Improvement of Air and Water Quality Around Livestock Confinement Areas Through the Use of Shelterbelts

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Introduction

The goal of this literature review is to examine the available sources and to assess if there is enough evidence to determine 1) if the use of trees and shelterbelts around livestock confinement areas may improve air quality through controlling odor or improve water quality by filtering wastewater runoff, and 2) if this technology is economically feasible for livestock producers.

The growing trend in livestock production is industrialization, although this review is based on livestock facilities of any size. With the occurring trend, most facilities are becoming larger and contain increased numbers of animal units per farm system. This increase in size and number is mainly due to the thought that operations will benefit from economies of scale, in the aspects of labor, feed, and facilities (SOTF, 1995).

According to the US EPA (1999), from 1978-1992 overall animal production has increased, but the number of livestock facilities has decreased.

- In the U.S., during the above time period, cattle operations increased by 56%, dairy by 93%, hogs by 134%, and layer poultry by 176% in the average number of animal units per facility (US EPA, 1999).

- During the same time period the number of facilities dropped by over 40% in the cattle industry, and over 50% in the dairy, hogs, and layer poultry industries (US EPA, 1999).

This increase in number of animals and increased size of production facilities has created larger amounts of animal waste confined in smaller areas.

- According to the US Senate Committee ANF (1997), about 130 more times animal waste is produced annually than human waste.

- US livestock produce more than 1.4 billion tons of manure annually (US Senate Committee ANF, 1997).

With the increase in size and number of animal units increasing per livestock facility they are often coming in closer proximity with people and water sources, which brings us to the second part of the research.

Buffer strips placed along water sources that may be affected by livestock runoff, or nonpoint source pollution, has been proven to filter particulate wastes and sediment-attached contaminants. Poplar trees have also been known to absorb a certain amount of nitrates from shallow groundwater improving water quality (Dosskey et al., 1997).

Shelterbelts and Odor Dispersion

Shelterbelts do have the potential to be an effective and inexpensive odor control method if carefully planned and executed properly because of several general characteristics of odor plumes. These characteristics, stated by Smith (1993) are:

- The livestock odor source is at or very near ground level
- Certain weather conditions restrict the rising of the odor plume
- An odor plume has spatial and temporal variability
- A plume may cover a large land area
- Critical receptors of odor, such as people, are often in close proximity
- Odors that are generated by livestock facilities can be detectable over long distances and travel as aerosols (Hammond et al., 1981)

The evidence that windbreaks do affect these characteristics is compelling and shows to lessen the impact that this odor has on the environment and people. Because the odor plume has a tendency to travel near the ground (Takle, 1983), windbreaks of approximately 20-30 feet are ideal for the interception and disruption of odor (Heisler and Dewalle, 1988; Laird, 1997; and Thernelius, 1997). Since shelterbelts are so adaptable each one should be designed for the specific location, according to expected and experienced odor plumes, and so that the tree or shrub species can provide year round interception of odor plumes and aerosols.

According to Tyndall and Colletti (2000), livestock odors can be dispersed four ways through interaction with shelterbelts. Those methods are:

- By dilution of gas concentrations into the lower atmosphere
- By the deposition of dust and other aerosols from reduced wind speeds
- By physical interception of dust and other aerosols by trees and shrubs
- By acting as a sink for the chemical elements of odor after interception

Some of the key research results supporting the fact that odor is dispersed by interaction between shelterbelts and odor are listed and presented for each effect.

Dilution of gas concentrations of odor into the lower atmosphere

Shelterbelts create turbulences at the surface of the terrain that intercept and disrupt odor plumes that travel in a laminar flow helping to push the plume into the lower atmosphere facilitating dilution (OCTF, 1998 in Tyndall and Colletti, 2000; SOTF, 1995; and Takle, undated). Windbreaks deflect and lift air streams into the lower atmosphere. This lifting usually begins some 2-5 H (times the height) of the shelterbelt on the windward side. When the air stream is compressed, it is redirected and air speeds increase and can reach 1.5 to 1.7 H. A quiet zone, an area of no turbulence, is created on the leeward side of the shelterbelt an average of 8 H (McNaughton, 1988).

Lowering wind speeds over storage lagoons can reduce convection of odorous compounds from the surface and allow for slower release of the odor plume which also facilitates dilution (Bottcher et al., 1999). As density of the shelterbelt decreases (<50%), the turbulence increases in the turbulent zone. This zone, depending upon the height of the shelterbelt, is where most of the dilution of the odor plume takes place (Tyndall and Colletti, 2000).

In planning of a shelterbelt design, it is beneficial to know that wedge shaped shelterbelts facing the prevailing winds create the most turbulence and have a tendency to push air higher into the lower atmosphere, thus increasing effective dilution. A simple three-row shelterbelt seemed to be the most effective while striving to be beneficial economically as well. A fast growing deciduous species, such as a poplar, should be planted on the leeward side. A slower growing species from the conifer family is most beneficial in the middle, and a shrub species should be planted on the windward side to achieve the desired wedge effect (Tyndall and Colletti, 2000).

Deposition of dust and other aerosols by reducing wind speeds

Shelterbelt density is the most important factor in determining wind reductions. A density of approximately 40-60% is the most beneficial (Brandle and Finch, 1991). Reductions on the windward side generally average 2-5 H. Reductions on the leeward side vary and have been measured at up to 50 H, but measurements of 30 H are more typical. At 8 H the wind velocity is approximately at 25-50% of the open field wind velocity, and at 10-20 H it usually measure at about 50-80% of the open field wind velocity (Wray et al., 1997). Spacing of the trees both between rows and between trees of the same row will affect density. A skilled conservation district employee or Extension educator or should be consulted to achieve the correct spacing. The fact that deciduous species tend to be more open closer to the ground and conifers have branch cover close to the ground should also be taken into account. Both of these factors will affect spacing and overall density.

