Mitigating Swine Odor with Vegetative Environmental Buffers: A Review

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Funded by:

NATIONAL AGROFORESTRY CENTER

CSREES

USDA National Research Initiative Integrated Programs

USDA NRI Grant #: 0188753

Introduction:

There is compelling evidence that shelterbelts can ameliorate livestock odor. Because the odor source is near the ground and the tendency of the plume is to travel along the ground, shelterbelts of even modest heights (i.e. 20-30 ft) may be ideal for plume interception, disruption, and dilution (Lin et al., 2006; Bottcher, 2001; Laird, 1997; Thernelius, 1997; Takle, 1983).

Based on research literature (Tyndall, 2003), there are four primary ways that shelterbelts can mitigate livestock odors:

1. Turbulence induced dispersion into the lower atmosphere & dilution of downwind odor. (Figure 1.)
2. Interception & capture of odor-laden dust by trees & shrubs. (Figures 2 & 3)
   - Acting as a biological sink for the chemical constituents of odor after interception. (Figures 2 & 3)
3. Deposition of odor-laden dust and other aerosols from reduced wind speeds. (Figure 4)
4. Enhancing the aesthetics of pork production sites & rural landscapes. (Figure 5)

The USDA's National Animal Health Monitoring System Swine 2000 report noted that 33% of respondents across 17 states use shelterbelts/windbreaks specifically for air quality management (Vansickle, 2002). A recent Iowa swine producer survey indicates that 38% of the respondents (n=562) use shelterbelts for odor mitigation purposes and 64% are quite satisfied with their effectiveness and management – only 0.9% were unsatisfied with the practice (Lorimor and Kliebenstein, 2004).

1. Dilution of gas concentrations of odor into the lower atmosphere.

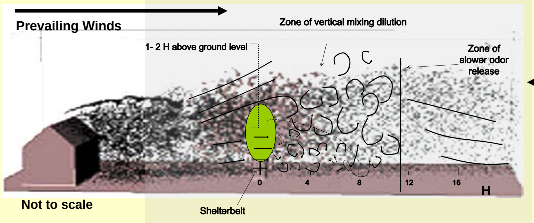


Figure 1. Computer simulation of swine building particulates being intercepted by a single row of trees by Lammers et al., 2001; Wind dynamic overlay adapted from Raine (1974) as used in McNaughton (1988)

Key Issue in Dilution Dynamic: Due to simplified landscapes (limited mechanical turbulence) and common weather conditions (e.g. radiational inversions) there often is limited odor plume rise.

Selected Empirical Evidence:

- Shelterbelts create turbulence at ground level that intercept and disrupt odor plumes helping to push the plume into the lower atmosphere (upwards of 2 times the height of the tallest tree) facilitating dilution (Bottcher et al., 2001; OCTF, 1998; McNaughton, 1988).
- Using 3D fluid dynamic algorithms with simultaneous diffusion calculations, Lammers et al. (2001) observed that the impact of a single-row shelterbelt shows a plume pattern with an elevated mainstream and a more uniform dispersion – thus a diluted downwind emission stream (Lammers, Pers. Comm., 2003).

2) Physical interception of dust and other aerosols

Figure 2. Northern White Cedar (*Thuja Occidentalis*) outside of poultry building in DE – research site University of Delaware.

Figure 3. E. Red Cedar (*Juniperus virginiana*) outside of poultry building in IA – research site Iowa State University.

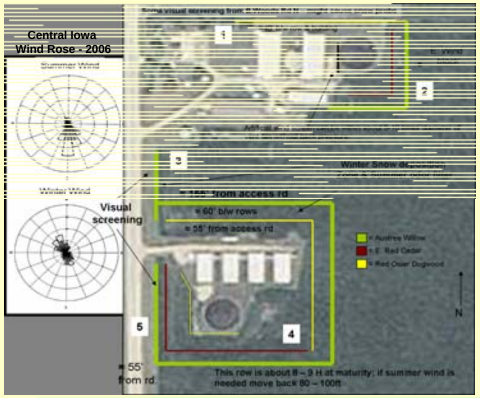
Key Issues in Interception Dynamic: The majority of odorous chemicals & compounds are absorbed onto, concentrated by, and carried on particulates generated in animal facilities and from land application (Bottcher, 2001; Hammond and Smith, 1981).

Selected Empirical Evidence:

- Trees and other woody vegetation are among the most efficient natural filtering structures in a landscape in part due to the very large total surface area of leafy plants, often exceeding the surface area of the soil containing those plants by over 400- fold (Schultze, 1982).
- Interception & impaction by tree surfaces typically involves particulates with diameters between 0.1 and 10 μm (within the PM 2.5 & PM10 range) (Beckett et al., 2000). Studies have shown that upwards of 90 + % of the particles associated with swine finishing facilities were 5.2 microns and smaller (Stroik and Heber, 1986).
- Nitrogen based Volatile Organic Compounds (VOC's) – the offensive smell in livestock manure- have a distinct affinity to the lipophilic membrane (the cuticle) that covers plant leaves and needles. Studies are underway to examine the capture efficiency of various plants (Beattie et al., undated).

