United States Department of Agriculture

TECHNICAL NOTE

Iowa Woodland Technical Note 21:

Windbreak/Shelterbelt - Odor Control

Introduction

Preliminary research and observations made by farmers suggest that windbreaks placed around livestock production facilities may effectively reduce movement of odors emitted by manure to neighboring properties. Essentially, trees can be 'put to work' to reduce the movement of livestock production odors off-site.

Although the idea of placing vegetative windbreaks and shelterbelts around agricultural buildings and farm fields is not new, additional benefits from farm windbreaks continue to be learned and tested. Windbreaks alone will not prevent odor problems associated with intensive livestock production but may provide farmers with one more tool to help reduce negative visual perceptions and detection of smell by neighbors and surrounding communities.

Figure 1. A windbreak of maturing conifers can significantly change the appearance of livestock production facilities and help filter out odor particles.

An odor-emitting source can include a livestock production barn, manure storage or a farm field where manure is being spread. Windbreaks have the ability to reduce odor concentrations significantly at or very near the source, which greatly improves the effectiveness of separation distances.

There are six ways that windbreaks and shelterbelts can reduce the effects of livestock odor and improve visual perception of production buildings:

1. Dilution and dispersion of gas concentrations of odor by a mixing effect created by windbreaks.
2. Deposition of odorous dusts and other aerosols (like snow fencing) to the windward and leeward sides of windbreaks.
3. Collection and storage (sinks) within tree wood of the chemical constituents of odor pollution.
4. Physical interception of dust and aerosols odor particles on leaves, needles and branches.
5. Containment of odor by placing windbreaks fore and/or aft of the odor source.
6. Aesthetic appearance:
   - Trees create a visual barrier to livestock barns
   - Trees can make cropped fields and pastures more pleasing to look at
   - Trees represent an 'environmental statement' to neighbors that the producer is making every effort to resolve odor problems in as many ways as possible.

This information sheet is adapted from the following references: "Using Shelterbelts to Reduce Odors Associated with Livestock Production Barns" (January 2004) by Todd Leuty, Horticulture/Agroforestry Specialist, Ontario Ministry of Agriculture and Food. "Air Quality and Shelterbelts: Odor Mitigation and Livestock Production – A Literature Review" 1999. John Tyndall and Joe Colletti; Iowa State University."Designs for Windbreak Walls for Mitigating Dust and Odor Emissions from Tunnel Ventilated Swine Buildings" 2000. R. Bottcher, R. Munilla, G. Baughman, and K. Keener. North Carolina State University.

Dilution and dispersion

Without wind management, odors emitted from livestock facilities and manure storage areas tend to travel along the ground as a plume with air movement, especially during atmospheric inversions with little or no dilution of odor occurring.

Figure 2. Without windbreaks and without wind management, the odor plumes are picked up by passing air masses and travel near the ground with little or no dilution or filtration.

Windbreaks create an obstacle for moving air masses. When designed properly, windbreaks force turbulent fresh air up and over the tree row and will also moderate and evenly distribute a more gentle airflow through the trees. Less air movement past barns will mean less pickup and movement of odor off site.

It is believed that windbreaks have the ability to lift some of the odor plume into the lower atmosphere where winds aloft mix and dilute the odor. The greatest dilution of odor occurs above and downwind from the quiet zone created by the action of wind passing over the windbreak. Beyond the quiet zone, more fresh air and less odorous air returns to the ground, thereby reducing movement of livestock odors off site.

Approximately 60 percent of the wind should be deflected up and over the windbreak and 40 percent should pass through the canopy of the trees. Two to three rows of trees can provide an ideal 60 percent density (or 40 percent porosity) through the tree canopy. Windbreaks are less effective for odor reduction when wind is minimal but the visual appearance remains in place.

Windbreaks create a 'quiet zone' of air that measures a distance of 8 to 10 times the height of the tree row downwind of the windbreak, and an additional moderation of wind speeds 10 to 25 times tree height, beyond the windbreak. Back-pressure created by the blocking effect of the tree row also creates a small quiet zone upwind of the tree line that is equal to 2 to 3 times the height of the trees.

