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The Use of Vegetative Environmental Buffers for Livestock and Poultry Odor Management

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Abstract

An odor mitigation technology that is drawing a lot of attention in Iowa and in other livestock producing states is the strategic use of shelterbelts – purposefully planted trees and shrubs usually arranged in linear patterns; a technical term for shelterbelts being used for odor mitigation is Vegetative Environmental Buffers or VEBs (Malone et al., 2006). Research evidence suggests that VEBs strategically located near and around livestock facilities can play an important incremental role in bio-physically and socio-psychologically mitigating odor in an economically feasible way (Tyndall and Colletti, 2007).

Keywords

odor mitigation, shelterbelts, vegetative environmental buffer, VEB, animal housing, manure storage

Disciplines

Animal Sciences | Environmental Indicators and Impact Assessment | Natural Resources Management and Policy

Comments

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The Use of Vegetative Environmental Buffers for Livestock and Poultry Odor Management

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Species:	Swine, Poultry, Beef, Dairy
Use Area:	Animal Housing and Manure Storage
Technology Category:	Environmental Barriers
Air Mitigated Pollutants:	Particulate Matter, Odor and Ammonia

Description:

An odor mitigation technology that is drawing a lot of attention in Iowa and in other livestock producing states is the strategic use of shelterbelts – purposefully planted trees and shrubs usually arranged in linear patterns; a technical term for shelterbelts being used for odor mitigation is Vegetative Environmental Buffers or VEBs (Malone et al., 2006). Research evidence suggests that VEBs strategically located near and around livestock facilities can play an important incremental role in bio-physically and socio-psychologically mitigating odor in an economically feasible way (Tyndall and Colletti, 2007).

Mitigation Mechanism:

To a large degree the current livestock odor problem is characterized by high concentrations of odorous emissions (Volatile Organic Compounds – VOCs) that travel mostly unimpeded across highly modified agricultural landscapes. Research has demonstrated that tree barriers can impede, alter, absorb, and/or dissipate odor plumes and other emissions prior to contact with people. As air moves across vegetative surfaces, leaves and other aerial plant surfaces remove some of the dust, gas, and microbial constituents of airstreams. 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 upwards of several hundred-fold (Tyndall and Colletti, 2007).

Vegetative Environmental Buffers have been shown to incrementally mitigate odors, particulates, and ammonia through a complex of dynamics (Tyndall and Colletti, 2007; Lin et al., 2006; Patterson et al., 2007). Among the most important dynamics are: 1) enhancement of vertical atmospheric mixing through forced mechanical turbulence – leading to enhanced dilution/dispersion of odor; 2) odor filtration through particulate interception and retention – odor largely travels by way of particulates; capturing particulates also captures odors; 3) odor/particulate fallout due to gravitational forces enhanced by reduced wind speed; 4) adsorption and absorption of ammonia onto and into the plant – this is due to a chemical affinity that ammonia has to the waxy coating on tree leaves; 5) softening socio-psychological responses to odor due to improved site aesthetics and creating "out of sight, out of mind" dynamics; and 6) improved producer/community relations by using highly visible odor management technology.

The quantification of odor mitigation via the use of VEBs is a difficult process and is approached in a multi-analytic way by means of field trials, wind tunnel examinations and computer simulation. Field quantification is particularly difficult and explains the general paucity of data available for assessment (Colletti et al., 2006). Still, a few studies have recorded incremental mitigation benefits in the form of reduced particulate and odor movement downwind. For example, at a working pullet facility in Delaware Malone et al., 2006 analyzed the impact of a simple VEB and recorded a 49% reduction in particulate movement, a 46% reduction in downwind ammonia concentration, and a 6% (but not statistically significant) reduction in downwind poultry odor concentration. Lin et al. (2006) discusses a 22% reduction in downwind swine odor distance and states that odor concentration was reduced by a factor of three in a series of Canadian field studies examining VEBs. Wind tunnel and computer simulations have also quantified reduced particulate and odor movement due to the presence of strategically located trees (Laird, 1997; Lammers et al., 2001); for example, at Iowa State University, Laird (1997) recorded via wind-tunnel modeling a 56% reduction in off-farm dust movement. Figure 1 below displays the general bio-physical dynamics.

