3$ concentrations.

Norway spruce foliage from the three commercial poultry farms herein showed a 1.6-fold increase in N levels because of close proximity to the exhaust fans. Poplar samples from the two layer farms showed more than a 1.5 fold greater foliar N than control plants at 40 to 48 m distance from the fans. Pitcairn et al.[19] documented fewer numbers of nitrophilus plant species with greater distances downwind of the fans on livestock farms. And, in a study at The Pennsylvania State University Poultry Farm, five plant species (Canaan fir, juniper, hackberry, lilac, and Streamco willow) downwind of four fans (average: 51.5 ppm $NH_3$) demonstrated a linear decline in foliar N as distance increased from 0 to 50 m in 5 replicate rows from the fans.[20]

Seasonal T differences were significant and are a critical factor in selecting suitable plants for Pennsylvania poultry farms. However, T was not a source of plant stress or concern for plants located close to exhaust fans. Data from the eight farms over four seasons suggested an amazing similarity with overall means of 13.04°C in control areas vs. 13.03°C near fans. This indicated heat from the poultry house was not modifying the microclimate of plants near the fans, or interfering with plant dormancy. Other stressors may be significant but can be mitigated with adequate nutrition, weed control, and irrigation for successful plant establishment and survival. Lastly, the location by season interaction was also not significant, indicating in no season: summer, winter, spring, or fall was there a T effect due to proximity to the fans.

## Conclusions

Environmental T monitored near commercial poultry house fans (11.4 to 17.7 m) did not differ from those at control distances from the fans (48 m) during any of the four seasons in Pennsylvania. Spike hybrid poplar and Norway spruce foliar N concentrations were greater near the exhaust fans compared to control plants at 40 m or more distance. Spike hybrid poplar was found to retain greater foliage N than Norway spruce. Based on previous studies documenting $NH_3$ emissions from commercial poultry farms, it would appear that under the conditions of this study, both the Spike hybrid poplar and Norway spruce were able to trap aerial $NH_3$-N emissions near the fans and tolerate the climatic conditions and emissions on these commercial farms.

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