Vegetative environmental buffers (VEBs) for mitigating air emissions from livestock facilities: A Review

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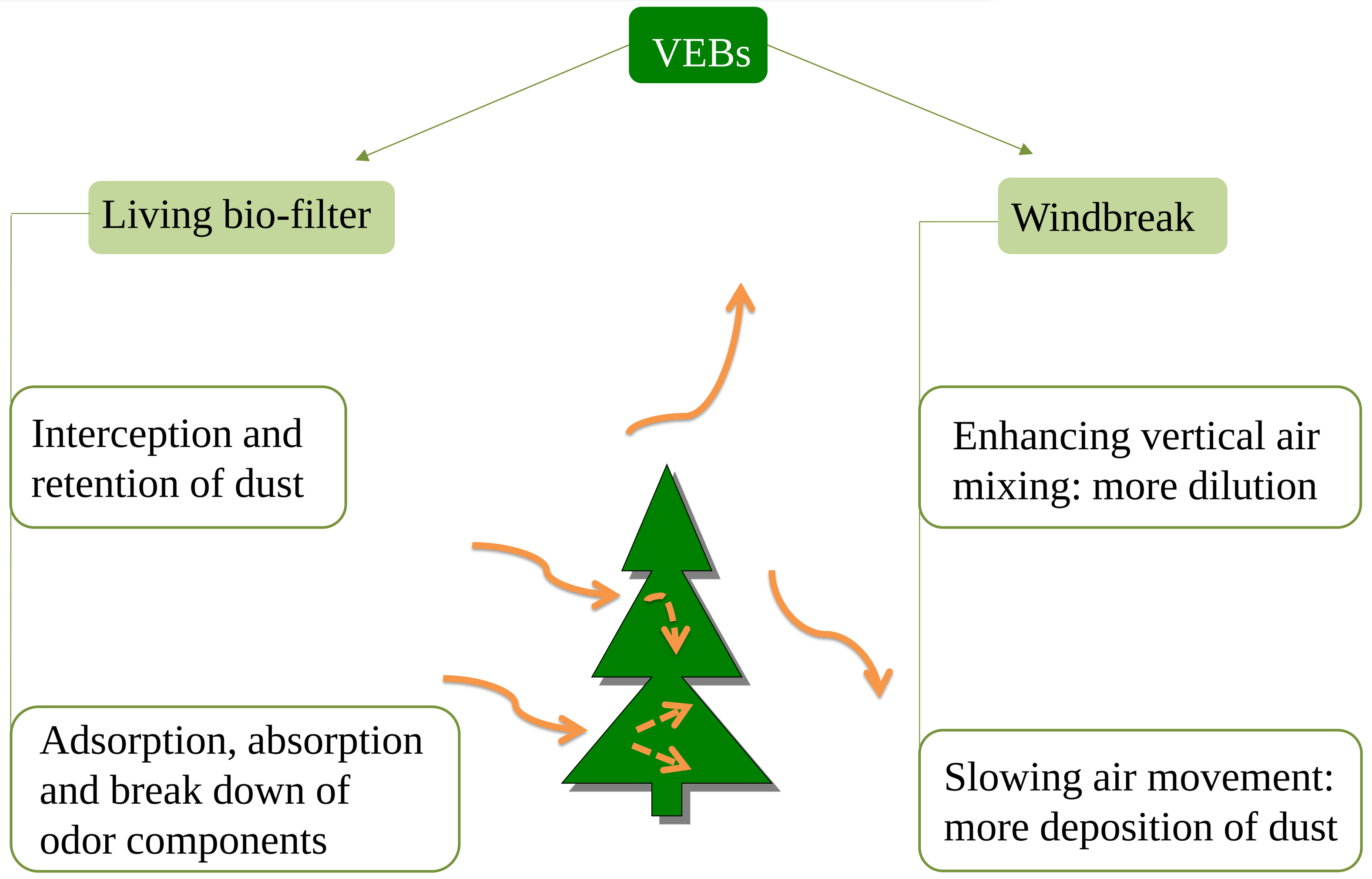
Background

Emissions of dust, odor and other air pollutants from livestock facilities are receiving increasing concerns related to nuisance, health and upcoming air quality regulations. Vegetative environmental buffers (VEBs) have been proposed as a potential cost effective mitigation strategy. Tyndall (2009) reported 75% of swine producers surveyed in IOWA are interested in using VEBs for odor management. But lack of information on performance, cost and technical guidelines are barriers to adoption of VEBs.