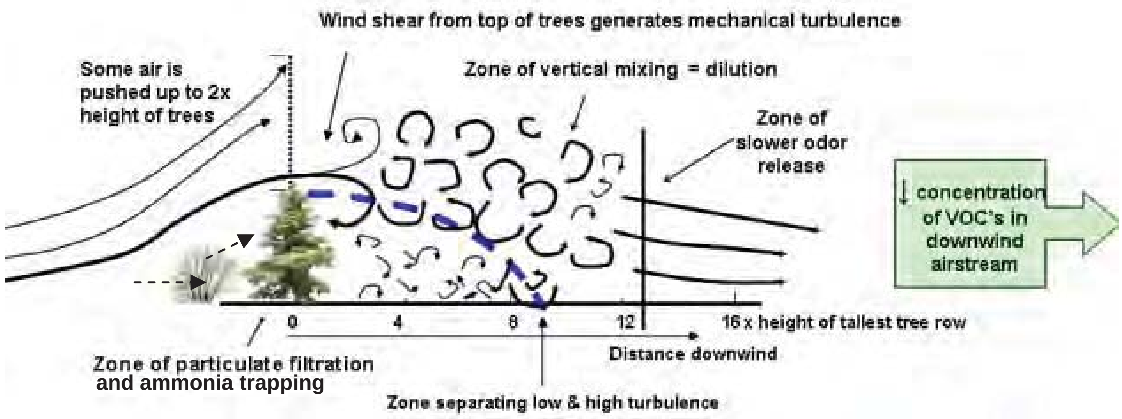

Figure 1. Generalized schematic of VEB odor mitigation dynamics. Note that the magnitude of dynamics listed in text above and shown here are site and VEB specific.

Applicability:

VEBs have been examined primarily in swine and poultry contexts (e.g. swine: Tyndall and Colletti, 2007; poultry: Malone et al, 2006), but have also been recommended for dairy producers (Bolinger and May, 2006). As an odor mitigation technology VEBs have advantages over many other approaches in terms of application. VEBs are adaptable to the landscape and production variability of different livestock production sites and production regions and are amenable to use near or around all sources of livestock odors (e.g. animal buildings, manure storage areas, and crop land receiving manure applications). A VEB is a technology that can be considered production technology neutral, in that producers who raise animals in a variety of ways—confinement (mechanically or naturally ventilated), hybrid confinement, hoop house, pasture—can plant designed VEB systems. There is also information that the presence of trees in agricultural landscapes has socio-aesthetic advantages that most other odor mitigation technologies lack completely (Tyndall and Colletti, 2007). VEBs are a size neutral odor mitigation technology, that is, production sites of all scales can plant trees. Furthermore, as opposed to other odor mitigating technologies that are mechanistic and tend to depreciate over time with concomitant higher maintenance requirements and cost, VEBs may be the only odor control technology that theoretically increases in effectiveness over time. The effectiveness of VEBs in mitigating odor comes from providing complex ecological infrastructure within an otherwise ecologically simplified system. As the trees grow larger and more morphologically complex their ability to mitigate odors through particulate filtration and increased landscape turbulence can become increasingly efficient. Of course, this implied improvement over time is contingent upon the long term health and management of the VEB system and continuance of appropriate manure management.

Limitations:

The physical effectiveness of VEBs in mitigation is extremely site specific and ultimately a function of a myriad of factors: VEB design, ambient weather conditions, landscape topography, direction and distance to nearest critical receptor (e.g. neighbors, communities), scale of emissions, manure management protocols followed and other odor mitigation technology utilized. Therefore, from an odor mitigation perspective, site specific VEB design is of critical importance. There is also a distinct difference between a production site that has a strategically designed VEB and a site that simply has "trees on it". Studies have shown that "strategically" placed trees have a beneficial physical impact on downwind odor (Tyndall and Colletti, 2007), whereas trees used simply for visual landscaping or are naturally part of the landscape may not (Nicolai et al., 2004). Furthermore, "mitigation" does not mean odor elimination and the degree to which VEBs contribute to odor mitigation will vary from farm to farm. While VEBs have been shown to contribute in incrementally reducing the downwind concentrations of odorous chemicals/ compounds and particulates, what this means to the highly subjective perception of odor being a "nuisance" is a very difficult question to answer. The benefits of the incremental contribution of VEBs to odor reduction are likely to be found in variously reducing the combined effects of the FIDO factors of an odor event – the frequency, intensity, duration, and offensiveness of odor. Therefore the use of VEBs is not a substitute for comprehensive odor management strategies rather their use should be thought of as complimentary technology used within a "suite" of odor management strategies.