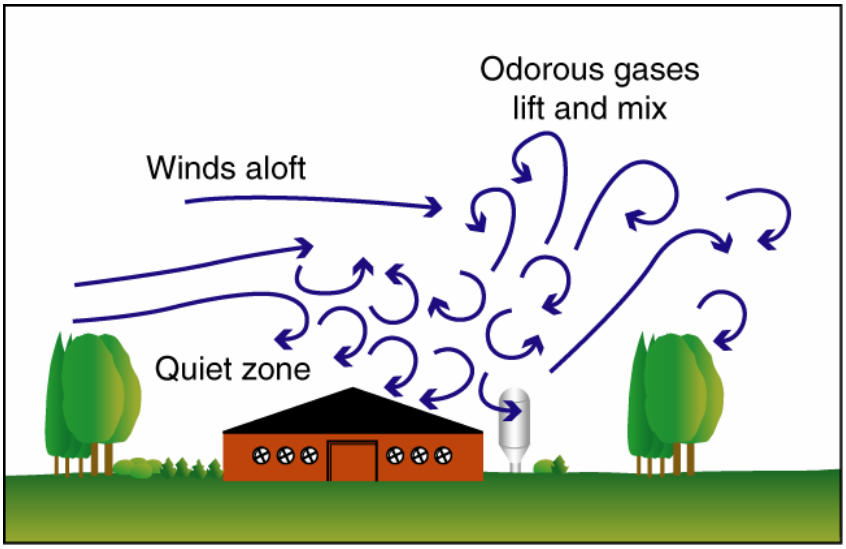

Figure 3. Windbreaks located upwind and downwind of livestock facilities will reduce and manipulate air flow around the facility to reduce the spread of odors. Overhead winds can lift particles and gases into the lower atmosphere to help dilute and disperse odors. Also, more clean air diverts up and over the source of odor.

Livestock barns and manure storage areas are best located in the quiet zone 50 to 100 feet downwind of windbreaks. In addition, windbreaks located downwind of the odor source are also important for filtering, absorption and trapping odors. Therefore, placing windbreaks around the entire perimeter of livestock production areas is ideal. Windbreaks should also be at least 75 to 100 feet from access roads and driveways to prevent snowdrifts from blocking farm vehicles during winter.

Deposition of odorous dusts

Windbreaks create a physical barrier to wind and air movement. The trees absorb wind energy and reduce its speed near the ground. As a result, fewer dust particles and less odorous gases will be picked up by the air coming from livestock facilities. Also in calmer air, dusts and gases already caught up in the air will be more likely to settle back to the ground on the downwind side of the windbreak. This deposition effect is commonly seen with snow fencing where snow settles downwind of the fencing or trees due to reduced wind speed.

Figure 4. Reduced wind speed in the quiet zone that is created downwind from a windbreak allows odorous dusts and particles to settle to the ground, similar to what happens with settling and drifting of snow.

To be most effective for deposition of odorous dust, windbreaks need to be located upwind and downwind of odorous livestock facilities. Upwind windbreaks reduce the quantity of dust and odor that is picked up by wind, and windbreaks located downwind of the facilities will further reduce wind speeds to allow settling of odorous dusts that have become airborne.

For cropland, the same may hold true for reduction of odor movement where manure is being spread onto farm fields. Windbreaks established around the full perimeter of farm fields should reduce movement of odor and can accommodate winds that are approaching the farm from any direction.

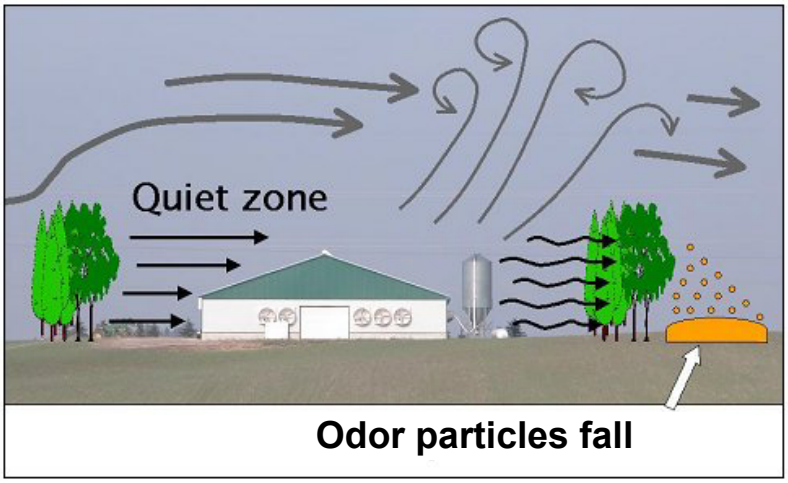

Figure 5. Windbreaks located downwind of livestock production barns allow settling of odorous wind-borne dust particles. Windbreaks should be located 75 to 100 feet away from barns.