Objectives

- Review published research on effectiveness of VEBs for mitigating air emissions from livestock facilities.
- Develop general guidance for VEBs design.

Mitigation Mechanisms



- ~ 90% of dust are in the size range best captured by trees (Tyndall, 2010)
- Odor is often carried on dust particles. So odor is reduced when dust is reduced.
- The waxy leaf surface area (cuticle) has an affinity for N-based chemicals (Walter, 2010).

Advantages of VEBs

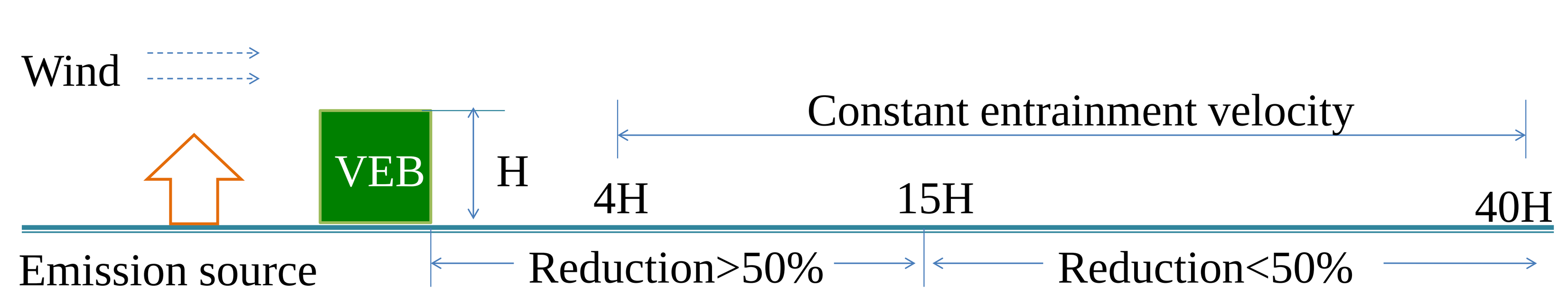
- ✓ Visual screen (aesthetics value)
- ✓ Improved neighbor-relations (highly visible)
- ✓ Increased effectiveness over time
- ✓ Production tech and size neutral (can be adopted by any farm)
- ✓ Potential energy benefits (buffer for extreme temperature fluctuations)
- ✓ Snow fences
- ✓ Wild life habitat
- ✓ Soil C sequestration
- ✓ Potential soil erosion control

Effectiveness of VEBs

Authors	Farm, location	VEBs	Effectiveness
Hernandez et al., 2012	Swine, Iowa	Single row of Austree willow, 52-100m from house, 9m tall	40-60% reduction in odor compounds; 40% reduction in dust across the VEB
Parker et al., 2012	Swine, Missouri	Five rows, 9-12m from fans, 2.4-3.6m tall	66.3% reduction in odor at 15m; no reduction at 150m & 300m downwind
Burley et al., 2011	Laying hen, Pennsylvania	Four rows, 17.7m from fans, 1.5-2.1m tall, 12.8m in depth, 11m in width	No effect on dust
Nicolai et al., 2010	Swine, South Dakota	One to three rows	Most effective reduction occurs just beyond VEB; little effect after 500m
Patterson et al., 2009	Laying hen, Pennsylvania	Four and five rows, 11.4-17.7m from fans	34% reduction in odor with a 4-row VEB; 46-54% reduction in odor with a 5-row VEB
Adrizal et al., 2008	Poultry, Pennsylvania	Three to twelve rows, 11.4-17.7m from fans	Greater foliar N concentration near the fans suggests entrapment of airborne NH_3 by the plants
Malone, et al., 2004 and 2008	Poultry, Delaware	Three rows, 9m from fans, 4.8m tall, 6.7m in depth	56%, 54%, 26% reduction across VEB in dust, NH_3 and odor, respectively; 19% reduction in aerosol bacteria
Tyndall, 2008	Swine, Iowa	-	6-15% reduction in odor, up to 50% reduction in NH_3 and dust
Lin et al., 2006	Odor generator, Canada	Single row, 15-60m from odor generator, 7.6-18.3m tall	Reduction in odor: 68% at 117m downwind; 3% at 520m downwind
Nicolai et al., 2004	Swine, South Dakota	The mature VEB: 8 rows, 1.8m from manure storage, 9m tall, 42m in depth; the immature VEB: 2 rows	85% reduction in H_2S for the mature VEB; reduction in H_2S was significant only at V<5mph for the immature VEB
Laird, 1997	Wind tunnel modeling, Iowa	Three rows	56% reduction in dust