Cost:

Costs for VEB systems are highly variable and are site/design specific. There are three main categories of expenses associated with VEBs: 1) Site prep costs, 2) tree establishment costs, and 3) long term maintenance costs. Table 2 below outlines the typical expenditures that a producer might expect in establishing and maintaining a VEB system. It should be noted that the majority of the total cost (usually in the range of 40-70%) is "upfront" and is tied to the cost of the initial planting stock (e.g. older, larger nursery stock can be considerably more expensive than bare-root seedlings but such an investment may "buy time" in VEB establishment). Long term maintenance costs vary depending upon the design and overall health of the VEB. It should be recognized that there are expenditures that occur regularly throughout the life of a VEB and maintenance is an annual process, however as a VEB system matures the annual maintenance requirements will likely decrease over time.

Table 2. Custom rate survey of typical VEB transaction costs and year(s) in which they occur.

Cost item	Year(s)	Price/ Unit [1] (US 2008 $)	Source of Price Information [1]
Site Prep			
Plowing	0	$13.60/ac	a
Spray purchase	0	$1.25/ac	b
Spraying operation	0	$19.00/ac	c
Disking	0	$20.00/ac	c
Shelterbelt Establishment			
Tree purchase costs	1	Variable [2]	d,e,f [2]
Shrubs purchase cost	1	Variable [2]	d,e,f [2]
Tree planting cost	1	$1.00 – $5.00/tree	c
Shrub planting cost	1	$1.00 – $5.00/tree	c
Permeable plastic mulch	1	$633/linear mile	g
Long Term Maintenance			
Tree replanting	2-4	Variable [3]	d,e,f
Shrub replanting	2-4	Variable [3]	d,e,f
Weed control (e.g. mowing)	Annual	$31.46/linear mile	c
Tree Pruning	Every 3-5 years	$31.46/linear mile	c
Other relevant costs			
Overhead/management [4]	Annual	Variable	-
Land rent [5]	Annual	Variable [5]	h

[a] Iowa State University, 2008.; [b] Based on 2008 cost of 2.5 gallon container of generic glyphosate; [c] Iowa State University, 2003; [d] Cascade Forestry Nursery, 2007; [e] Kelly Tree Farm (online catalog), 2008; [f] Iowa Department of Natural Resources, 2007; [g] PFRA, 2008; [h] Iowa State University, 2007.

[1] Units are variable depending upon cost item; prices listed as per linear mile assume a treatment strip of 10' by 5280' or a "price/ acre" to "price/ linear mile" conversion factor of 1.21. All costs include labor and fuel where relevant. Unless otherwise given, all listed costs represent an average price presented in the various Custom Rate Surveys used; [2] Species and plant size specific; [3] It is assumed that tree and shrub mortality will equal 8% during the second through the fourth years after establishment; [4] Includes taxes, insurance, energy requirements, etc; [5] If any land is taken out of production for the planting of a VEB then land rent should be factored in.

Implementation:

When implementing a VEB, there are several key design issues. A proper VEB can serve as both a visual screen and an odor filter. To this end, one needs to account for prevailing summer and winter winds and key visual pathways (e.g. screening a manure storage area from passing traffic). Key planting zones can then be identified so as to maximize the effects of filtration and increased turbulence and provide screening from desired angles and directions. See Figure 2 below for an example VEB design and Table 3 for a financial analysis of this example system.