Wind tunnel studies of mass transport have shown that windbreaks can remove 35 to 55 percent of dusts being carried in moving air which would provide a substantial reduction of offensive odors carried off-farm. The amount of dust that is picked up or allowed to settle will depend on wind speed, direction of the wind, density of windbreak trees, height of windbreak trees and number of windbreaks.

Figure 6. Mature windbreaks around cropped fields may help lift and disperse odors during application of manure as nutrient soil amendment, in addition to sheltering crops from damaging wind.

Collection and storage of pollutant odors within trees (sink)

Scientific evidence of plant intake of livestock odors in field situations is limited, however there have been many studies done on the ability of plants to absorb air-polluting odors and chemicals. Trees and shrubs clean the air of micro-particles of all sizes by interception. Interception of air pollutants may be 20 times higher in treed or forested areas than non-forested cropped or barren lands. Conifers show a better ability to absorb air pollutants than deciduous trees.

Figure 7. In air pollution research, odorous gases and particles can be absorbed into the foliage of conifers and deciduous trees during the growing season. Pollutants diffuse inside leaves and needles through tiny openings called stomata or adsorb into waxy coatings that naturally cover leaf surfaces.

Odorous gases, chemicals and dust particles can become fixed to plant surfaces and can enter into the plant tissue in three ways: 1) gaseous diffusion through open stomata, 2) on wet leaves, soluble air pollutants can enter through stomata in a dissolved liquid form, 3) pollutants can absorb directly into plant tissues.

Windbreak trees and shrubs absorb air pollutants when they are healthy and not under drought stress. Trees and shrubs absorb more air pollutants when leaf surfaces are wet. Higher humidity can increase uptake of air pollutants into trees, which is commonly measured within tree canopies.

Micro-organisms cover plant surfaces and there is evidence that these micro-organisms associated with windbreak trees also contribute to absorbing odorous chemicals. Forests are often referred to as pollutant air filters. This may also apply to windbreaks trees.

Physical interception of odor particles

Trees are highly effective at physically intercepting dusts, gases and microbial particles that are carried in the wind. Windbreaks are commonly used to intercept and drop blowing snow, act as barriers to trap blowing sand and soil caused by wind erosion, catch spray drift of agricultural chemicals, and reduce and catch pollen drift from agricultural crops.

As leaf surface roughness increases, the capture ability of particles and odor increases. Leaves with complex shapes (large circumference to area ratios) collect particles most efficiently. Therefore, conifers may be more effective at intercepting livestock odors than deciduous tree and shrub species. Conifers also have leaves (needles) year around.

Figure 8. Like the air filters of home furnaces, windbreak trees, especially conifers, physically catch wind-borne odorous particles. Conifers have foliage year-round.

Windbreak design and planting

Selecting the species of trees and shrubs to plant will vary at each livestock facility and farm field site. Species selection should be based on the characteristics of each site including: soil type, natural drainage, common wind conditions, annual precipitation, natural range of each tree and shrub species and site needs. In addition, to maximize particulate trapping, select species based on high leaf surface roughness (plants with leaf hairs, leaf veins, small leaf size), complex leaf shapes, large leaf circumference to area ratios and medium to rapid growth rates.

It is usually best to select several species of trees and shrubs for use in windbreaks to prevent loss or destruction of the entire windbreak if attacking insect pests or tree diseases occur. Having diversity also offers a better chance for tree survival during alternating seasons of drought and wet soil conditions.

Windbreaks should consist of one to three rows of alternating conifer and deciduous species while windbreaks may be wider with more tree rows. Shrubs are generally planted in the outside or inside rows, followed by conifers with deciduous hardwoods towards the middle or along the downwind side where they can grow more efficiently. Tree varieties and placement for the windbreak should be managed to maximize odor interception and dilution of air, and reduce odor leaving the source.

Where site conditions allow, place plantings around the entire perimeter of the odor source.

Adjust windbreak porosities/densities to meet air movement needs for naturally ventilated livestock confinement systems.

Keep the inner row of windbreak plantings from all buildings and waste storage areas at least 10 times the exhaust fan diameter or 50 feet, whichever is farther.