Lessons Learned

- A greater species diversity and a combination of plant growth rates are recommended to make a robust and mature VEB system (Tyndall, 2008; NRCS, 2007). A row spacing of 16 to 20 ft is recommended by NRCS.
- Appropriate site preparation is critical to the long term health of tree plantings and will contribute toward lower tree mortality and faster tree growth. Many VEBs fail (e.g. high tree mortality) because of inadequate site preparation (Tyndall, 2008).
- Design of VEBs should consider air circulation near and through animal houses. Minimum distances of 75 and 100 ft away from house are recommended for mechanical and natural ventilation, respectively (May, 2011).
- Most effective reduction occurs just beyond the VEB (Parker et al., 2012; Nicolai et al., 2010; Lin et al., 2006). Wind tunnel simulation on barriers at roadside showed that percentage reduction decreasing with downwind distance, and they are generally below 50% beyond 15 barrier height (Heist, 2009).



Promising plants for VEBs

Name	Size (H×W)	Growth rate	Name	Size (H×W)	Growth rate
Austree hybrid willow	60' x 15'	very fast	Norway spruce	50' x 25'	moderate to fast
Leyland cypress	100' x20'	very fast	Eastern red cedar	40' x 20'	moderate
Arborvitae	60' x 20'	fast	American holly	40' x 20'	slow to moderate
Hybrid poplar	70' x 30'	fast	Bald cypress	70' x 20'	slow to moderate
Honeylocust	50' x 50'	fast	Jack pine	50' x 30'	slow to moderate
Nellie Stevens holly	20' x 15'	fast	Miscanthus x giganteus grass	9-12' H	very fast

(Adapted from NRCS, 2007; Burley, 2011 and Patterson, 2009)

Costs

- Costs for VEBs include upfront costs (site preparation, tree stock & establishment, 40-70% of total costs) and maintenance costs (Tyndall, 2008).
- Site preparation: $53.85 per acre; tree stock: from $0.75 (15" Austree willow) to $18 (2-3' Eastern red cedar) per tree (Saucer, et al., 2008).
- ~$5,500 ($1,500-$12,000) for existing poultry farms (Malone et al., 2008).
- Cost per head of swine: ~20 cents (from IOWA demonstration cooperators).

Challenges

- Supportive policy, cost sharing opportunities.
- Technical assistance in the design, implementation and maintenance of VEBs.
- Cost-benefit analysis.

Summary

- VEBs have been examined primarily in swine and poultry farms. Iowa, Pennsylvania and Delaware are actively involved in research and implementation of VEBs for livestock farms.
- VEBs are potential cost effective strategy for reducing dust, odor, NH_3 and H_2S from farms, although effectiveness and costs are highly variable and depend on site specific design.
- Further research is needed for development of technical guidelines for VEBs.

Future Research

- How will VEBs affect the transport of air emissions under a variety of weather conditions? How will VEBs affect odor footprint and reduce the needed separation distance from neighbors?
- What are the key design parameters for VEBs (height, thickness, porosity, tree species, location)? How can they be managed to maximize effectiveness with limited costs?

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