Pesticide drift mitigation research suggests that, due to reduced wind speeds, drift pesticide will drop from the air stream as much as 70% (no leaves) and 90% (in leaf) among broadleaf species (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).

Wind tunnel modeling of a three-row shelterbelt system has quantified reductions of 35% to 56% in the downwind drift of dust and aerosols (Laird, 1997; Thernelius, 1997).

Physical interception of dust and other aerosols

Meister et al. (1984) suggests that a forest can clean the air of microparticles of all sizes twenty times better than barren land. This is accomplished by the capture efficiency of leaves.

This efficiency increases for particles of 5μm or less as the leaf roughness increases. Increased surface roughness decreases the stability of the boundary layer, which increases the particle impaction. Leaves with a complex shape and a large circumference-to-area ratio collect particles most efficiently. This increases the effectiveness of conifers as compared to deciduous species, not to mention the temporal advantage of conifers being “in leaf” year round (Smith, 1994).

Acting as a sink for the chemical elements of odor after interception

Volatile Organic Compounds (VOC’s)- the offensive smell in livestock manure- have a distinct affinity to the lipophilic membrane (the cuticle) that covers the leaves and needles. Studies are underway to examine the efficiency of various plants (Beattie et al., undated in Tyndall and Colletti, 2000). One idea that has been studied is that wet plant surfaces may remove pollutant up to ten times faster than dry plant surfaces. Wind tunnel experiments have shown that trees with wet leaves accumulated 100 times more aerosol sulfur than dry trees (Horn and Vedt, 1980). Researchers have quantified measurable quantities of anthropocentric VOC’s that have accumulated at the surface of plants (adsorption) and within the plant tissues (absorption) (Reischl et al., 1989; Reischl et al., 1987; Gaggi et al., 1985). Preece and Dickenson (1977) also found that microorganisms dominate the surface of plants. These organisms also adsorb and absorb VOC’s and provide additional surface area for pollution collection. They also have the ability to metabolize and breakdown VOC’s (Schreiber and Schonherr, 1992; Beattie et al., undated in Tyndall and Colletti, 2000).

Cost Analysis

Cost will vary from site to site. Species should be selected by how well they can adapt to soil composition at the site and to climate changes. One scenario was given in Tyndall and Colletti (2000). This particular example was for an 871-tree shelterbelt for a 3000 head swine facility. The site was given two different scenarios. The “high” scenario was $10/ tree and shrub, and the “higher” scenario was for $25/ tree and shrub. The “high” scenario came out to $0.30/pig, which, if capitalized at 5% over 20 years, came out to be $0.06/pig. The “higher” scenario was given the same calculations and came out to be $0.68/pig. If this were capitalized at 5% for 20 years, it would cost approximately $0.09/pig. The annual maintenance over the 20 years was included in the price.

Shelterbelts and Water Filtering

Hybrid poplars seem to be well suited to use with agricultural, industrial and community wastewater. Through the combination of both trees and shrubs in conjunction with strips of grass, an effective filtering system can be provided to remove nitrates and other harmful pollutants from wastewater to reduce the risk of contamination to humans and other aquatic organisms (Kuhn and Nuss, 2000; Dosskey et al., 1997; and Stanosz and Calabro, 2000).

The hybrid poplars act as a nutrient sink for wastewater. Some poplars are well adapted to moist soils and can tolerate short periods of standing water. Studies have shown that poplar trees can retain as much as 68-99% of nitrates and 75% of sediment compared to an unbuffered strip of land (Stanosz and Calabro, 2000). The particulate wastes and sediment-attached microbes are filtered along with the sediment. The plants and soil microbes uptake the soluble contaminants from surface runoff and shallow groundwater.

Conclusion and Summary

There is strong evidence to support that trees do improve 1) air quality and 2) water quality. They also have the potential to be economically feasible to most livestock producers. Cost will vary from site to site along with the different species of trees and shrubs that will be used, and the specific design of each windbreak. Poplar species seem to be a common element in both odor dispersion and buffering of wastewater runoff. These are fast growing species that can serve as nursery trees to the longer-living slower-growing species in each windbreak.

There are still areas that need more research data to support the significance of trees around livestock facilities. Density or porosity of a particular shelterbelt seems to be a very significant element in dispersion and turbulence, but there is no clear way to determine how to measure this and plan for the most beneficial spacing throughout a shelterbelt. Research on particular species being more beneficial for odor removal or wastewater uptake seems to be lacking. In most cases, trees and shrubs will have to be planted according to different site specifications, such as soil type and consistency, weather elements, and available water. Are there particular species of trees and shrubs that cannot handle the high nitrate levels of livestock runoff? It would not do any good if trees were planted to buffer wastewater, but were harmed by these high levels of contaminants.

Another area that is lacking in research is how odor is measured and how it travels. If it could be understood how far and in what fashion odor travels, limitations could be set on how close facilities can be to certain receptors, such as people. It is understood that odor plumes travel near the ground, but under what conditions do they travel at certain distances and what level of the atmosphere? Temperature and wind speed will have an obvious effect on this.

Studies need to be done on how local people perceive odor and the livestock facility. Will it change their perceptions of the facility if they know that the livestock producer is taking steps toward odor control and improving surrounding water quality? Are these people willing to take on some of the costs that could be handed down to them through the extra financial burden on the livestock producer? Evidence supports the facts that trees can help improve air quality through odor dispersion and water quality through filtering wastewater. The costs are relatively low on a per head basis to a livestock facility, but the people complaining are the ones that need to be satisfied. Will these extra steps improve their quality of life?

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