Use wide “between row spacing” to increase particle surface area contact and foliage light levels.

Ideally once established, the tree barrier should have a density of about 60 percent for best results for wind management. Conifers such as spruce will provide uniform branch coverage from the ground level up. Tree rows should be spaced wide enough apart to allow access by a small tractor for mechanized management of vegetation.

Weed management is important during the first five years of tree establishment using herbicides, or plastic or organic mulch. Weed management is important until the young windbreak trees have overtopped most weed competition and are free to grow.

Managing Odor

Odor management is a result of the overall management of the farm operation. General maintenance of the buildings and the nutrition of the feed ration are normal farm management needs that can influence odor emissions. Waste management plans have become a standard part of livestock operations in recent years. Livestock odor management techniques fall into three areas:

1. *Preventing the generation of odor*, including feed additives, aeration, manure additives, etc.
2. *Capturing and destroying the odor*, including biofilters, waste storage covers, organic mats, etc.
3. *Dispersing or disguising the odors*, including vegetative or structural windbreaks, setback distances, site selection, etc.

In particular, structural or vegetative windbreaks placed near exhaust fans on tunnel-ventilated livestock and poultry buildings appear promising, primarily because the air jets issuing from the exhaust fans are diverted upward. This effect promotes mixing of the odorous, dusty airflow with the wind passing over the building, so that the plumes of air pollutants originating from the fans are made larger (extend higher) in addition to the physical trapping of odor particles on the windbreak.

Figure 9. Relevant design considerations and low-cost designs using UV-resistant tarpaulin or plastic material, roofing, or wood fastened to anchored pipe frames or posts are potential options for windbreak walls.

Windbreak structures may either be designed to withstand the same wind speeds as the buildings and be insured with the buildings, or lower wind speeds at reduced cost. If the windbreaks are not designed for maximum design wind speeds, a method of ensuring non-catastrophic failure is needed, such as breakaway ties fastening material to frames. The location of the

windbreak affects the diversion of airflow from exhaust fans. Observations of windbreak action in several locations suggest that the windbreaks should be placed two to four fan diameters downwind from the fans to deflect fan airflow without back pressures, (Figure 11) and extend high enough to fully intercept the plumes of airflow issuing from the fans (e.g. 10-12 feet high for typical buildings).

Biofilters using biomass and microorganisms to treat ventilation air as it leaves the building have been used in the U.S. Some producers have installed windbreak walls using straw or other biomass. Windbreaks made from or incorporating straw have been installed on swine farms in North Dakota, Minnesota and Missouri and received favorable results. One facility in Minnesota with a biofilter achieved odor and H_2S reduction of 80-90% and NH_3 reduction of 50-60%. Weed control and rodent control were the primary problems experienced. A critical element in the use of biofilters is their dependence on power ventilated buildings where fans push the air through the filter. They don't work on naturally ventilated buildings.

Other benefits

In addition to odor management, vegetative windbreaks also act to reduce the seasonal cost of heating and cooling of farm buildings without disrupting ventilation in livestock barns.

Windbreaks may also reduce the spread of specific infectious disease of livestock by blocking, intercepting or diverting wind-borne infectious organisms away from buildings.

Windbreaks placed around farm fields reduce damage to forage and crops (preserve crop yield potential) caused by damaging turbulent winds while allowing normal air circulation to continue. Windbreaks reduce soil erosion by wind. Around pastures, mature windbreaks will relieve livestock of stress during hot summer days and cold windy winter conditions. Avoid planting trees and shrubs around livestock that are known to be poisonous.

Figure 10. Where barns are surrounded by solid forest plantation, it is important not to block ventilation fans with excessive tree growth. Thinning the plantation and pruning off lower branches can improve air circulation. Fifty to 100 feet is a good separation distance between trees and barn.