Demonstrations:

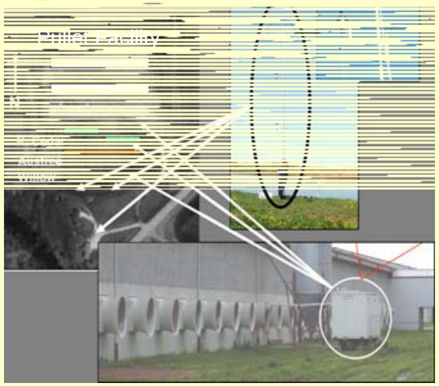
Extension and Design Example



Extension example: - Wean to finish dual facility in Central Iowa, 2006:

1) Starts with site visit & producer interview,
2) Orthophoto and soil map analysis;
3) Design recommendation guided by soils, site characteristics (e.g. wind patterns, topography, property lines, etc.) and producer goals;
4) Cost analysis & long term management plans

Current Field Research



General outline of current ISU Shelterbelt Poultry odor field research - a three year USDA National Research Initiative project. Currently in year 2. Using a Mobile Emissions Laboratory (MEL), building & field emissions testing have been conducted before and after shelterbelt installation. Installed Red Cedar trees are 8 – 10 feet tall to mimic a 6 year old shelterbelt (Contact Dr. Steve Hoff, Professor, Iowa State University, hoffer@iastate.edu, for more details).

Technology Advantages

Shelterbelts are a technology that can be considered "production technology and size neutral" in that swine producers of all kinds – confinement, modified confinement, hoop house - and sizes can plant shelterbelt systems. Shelterbelts, very uniquely, offer a technology that both producers and rural residents and communities can use, suggesting "user neutrality". Further, as opposed to other odor mitigating technologies that depreciate over time, shelterbelts may be the only odor control technology that theoretically increases in effectiveness over time assuming tree health over time.

3) Deposition of odor-laden dust and other aerosols from reduced wind speeds

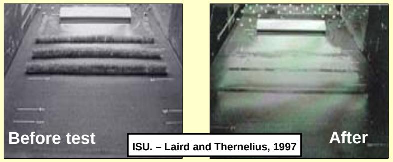


Figure 4. Open circuit wind tunnel and model open air hog confinement building with simulated shelterbelt system. Hog house dust was simulated with highly ground walnut shells. Digital imaging was used to examine the brightness of the wind tunnel floor as a measure of dust deposition behavior. Multiple scenarios were tested examining differences in particle deposition due to: # of parallel shelterbelts, heights/ thickness, wind speeds and wind angles.

Selected Empirical Evidence:

- Wind tunnel modeling of a 3 row shelterbelt system has quantified reductions of 35% to 56% in the downwind mass transport of odor bearing particulates (dust and aerosols) (Laird, 1997; Thernelius, 1997) – Figure 4 above.
- Pesticide drift mitigation research suggests that due to shelterbelt induced reduced wind speed, portions of drift pesticide (within the PM 2.5 range) will drop from the air stream. In broadleaf species, downwind drift reductions of 70% (no leaves) to 90% (in leaf) have been recorded (Porskamp et al., 1994).
- Numerical simulation of the effects of tall barriers around manure lagoons predicted reductions in downwind malodorous lagoon emissions of 26% to 92% (Liu et al., 1996).

4) Enhancing the aesthetics of pork production sites & rural landscapes.

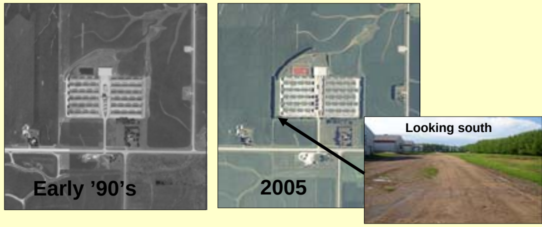


Figure 5. Rose Acres Poultry facility in Winterset, Iowa. Single row Austree Willow (*Salix matsudana x alba*). This facility has become a Showcase facility and has generated significant "word-of-mouth" exposure to the aesthetic and visual screening benefits of tree planting.

Key Issues in Interception Dynamic: "Visual diversity…(is) preferred to open landscape" (Ronneberg, 1992). The "softening" of visual cues is a key to improved subjective odor perception (Kreis, 1978).

Selected Empirical Evidence:

- Livestock professionals generally accept that a well-landscaped operation, which is visually pleasing or screened from view by landscaping is much more accepting to the public than one which is not (Lorimor, 1998).
- Mikesell et al. (2001) interviewed all the neighbors within 1 mile of 7 large swine farms in PA and recorded an inverse relationship between the "attractiveness" of a farm and reported negative odor intensity ratings – (all other issues being analytically controlled for).
- Sullivan et al. (2004) recorded high visual approval ratings from IL farmers, rural residents & academics for shelterbelt "odor buffers" planted around a large scale swine confinement.