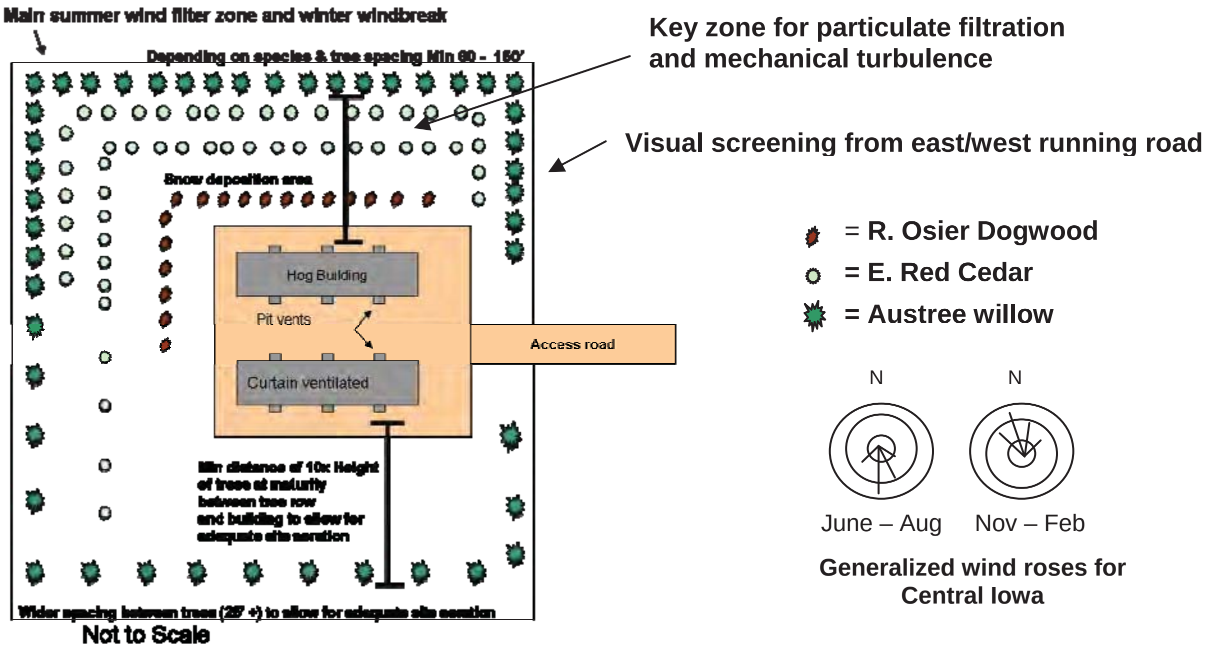

Figure 2. Example general VEB design for a two building swine finishing unit. VEB is designed for Central Iowa wind patterns. Ultimately VEB designs (e.g. planting patterns, locations, species used) will be variable and site specific. Figure modified from Tyndall and Colletti, 2007.

The calculated costs of the example VEB (Figure 2) are presented in a number of ways in Table 3 below. The present value of costs (at 7%) for each scenario was calculated to capture the total costs of establishing and maintaining the shelterbelts over a 20 year period. This was calculated with and without land rent factored in. Because 40% of the total costs of this example VEB comes during the site preparation and establishment phase (primarily from the costs of the planting stock) these "up-front" costs are isolated and presented. Total costs were also calculated as annual capital recovery payments (total costs in the form of uniform annual payments over a 20 year period). Additionally, costs per pig produced are also presented.

Table 3. General shelterbelt parameters and financial analysis for VEB in Figure 2. Summary of the total costs at 7% (real alternative rate of return). All costs are presented in 2008 dollars US.

Figure 2 VEB				Cost Presentation for Figure 2 VEB	
Total trees planted	140	81	33	Present Value Costs w/o land rent	$1,741
Space between trees (feet):	6 - 25'	15 - 25'	6'	Present Value Costs with land rent	$2,452
Species planted	Austree willow	Eastern red cedar	R. Osier Dogwood	Upfront costs (Site prep & establishment only)	$737
Initial planting stock size [1]	15" cutting	18"-24" bare root	2'-3' potted	Capital Recovery Costs (Annual cost over 20 years)	$164
General growth rate for species [1]	Very fast; 5-10 ft/yr	Medium; 1-2 ft/ yr	Medium to fast; 2+ ft/yr	Total costs per pig produced over 20 yr period	$0.05/ pig

[1] Larger planting stock is more expensive but with these initial stock sizes in 3 years Austree willow ≈ 25'-30'; Red cedar ≈ 6'- 9'; Red osier Dogwood ≈ 4' - 5'. Growth rates, however, are variable depending on site conditions, health of planting stock and region.