Acknowledgements

References used in this information sheet:

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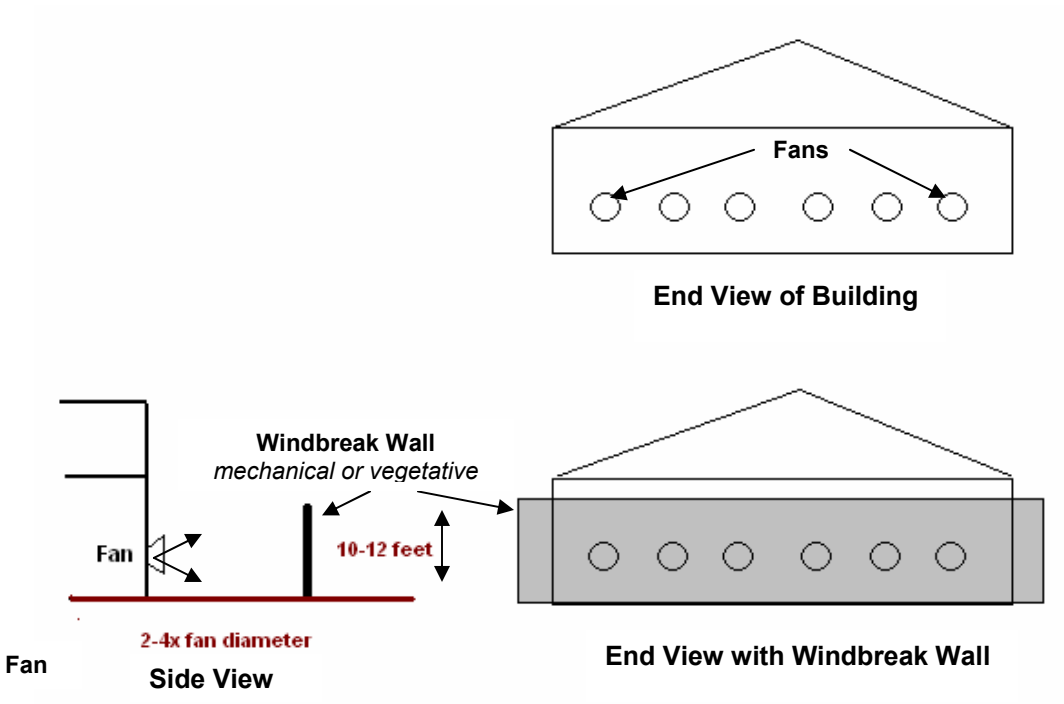
"Air Quality and Shelterbelts: Odor Mitigation and Livestock Production – A Literature Review" 1999. John Tyndall and Joe Colletti; Iowa State University.

"Designs for Windbreak Walls for Mitigating Dust and Odor Emissions from Tunnel Ventilated Swine Buildings" 2000. R. Bottcher, R. Munilla, G. Baughman, and K. Keener. North Carolina State University.

Figure 11. Example layout of windbreak wall or biofilter for typical tunnel ventilated building.



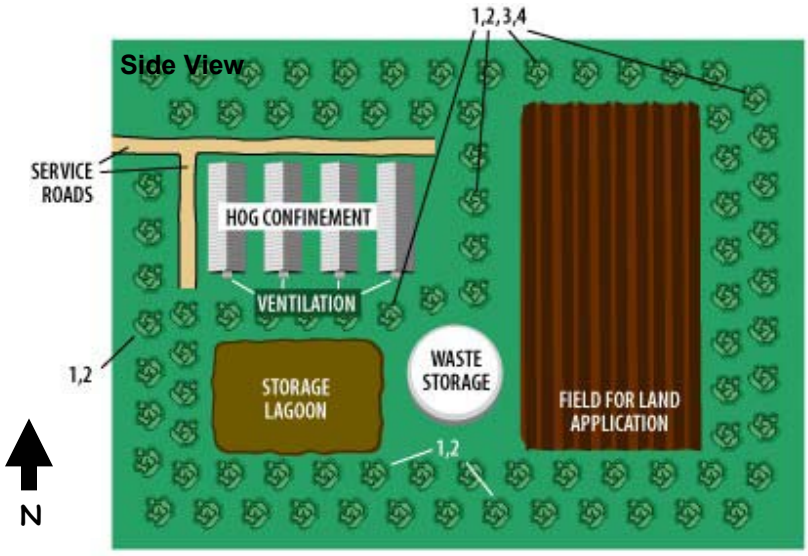


Figure 12. A hypothetical windbreak design for a swine facility. The numbers refer to the interaction and means by which the windbreak will mitigate livestock odor.

1. *Creation of air mixing turbulence*
2. *Dust deposition*
3. *Particulate interception*
4. *Pollution sinks*

Other important design considerations include: livestock type, odor sources, air/wind patterns, tree/shrub species, and aesthetics.

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