For the VEB shown in Figure 2 above, a VEB system as outlined in Table 2 would cost a producer over a 20 year period a little over $1,741, with about $737 (42% of the total cost) coming during the initial establishment phase. These total costs translate to about $0.05 per pig produced.

All VEBs need to be established in appropriately prepared planting areas (see section below on site preparation) using regionally appropriate nursery stock. As suggested in Table 2 above, all VEBs should have a well thought out long-term maintenance plan to ensure the overall health of the system and to keep long term costs/labor down. Another key design factor is mixing the species used. This is recommended for two main reasons: 1) increased species diversity reduces the risk of whole scale pest/pathogen loss, and 2) some species (e.g. hybrid willows and poplars) feature very rapid growth but often have relatively short healthy life spans (e.g. 15-20 years), mixing in slower growing but longer lived species will allow for a robust and mature VEB system to remain after other species are removed.

There are three main hazards that must be avoided when utilizing VEBs yet these are all easily avoided with proper VEB design and implementation. VEB designs need to prevent: 1) winter snow deposition problems by planting trees too close to access roads and buildings. In Central Iowa for example winter winds largely come from the North/Northeast. Therefore VEBs planted to the north and east of buildings/roads should plan for a planting distance anywhere from 50-200' away. 2) Trees should not be planted so close to buildings that they prevent appropriate air flow into and out of the buildings. For mechanically ventilated buildings trees can be planted as close as 5-6 times the diameter of the fans and avoid causing back pressure, but that distance may not be healthy for the trees. A minimum distance of 40 feet away from fans has been recommended (Malone et al., 2006). For naturally ventilated systems, one does not want to impede necessary summer winds (which in Central Iowa tend to come from the South/South east) blowing into the buildings. 3) Visibility into and out of the facility grounds is important, so keep the mature heights of trees in mind when planting trees near access roads.

Appropriate site preparation is one of the main keys to the long term health of tree plantings and will contribute toward lower tree mortality, faster tree growth and ultimately, lower time, money and effort in managing the system over the life of the operation. In many cases the grounds of a livestock facility - the area where trees are to be planted – features highly compacted soils, subsurface soil piling, poor drainage, etc. Many VEBs fail (e.g. high tree mortality) because of inadequate site preparation. When planting trees directly into tilled crop ground, site preparation requirements will likely be lessoned. Table 4 below outlines possible site preparation requirements prior to tree planting. It is always recommended that a producer seek advice from a forestry professional before proceeding with a VEB system.

Table 4. Generalized site prep requirements prior to tree planting for new livestock facilities:

1 year before VEB establishment (Fall: Oct-Nov):	Year 1 (Spring – late April/Early May)
– 4' Kill strip (e.g. Round Up) – Disk/cultivate (work soil to 8" depth) – Seed cover crop (e.g. clover, rye)	– Disk/ cultivate again & if possible rototill – Soil should have no clumps & minimal residue – Grass seed may be desired (sow outside of mulch and or weed mat zones)

Technology Summary:

Tree based Vegetative Environmental Buffers (VEBs) can be a cost-effective way for livestock producers to incrementally mitigate odors, particulates and ammonia emanating from their sites. Research supports the possibility of 6-15% reduction in odor and in certain situations possibly up to 50% reduction in ammonia and particulates. As air moves across vegetative surfaces, leaves and other aerial plant surfaces remove some of the dust, gas, and microbial constituents of airstreams while increased mechanical turbulence can boost the vertical mixing of air streams thereby enhancing dilution. VEBs are relatively inexpensive and straight forward to manage and therefore in many cases can easily fit into current odor management plans. While the physical effectiveness of a VEB in mitigating odors and the overall expense of establishing and managing a VEB are highly variable and site specific, their use can incrementally enhance (in an additive way) a livestock production system's ability to reduce negative odor impacts for just a few cents per animal produced.

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